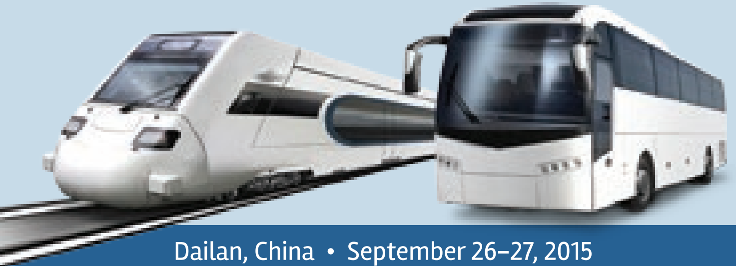
ICTE 2015

Proceedings of the Fifth International Conference on Transportation Engineering



Dailan, China • September 26–27, 2015

EDITED BY Qiyuan Peng, Ph.D.; Kelvin C. P. Wang, Ph.D.; Xiaobo Liu, Ph.D.; and Bingzhi Chen, Ph.D.

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PROCEEDINGS OF THE FIFTH INTERNATIONAL CONFERENCE ON TRANSPORTATION ENGINEERING

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Transportation & Development Institute
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Preface

We are fortunate to have Southwest Jiaotong University (SWJTU, Chengdu, China) to host the Fifth International Conference on Transportation Engineering (ICTE 2015). Transportation and Development Institute (T&DI) of the American Society of Civil Engineers (ASCE) is a key sponsor of the conference and ASCE is the publisher of the conference proceedings. SWJTU, formerly known as Tangshan Jiaotong University, is renowned for its prestigious engineering programs in various transportation related disciplines, dating back to 1896. The editors are grateful for the kind support of SWJTU, and the organizations and individuals who played important roles for the success of the conference, which are acknowledged at the beginning of the proceedings. This conference is held in the city of Dalian with outstanding support of Dalian Jiaotong University. This is the first time that ICTE is held outside of Chengdu, China. We all appreciate the diligent work by Dalian Jiaotong University for ICTE.

The motif of ICTE 2015 is "Comprehensive, Wisdom, Green, Safety, High-Speed and Innovation". ICTE 2015 is a platform of communication and discussions among worldwide experts and scholars in the field of transportation engineering. During the conference, they will present their latest achievements and innovations to promote mutual study and collaboration.

All papers in the proceedings were peer-reviewed resulting in over 400 papers selected for publication. The School of Transportation and Logistics of SWJTU provided various support for the conference, including soliciting abstracts and papers, organizing sessions and presentations, and managing the peer-review process.

There were a number of volunteers who reviewed the submitted papers. The conference and the editors appreciate their valuable work. The editors thank their important contributions to the conference. The diligent work by members of the Secretariat in organizing the vast number of papers is critical for the publisher to meet the deadlines.

Lastly, we would like particularly thank ASCE T&DI Director, Mr. Muhammad Amer, and staff of ASCE publications for their support of this conference.

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Vehicle Operation Application Engineering

Fuzzy Comprehensive Evaluation for the Implementation Effect of Credit Policy on Post-Disaster Reconstruction

Manping Tang[1]; Caijin Wang[1]; Yunchen Wang[1]; and Zihan Zhao[2]

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Abstract: The present paper hypothesizes that when the safety motive of sustainable development pursued by financial organizations and the service motive aimed by government financial control contradict, effectiveness of policy conduction would be undermined. Fuzzy comprehensive evaluation method is employed by different target groups to evaluate policy satisfaction. The study has shown that target groups are satisfied with credit system in post-disaster reconstruction.

Keywords: Post-disaster reconstruction; Credit policy; Fuzzy comprehensive evaluation method; Policy evaluation.

1 Introduction

In accordance with monetary policy, credit policy, an integral part of national Macro-economic Control system, led by industrial policies, exercised by commercial banks, whose principles of safety, fluidity and profitability are respected by central bank, cooperates national social and regional development policies, guides and standardizes bank credit funds channeled by a series of policies and regulations and regulatory system (Tang Yingwei, Hong Bo, 2012). Some scholars claim that in post-disaster reconstruction, powerful monetary policy can provide efficient and reliable, long-term and standardized capital supply for relief and rehabilitation work. (Song Xuguang, Pang Mingchuan, Wang Xiaoling etal, 2008). Meanwhile, some scholars maintain that principles of safety, profitability and fluidity pursued by commercial banks when allocating credit will undermine the role of control played in emergency rescue and post-disaster reconstruction (Feng Xiaobin, Wang Yong,2010). Especially at present, China's financial system inadequate to catastrophe relief and precautions is insufficient to carry out post-disaster reconstruction. (Qin Chijiang, 2009). The present paper hypothesizes that when the safety motive of sustainable development pursued by financial organizations and the service motive aimed by government financial control contradict, the effectiveness of policy conduction would be affected.

At the same time, different policy-targeted groups' or stakeholders' subjective evaluation of policy implementation and relevant effects results from such facts as the relatively long time-lag between credit policy implementation and anticipation of target groups in post-disaster reconstruction, the manifestation of loan benefits (such as income change, project progression, production restoration .etc) brought by preferential credit policy, which target groups participate, and emergency of conflicts between target groups' policy anticipation and the goal of government macro-economic control.

2 Proposal of Evaluation Scheme and Establishment of Index System

2.1 Design of evaluation scheme

The target groups of credit policy on post-quake reconstruction are mainly afflicted inhabitants and small and medium-sized enterprise. This study is conducted with questionnaires, and afflicted inhabitants and small and medium-sized enterprises are survey target. Counties (prefecture or district) with an economic edge in pre-disaster days that are severely affected by earthquake and recovered significantly in post-disaster days, are within our sample scope. Sample size is devised according to the principle of average sample size conforming to normal distribution. Questionnaire informs the present authors of the afflicted inhabitants' and small and medium-sized enterprises' evaluation results of credit policy implementation and relevant effects. In the process of data organization and analysis, a fuzzy mathematical method is used to analyze the final membership grade level of policy implementation effects so as to investigate the implementation results of customer-led credit policy in post-disaster reconstruction, namely afflicted inhabitants' and enterprises' satisfaction level of policy.

2.2 Selection of samples and description of data

Of the 40 heavily and severely afflicted counties (prefectures, districts), Aba prefecture, Chengdu and Mianyang are chosen to be the key areas to be investigated, and 11 counties (prefectures, districts), which account for 25% of heavily and severely afflicted counties, are included to be our survey target. Questionnaires are distributed to afflicted inhabitants and enterprises who enjoyed preferential credit. Valid questionnaires obtained from afflicted rural inhabitants, urban inhabitants and small and medium-sized enterprises are with efficacy rate of questionnaires being 85.46%, 76.36% and 87.27% respectively.

2.3 Establishment of index system and rating scale

(1)Determination of index system

On the basis of evaluation index system related to credit policy, integrating practical credit situation of post-Wenchuan Earthquake reconstruction, index system of satisfaction evaluation, which can reflect different target groups' anticipation of credit policy, is screened through credit policy of key support work aimed at different target groups.

The evaluation of implementation effects of credit policy on post-Wenchuan earthquake reconstruction is shown in table 1.

Table 1. Evaluation of implementation effects of credit policy on post-Wenchuan earthquake reconstruction

Fist class index	Second class index	Third class index
Target groups'satisfaction evaluation of credit policy on post-Wenchuan Earthquake reconstruction R	Afflicted rural inhabitants' Satisfaction evaluation R1	Evaluation of credit cost in housing reconstruction x1
		Evaluation of infrastructure after credit investment x2
		Evaluation of agricultural restoration after credit investment x3
		Evaluation of post-quake income change x4
	Afflicted urban inhabitants' satisfaction evaluation R2	evaluation of loan interest after adjustment y1
		Evaluation of maximum loan limit after adjustment y2
		Evaluation of credit period after adjustment y3
		Evaluation of approval efficiency y4
	Afflicted enterprises' satisfaction evaluation R3	Evaluation of approval efficiency z1
		Satisfaction evaluation of fund supply z2
		Evaluation of "Four Nos" policy z3
		Evaluation of support magnitude of credit policy z4

(2)Determination of rating scale

This paper grades influence factors of credit policy on post-Wenchuan Earthquake reconstruction on the scale of "very satisfied", "adequately satisfied", "not very satisfied", and "extremely not satisfied".

$$B = \{b_1 \quad b_2 \quad b_3 \quad b_4\} = \{\text{VS} \quad \text{AS} \quad \text{NVS} \quad \text{ENS}\}_*$$

(*VS=Very satisfied, AS=adequately satisfied, NVS=not very satisfied, ENS=extremely not satisfied)

3 Systematic Analysis of Fuzzy Comprehensive Evaluation of Credit Policy on Post-Wenchuan-Earthquake Reconstruction

3.1 Satisfaction evaluation of different target groups

Probability and statistics are employed to evaluate different target groups' policy implementation satisfaction, on the basis of which evaluation matrix Ri can be obtained.

Every respondent made their sole satisfaction evaluation of credit policy on post-quake reconstruction. After normalizing frequency of statistics results, with satisfaction value of each factor in the range of 0 to 1, with the sum of satisfaction value of every factor totaling 1.

3.2 Determination of index weight

The result of first-level index weight and second-level index weight obtained after standard treatment of original matrix and entropy calculation are as follows:

Fist-level index weight: $W = \{0.273 \quad 0.281 \quad 0.446\}$

Rural index weight of the second-level index: $W_1 = \{0.221 \ \ 0.221 \ \ 0.273 \ \ 0.285\}$

Urban index weight of the second-level index: $W_2 = \{0.245 \ \ 0.269 \ \ 0.255 \ \ 0.23\}$

Enterprise index weight of the second-level index: $W_3 = \{0.223 \ 0.326 \ 0.246 \ 0.205\}$

Every index weight stands for the influence the index has on the target level. And weight value is proportional to its influence.

3.3 Different target groups' satisfaction evaluation of credit policy on post-quake reconstruction

Weighted average method ($\cdot$, $\oplus$)with the advantage of comprehensiveness, intensification of the role played by weights and full exploitation of result matrix R, is chosen to be the fuzzy operator in this paper. Relatively objective and precise fuzzy evaluation results can be conducted and the weakness of little difference between rating scale and evaluation results can be effectively overcome. Such a result as table2 can be got at last.

Table 2. Different target groups' satisfaction evaluation of credit policy on post-quake reconstruction

Index Level	Membership grade			
	VS	AS	VNS	ENS
B1	0.1907	0.6034	0.1765	0.0293
B2	0.1025	0.6032	0.2565	0.0378
B3	0.3608	0.2730	0.2884	0.0777
B'	0.2768	0.3089	0.2826	0.1317

(1)Analysis of afflicted rural inhabitants' satisfaction evaluation

Afflicted rural inhabitants are adequately satisfied with the overall evaluation factors of implementation effects of credit policy（B1=0.6034）, with its weight influence factors sequencing x4>x3>x1>x2; According to the frequency statistics of evaluation matrix, the sequence of factors that afflicted rural inhabitants that are very satisfied with is x3>x1>x2>x4; the sequence of factors that they are extremely not satisfied with is x4>x1>x2=x4. It can be seen that afflicted rural inhabitants are adequately satisfied with the overall implementation effects of credit policy, and that the result of income raise, which they concern most, failed to meet their expectation of credit policy on post-disaster reconstruction.

(2)Analysis of afflicted urban inhabitants' satisfaction evaluation

Afflicted urban inhabitants are adequately satisfied with the overall evaluation factors of implementation effects of credit policy（B2=0.6032）, with its weight influence factors sequencing y2>y3>y1>y4;According to the frequency statistics of evaluation matrix, the sequence of factors that afflicted urban inhabitants that are very satisfied with is y4>y1>y2>y3; the sequence of factors that they are extremely not satisfied with is y3>y1=y2>y4. Judging from frequency statistics of the survey results, the proportion of evaluation factors that afflicted urban inhabitants rated "very satisfied" is low, and the score of every evaluation factor on the "very satisfied" scale is less than 0.2. Less than 10% of afflicted urban inhabitants are very satisfied with maximum credit limit and credit period, while around 30% are not very satisfied.

(3)Analysis of afflicted enterprises' satisfaction evaluation

Afflicted enterprises are very satisfied with the overall evaluation factors of implementation effects of credit policy（B3=0.3608）, with its weight influence factors sequencing z2>z3>z1>z4; according to the frequency statistics of evaluation matrix, the sequence of factors that afflicted enterprises that are very satisfied with is z3>z4>z2>z1; The sequence of factors that they are extremely not satisfied with is z4>z2>z1=z3; The main reason behind it is that though the policy did not last long, it greatly alleviated repayment pressure of afflicted enterprises, transferring their risks to financial organizations. But in the meantime, it means that the policy poses a challenge to sustainable development of financial organizations and increases the pressure of exposing the financial organizations to bad loans.

(4)Target groups' satisfaction evaluation of credit policy on post-Wenchuan Earthquake reconstruction

Target groups are adequately satisfied with credit policy on post-Wenchuan Earthquake reconstruction (after normalization B'=0.3089).The overall satisfaction evaluation integrates afflicted rural and urban inhabitants' and enterprises' satisfaction evaluation. Enterprises are most satisfied with overall policy framework, afflicted rural inhabitants are not satisfied with it, and afflicted urban inhabitants are least satisfied with it.

4 Conclusions

Here we may draw the following conclusions:

(1)In general, Target groups are adequately satisfied with credit policy on post-Wenchuan Earthquake reconstruction (B'=0.3089), the implementation of the credit policy effect is positive.

(2)In terms of the target groups' importance, enterprises accounted for the largest in the three groups (W = 0.446), and largely affected the final result. Hence, there is a necessity to strengthen the credit policy support to enterprises.

(3)In terms of the target groups' satisfaction, rural inhabitants and urban inhabitants are most satisfied with credit policy, the AS>0.5. By contrast, enterprises satisfaction with credit policy is low, and its VS and AS are both less than 0.5. In line with(2), the credit policy still need to focus on enterprises.

5 Suggestions on the Perfection of Credit Policy on Post-disaster Reconstruction

According to the target groups' satisfaction survey, the credit policy on post-Wenchuan Earthquake reconstruction has been recognized by target groups. Judging from the recovery and development level of regional economy and social enthusiasm, the policy has basically achieved its goals. Meanwhile, to form effective governmental coping experience of economic policy under emergencies, there is room for improvement. Firstly, in the process of policy formulation, adhere to the commercial banks' principle of safety, fluidity and profitability, government should play an dominant role, give priority to actual demand and interest of financial organizations and individuals and shorten the time-lag of fund demand in afflicted areas. Secondly, financial support system of post-disaster reconstruction should be further improved, the role that policy finance plays should be reinforced, domestic demand should be reasonably regulated and controlled, economic growth should be steadied and development of regional economy should be stimulated and the skills of afflicted inhabitants to recover production should be elevated. Thirdly, the building of catastrophe insurance system should be strengthened, and ability of financial organizations to cope with catastrophes should be improved to alleviate the burden of shouldering catastrophic risks.

Acknowledgment

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References

Feng Qiaobin, Wang Yong.(2010). "Post-disaster Reconstruction: Commercial Credit Funds, Policy-based Financial Aid and Construction of Funds Guarantee System of Three-dimensional", *Fiscal Study*, (02), 2-6.

Qin Chijiang.(2009)."Post-disaster Reconstruction and Perfection of Chinese Financial System". *Journal of Guangdong University of Finance*, (1), 12-17.

Song Xuguang, Pang Mingchuan, Wang Xiaoling, etal.(2008)." Policy Framework and System Reestablished after Huge Natural Calamities--A Case study of Wenchuan Earthquake".*Research on Financial and Economic Issues*, (09), 10-18.

Tang Yingwei, Hong Bo.(2012). "Practice and Thought on Evaluation of Guiding Effects of National Credit Policy." *Shanghai Finance*, (06), 38-41.

Connection-Consider Decision-Making Model of Emergency Rescue Scheduling under an Earthquake

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Abstract: After the earthquake, road transport lifelines were seriously damaged, for this situation, this paper presents the concept of emergency rescue scheduling decision under earthquake, which is, when the road traffic is interrupted, other modes of transport connections will replace to ensure the fluency of traffic lifelines. Based on the theory of traffic ergonomics, timeliness, security and economy, the three properties of emergency rescue connection, were nondimensionalized and polymerized by weight. Using the multi-attribute decision-make theory, established the utility function model, Finally, verified the model through concrete examples.
Keywords: Traffic engineering; Earthquake disaster; Emergency rescue; Connections.

1 Introduction

Natural disasters occurred frequently in China, especially earthquakes, brought huge losses to economy and society. To reduce the loss caused by disasters, the state departments developed appropriate emergency response plans for different disasters. Transportation program of emergency relief supplies plays an important role in the rescue work, in which the scheduling of transport vehicle is the key. During earthquake, the road transport lifelines, including roads, bridges and tunnels, are easily damaged, for the security and quick transportation of people and supplies, the lifeline need to be connected by air, water or rail.

2 Description of the Model

Emergency transportation decision-making model refers to a decision-making model for decision-makers alternative which within the scope of an integrated transport network, depending on the level of emergency needs, give the appropriate connections program based on different security, economy and timeliness. The model includes not only the choice of transport routes, more important is to choose the modes of connection, the existing connections to a road-main emergency lifeline are: highway - aviation - highway; highway -waterway - highway; highway - railway - highway. The process of integrated transport connections can be expressed by Figure 1.

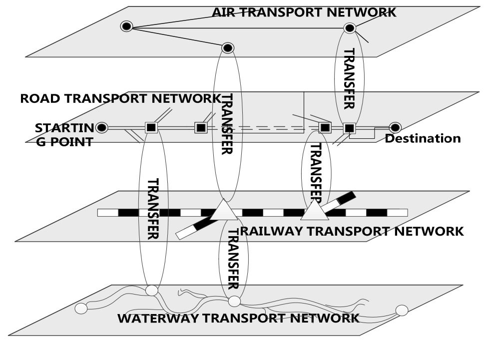

Figure 1. Process of integrated transport connection

2.1 Process analysis

From the factors and nature of the transport scheduling decision in emergency situations, it can be seen that the choice of emergency connection modes, can be seen as a multicriteria decision problem. Its decision-making goal is to select the transport route which make three attribute vectors (timeliness, security and economy) achieve the ideal value (maximum or minimum). The key to solve this problem is to construct the utility functions of attribute components (FU Jialiang, 2006). According to the multi-attribute decision theory, the properties of each attribute component of the alternative routes should be nondimensionalized firstly, and then determine the weight of each attribute, and then each component is polymerized by the decision utility function. Finally select the maximum expected utility value as a recommended decision program.

2.2 Parameter analysis

Based on the points of chapter 2.1 , transportation scheduling decision of emergency rescue needs considering timeliness, security and economy. We can construct the following network diagram (Xu Peiwen, 2011):

$$B = \begin{cases} E = \{0,1,2,\dots,k\} \\ F = \{(a,b)|a,b = 0,1,2,\cdots,k, a \neq b\} \\ G = \{(m,n)|m = 1,2,3; n = 1,2,\cdots,s\} \\ H = \{h_{ab}(a,b)|a,b = 0,1,2,\cdots,k, a \neq b\} \end{cases}$$

E and F are the sets of nodes and lines that vehicles may go through during the process of transportation, a and b are any two nodes of set E, showing the two ends of a line; G is a set of modes and frequency of connections, $m = 1,2,3$ respectively represents air, waterway and railway connection. n represents the frequency of each connection modes from starting points to the destination; H is the set of road rights, represents the weights of (a, b), indicating its importance of particular attributes (or a comprehensive attribute) in decision-making; Q is the set of connection rights, indicating the weights of connection mode in a connection. Such multicriteria decision problem can be solved with the linear assignment.

The objective function is constructed as follows:

$$\min\left[\sum_{a=1}^{k}\sum_{b=1}^{k}x_{ab}+\sum_{m=1}^{3}\sum_{n=1}^{s}y_{mn}q_{mn}\right],$$

$$\text{when:}\begin{cases} x_{ab}=\begin{cases}1, & When\ the\ vehicle\ through\ line(a,b);\\ 0, & when\ the\ vehicle\ does\ not\ through\ line(a,b).\end{cases}\\ y_{ab}=\begin{cases}1, & When\ \ mode\ m\ is\ used;\\ 0, & When\ \ mode\ m\ is\ not\ used.\end{cases}\end{cases}$$

$h_{ab} = M$, $q_{mn} = N$, M and N are sufficiently large integers; k is the total number of nodes in the road network, s is the number of connections in the process of comprehensive transportation.

The objective function satisfies the following constraints:

$$\begin{cases}\sum_{a=0}^{k}x_{ab}=1, b=0,1,2,\cdots,k;\\ \sum_{b=0}^{k}x_{ab}=1, a=0,1,2,\cdots,k;\\ \sum_{m=1}^{3}y_{mn}=1, n=0,1,2,\cdots,s;\\ \sum_{m=1}^{3}\sum_{n=0}^{s}y_{mn}=s,\\ X=(x_{ab})\in S.\end{cases}$$

According to the above mathematical model, we can obtain three components of the objective function:

（1）Timeliness

Time calculation obey the addition rule, we can set T as the total time from the starting point to demanding point of any transport route. T_{ab} is the travel time for vehicles in the line (a, b), t_{mn} is the travel time of connection NO. n using mode m, the objective function of time component is:

$$\min T=\min\left[\sum_{a=1}^{k}\sum_{b=1}^{k}T_{ab}x_{ab}+\sum_{m=1}^{3}\sum_{n=1}^{s}y_{mn}t_{mn}\right]$$

（2）Security

The security attributes of transport scheduling scheme is generally represented by the probability of security pass, its operations obey the multiplication rule, in order to ensure its consistency with the transport distance algorithm (timeliness property has the consistency), Need to do Mathematical transformation for the probability of security pass, so that the resulting index can obey the addition rule, logarithmic way just meet this requirement (Li Mao, 2008).

Suppose P is the total security pass probability of transportation routes from the start point to the demand point, P_{ab} is the security pass probability of line (a, b), P_{mn} is the security pass probability of connection (m, n). In the alternative route u_{st}, P_i is the security pass probability of the line No. i, P_j is the security pass probability of the No. j connection point. Entire transportation route consists of m lines and n connection points. The security pass probability of route u_{st} is:

$$P(u_{st}) = \prod_{i=1}^{k} P_i \cdot \prod_{j=1}^{s} P_j$$

To ensure its additivity and non-negative . Both sides multiplied by "-1" after taking logarithm:

$$-\log P(u_{st}) = -\sum_{i=1}^{k} \log P_i - \sum_{j=1}^{s} \log P_j \qquad 0 < P_i, P_j \le 1$$

So the objective function based on security attribute is:

$$\max P = \min\left[\sum_{a=1}^{k}\sum_{b=1}^{k} x_{ab}(-\log P_{ab}) + \sum_{m=1}^{3}\sum_{n=1}^{s} y_{mn}(-\log P_{mn})\right]$$

（3）Economy

Suppose E is the total economic consumption of route from the starting point to demand point, E_{ab} is the economic consumption of line (a, b), e_{mn} is the economic consumption of connection (m, n), Economic attribute similar to the time attribute, they obey the addition rule.

Similarly, the objective function based on economic attribute is:

$$\min E = \min\left[\sum_{a=1}^{k}\sum_{b=1}^{k} E_{ab}x_{ab} + \sum_{m=1}^{3}\sum_{n=1}^{s} y_{mn}e_{mn}\right]$$

2 Establishment of the Model

According to the multi-attribute decision theory, Because of the relative independence among timeliness, security and economy of the relief supplies transportation after the earthquake disaster, the utility function of multi-attribute model can be expressed as the sum of each single-attribute utility in a unified dimension. According to the previous results of the parametric analysis, Each property has maintained consistency in the form of transport distance algorithm, so, Dimensionless Processing for The resulting utility function of each attribute is just need, the sum of Dimensionless index can be easily attained (Wang Qiang, 2013).

Assume that T_{min} and T_{max} are the minimum and maximum transit time, P_{min} and P_{max} are the minimum and maximum security pass probability, E_{min} and E_{max} are the minimum and maximum transit economic cost.

Assume that the set of the transportation scheduling schemes from starting point to demand point is:

$$M = \{i | i = (a, b, m, n), a, b = 0,1,2, \cdots, k, m = 1,2,3, n = 0,1,2, \cdots, s\}$$

g_i is the dimensionless index of total transport time of option NO. i, T_i is the total transport time of option NO. i, T_{max} and T_{min} are the maximum and minimum transit time of all the options. According to the dimensionless principle (Yu Wuyang, 2013), it can be Obtained:

$$g_i = \frac{T_{max} - T_i}{T_{max} - T_{min}}, \quad T_{min} \leq T_i \leq T_{max}, \ i \in M$$

Assume that h_i is the dimensionless index of transportation security of option NO. i, P_i is the safe pass probability of option NO. i, P_{max} and P_{min} are the maximum and minimum safe pass probability of all the options. To ensure the consistency of each property component indicator, we hope that h_i will increase with the increasing of safe pass probability, According to the dimensionless principle, it can be obtained:

$$h_i = 1 - \frac{P_{max} - P_i}{P_{max} - P_{min}}, \qquad i \in M$$

Assume that k_i is the dimensionless index of transportation economy of option NO. i, E_i is the economic cost of option NO. i, E_{max} and E_{min} are the maximum and minimum economic cost of all the options. According to the dimensionless principle, it can be obtained:

$$k_i = \frac{E_{max} - E_i}{E_{max} - E_{min}}, \qquad i \in M$$

Assume that the weight of timeliness, economic and security the dispatchers give is (Vaidya, 2006):

$$\lambda = (\lambda_1, \lambda_2, \lambda_3)^T, \qquad \begin{cases} 0 \le \lambda_1 \le 1 \\ 0 \le \lambda_2 \le 1 \\ 0 \le \lambda_3 \le 1 \\ \lambda_1 + \lambda_2 + \lambda_3 = 1 \end{cases}$$

Based on the above analysis, the utility function model of transportation scheduling scheme under emergency conditions is:

$$G_i = \frac{\lambda_1(T_{max} - T_i)}{T_{max} - T_{min}} + \lambda_2\left(1 - \frac{P_{max} - P_i}{P_{max} - P_{min}}\right) + \frac{\lambda_3(E_{max} - E_i)}{E_{max} - E_{min}}, G_i \in [0,1]$$

In the formula, G_i is the decision utility index of NO. i alternative transportation scheduling scheme. Larger G_i indicates better comprehensive evaluation result of transportation scheduling scheme, so, we choose the transportation scheduling scheme which have the maximum G_i as the final decision result.

3 Analysis of Example

3.1 Introduction

March 10, 2011, a 5.8 level earthquake occurred in Yingjiang in Yunnan. The earthquake caused damage to roads and bridges in varying degrees, But the earthquake did not cause traffic disruption，the major trunk roads leading to Yingjiang can meet the basic requirements for access. Rescue vehicles arriving Yingjiang are mainly from Baoshan, so the purpose of this example is to find the optimal path from Baoshan to Yingjiang. The surrounding road network of Yingjiang is schematically shown in Figure 2, the path Information is shown in Table 1.

Table 1. The basic information of section

Routes	Safe pass probability	Lines	Connection points	Length （km）	Speed （km/h）
A—B—C	0.9 0.7	G56—S317	— —	23 57	60 40
A—D—C	0.9 0.8	G320—S317	— —	50 52	60 40
A—E	0.9	G320	waterway	181	60
C—F	0.6	S233	aviation	83	40
E—F	0.7	S233	—	100	40

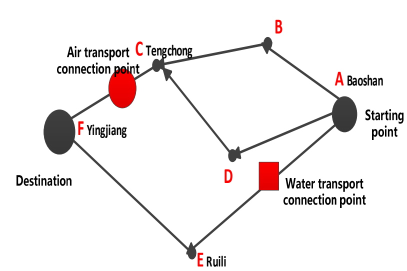

Figure 2. Network diagram

3.2 Discussion of optimal connections program

(1) Decision parameters

Follow the route segment of Table 1, determine the Decision Parameters as Table 2 (Zhang Yi, 2008).

(2) Weights

Calculate the weight of the three indicators by the analytic hierarchy process, Assume in the three factors of security, timeliness and economy, timeliness is slightly more important than security, security is Significantly more important than economy, timeliness is strongly important than economy, we can list the judgment matrix as Table 3 (Zhou Ping, 2010).

Table 2. Decision parameters

Routes	Timeliness	Security	Economy
A—B	12.7	35.6	9.2
B—C	40.1	53.5	22.8
A—D	27.6	35.6	20.0
D—C	36.6	41.0	20.8
A—E	100.0	35.6	72.4
C—F	58.4	100.0	33.2
E—F	70.3	67.9	40.0
Waterway connection	13.9	100.0	200.0
Aviation connection	111.2	35.6	9.0

Table 3. Judgment matrix

Index	Security	Timeliness	Economy
Security	1	2/3	6
Timeliness	3/2	1	9
Economy	1/6	1/9	1

Through consistency test, its matrix consistency ratio $CR=8.28\times10^{-3}<0.1$, the inconsistency of the matrix within the allowable range. The weight vector of Each attribute can be obtained under the above conditions prevailing emergency as follow:

$$(\lambda_1, \lambda_2, \lambda_3) = (0.375, 0.562, 0.063)$$

According to Figure 2, there are three possible transportation scheduling schemes: $A-B-C-F, A-D-C-F, A-E-F$ the attribute index and utility function value of each scheme can be listed as Table 4 (Shen Zhiyun, 2011):

Table 4. Calculation of decision effect

Scheduling scheme	Standardized time	Standardized security index	Standardized economic index	Decision effect index
A-B-C-F	1.000	1.000	0.058	0.941

A-D-C-F	0.927	0.917	0.000	0.863
A-E-F	0.000	0.000	1.000	0.063

It can be concluded that under the assumption of emergency traffic conditions, scheme $A-B-C-F$ can get a larger effect index, should be recommended as an emergency transport scheduling scheme under this kind of situation.

4 Conclusions

Analyzed the differences of transportation scheduling decisions goals between emergency and general situations through the three properties of timeliness, security and economy, pointed out that the issue of transport scheduling decisions under emergency conditions essentially is multicriteria decision problem， firstly nondimensionalized each attribute components, then obtained the decision utility function by polymerizing the attribute components with the weighting method, the multicriteria decision problem changed into a single one, Successfully established a mathematical model, chose the scheme has the highest expected utility as the decision-making program. Finally, verified the model with an example, the results are close to the actual, proved its applicability. This model can also be used in the general transport scheduling decisions. The further study will be expanding the scope of the model.

References

Fu Jialiang (2006). Operations research methods and models. *Fudan University Press*, Shanghai.

Li Mao (2008). “Study on the Model of Urban Emergency Rescue Force Deployment”, Xi`an University of Science and Technology, Xi`an.

Shen Zhiyun (2011). Transportation Engineering. People's Communications Press, 88-91. Beijing

Vaidya (2006). “Hierarchy Process: An Overview Of Applications”. European Journal of Operational Research, 169(1),1-29.

Wang Qiang, Li Heng, Cui Zi-qing (2013). “The Research of the Best Way on Sending Oil to Forward Depot during Wartime Based on Passes Probabilities”. Logistics Sci-Tech, (3), 85-87.

Xu Peiwen, Hao Juan (2011). “Design of Earthquake Emergency Rescue System Based on the Internet of Things”. Computer＆Telecommunication, (4), 41-43.

Xu Wei (2011). “Optimally Select The Scheduling of Emergency Resource During Earthquake”. Mathematics In Practice And Theory. 41(6), 30-37.

Yang Ming (2008). “A Study on the Theory and Methodology of Military Highway Transport Command Decision-Making”. Hefei University of Technology, Hefei.

Yu Wuyang (2013). “Relief Goods Transport Model Based on the Survival Probability Function”. Statistics and Decision, (15), 73-75.

Zhang Yi (2008). “Study on Decision Making Theory and Method of Disaster Relief Materials Logistics Based on Natural Disasters”. Changan University, Xi`an.

Zhou Ping (2010). “Vehicle Routing Problem of Emergency Relief Supplies Distribution”. Harbin institute of technology, Harbin.

Analysis of Forbidden Policy's Impact on Motorcycles in Changzhou, China

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Abstract: In consideration of the insecurity and high energy consumption of motorcycle, over 200 Chinese cities have implemented motorcycle forbidden policy since 1985. Taking Changzhou as an example, this paper firstly summarizes the policy implemented in Changzhou, and then analyzes the impaction upon motorcycles, including the deceleration of motorcycle ownership, change of usage and improvement of safety. Changzhou's experience shows that the ban has obvious effect on reducing the ownership and usage of motorcycle. But there is still strong demand for motorcycle in the suburb area. The ban policy should be strengthened progressively and varied in different zones rather than one-style-fits-all or one-step-fits-all.
Keywords: Motorcycle; Forbidden policy.

1 Introduction

Motorcycle, as a convenient and efficient individual traffic, used to play an important role in urban traffic system. (Zhao, 2007) At the end of twentieth century, the development of motorcycle reached the peak point and it was common that over 20% of all trips were motorcycles'. But the rapid growth stood out the weakness of motorcycle like insecurity, high energy consumption and air pollution. (Wang, 2003, Xu, 2005 and Zhao, 2005) In view of this, over 200 Chinese cities have implemented motorcycle forbidden policy since the first motorcycle ban in Beijing in 1985. (Deng, 2009, Huang, 2005 and Lin, 2007)

Changzhou implemented motorcycle forbidden policy in 2005. Taking it as an example, this paper summarizes the motorcycles' characteristics before and after the ban, including the deceleration of motorcycle ownership, the change of usage characteristic and the improvement of safety. Finally, the applicable countermeasures are put to solve the problems existed in the period of the traffic mode transferring.

2 Motorcycle Forbidden Policy in Changzhou

2.1 Background

Changzhou is a city in Jangsu Province in China with an area of 4385 km^2. There are totally 4.65 million people in 2012. The whole city can be divided into the central part and the suburb area. The central part of the city is 616.12 km^2 with a population of 1.75 million.

Before the implement of the motorcycle forbidden policy in 2004, there were over 140,000 motorcycles in Changzhou, accounting for 68.6% of the total motor vehicles. Every 6.5 person owned a motorcycle calculated on the urban resident population of 920,000. There were more than 250,000 vehicle-times per day at that time. The excess motorcycles brought a series of problems like chaotic traffic order, air pollution, traffic accidents and motorcycle robbery.

Chaotic Traffic Order. In 2005, there were averagely 2800 motorcycles entering intersection in peak hour. If converted into equivalent car, the motorcycle flow will account for more than 30% of the whole traffic volume. What's worse, the motorcycle illegal rate up to 40% on average in central part of the city.

Air Pollution. In 2003, motorcycles totally discharged 78.5% carbon monoxide, 60.2% nitrogen oxide and 74.7% Non-methane hydrocarbon of all urban vehicle emissions. The concentration of Carbon monoxide was seven times as the national standard.

Traffic Accidents. From 2002 to 2004, the traffic accidents caused by motorcycles were 1183, 5089 and 12495 respectively, which were 9.9%, 24.6% and 46.8% of all vehicle accidents. What's worse, over 300 people died in the motorcycles' accidents.

Motorcycle Robbery. There were totally 879 motorcycle robberies in 2004 which were a threat for residents' properties as well as psychological insecurity.

2.2 Evolution of the motorcycle forbidden policy

Faced with the problems, Changzhou issued a document called "Suggestion on Motorcycle Limited Development in Changzhou" to restrict motorcycle development on October 15, 2005. Since then, the authority stopped motorcycle registration in the central part of city.

The ban policy has experienced three times adjustment on enlarging the limited scope and extending the limited time. Before 2005, there was no limitation on motorcycle travel. Since October 15, 2005, all kinds of motorcycle traffic were banned in a heart area (3.32 km^2) of the downtown from 8:30 to 17:00. Since January 15, 2007, the limited scope expanded from the original 3.32 km^2 to 34.58 km^2. On March 20, 2008, the local authority extended the limit time from 8:30-17:00 to 8:00-18:30, meanwhile some of the street in the core area banned on motorcycle traffic throughout the day.

In aspect of supporting facilities, Changzhou worked mainly for three aspects: one was the installation of 284 road signs on the 127 entrance around the limited area; Secondly, construct 57 motorcycle parking lot around the limited area; thirdly, set up a motorcycle trading market and three motorcycle scrap points to ensure the scrap of transfer of the motorcycle. In 2008, the local authority set 114 more traffic signs and adjusted 152 original signs to ensure the completeness of the indicators.

3 Impaction upon Motorcycles

3.1 Motorcycle ownership

(1) Ownership of motorcycles

The ownership of motorcycle in central part fell steeply since the forbidden policy adopted in 2005. The ownership of motorcycle in 2006 decreased by 53.5 thousands (34.5%) compared with 2005. In 2013, the motorcycle ownership is only 28.2 thousands, which is about 1/6 of that in 2005. 64.7% of all vehicles are motorcycles in 2005, while it is only 11.6% in 2013. (Figure 1) According to the forecasting of the authority, motorcycles will completely disappear in 2018 in central part of the city.

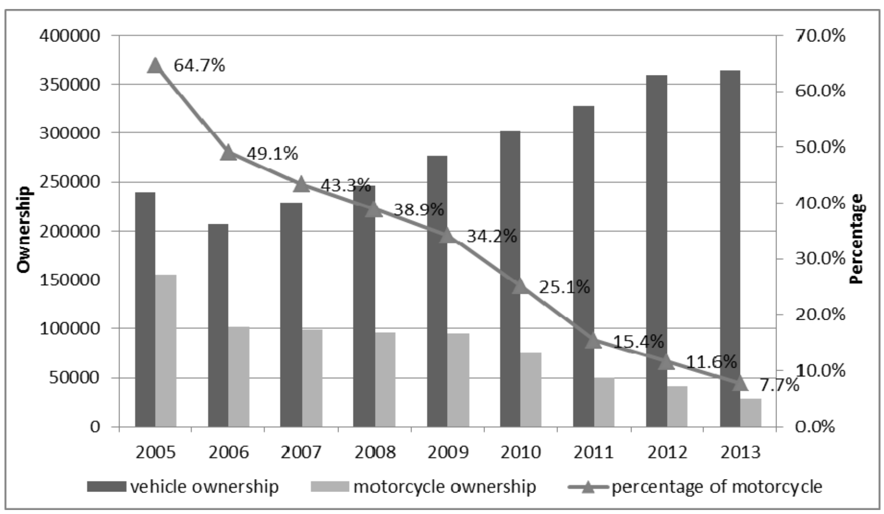

Figure 1. Development of Motorcycle and Vehicle

(2) Regional difference

Although the motorcycle ownership has declined, but in suburb area motorcycle is still a very important means of transportation.

In 2005, 78.3% of all vehicles are motorcycle in suburb area. From 2005 to 2013, the motorcycle ownership of suburb area dropped from 350 thousands to 241 thousands. But the percentage of motorcycle is still 39.2%. In some district like Jintan County, motorcycles still occupied more than half of the whole motor vehicles in 2013. It can be seen that motorcycle is still an important traffic tool in suburb area.

3.2 Usage of motorcycles

(1) Mode share

Motorcycles were once the most important transportation mode in Changzhou. According to the residents' trip survey in 2004, the motorcycle trip proportion accounted for 26.2% of all modes, ranking secondary to the bike. The data showed that motorcycle used to be the initial motorized mode. The proportion of private cars and public transportation was only 4.72% and 8.39% respectively at that time.

Since the ban, motorcycle share rate has dropped rapidly. From 2001 to 2009, it dropped from 27.9% to 14.5%. (Figure 2) What' more, motorcycle trips occurred mainly in suburbs where motorcycles were not limited. According to an investigation in 9 intersections in the central part of Changzhou, motorcycle traffic accounted for only 0.4% of the total flow in 2013.

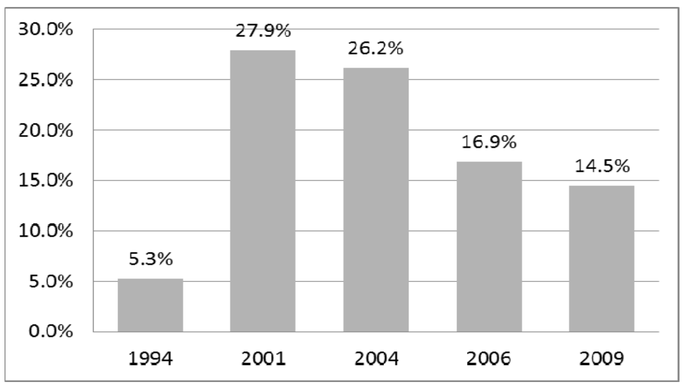

Figure 2. Mode Share Rate of Motorcycle

(2) Travel purpose

Motorcycle used to be the main commuter traffic tool. In 2004, 45% of total motorcycle travel purposes were "go home" and 36% were "go to work". While the travel purpose like sports, shopping, visiting friends or other recreational elastic trips were rarely. However, after the extension of the ban time for 8:00-18:30 in 2008, rigid demands like "go to work" cannot be satisfied by motorcycle. Thus the demand of motorcycle was switching to other traffic tools.

3.3 Improvement of motorcycle safety situation

A large number of traffic accidents were caused by motorcycle before the ban. In 2004, most of motorcycles in Changzhou were straddle motorcycles or mid-range motorcycles. The poor stability and bad braking performance make the rider unsafe. What's worse, the safety awareness of motorcycle drivers was poor, illegal drive behaviors like driving without a helmet or without a license are common.

These reasons led to a growing number of motorcycle accidents. From 2002 to 2004 motorcycle accidents rose from 1183 to 12495 and the proportion of motorcycle accidents grew from 10% to 47%. What's worse, the numbers of deaths grew from 45 to 170. The annually growth rate was 108%. (Figure 3) 6138 persons were injured in motorcycle accidents in 2004 as well.

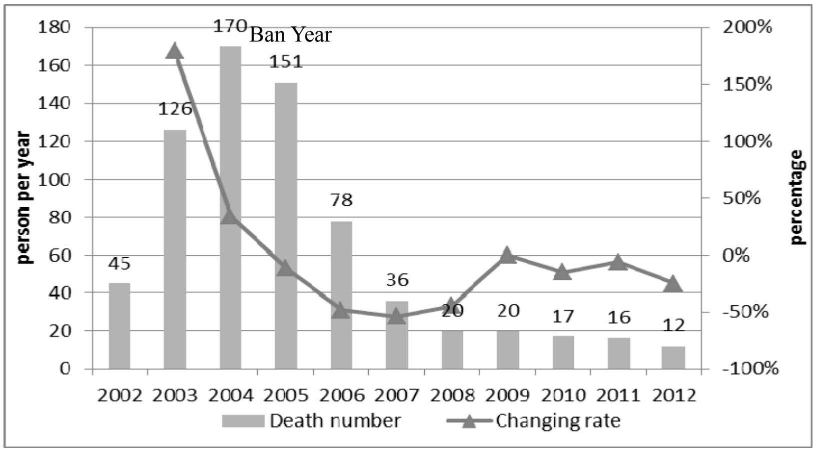

Figure 3. Death Number Change of Motorcycle Accidents (2002-2012)

After the ban, the number of deaths caused by motorcycle accidents reduced year by year. It dropped from 78 in 2006 to 12 in 2012. (Figure 3) From 2004 to 2013, the proportion of deaths caused by motorcycle accidents has fallen from 40.96% to 20% according to the local traffic department. Most of the motorcycle accidents happened in the suburbs like Wujin district.

3.4 Transformation to electric bicycle

Electric bicycle is quite similar with motorcycle in convenient and efficient. But electric bicycle don't need driving license and much cheaper than motorcycle. After the motorcycle ban, electric bicycle developed rapidly. In 2013, the electric bicycle ownership was as high as 1.39 million. (Table 1) What's more, the electric bicycle mainly developed in the central part. It has become the main traffic mode for the dwellers.

Table 1. Development of Electric Bicycle in Changzhou(2011-2013)

Zone	Ownership （2011）	Ownership （2012）	Growth rate compared with 2011	Ownership （2013）	Growth rate compared with 2012
All zone	1143377	1313433	14.9%	1395562	6.3%
central part	631110	753171	19.3%	819711	8.8%
Wujin district	351976	391455	11.2%	402838	2.9%
Liyang county	97666	106182	8.7%	110388	4.0%

Electric bicycles has replaced motorcycle and become the main body of traffic accident. In the first quarter of 2013, accidents involved with electric bicycle accounted for 48.7% of all. What's worse, 30% of the death accidents are involved with it. Abundant overweight and overspeed electric bicycle is one reason. Electric bicycle riders don't need professional training or driving licenses. The lack of driving skill and safety consciousness are more significant.

4 Conclusions

The motorcycle forbidden policy in Changzhou achieved the predicted result. The ownership, mode share rate and motorcycle accidents are all dropping rapidly since the ban. In 2013, there are only 28,151 motorcycles left in the central part. Meanwhile the death number caused by motorcycle accidents is less than one-tenth of before.

But it should be noticed that there is still strong demand for motorcycle in suburb area. The motorcycle percentage of all kind motor vehicles is still nearly 40% in 2013. Meanwhile the suppressed demand will transfer to the other modes like electric bicycles. If not handled properly, the motorcycle forbidden policy will just transfer problems from one to another.

Changzhou's experience shows that the ban policy should be different in different zone and limited level should be strengthened step by step rather than one-style-fits-all or one-step-fits-all. Meanwhile the assorted measures should be implemented ahead to lead the motorcycle demand to a sustainable way.

References

Deng, X., Xu, J. and Wang, B. (2009). "Traffic Counter measures Research for Guangzhou City in Traffic Mode Transferring Period after Motorcycle Forbidden Ban Effect." *Journal of Transportation Systems Engineering and Information Technology*, 8(4): 145-150.

Huang, Z. (2005). "A study on the motorcycle traffic characteristics and the related problems." *Technology and Economy in Areas of Communication*, (2).

Lin, H., Li, J. and Fang, M. (2007). "Analysis of Motorcycle Forbidden Policy's Impaction upon the Resident Trip Mode in Guangzhou." *Communications Standardization*, (12).

Wang, Z. (2003). "A study on the motorcycle traffic problem and solution methods of Foshan city." *Journal of Transportation Systems Engineering and Information Technology*, 3(1): 80-83.

Xu, L. and Qian, Z. (2005). "Urban motorcycle traffic problems and counter measures." *Journal of Luoyang University*, (2).

Zhao, L., Jin, W. and Yang, Y. (2007). “Analysis on the Trip Characteristics of Urban Motorcycle Traffic.” *Journal of Transportation Systems Engineering and Information Technology*,7(4): 143-147.

Zhao, Z. Xiang, Q. and etc. (2005). “Impact analysis of motorcycle traffic on urban traffic system.” *Journal of Transportation Systems Engineering and Information Technology*, 5(1): 111-114.

Traffic Characteristics of Electric Bicycles and Application Management

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Abstract: As for some Chinese cities as Chengdu which is mostly flat, electric bicycles take the place of manual bicycles to become the first choice of middle and short distance transport for lower-and-middle income groups due to their low cost, higher speed and carrying capacity. But more and more traffic problems resulted from a large magnitude of electric bicycles appeal to universal attention. Aimed at the absence of practical survey and research on electric bicycle traffic, this paper carried out practical traffic survey on electric bicycles in Chengdu, presents statistical analysis on the structure scale, traffic volume, violations and proportions, especially on the speed distribution. According to traffic practices of electric bicycles in Chengdu, this paper affirms their main body position, proposes type selection diversification, coordination with urban transit, standardization and strict management, and humanization in traffic organization. And eight strategies and five kinds of facility designs are pointed out.
Keywords: Non-motorized vehicle transport; Electric bicycles; Traffic characteristics; Application management.

1 Introduction

Urban development requires a multilayer transport network with reasonable structure. Biking trips are favored by lower and middle income groups as a cheap, green and fast alternative for trips up to a distance of some 3.5 km. Applied as the transfer mode for mainline trips of urban transit, bicycles are also considered as an essential mode of urban traffic system.

Just as electric vehicles in comparison with the traditional fuel motors, electric bicycles not only inherit such advantages as green, cheap and healthy of manual bicycles, but also add the new functions of fast, high bearing and transporting capacity similar to automobiles. That makes electric bicycles develop rapidly, especially in the plain districts suitable to their driving properties. And electric biking trips have become a primary travel type for the citizens in Chengdu, Sichuan Province. The total amount of electric bicycles in this area reached 5 million (Li Xin, 2013), accounting for more than 90% of the total amount of non-motorized vehicles. The traditional manual bicycle proportion is decreasing year by year, urban trip structure has changed greatly.

New traffic structure has led to the urban transport in Chengdu city highlights a series of sharp contradictions. There are frequent electric bicycle traffic violations, speeding, ignoring red lights, illegal carrying things and taking more riders, and so on. Many motor vehicle accidents are caused by electric bicycle violations. At intersections, their competing to go through, occupying the space of motor traffic and riding on the motor carriageway have become the causation of the decreasing capacity and growing congestion of urban road network. These problems result from both the lack of awareness of civilized traffic behavior, and the vehicular and traffic characters that different from manual bicycles' characters. Are electric bicycles the "trouble-maker" or the key factor of urban traffic system? Should the total amount of electric bicycles be controlled? Or should electric biking traffic be lead in cooperation with other urban transport types? It is necessary to study the traffic characteristics of electric bicycles deeply in order to orient electric bicycles correctly and optimize their application and management.

2 Review of current applications and researches

The studies on the traffic characteristics of electric bicycle are relatively less, especially little attention has been paid to such a topic abroad where there is a lower non-motorized proportion. The existing literature and data emphasize mostly on the design and improvement of the vehicle structures and overall management tactics. Some strong correlation results include: Ma Guozhong et al. pointed out that the design speed and weight of electric bicycles are the main factors to influence the traffic safety (Ma Guozhong et al., 2006). Zhu Wenting et al. discussed the relationship among traffic accident, speed and load, deduced different safe braking distances under the road, speed and load conditions respectively (Zhu Wenting et al., 2011). Zhou Wenhua et al. analyzed the influence of electric bicycles to urban traffic structure in China (Zhou Wenhua et al., 2005). Chen Yanyan et al. researched the development of electric bicycles in Beijing from safety, environment, urban transport strategy and so on (Chen Yanyan et al., 2002). Ye Xiaofe et al. obtained that the conversion coefficient of electric bicycle relative to manual bicycle is 1.2295 based on the data of traffic survey in Nanjing City (Ye Xiaofei et al., 2012).

Altogether, the present researches fall short in the group behaviors, macro and micro characters descriptions under practical traffic environment. And domestic management regulations of electric bicycles are formulated mostly from the perspective of administrators or by means of artificial experiences, there is a urgent need of research on practical traffic operation of electric bicycles.

3 Traffic survey on electric bicycles

3.1 Operation overview

This survey focused on where are No.3 ring road and the sections of radial main road. In consideration of the road network structure in Chengdu City, with the land layout and development, population distribution and economic development and so on, 16 intersections, 32 sections of urban roads and 4 roads out of the city were selected as the survey spots. The investigations included traffic volume, speed, violation behavior and infrastructure, and the works started at the end of October and finished at the beginning of November in 2012. The investigating time ranged over morning and evening rush hours.

3.2 Data analysis

By statistical analysis on the practical investigating data (Chengdu Transportation Committee and Southwest Jiaotong University, 2013), some results can be found. For example, the electric bicycle traffic accounted for above 70% of non-motorized traffic. The proportion of electric bicycles to non-motorized vehicles on over 88.2% survey spots is over 75% and on over 50% spots is over 80%. So it indicates that electric bicycles have been replacing manual bicycles as the main transporting types of personal traffic in short distances in Chengdu.

Electric bicycles in Chengdu tend to light motorization corresponding with their taking dominant position increasingly. Due to higher speed, greater mass, large number and good mobility of electric bicycles, the traffic accidents related to them appear the characteristics of higher accident prone and severity. The common violation behaviors take many forms as speeding, carrying people and cargo together, competing to occupy motorway, riding on the wrong side of the road, running the red light or across the stop line at intersections. Through sampling observation of sections, it could be found that some riding on the wrong side of the road are resulted from the absence of convenient crossing facilities. For example, the crossing road is too far, overpass or underpass are planned and designed irrationally that is unable to meet the demand of the electric bicycle crossing the street. From the data on the 16 intersections and their 32 approaches, it also can be seen that running the red light or across the stop line at intersections accounted for 40.8% of the total traffic violations and 10% of total traffic volume, resulting in more serious safety problems. Electric bicycles often compete with motor vehicles for traffic time and space. There exist serious conflicts and interferences of the electric bicycles and motor vehicles at large intersections. At some bus stations, the non-motorized vehicle lanes are occupied by the platforms. Not only the lane width is cut down but the normal electric bicycle riding also disturbed seriously by the passengers waiting at the stations. That results in the poor continuity of non-motorized traffic.

The average speed of motor vehicles on the main roads downtown in Chengdu is 18 km/h. But the running speeds of electric bicycles are generally above 15 km/h, around 17-20 km/h far more than the average speed of about 10 km/h of manual bicycles. The practical running speed of electric bicycles has been in close to that of motor vehicles. In other words, the motor vehicles have not any advantages compared to the electric bicycles from the perspective of speed during rush hours. For example, the electric bicycle speeds and corresponding frequencies on Xihua Avenue are shown as Figure 1.

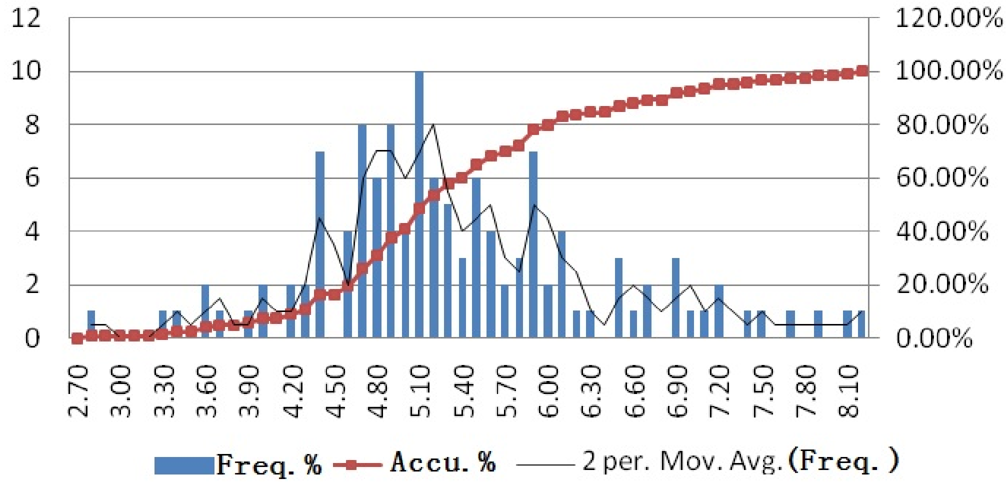

Figure 1. The speed –frequency distribution of electric bicycles

Figure 1 indicates that even in the traffic peak period the electric bicycles still maintained a high speed, about 70% of electric bicycles ran at the speed from 15 km/h to 23 km/h, over 70% of electric bicycles ran at more than 20 km/h, far exceeding the upper bound of 15 km/h regulated by the *Chengdu Non-motorized Vehicle Management Rules* (CNVMR).

4 Development orientation and mode

According to the traffic characteristics of electric bicycles, as well as their advantages and disadvantages in the practical operation of Chengdu, the development orientation in Chengdu should be positioned as main body of non-motorized vehicles ownership, type diversity, coordination with urban transit, standardization and strict management, and humanization in traffic organization. By extension some instructions could be obtained as below.

(1) Electric bicycle is the direction of development of non-motorized travel.

(2) Electric bicycle should be promoted to develop orderly as the structural element of the comprehensive transportation system by scientific guide.

(3) More strict regulations and implementations.

(4) To enhance the level of traffic service facilities for electric bicycles.

For electric bicycle travel, the transfer mode of “electric bicycle + public transport” should be implemented, and B+R (Biking & Riding) transfer system should also be established.

This is a green development mode consistent with the actual traffic in Chengdu. On the one hand, the normal "manual bicycle mode" in transferring has been converted into the "parallel mode of electric and manual bicycles" from such aspects as policies, going and parking facilities, improving electric bicycle travel conditions. On the other hand, the speeding and other violations of electric bicycles have been controlling strictly and the electric bicycles exceeding national standard have been reduced and will be eliminated, promoting electric bicycle transport into effective and sustainable development.

5 Application management

Electric bicycle transport problems couldn't be simply attributed to the product or industry itself. The causes include riders, vehicles and facilities. But the main problem is management. With further popularization of electric bicycles, higher and higher traffic pressure will be induced, forming a series of challenges on road traffic management. It is necessary to present systematic countermeasures to solve new traffic problems due to electric bicycles.

5.1 Basic strategies

In general, there are eight aspects of contents:

(1)To implement the registration mechanism of electric bicycle;

(2) To implement the qualified products list management for electric bicycles;

(3) To strengthen the enforcement of relative laws and regulations on the traffic violations of electric bicycles;

(4) To establish the waste battery recycling system for electric bicycles;

(5) To strengthen the supervision and management of the electric bicycle production and sales from source;

(6) To make a clear distinction among the relevant management department responsibility, improve the efficiency of management;

(7) To improve relevant laws and regulations

(8) To improve the supporting facilities in order to ensure the effect of measures.

5.2 Traffic facility design

Firstly the coordination planning should be prepared comprehensively among the traffic facilities of electric bicycles and other vehicles, as well as urban architecture. Then the detailed engineering works include traffic designs on the non-motor vehicle lane, non-motor vehicle crossing facilities, non-motor vehicle parking facilities, non-motor vehicle traffic signs and markings, and non-motor vehicle lighting system.

How to implement the above strategies and take or select the designing parameters could refer to the *Study on the Orientation and Guidance Strategies of Non-motorized Vehicle Development* (Chengdu Transportation Committee and Southwest Jiaotong University, 2013), which is developed by Prof. Liu Lan and his team.

6 Conclusion

Chengdu's practices indicate that electric bicycle is a kind of energy saving, environmental protection, economic, fast and safe transport means. And it is an effective way to solve the travel problem for low-income groups in urban districts. And it is also an important element of urban integrated transport system. Electric bicycles should be selected as one of the main transport means in urban districts. But they may also become the important causes of traffic violation and congestion due to their special characters of speed, weight and size, which is different from manual non-motorized vehicles.

It is necessary to represent a compromise to balance the interests of all parties, neither harming electric bicycle production enterprises and riders, nor ignoring the dangers of electric bicycles. Therefore strict production supervision and traffic management should be implemented for electric bicycle traffic. And the service facilities must be improved to match traffic characteristics of electric bicycles. It is worth noting that the transfer trip with mass transit would be the function orientation and application direction for electric bicycles. Such application requires perfect biking and riding facilities and effective information service system.

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References

Chen Yanyan, Liu Xiaoming, Hong Feng, et al. (2002). "The study of development strategies for electric bicycles in Beijing". *Road Traffic and Safety,* 4, 14-17

Chengdu Transportation Committee (CTB), Southwest Jiaotong University (SWJTU). (2013). Study on the Orientation and Guidance Strategies of Non-motorized Vehicle Development, Chengdu, Sichuan Province.

Li Xin (2013). "The Journalist's investigation: 5 million electric bicycles in Chengdu going beyond the amount of motor vehicles." Sichuan online-Huaxi Metropolis Daily, Mar. 20

Ma Guozhong, Ming Shi-jun, Wu Hai-tao (2006). "On safety character of electric bicycle". China Safety Science J., 16(4), 48-52

Ye Xiaofei, Chen Jun, Gu Shanshan (2012). "Conversion coefficient of electric-bike into bicycle on urban road section". J. Highway and Transportation Research and Development, 29(10), 109-116

Zhu Wenting, Xu Cong, Shi Jianrong, et al. (2011). "Relationship between load and speed and traffic risk of electric bicycle". J. Tran. Info. And Safe., 29(5),

92-95
Zhou Wenhua, Xu Zhixiu (2005). “Discussion on effect from the development of electric bicycle on traffic configuration in domestic cities”. Communications Standardization, 141, 116-120

Network Development of Modern Trams

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Abstract: In the trends of rail transit network development, this paper gives a brief analysis of the superiority and impact factors of the modern tram network development. On this basis we present three kinds of adaptation modes of the modern tram network development. These three modes respectively focus on the small and medium-sized cities groups, the new town in big cities and the ecological tourism zone. At the same time we conduct the case studies.
Keywords: Modern tram; Network development; Adaptation mode.

1 Introduction

Since the 1990s, a large number of major European countries restore or create some new modern tram lines, which are planned into networks in small and medium cities to replace the buses. The modern tram's revival gradually attracts our country's attention, and lead to a construction boom by virtue of its own advantages. By the end of 2013, a total of 24 cities planned or constructed the modern tram, some had already completed the construction and put into operation (LAN Lan,2014). With the growing scale of the modern tram construction, the pace of its network develops faster and faster. Combining the modern tram's system characteristics, we research on its own advantages, factors and applicable models in network development, to provide the impetus and further promote to China's modern tram scientific network development and operations.

2 Rail Network Features

Rail network operators system emphasizes the result itself overall functionality and scale effects with respect to a single line when the size of urban rail transport network develops by a number of rail lines staggered convergence to form an overall "net" system. Rail network evolution process can be viewed as a development process from a single independent rail line to rail network operators having functional classifications, shown in Figure 1.

Figure 1. Rail Network Diagram

Rail network development will significantly improve the network traffic attractive features and enhance the function in the transportation system. According to the domestic rail network mileage scale threshold defined in accordance with the rail singlet average length estimates, the rail network usually develops into a rapid stage by the construction of 2 to 3 rail singlet and develop into a stable stage by the construction of 8 to 9 rail singlet (GUO Xiucheng, et al,2013).

3 Modern Tram Network Development Advantages

Modern trams system is in the volume of rail transport. Its main functions are regarded as a link connecting the metropolitan main city and outlying areas, and as the backbone transportation bearing peripheral groups in big cities and main areas in small cities (ZI Haibo, et al,2009). The former is the extend and complement for large capacity rail network. Its lines are relatively fragmented and low degree of networking. The advantages of modern tram network development are highlighted in the latter one, mainly shown in the following points:

(1) Highlight the advantages of green transport

Domestic cities in the process of economic development are always bound to face such problems as traffic congestion, excessive energy consumption and pollution. Urban transport system is one of the main sources of energy consumption and environmental pollution. So the development of non-polluting, energy-efficient modes of transportation undoubtedly is the promotion to solve urban social problems. Modern tram is a clean and energy-saving mode of transportation by electric driving without consuming non-renewable resources such as oil. Its introductions improve urban transport system structure. After a net operating the entire modern tram system efficiency will be enhanced, and so do the traffic environment capacity. At the same time it will reduce environmental objective constraints sustainable of urban transport development.

(2) Flexible running cross path

Modern trams can take unique or mixed road rights, also can take a variety of different running cross paths after network. Trains can run line collinear, or choose a variety of lines. It can give better service comparing to other rail transportation cross-line operations which mature technology is not yet convenient and flexible.

(3) Network effects reflect the value-added benefits

There are two points to rationally plan the modern tram network to reach a certain scale, coverage and liquidity. On one hand through the plan of network layout, construction sequence, transfer node program and entrances and exits, can attract tourists to achieve the network passenger benefits. On the other hand at the site perimeter do the implementation of property development, business development, media and information development and other aspects of the whole network co-ordination, to enlarge the value of the network operators and increase non-fare revenue sources. Network efficiency and value-added benefits of passenger will be bumper.

(4) Humanistic philosophy more in-depth

Modern trams own beautiful appearance and sit comfortable. It can run with undulating terrain and landscapes to make urban transport and natural landscape complement. With its network development, modern tram have become ubiquitous network traffic landscape. It carries the characteristics of different cities and cultures, deepening the humanities transportation philosophy, playing an important advocacy role values heritage and humanities. It has considerable recognition.

4 The Modern Tram Network Development Affecting Factors

Modern tram has developed over 120 years so far. The technical conditions of separate construction are more mature. The construction of modern tram in our country is changing from simple "Line type" to "Network type". Only when the transition fully completed, the modern tram's advantages are in order to truly reflect such as large capacity, convenient, safe and quasi-point. It is worth noticing that the network development process will bring opportunities. But the development is affected by many factors, mainly on national policy, urban environment, planning and operational control and the operational organization.

(1)National policy

There are many rail alternative ways, so we should consider many factors in the choice of city rail transportation, including national policies on rail transport like development strategy and overall development plan. China has not yet issued any relevant policies of the modern tram construction. The existing city modern tram networks are mostly in infancy. We need national policy to support providing more evidence and guarantee for the development of the modern tram network.

(2)Urban environment

Modern tram network development needs both in-depth studying of its own network characteristics and paying attention to study the relationship between the modern tram and other external networks like urban master planning and urban bus network. It helps further optimize the network structure, play network efficiency, and improve operational efficiency of the whole urban transport system. In addition, more considerations need to focus on urban geography and climatic conditions, especially those areas in special or bad weather. We should ensure the modern tram having safe and efficient operations.

(3)Planning and operational control

It's easy to implement the project at formation stage of the early modern tram network because the factors subjecting to construction are few in each line. The network construction will be related to the multi-line hubs operating line constructions, and more affected by the constraints. The implementation of the project is extremely difficult. Its main feature is the high construction of large-scale, complexity, quality, engineering, and technology risks content. Network constructions are reflected in the planning stage. Whether the transfer station synchronized planning, implementation, or network parking depot, the network level of planning control center, are extremely important to the main substation.

(4)Operational organization

The modern tram network development requires operators to organize urban spatial, land use and traffic adapted distribution. Operations management should change from a single sub-population management to co-ordinate transformation management. Regulatory should approach to the fine transition. Data management should focus on sharing information. By this way the lines or a combination of cooperation can form a unified overall operational efficiency. For example, wire mesh size, the lines and transfer passengers are increasing. There are more needs to select a matching cross-road tram running form and train plan. At the same time, the setting of lines in the transfer station, back line, lines cord, tie lines and other infrastructures, can also restricts the application of network operations organization methods and techniques.

5 The Modern Tram Network Development Adaptation Model

Modern tram network has significant advantages. The modern tram "into a network " is different from the "line type" modern tram because the former come up a higher requirement. By studying the modern tram network adaptation mode can provide theoretical guidance to the development of modern urban tram network. Most of our cities are pushing bus priority development strategy. Small and medium cities are suitable for building the modern tram. Building a modern tram network as the backbone of transportation to guide the development of public transport, supplementing by regular buses, taxis and other modes of transport, can be order to create efficient multi-level comprehensive urban transportation system. But for large cities inside, traffic resource constraints. The development of high strength, concentration of high traffic and mixed traffic issues are outstanding. More and more objective environmental constraints require large volume of rail lines as the backbone network and the modern tram extend and complement the backbone network. Therefore the scope of the modern tram network development should be explored combining the characteristics of urban development needs and considering the special circumstances.

5.1 Between small and medium cities groups

With the development of small and medium cities, urban space functional structure is gradually clear. It forms some different city groups, focusing on the development of competitive industries or economic characteristics, or achieving specific social function. Among different functional small and medium city groups there are greater demand for transport corridors. Taking into account the moderate population and land size, it is particularly suited to modern tram network development by different group centers. By this way meet passengers demand and use rail network radiation to adjust and optimize the function of each tour location. Similarly, no matter what kind of functional group, they all need fast and convenient transportation to increase green area attractivity. The modern tram network uses its advantages to create a harmonious and comfortable traffic environment. So it can largely replace private cars and long-haul buses for those powerful life groups. The modern tram spread internal group to external access site for the center of the ring-type network. Thus it focuses the internal life of the area around the site and creates a "door to door" traffic community development models, build a beautiful environment, quiet life living area (WANG Mingwen, et al,2007). With the development of modern tram network, residents can also customize the modern tram's time of departure frequency according to their needs. For example, at the peak of shorter headway, schedule most vehicles to meet peak passenger flow direction, and at night to reduce the train to mitigate the impact on the lives area. In special events we increase train to meet the special needs of passenger flow, make the modern tram operating organization more efficient, humanistic, a resident of their own "private train".

Yibin is planning the modern tram which belongs to this model. Yibin is in the full implementation of bus priority development strategy, planning to build 7 tram lines into the net total of 168.1km. It strives to form integrated public transport system that the modern tram as the backbone system, regular bus as the main body, small buses and ferry system as the complement. Yibin is a typical urban development group city. The modern tram lines network plan cover all 15 groups, and make each of the core groups together. Thus it separates groups in old city area's population, eases traffic pressure, promotes the development of new groups, and enhances the overall quality of the city center. At the same time it forms the special features of the landscape along the belt line, rail travel fast lane, airport express high-speed rail lines. T4 line in network goes into a ring at the South Stream independent groups which is a national industry model. So the internal groups travel more convenient and comfortable. The South Stream live groups can concentrate on creating "door to door" transportation community development model, making the development of the modern tram network into a deeper level.

5.2 Inside metro cites

When urban development reaches a certain size, it will make the original spatial organization development model change to begin gradually expanding the space outside the city that is the construction of the metro. As the expansion of the metro area shares the downtown urban functions, it generally drive the development and utilization of regional economic development along transportation through the construction of rail transit or urban freeway. At the same time it support and guide the metro superior resources. Peripheral metro is in the development stage, which generally have a clear function of unified planning. It has more moderate passenger demand and road construction is also in the initial stage. But planning perspective passenger demand is growing faster, having higher capacity loading rate environment. These are suitable for modern tram network development system. From the development of long-term strategic significance, the area plan overall in advance, and the modern tram take advantage of green transportation and create a livable town.

The development of modern tram network makes the new town transport no longer route through a single connection into the center of the city. It greatly facilitates the travel of passengers, also share the single connection point at traffic congestion, make the traffic channel between town and the downtown unimpeded. Due to the lower bound metro road environment, the modern tram lines network can use a central green belt laying unified way. It should be considered to construct contact line between different lines, to make up trams better.

The modern tram construction in Hunnan new town in Shenyang belongs to this model. Shenyang City let the "Golden Corridor, silver belt" as the skeleton, plan the “two cities, two districts, multi-center” to form a spatial structure. Hunnan area focuse on the development of large business exhibition, researching, recreational sports and other modern services. It will become the city's future administrative and cultural center. So till 2013 there is an opportunity to build a modern tram network, a one-time planning and construction of nine lines, length of 139.3km (WANG Yingjie, et al, 2014). Hunnan modern tram network as trunk transportation full account of the extended reservation network operators to meet the needs of rail transport separation, to meet future demand for passenger transport development corridor. It not only provides a safe, comfortable, fast, user-friendly service , but also makes full use of the existing road resources to provide a solution for metro transportation development model. It’s guided by the construction of public transport infrastructure in advance of travel modes and residents car regulatory development. Thus promote the metro ecological sustainable development of Hunnan new area.

5.3 Eco-tourism zone

Eco-tourism industry due to its characteristics, urban transportation needs seasonal change, and visitors have a motorize, individual tendencies. Urban transport systems assume the dual pressures of local and foreign traffic. Urban residents and visitors focus on the different transport services. This requires the construction of transportation systems with eco-tourist attractions. Modern streetcar system’s fast, comfortable, green, and other features in such a city will be fully reflected. But considering the limitations factors, we particularly definite the eco-tourism zone as the fitness area the modern tram network development.

Eco-tourism zone, which is special ecological environment and tourist attractions in eco-tourism city, gather related services industries driven by scenic or ecological tourism development. Modern tram network cover the entire eco-tourism zone and band together to support their strengths and meet the different seasonal variation, high mobility, strong individual tourist flows, acting as a wide range of "public tourist traffic". Thus not only meet passengers traveling quality, comfort and high travel requirements, but also service as a unique transport landscape itself into eco-tourism area, to develop related industries.

Here we need also talking about crossover model of eco-tourism zone network development. If the zone is located in the center of major cities, where has been built a higher level of rail transportation such as subways, then the modern tram network development's main direction is the existing rail line network encryption, characterized by emphasis on the existing rail. Each line is wire short length and complex. If the zone is located in the center of the small and medium city, then modern tram network development's direction will also consider both factors among small city groups and ecological tourism function. Similarly, if the zone is located in the metro or district, also take into account two models of new city and ecological tourism.

SND(Suzhou New District) modern trams is this development model that make eco-tourism zone and the metro district balanced. SND is located in the core area of the Yangtze River Delta, west downtown of Suzhou. It will create an overall spatial structure called "one core, one center, two biaxial, three areas". SND plan to construct six modern tram lines, total length 80km, including three basic lines, two complementary lines and a characteristic line. Thus will form four integrated transport hub including Suzhou park, intercity rail, eco-city and wetland (MIAO Caixia, 2013). The role of T1, T2, T4 line are connections between high-tech zone and the main city rail to play extended transitional and complementary. These six lines as the backbone of transportation systems adapt to high-tech zones to guide urban development. At the same time gather the scenic Taihu, Wetland Park, Suzhou park and related industries eco-city linking up, belong to the eco-tourism zone network development model. It shows the ecological characteristics of the bus system style of high-tech zones.

6 Conclusions

The development of modern tram network, takes advantages in the economic, safe, convenient, environmentally friendly, humane, and enhance to be further "green transport" and "human traffic" reflect. It is great significance for the improvement of urban transport environment, reducing urban traffic pressure and improving the image of the city. Therefore, to those small and medium cities which have built the modern tram lines, should actively promote their construction development. To those big cities which overall plan and integrate metropolitan transportation planning, should recognize the role of the modern tram fit. It should be recognized in demand, function, sustainable development and other aspects, choose rational planning and compatible network construction mode of urban development.

References

LAN Lan. (2014). “National Modern Tram Construction”. *Construction Machinery Digest,*04:81-86.

GUO Xiucheng, KONG zhe. (2013). “Evolution Mechanism and Generation Method of Urban Rail Transit Network.” *Science Press.*

ZI Haibo, GUO Xiucheng and YANG Jie. (2009). “On the Application and Adaptabilit of Modern Tram car.” *Urban Mass Transit,* 02:46-49 .

WANG Mingwen, WANG Guoliang and ZHANG Yuhong. (2007). “Modern Trolley and Urban Development: How Do They Fit Together ?.” *Urban Transport of China,*06:70-72.

WANG Yingjie, WANG Jingyi. (2014). “Planning and Construction of Modern Streetcar System in Shenyang City.” *Urban Mass Transit,*02: 125-128 .

MIAO Caixia. (2013). “Characteristics of Modern Tram and Its Application Prospect.” *Urban Rapid Rail Transit,*03: 9-12.

Lightweight Design of Vehicles under Green Traffic

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Abstract: The lightweight design of vehicle has become an important research topic of green transportation because of many advantages with high security, energy-saving, emission reduction and so forth in the environment of the green traffic. In a premise of clear understanding of lightweight vehicles, the article discussed the factors influencing lightweight vehicle design from the two aspects of design cost and vehicle energy consumption. The research results show that: through the use of green welding forming technology, it can effectively reduce the vehicle quality and the energy consumption. By using aluminum alloy, weathering steel and composite material composite structure design, not only it can satisfy the requirements of the integration of the vehicle structure, but also can reduce the vehicle weight to realize the balancing of benefits and costs so as to provide a good direction for the green traffic to build a resource conserving and environment friendly society.
Keywords: Green transportation; Structure design; Lightweight design of vehicle; Green manufacturing.

1 Introduction

1.1 The Green Transportation and the lightweight design of vehicle

The Green Transportation is important for the inevitable choice to acquire sustainable economic development. It also plays an important role for providing a humanity living environment. The core of Green Transportation includes trip accessibility, passenger safety and convenience, minimization of the expense of the resource and land, compromise between transportation and environment, and the system self extensibility.

For conventional fuel vehicles, the current research and development are heading for efficient, low energy consumption and emission development, these indicators are closely related with the quality of automobile. Also, automobile lightweight is the most effective way to reduce vehicle fuel consumption and emissions.

For the sustainable development of the automotive industry, energy saving, environmental protection and safety problems have been in urgent need to solve, where the lightweight design of vehicle ought to be put forward.

1.2 Research status

Cristello put natural frequency, torsional and bending stiffness, maximum Mises stress as constraint, considering the quality, manufacturing speed reduction and the collision process, the use of multidisciplinary optimization design method of zero emission vehicle frame is optimized.

Abhijit Londhe uses the method of test design of lightweight design of natural frequency, stiffness and strength of a SUV model based on the research.

Alimardani considers the car dashboard support NVH and crashworthiness, and use the size optimization method to carry on the structure lightweight design.

Based on the Cui Xintao body quality, structure performance and cost, using the method of lightweight multi material body, in all parts of the body material type and thickness as design variables to build the body material and structure optimization design mathematical model, finally has carried on the optimization using genetic algorithm.

Zhang Weigang for automobile front rail structure, optimize the use of the structure of the multi objective optimization design method of stepwise regression model based on the research.

2 The forming of lightweight technology

As is discussed above, lightweight automobile body is the purpose of the car performance unchanged as the premise, reduces the quality of body in order to reduce the vehicle quality, thus reducing the fuel consumption, reduce pollution, but also the manufacturing cost of automobile try not to be improved. At present, the main ways to reduce mass of body including the use of lightweight materials, advanced forming technology and manufacturing process and body structure optimization design.

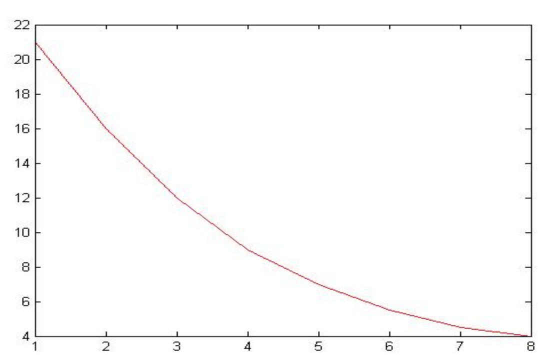

Fig. 1 Lightweight and body weight diagram

As is shown from the diagram drawn in matlab. Light weight does not necessarily reduce the performance of the vehicle, the automobile lightweight in reducing vehicle quality and can also reduce the vehicle 's center of gravity, thus effectively improving the performance of motor vehicles; smaller car quality can improve drivetrain load; in passive safety, lightweight can shorten the braking distance and reduce the collision process of inertia and kinetic energy in the collision of the automobile lightweight; at the same time can also reduce the automobile in the running process of a lot of resistance.

The forming of lightweight technology refers to meet the application of high strength material, and realizes the part integrated design need to adopt technology. At present, these are the widely used: TWBs Technology (TWB), hot pressing forming technology (HPF) and hydraulic forming technology (HF) etc..

2.1 TWBs Technology

Over the past 10 years, the rapid development of technology in aerospace and automobile industry in laser welding. Tailor welded blanks can according to the requirements of the different properties of each part of body parts, the use of welding method to weld two block or plate of different thickness, performance or materials together, the formation of laser tailor welded blanks (TWB) for stamping, so as to reduce the number and weight of parts and reduce the cost for such purposes, at the same time also ensure the integrity of structure and precision of variable cross section plate; continuous extrusion (TRB) is the use of flexible rolling technology a sheet rolling forming. Due to the continuous change of the cross section shape, compared to the performance of TWBs with material has better. In recent years, variable cross section plate technology has been widely used in the automotive industry.

2.2 hot pressing forming technology

Plate body structure and body used determines the body strength, the body of some key parts often need steel high strength steel plate. Hot forming is one of the many solutions. Hot forming, the yield strength of the steel plate can reach more than 1000Mpa, if the use of heat molding plate in the body, it can be in constant mass based on the strength is improved 30%. And the tensile strength of steel plate, hot forming is about 3 times that of ordinary steel, but also have very high hardness of both the steel toughness. Application of hot forming of steel can greatly improve their safety performance, the collision process can give good protection of occupant.

2.3 hydraulic forming technology

Hydroforming is a plastic processing technology for force transmission medium using liquid alternative to traditional die or punch to make parts processing. Technology is not only used in the precondition of ensuring the parts stiffness, strength and uniformity of the lower hydraulic forming, but also can improve the quality of products and forming limit.

3 Lightweight technical indicators

Lightweight technical indicators can give body to develop a directional guidance, it is difficult to form a highly recognized in the industry index. The following is the application of several kinds of lightweight car body index:

(1) Light Weight Index

Type (1) is defined as a light Weight Index:

$$L = \frac{M}{C_T \cdot A} \times 10^3 \tag{1}$$

In the formula, L is a light Weight Index; M for body in frame quality, kg; C_T for static torsional stiffness, Nm/ (DEG), including the windshield and side frame; A is the projection area, m^2; A= wheelbase * (track front + rear wheel) /2.

(2) The minimum yield strength

The minimum yield strength reflects the high intensity ratio of timber in the body, the body is minimum yield strength per unit mass of the yield strength values, the calculation method of formula (2):

$$R = \frac{\sum_1^n R \times m_i}{\sum_1^n m_i} \tag{2}$$

In the formula, n is the number of body parts; m is the quality of the parts; R is the yield strength of the material.

In the process of lightweight design, using different types of stainless steel with different yield strength and tensile strength, the relevant mechanical properties of common stainless steel material in the vehicle design comparison diagram, including the yield strength, tensile strength and elongation of the comparison in the concrete implementation step, should be based on the design of the construction unit requirements to determine the specific.

Table 1. The mechanical properties of different types of stainless steel sketch

Grade	Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation rate %
SUS301L-LT	≥215	≥550	≥45
SUS301L-DLT	≥345	≥690	≥40
SUS301L-ST	≥410	≥760	≥35
SUS301L-MT	≥480	≥820	≥25
SUS301L-HT	≥685	≥930	≥20
SUS304	≥205	≥520	≥40

(3) The quality of body volume unit

Body mass per unit volume refers to quality in the whole body in space in the unit volume of material contains, the calculation method of formula:

$$Q=\frac{M}{V}=\frac{M}{L\cdot H\cdot W} \tag{3}$$

In the formula, M is the quality of body; L, W and H respectively for white body length, width and height.

(4) Lightweight cost coefficient

In modern lightweight trolley in design process, the design cost lightweighting is for lightweight design can fully applied to an important constraint condition of the course of events. Therefore, how to coordinate the application significance of lightweight design and cost of the technology is very practical.

In the green traffic environment, the design of the lightweight body needs not only many physical properties of the vehicle's consideration, also need to ensure energy conservation and environmental protection concept of green transportation, so in the light of quantitative assessment index, need to research and development, materials, repair and so on. The calculation method of the following specific formula is shown:

$$LC=\frac{\sum h_i\times k_i\times t_i}{K\times T} \tag{4}$$

In the formula, h refers to the number of design units, k refers to the unit cost of the design units, t refers to the unit time design. K refers to the total cost of the design units, t refers to the total time design.

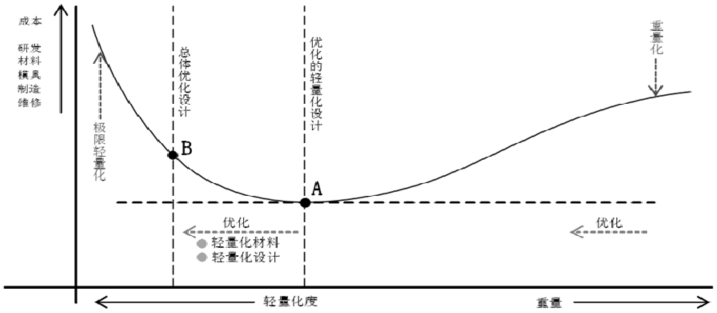

Fig. 2 Relationship between the lightweight design and technology costs diagram

From Figure 2, the existence of optimization of the lightweight design of A and the total light weight design of B between the vehicle's lightweight degree and cost of the technology, according to the actual need proper selection of the weight of the meet, in the appropriate technologies cost range, get the optimal design of vehicle lighter .

4 Sensitivity analysis

Sensitivity analysis of the objective in lightweight optimization of body structure design, is not only to determine the body in structure on its performance but also to design sensitive variables to lose weight.

The response of a system is determined by the properties of composition of the various parts of this system, and each attribute parts and the influence degree of the system response of each are not identical. Sensitivity analysis can be obtained which attributes influence on the response of the system to larger or smaller, so as to provide suggestions for designers.

In the sensitivity analysis method, the parameters of the system by using the variable V_i parameter, for the design goal of G, the function relation is formed between V_i and the design variables, namely g=G (V_i), if the design of the variable V_i has small changes, the design goal was to produce corresponding change:

$$\Delta g = \frac{\partial G}{\partial V_i} \Delta V_i \tag{5}$$

When the design variables change the same value, namely the I Delta V = Delta, Delta and variation of the design goals of g each are not identical, iGv can sensitivity is defined as the design goal of G to the design variables V_i. Using the body stiffness sensitivity of each plate thickness analysis as an example, the finite element equilibrium equation for elastic statics:

$$[G]_{n\times n}[J]_{n\times 1}=[F]_{n\times 1} \tag{6}$$

In the formula, N is the degree of freedom; $[G]_{n\times n}$ is the the total stiffness matrix; $[J]_{n\times 1}$ is the structure of displacement vector; $[F]_{n\times 1}$ is the load vector.

On the design variables V derivative can be obtained:

$$[G]_{n\times n}\left\{\frac{\partial J}{\partial v}\right\}_{n\times 1}+\left\{\frac{\partial G}{\partial v}\right\}_{n\times n}[J]_{n\times 1}=\left\{\frac{\partial F}{\partial v}\right\}_{n\times 1} \tag{7}$$

Among them, the design variables can be focused on the lightweight design according to different determined, and then complete the sensitivity analysis of lightweight car body design.

5 Model of lightweight design

The design variables, constraints and the objective function are the three elements of the optimization design. In the lightweight body structure design, with each plate thickness as design variables and body first-order torsion and bending natural frequency as the constraint conditions, using the body quality minimum, torsional and flexural rigidity and maximum the optimization goal, the definition of the natural frequency changes the amount not less than the original frequency of 95%, and the lightweight cost coefficient of cost and weight coefficient of the standard deviation of not more than 30% to get the body of multi-objective lightweight optimization design mathematical model:

$$\min f(x)=\{f_G(x),-f_{\Delta L}(x),-f_b(x)\} \tag{8}$$

$$f_{\Delta L}(x)=\sqrt{|f_L(x)-f_{LC}(x)|} \tag{9}$$

Among them, $f_L(x)$, $f_{LC}(x)$ need through the following algorithm for data standardization processing, then into operation of $f_{\Delta L}(x)$:

```
X=X/;
Stdr=std(x);
[n,m]=size(x);
Sddata=x/stdr(ones(n,1):);
```

Then:

$$f_{\Delta L}(x) \leq 0.3 \tag{10}$$

$$\frac{g_b(x) - g_{ob}(x)}{g_{ob}(x)} \leq 0.05 \tag{11}$$

$$\frac{g_b(x) - g_{\mathrm{ot}}(x)}{g_{ot}(x)} \leq 0.05 \tag{12}$$

$$x = [x_1, x_2, x_3 \cdots, x_i]^T, i = 1,2,\cdots \tag{13}$$

$$-0.1 \leq \frac{x_{oi} - x_i}{x_{oi}} \leq 0.3, i = 1,2,\cdots \tag{14}$$

In the formula, $f(x)$ is the objective function; $f_G(x)$ respectively for yield stiffness objective function ; $f_{\Delta L}(x)$ is the quality objective function; $f_b(x)$ is the torsional rigidity of objective function; $g_b(x), g_t(x)$ is first order bending natural frequency model and first-order torsional inherent frequency during the process of optimization, $g_{ob}(x), g_{ot}(x)$ is first order bending natural frequency model and first-order torsional inherent frequency in the initial model.

6 Conclusions

The lightweight body structure multi-objective collaborative optimization design method to the body is established seeing the minimum mass and stiffness maximum as optimization objective. The whole body a twist modal frequency taken as constraints, design variables on the sensitivity analysis is about to determine the thickness of the multi object body the collaborative optimization design.

References

Calthorpe P. The next American metropolis: Ecology, community, and the American dream. *Princeton Architectural Press*, 1993.

G. H. Daneshi, S. J. Hosseinipour. Experimental study on thin-walled grooved tubes as an energy absorption device. Structures and Materials, 2002(11): 289-298.

M. Alimardani. Computational Optimum Lightweight Design of An Instrument Panel Support Structure. Toronto: University of Toronto (Canada), 2004

Powell M. J. D. Radial basis functions for multivariable interpolation: a review[C]. Proc. IMA Conference on Algorithms for Approximation of Functions and Data, Shrivenham, UK, 1985.

Uykan Z, Guzelis C, Celebi M E et al. Analysis of input-output clustering for determining centers of radial basis function networks. IEEE Trans. Neural Networks. 2000, 11(4): 851-858.

Wu Qiang, Gong Jinke, Chen Genyu, et al. Research on laser welding of vehicle body. Optics and Laser Technology, 2008, 40: 420-426

Y. Zhang, P. Zhu, G. L. Chen. Lightweight Design of Automotive Front Side Rail Based on Robust Optimisation. Thin-Walled Structures, 2007(45): 670-676.

Design and Simulation of a Battery Swap Station for Electric Battery Buses

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Abstract: Developing battery electric bus (BEB) has become a good means to help cut down the increasing greenhouse gas emissions and global crude oil demand. Due to the limited driving range and long charging time of BEB, battery swap station (BSS) seems the best option for BEBs to replenish energy at present. This paper presents a novel method to design the BSS for BEBs. Based on several assumptions and running rules for BEBs, the swapping and charging demand of BEB fleets are analysed to calculate the design scale of the BSS, which include the scales of battery packs, battery swapping system and battery charging system. As a case study, the BSS serving for 120 BEBs in World Expo 2010 Shanghai China, are simulated through a Matlab program. The results show that the simulation can provide an equivalent level of operation. And the scales calculated by the method are close to the actual values, which indicates that the design method we proposed is effective.
Keywords: Battery electric bus; Battery swap station; Swapping and charging demand.

1 Introduction

Developing battery electric bus (BEB) is a good choice to limit the emissions and demand for fossil fuel due to increasing number of vehicles. To overcome the disadvantage of driving range, it's necessary to construct charging/battery swap infrastructure for these BEBs.

There have been a number of studies related to this subject. But these studies mostly focused on the charging infrastructure for electric cars not including BEBs (Aultman-Hall et al. 2012; Dong et al. 2014; Kuhne 2010; Lee et al. 2014; Nie and Ghamami 2013; Sellmair and Hamacher 2014; Tuttle and Fellow 2012). The charging demands of BEB fleets are quite different from those of electric cars. So it's necessary to propose some new and special infrastructure planning methods for the BEBs.

On the other hand, most researches only study the charging station rather than the battery swap station. Only a few literatures involved the battery swapping. Yu et al. (2014) proposed a model and efficient method for the optimal planning of charging station and BSS, whoes results show that BSS is more suiTable for public transportation. Kaschub et al. (2012) proved the economic feasibility of BSS for

BEBs. But they did not discuss how to calculate the scales of the BSS based on swaping and charging demand of the BEB fleets. None of the existing literatures have ever studied the design of the BSS for BEBs.

The objective of this paper is to propose a method to calculate the economically ideal scales of swapping/charging facilities and battery packs that BSS should deploy to meet the swapping and charging demand. As a consequence, the BEBs can be widely adopted in the marketplace.

2 Method

2.1 Running Rules of BEBs

Several assumptions and rules are made for BEBs to follow.

Assumption 1: The BSS is built near by the bus terminal station of several routes.

Assumption 2: Each battery pack in BEB is full initially and will be replaced with another full one in BSS;

Assumption 3: The energy consumption of battery pack is linearly associated with mileages ignoring the impact of weather and passenger flow;

Assumption 4: The charging time of battery pack is in direct proportion to charging depth, in inverse proportion to charging rate.

Rule 1: BEB only departs from bus terminal station, running back and forth along the route counts as a round. All BEBs of the same route go to the same BSS for battery swapping, then back to bus terminal station waiting for next round;

Rule 2: BEB won't go to the BSS during a round until it has finished this round. Namely, if the energy is not enough to support next round, it's time for the BEB to swap battery;

Rule 3: When BEB finishes the daily running hours, it heads for the BSS to replace the battery pak with a full one, no matter how much energy is left. Then, back to the bus terminal station for parking, ending the operations of a day.

The running track of BEB is showed in Figure 1.

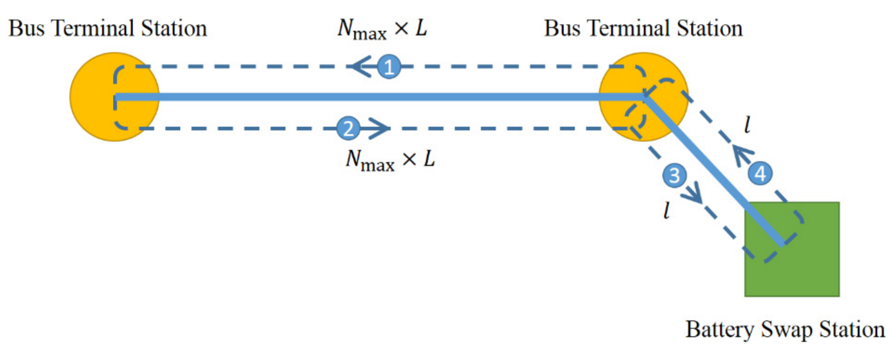


Figure 1. The running track of BEB.

Given the operating schedule of the route, departure and arrival time of each BEB can be obtained, then:

$$Arrive(m,n) = Depart(m,n) + T_c \quad (1)$$

$$T_c = \frac{L}{V} \times 2 \times 60 + n_{stop} \times t_{stop} \times 2 \quad (2)$$

$$N_{bus} = \frac{T_c}{I_P} \quad (3)$$

where n the serial number of each bus, *m* the serial number of each departure, *Depart(m,n)* represents m-th departure time of the bus n, *Arrive(m,n)* represents m-th arrival time of the bus n, T_c the cycling time of the route (min), *L* the route length, *V* the average speed of buses (km/h), n_{stop} the number of stops in the route, t_{stop} the average time of each stop (min), N_{bus} the bus configuration of the route, and I_P the departure interval in peak hours(min).

2.2 Swapping and Charging Demand Analysis

2.2.1Time Distribution of Battery Swapping

Plenty of researches show that depth of discharge between 70% and 80% is beneficial to the life of battery and provides a favorable working environment for BEB. So we make SOC_{min}>0.3, then actual max range of BEB can be calculated as follows:

$$range = Range \times (1 - SOC_{\min}) \quad (4)$$

where *Range* is the theoretical max range of BEB (*km*), and *range* the actual max range of BEB (*km*). Then max number of rounds per charge is calculated.

$$N_{\max} = fix(\frac{range - 2 \times l}{2 \times L}) \quad (5)$$

where *l* is the distance from bus terminal station to the BSS (km), fix(x) rounds the x to the nearest integer towards zero.

Whenever the BEB finished N_{max} rounds, it should run to BSS from terminal station for battery swapping. The swapping start and end time of BEB can be calculated based on arrive time of the last round.

$$SwapS(h,n) = Arrive(h \times N_{\max}, n) + \mathrm{T}_l \quad (6)$$

$$SwapE(h,n) = SwapS(h,n) + T_s \quad (7)$$

where *SwapS (h, n)* represents the start time of *h*-th swapping of the bus *n*, *SwapE (h, n)* represents the end time of *h*-t swapping of the bus *n*, both of them are $h \times n$ matrixes, T_l the time of BEB running from terminal station to BSS, and T_s the time each battery swapping should take. The number of battery swapping in every minute can be counted based on *SwapS (h, n)* and *SwapE (h, n),* which is denoted as *SwapDis(t)*, the time distribution of battery swapping.

2.2.2 Charging Time of Battery

The charging time of battery is determined by the depth of charge (*DOC*) which is equal to the depth of discharge (*DOD*). According to the Assumption 4, the charging time of battery is expressed as follow:

$$DOC = DOD = (N_{\max} \times 2L + 2 \times l) / Range \quad (8)$$

$$T_{ch} = \frac{1}{CR} \times DOC \times 60 \quad (9)$$

where T_{ch} is the charging time of the battery pack (min), *CR* the charge rate of the chargers.

2.2.3 Time Distribution of Battery Charging

In case the replaced battery pack will be transported to charging rack immediately, the start time of battery charging is equal to end time of battery swapping ignoring the transport time. Given the charging time, the end time of charging can be obtained.

$$ChargeS(b) = SwapE(h,n) \quad (10)$$

$$ChargeE(b) = ChargeS(b) + T_{ch}(b) \quad (11)$$

where *ChargeS(b)* represents the start time of *b*-th battery charging, *ChargeE(b)* represents the end time of *b*-th battery charging, both of them are $b\times1$ matrixes. The number of battery charging in every minute is counted based on *ChargeS(b)* and *ChargeE(b),* which is denoted as *ChargeDis(t)*, the time distribution of battery charging.

2.3 Design of the Battery Swap Station

The battery swap station maily consists of battery charging system, battery swapping system and monitoring system (Figure 1). Design of the BSS aims to decide the scales of BSS, which include the number of charging devices and swapping robots, the amount of battery packs, the power capacity of BSS, etc.

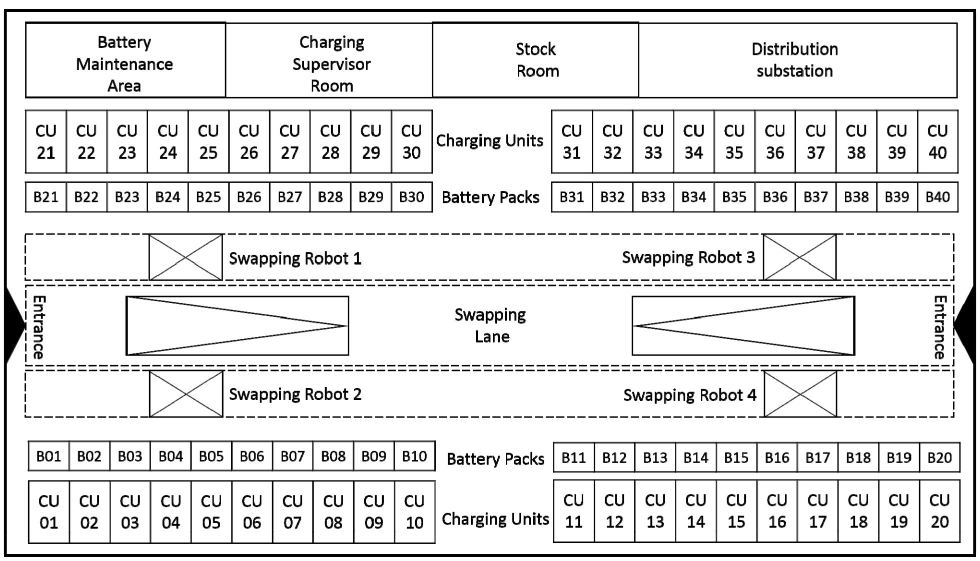


Figure 1. The example layout of battery swap station.

2.3.1 Scale of Battery Packs

With battery swap mode, BEBs should be equipped with a certain amount of backup battery packs to relive the disadvantages of short range and long charging time. So the number of the battery packs the BSS should hold is calculated as:

$$N_{Battery} = N_{Bus} + N_b \quad (12)$$

where N_{Bus} is the number of buses of all routes, N_b the number of the backup batteries. Due to the expensive cost of battery, the number of backup battery packs should be minimized when the normal operation is ensured. Therefore we propose an algorithm (Figure 2) to get the optimal number of backup battery packs.

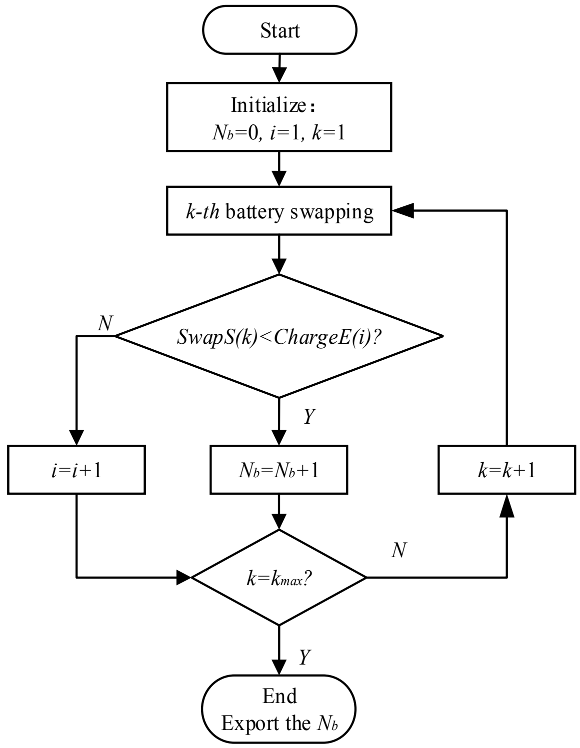


Figure 2. Algorithm of calculating number of backup battery packs.

2.3.2 Scale of Battery Swapping System

The battery swapping system is made up of several swapping units, each of which consists of a swapping lane and two swapping robots.When the BEB drives into the swapping lane and stops at specific location, the two robots can automatically complete the battery swapping. The number of battery battery swapping units (N_{SU}) is equal to the maximum number of BEBs whose batteries are being swapped at the same time in the BSS, which can be obtained from the time distribution of battery swapping.

$$N_{SU} = \underset{t=t_S}{\overset{t_E}{MAX}} \left(SwapDis(t) \right) \tag{13}$$

2.3.3 Scale of Battery Charging System

The battery charging system consists of a series of charging units responding to battery packs. Therefore the output power of charging unit should be matched with the energy of battery pack.

$$P_{CU} = \frac{U \times I}{\eta_{\max} \times \varphi} = \frac{U \times C \times RC}{\eta_{\max} \times \varphi} \tag{14}$$

where P_{CU} is the output power of the charging unit, U the charging voltage, I the charging current which is equal to the product of battery pack capacity(C) and charging rate(RC), η_{max} the max efficiency of charger, and φ the reactive loss of lines.

The number of charging unit (N_{cu}) should not be less than the maximum number of batteries that are charged at the same time, which can be obtained from the time distribution of battery charging.

$$N_{CU} = \underset{t=t_S}{\overset{t_E}{MAX}} \left(ChargeDis(t) \right) \times (1+\gamma\%) \qquad (15)$$

where t_S is the start of service time of BSS, t_E the end of service time, and $\gamma\%$ the design margin (10%~20%).

The power capacity of battery charging system depends on the output power and number of charging units in BSS, which can be expressed as:

$$P_S = N_{CU} \times P_{CU} \times (1+\gamma\%) \qquad (16)$$

3 Case Study

3.1 Data Preparation

The BSS of World Expo 2010 Shanghai China was the first large scale application in public transit system. There were 120 BEBs runnnig on 3 routes in the expo park (Figure 3).

Figure 3. Layout of BEB routes and BSS.

The operation and scheduling of the 3 BEB routes are shown in the Table 1.

Table 1. Operation and Scheduling of the BEB Lines (Cai 2012)

Details	Expo Avenue Cross-river Line	Expo Guozhan Line	Longhua East Road Line
Number of Buses	80	30	10
Service Time	9:00-24:00	9:00-24:00	9:00-24:00
Number of Stops	11	7	12
Length of Route	6.7 km	1.8 km	2.65 km
Average Speed	28 km/h	28 km/h	28 km/h
Distance between Terminal Station and BSS	3.3 km	1 km	3 km
Cycling Time of the Route[a]	40 min	15 min	18 min
Departure Interval (peak)	1 min	1-2 min	3-4 min
Departure Interval (off-peak)	30-45 s	30-45 s	2 min

[*a*]: average time of each stop is 0.5 min.

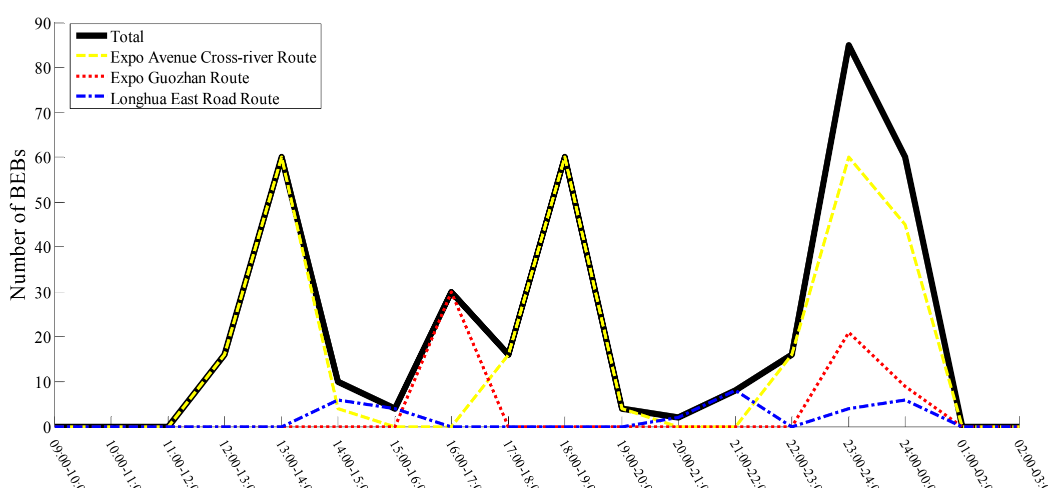
Other parameters for simulation are presented in Table 2.

Table 2 Simulation Parameter Setting

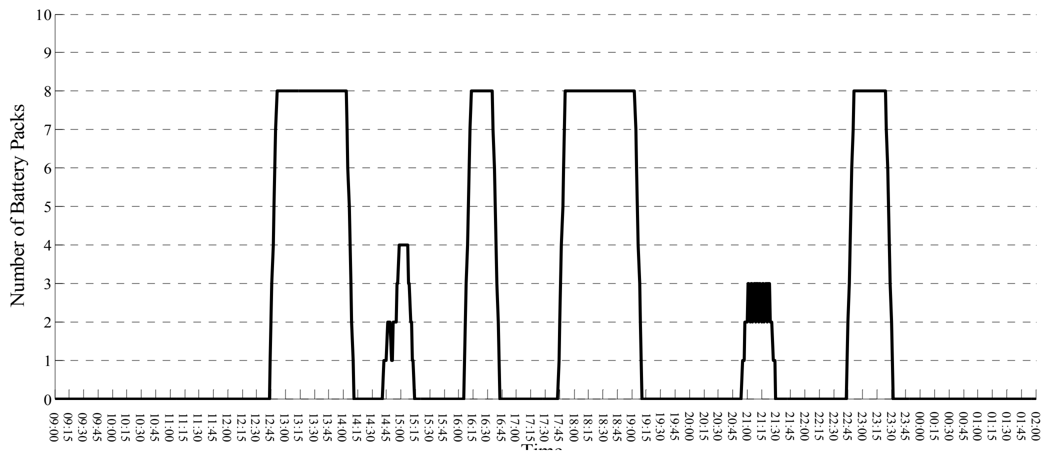
Parameter	C	U	I	RC	$Range$	SOC_m	η_{max}	φ	$\gamma\%$	T_s
Value	360Ah	440V	100A	0.3C	100km	30%	85%	90%	10%	8 min

3.2 Simulation of Operation

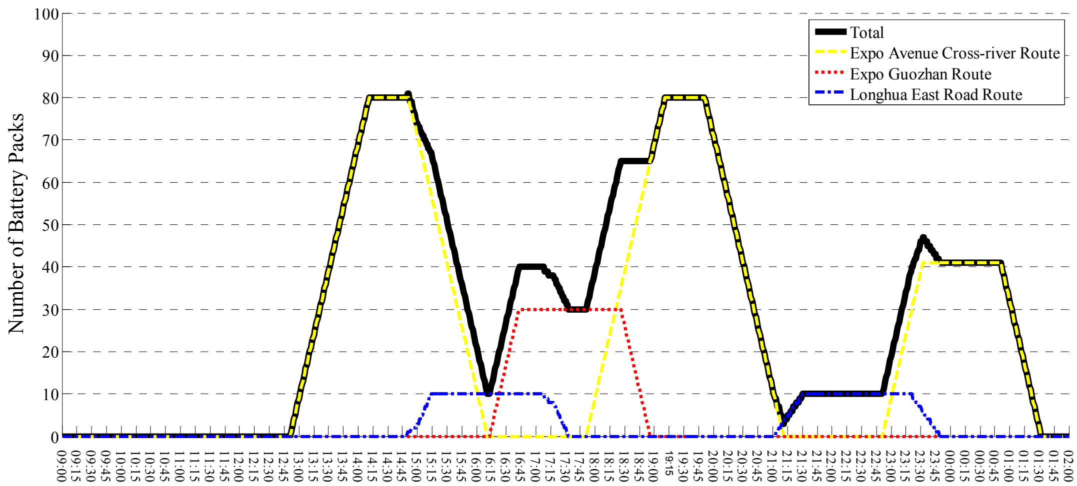
Based on the method proposed above, we designed a MATLAB program to simulate operation of the BSS and BEBs. Input the prepared data and run the program, the operation of the BSS in one day will be simulated minute by minute. As a consequence, the minutely state of the BEBs, swapping systems and charging systems can be recorded in matrixes: *Depart(m,n)* & *Arrive(m,n)*, *SwapS(h,n)* & *SwapE(h,n)*, *and ChargeS(b)* & *ChargeE(b)* respectively. By these matrixes, we can analyse the swapping and charging demand (Figure 4).



(a) Time distribution of BEBs arriving at BSS



(b) Time distribution of battery swapping



(c) Time distribution of battery charging

Figure 4. Swapping and charging demand analysis.

As shown in Figure 4(a), different routes have different time distributions of BEBs arriving at BSS. According to Rule 3, every BEB need go to swap battery pack after finished its last round of one day. Since there is no more tasks for the BEB, it is not necessary to complete the swapping and charging immediately. In consequence, we exclude the last swapping and charging of all BEBs when plot the Figure 4(b) and Figure 4(c). It can be concluded that there are at most 8 BEBs being swapped and 80 battery packs being charged at the same time, which decide the sacles of battery swapping systems and battery charging systems.

3.3 Results and Discussion

There are several parameters evaluating the operation of the BSS in Table 3. Comparing with actual values, the simulation provides an equivalent state of operation.

Table 3. The Simulated and Actual Values of the Operation Parameters

Operation Parameters	Number of BEBs	Average Daily Mileage	Max Range per Charge	Average Daily Swapping Times	Average Charging Time
Simulated Value	120	178.4 km	62.6 km	3.0	111.9 min
Actual Value	120	181.4 km	67.8 km	2.7	118.5 min
Deviation	0.00%	-1.65%	-7.67%	11.11%	-5.57%

Through the Matlab simulation of operation, we can calculate the design scales of the BSS. Compare the simulated values with actual values in Table 4. It indicates that the scales calculated by our method are close to the actual scales with small deviations, which verifies the validity of the simulation and method above.

Table 4. Comparison of the Simulated and Actual Scale of BSS

Scales	$N_{Battery}$	N_{SU}	N_{CU}	P_{CU}	P_S
Simulated Value	240	8	89	62 kW	7.2 MW
Actual Value	232	8	112	63 kW	8 MW
Deviation	3.45%	0.00%	-20.54%	-1.59%	-10.00%

4 Conclusions

This paper presents a novel method to design the battery swap station for battery electric buses. Base on the swapping and charging demand analysis of the BEB fleets, the design scale of BSS can be calculated, which include the scales of battery packs, battery swapping system and battery charging system. We verified the method via a case study of BSS in World Expo 2010 Shanghai China. With a Matlab program, we simulated one day operation of the 120 BEBs and analysed the swapping and charging demand for the BSS. The operation parameters and scales of the BSS in simulation are close to the actual values, which concludes that the design method is effective.

This paper contributes to the construction of the electric public transit system. It provides a planning and design guide for government, bus companies, infrastructure operators and other decision makers, avoiding blind constructions.

Acknowledgements

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References

Aultman-Hall, L., Sears, J., Dowds, J., and Hines, P. (2012). "Travel Demand and Charging Capacity for Electric Vehicles in Rural States.", 27-36.

Cai, X. (2012). "Expo New Energy Bus Research Series Third: New Energy Bus Running In Expo." Public Utilities,(05), 14-16.

Dong, J., Liu, C., and Lin, Z. (2014). "Charging infrastructure planning for promoting battery electric vehicles: An activity-based approach using multiday travel data." Transportation Research Part C: Emerging Technologies, 38, 44-55.

Kaschub, T., Paetz, A., Jochem, P., and Fichtner, W. (2012). "Feasibility of battery switch stations for local emission free public transport." Enerday 2012-7th Conference on Energy Economics and Technology, Dresden.

Kuhne, R. (2010). "Electric buses - An energy efficient urban transportation means." ENERGY, 35(12), 4510-4513.

Lee, Y., Kim, H., Kho, S., and Lee, C. (2014). "UE-based Location Model of Rapid Charging Stations for EVs with Batteries that Have Different States-of-charge." Transportation Research Board 93rd Annual Meeting.

Nie, Y. M., and Ghamami, M. (2013). "A corridor-centric approach to planning electric vehicle charging infrastructure." Transportation Research Part B: Methodological, 57, 172-190.

Sellmair, R., and Hamacher, T. (2014). "Method of Optimization for Infrastructure of Charging Stations for Electric Taxis." 93rd Annual Meeting of the Transportation Research Board, Washington, D.C.

Tuttle, D. P., and Fellow, R. (2012). "Electrified-Vehicle Technology Trends, Infrastructure Implications, and Cost Comparisons." 91rd Annual Meeting of the Transportation Research Board, Washington, D.C.

Yu, Z., Zhao, Y. D., Yan, X., Ke, M., Jun, H. Z., and Jing, Q. (2014). "Electric Vehicle Battery Charging/Swap Stations in Distribution Systems: Comparison Study and Optimal Planning." Power Systems, IEEE Transactions on, 29(1), 221-229.

Pricing Model of Railway Cargo Protocol Transport Based on Option Theory

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Abstract: For the bulk and stable cargo, railway commonly uses the protocol transport. The railway transport enterprise can avoid the market risk at the same time when providing security to transportation capacity. This paper introduces the option theory to the process of protocol transport in pricing, establishes the optimal decision model based on the largest returns of enterprise and customer and solves the problems of setting option exercise price and buying option quantity. This paper considers the changes in market prices and the competition of other modes of transport when building the model and finally applies the model to a simple example.
Keywords: Protocol transport; Option; The optimal decision; Exercise price.

1 Introduction

Option is a kind of derivative financial tools generated from the base of futures, refers to the buyers and sellers have a transaction of a certain number of the subject matter with a specific target price at a certain period of time or a certain time point in the future. During this process, the buyers can exercise option or not at expiry. In September 2012, the railway freight implements "real goods" reform and one thought of the reform is to ensure the transportation capacity of the bulk and stable cargo by protocol transport. In June 2013, the railway implements the reform of railway freight transportation which includes the protocol transport.

In the railway freight market, the transport demand of coal, ore and other large enterprises is relatively stable, so the railway transport enterprises usually sign transport protocols with these large enterprises, which stipulates the price, the amount of transportation capacity and the expiration and so on. In this way, these large enterprises provide stable, adequate supply of goods to the railway transport enterprises and the railway transport enterprises provide adequate, reliable transportation capacity. The railway transport enterprises can sell the remained capacity in the railway freight market. However, there is a certain risk of selling out the remained capacity because of the changeable demand and price in the railway freight market. According to the above analysis, we can find some similarities between option and transport protocol, so we try to introduce the option theory to the railway freight transportation.

2 Railway Freight Option

Railway freight option is a kind of option contract in which the railway transport enterprise is a seller, the large enterprise is a buyer (called protocol client) and the subject matter is the railway freight transportation service. At the same time, we need to make clear the following contents.

(1) The option premium: It means the fees that used to buy the option are given to the railway transport enterprise by protocol client.

(2) Strike price: It means the price of transport services that paid by protocol client when it received the rail transport services from the railway transport enterprise.

(3) Protocol expiration: It means the option is expired at the period of time or the time point agreed by railway transport enterprise and protocol client. After the period of time or the time point, the option is no longer in force.

(4) Quantity of the purchased option: It means the quantity of transport services that given to protocol client from railway transport enterprise by strike price.

After signing transport protocol, protocol client pays option premium which agreed by both sides to railway transport enterprise. During the protocol expiration, if protocol client exercises the option, it will buy the option quantity of transportation capacity from railway transport enterprise by strike price. If not, railway transport enterprise will sell out the option quantity of transportation capacity and not return the option premium.

3 Analysis of Railway Freight Transport Protocol Price Based on Option

Under a series of assumptions and base on the principle of maximize the revenue of railway transport enterprise and protocol client, this paper establishes the optimal decision model and determines a reasonable option strike price and quantity.

3.1 Symbol definitions and assumptions

p_0 means the unit price of transport capacity in spot market, p_u and p_d means the up or down unit price of transport capacity in spot market on option expiration day, $p_1^{'}$、$p_2^{'}$ means the average up or down unit price of transport capacity of other transport mode and u^*、d^* means the percent of up and down, r means risk-free rate, c_0 means the option premium of unit transport capacity, c means the strike price of unit transport capacity, n means quantity of the purchased option agreed by both sides, c_L、c_S means long or short preparation cost by providing unit transport capacity, KC means fixed cost by providing transport capacity. Equation

$D = a - bp + \varepsilon$ indicates functional relation between the market demand D and the price p in spot market. There are only two changes (up and down) with the price of transport capacity in spot market on option expiration day. Equation $c_0 = h(c)$ means option premium is influenced by strike price. Railway transport enterprise and protocol client can accept the price of transport capacity in spot market.

3.2 The establishment of model

According to the assumptions, $c_0 = (1-P)(p_u - c) + P(p_d - c)$, $r = (1-P)u^* + P(-d^*)$, $p_u = p_0(1+u^*)$, $p_d = p_0(1-d^*)$, then $P = \dfrac{u^* - r}{u^* + d^*}$. Assume $u^* = e^{\sigma\sqrt{t}/3} - 1$, $d^* = 1 - e^{-u^*}$ based on the data of different years, σ means standard deviation of railway freight market returns and t means the length of time (year).

Situation 1: During the protocol expiration, assume the unit price of transport capacity in spot market decline (probability is P) and less than the strike price of unit transport capacity, then protocol client dose not exercise the option.

(1)Protocol client still choose railway freight transportation (probability is P_1). The equation $C_G = \alpha T + \beta E$ means generalized cost include time cost and expenditure cost. α and β are conversion factors. Assume there are m kinds of transport modes, the probability of choosing railway is $P_1 = \dfrac{e^{-C_G^1}}{\sum_{i=1}^{m} e^{-C_G^i}}$, so the profit functions of protocol client and railway transport enterprises are:

$$G_1 = pD - c_0 n - p_d D = (p - p_d)D - c_0 n \tag{1}$$

$$Q_1 = c_0 n + p_d D - c_s D - KC = c_0 n + (p_d - c_s)D - KC \tag{2}$$

Bring in $D = a - bp + \varepsilon$ and the profit expected values of protocol client and railway transport enterprise are:

$$E(G_1) = \int_{-\infty}^{+\infty} [(p - p_d)(a - bp + x) - c_0 n] f(x) dx \tag{3}$$

$$E(Q_1)=\int_{-\infty}^{+\infty}[c_0n+(p_d-c_s)(a-bp+x)-KC]f(x)dx \tag{4}$$

(2)Protocol client choose other transport modes (probability is $1—P_1$) and the profit functions of protocol client and railway transport enterprise are:

$$G_1^{'}=pD-c_0n-s_1^{'}D=(p-p_1^{'})D-c_0n \tag{5}$$

$$Q_1^{'}=c_0n-KC \tag{6}$$

The profit expected values of protocol client and railway transport enterprise are:

$$E(G_1^{'})=\int_{-\infty}^{+\infty}[(p-p_1^{'})(a-bp+x)-c_0n]f(x)dx \tag{7}$$

$$E(Q_1^{'})=\int_{-\infty}^{+\infty}(c_0n-KC)f(x)dx \tag{8}$$

Situation 2: During the protocol expiration, assume the unit price of transport capacity in spot market rise (probability is $1-P$).

(1)Protocol client still choose railway freight transportation (probability is P_1). If the quantity of purchased option in protocol is greater than the actual demand when exercising option, it will need to buy $D-n$ transport capacity in spot market and consider choosing the railway or not. The profit functions of protocol client and railway transport enterprise are:

$$G_2=\begin{cases}pD-c_0n-cD, D\le n\\ [pD-c_0n-cn-p_u(D-n)]P_1+[pD-c_0n-cn-p_2^{'}(D-n)](1-P_1), D\succ n\end{cases} \tag{9}$$

$$Q_2=\begin{cases}c_0n+(c-c_L)D-KC, D\le n\\ [c_0n+(c-c_L)n+(p_u-c_S)(D-n)-KC]P_1+[c_0n+(c-c_L)n-KC](1-P_1), D\succ n\end{cases} \tag{10}$$

The profit expected values of protocol client and railway transport enterprise are:

$$E(G_2)=\int_{-\infty}^{n-a+bp}[(p-c)(a-bp+x)-c_0n]f(x)d(x)+\int_{n-a+bp}^{+\infty}Af(x)d(x) \tag{11}$$

$$E(Q_2)=\int_{-\infty}^{n-a+bp}[c_0n+(c-b_0)(a-bp+x)-KC]f(x)d(x)+\int_{n-a+bp}^{+\infty}Bf(x)d(x) \tag{12}$$

With

$$\text{A}=[(p-p_u)(a-bp+x)-c_0n-cn+p_un]P_1+[(p-p_2^{'})(a-bp+x)-c_0n-cn+p_2^{'}n](1-P_1)$$

$$\text{B}=[c_0n+(c-c_L)n+(p_u-c_S)(a-bp+x-n)-KC]P_1+[c_0n+(c-c_L)n-KC](1-P_1)$$

(2)Protocol client choose other transport modes (probability is $1—P_1$) and the profit functions of protocol client and railway transport enterprise are:

$$G_2^{'} = pD - c_0 n - p_2^{'} D = (p - p_2^{'})D - c_0 n \quad (13)$$

$$Q_2^{'} = c_0 n - KC \quad (14)$$

The profit expected values of protocol client and railway transport enterprise are:

$$E(G_2^{'}) = \int_{-\infty}^{+\infty} [(p - p_2^{'})(a - bp + x) - c_0 n] f(x) dx \quad (15)$$

$$E(Q_2^{'}) = \int_{-\infty}^{+\infty} (c_0 n - KC) f(x) dx \quad (16)$$

Comprehensive situation 1 and 2, the profit expected values of protocol client and railway transport enterprise are:

$$E(G) = P[P_1 E(G_1) + (1 - P_1) E(G_1^{'})] + (1 - P)[P_1 E(G_2) + (1 - P_1) E(G_2^{'})] \quad (17)$$

$$E(Q) = P[P_1 E(Q_1) + (1 - P_1) E(Q_1^{'})] + (1 - P)[P_1 E(Q_2) + (1 - P_1) E(Q_2^{'})] \quad (18)$$

Differentiate the equation (17) and (18) by n and equate to zero, we found

$$F(n - a + bp) = 1 - \frac{c_0 (2 - P_1 + PP_1)}{P_1 p_u - P_1 p_2^{'} + p_2^{'} - c} \quad (19)$$

$$F(n - a + bp) = 1 - \frac{c_0 (2 - P_1 + PP_1)}{-P_1 p_u + P_1 c_S - c_L + c} \quad (20)$$

Comprehensive equation (19) and (20), the optimal option strike price c is:

$$c = P_1 p_u - \frac{P_1 p_2^{'} - p_2^{'} + P_1 c_S - c_L}{2} \quad (21)$$

4 Example Analyses

Assume the protocol expiration in transport protocol signed by railway transport enterprise and protocol client is a half of a year and ε is the uniform distribution by [-100， +100], we found its density function and distribution function are $f(x) = \begin{cases} \frac{1}{200}, -100 \le x \le 100 \\ 0, \text{other} \end{cases}$ and $F(x) = \begin{cases} 0, x \le -100 \\ \frac{x+100}{200}, -100 \le x \le 100 \\ 1, x \ge 100 \end{cases}$. Assume risk-free rate r is 4%, standard deviation of railway freight market returns σ is 0.4068, the unit price of transport capacity in spot market p_0 is 100, long preparation cost by providing unit transport capacity c_L is 80, short preparation cost by providing unit transport capacity c_S is 120, the average up unit price of transport capacity of other transport mode in spot market on option expiration day $p_1^{'}$ is 95, the average down unit price of transport capacity of other transport mode in spot market on option expiration day $p_2^{'}$ is 105 and in order to simplify, assume P_1 is 0.9.

According to the above contents, we found u^*=0.10, d^*=0.095, P=0.308, $1-P$=0.692, p_u=110, p_d=90.5. Bring to the equation (21), the optimal option strike price c=90.25 and the option premium c_0=13.744. Bring to the equation (20), the optimal quantity of the purchased option n=279.

In this part, the paper just uses a simple example to apply the above model by simplifying the process and is aimed at proving the availability of the model.

5 Conclusions and Future Research

This paper introduces the option theory to the railway freight transportation and establishes the optimal decision model based on the largest returns of railway transport enterprise and protocol client. We explore the problems of how to reasonably set option exercise price and buy option quantity. During the research, this paper considers simple changes of supply, demand and price in spot market and competition among transport modes. However, the changes of supply, demand and price in real market are more and more complex than in this paper. This is the insufficient part of this paper, we hope for further study and analysis.

References

Fan Hua. (2013). "Some suggestions to improve the formation mechanism of transport price in China." *Journal of Integrated Transportation,* Nov. 11.

Feng Fenling, and LI Feifei. (2012). "Pricing mode of railway cargo transport based on option theory." *Journal of Railway Science and Engineering,* Apr. 2.

Li Wenxing. (2013). "Study on the problems of guidance price of the government in the railway freight transport." *Journal of Price Theory and Practice,* Nov. 11.

Wang Xiaozhe, and Yang Jinglei, and Liu Dongrong. (2009). "Study on the Transport Capacity Organization of the Freight Market Based on Option Theory." *Journal of Logistics Technology,* 28,12.

Zhang Junyong, and Sun Youcai. (2013). "Pricing orientation of railway after market-oriented reform." *Railway Purchase and Logistic,* Dec. 12.

Analysis of Heavy Haul Railway Wear on Wheel/Rail Contact Geometry

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Abstract: Nowadays railway transportation developed towards High-speed in passenger transport, heavy load in freight transport and High density in urban railway system. As a result, the rail/wheel wear become more and more serious, thus decreased the rail rigidity and changed the rail-wheel contact and impact the safety and comfort of railway transportation. In this paper, we are committed to make a precise prediction of rail wear in order to guide wheel/rail profile optimization and rail grinding cycle making by introduced a numerical model in predict of rail wear along with the passing gross weight grow. Firstly, a wheel-rail wear model based on non-Hertzian rolling contact theory and the energy dissipation principle are carried out with the help of vehicle-rail coupling dynamics software and MATLAB fixed-point iteration. Then, the wheel-rail contact geometry was calculated and the development of wear area, wear depth distribution along with the passing gross weight grow was calculated. At last, for the purpose of verifying the accuracy of the model, a comparison between the calculated results and the measured value was made. As a result of analysis the relationship between wear and passing gross weight, the impact of wear on the rail/wheel geometry is summarized.
Keywords: Heavy haul rail; Rail wear; Passing gross weight; Non-Hertzian rolling contact theory; Energy dissipation principle; Wheel-rail contact geometry.

1 MODEL ESTABLISHMENT

1.1 ROLLING CONTACT MODEL

At present, There are two theories in wheel-rail rolling contact investigation: Hertzian rolling contact theory and non-Hertzian rolling contact theory. Both of the calculation method have great accuracy and high calculate speed. The Hertz theory assume the contact patch is oval and the size of spot size is decide by the radius of the curve. The distribution of the normal force is ellipsoid and the curve radius is constant. But the curvature radius of wheel-rail contact surface apparently changes when wear appeared. The Non-Hertzian Contact Theory use the wheel/rail normal spacing to calculate the wheel/rail contact issues, and is applicable to most rail type condition except two-point contact with different normal direction and conforming contact with curved surface. It is obvious that the non-Herztian is more suitable to our calculation.

Trace line method is used to solve the relationship of wheel-rail contact geometry. The CONTACT is written with non-Hertzian theory by Kalker. Though it is precise enough but not suitable for repeated interactive process in wear calculation. We developed a fixed point interaction program instead of CONTACT. As the wear grinds on, the wheel/rail tends to conforming contact. In the computation model, increase the number of computing units with the growth of contact patch area to ensure the calculation accuracy and improve the computing speed. The results of compared CONTACT outcome with our program value is shown in Tab 1.

Table 1. Comparison result with CONTACT

Project	Optimized program	CONTACT	Differ
Normal force peak(MPa)	1896	1920	1.3%
Longitude shear force peak(MPa)	384	362	6.1%
Lateral shear force peak (MPa)	52	55	5.5%
Longitude creep force(N)	10749	10530	2.1%
Lateral creep force(N)	1770	1757	0.7%
Torque of spin creepages(N·mm)	4607	4926	6.5%
Number of stick zone cells	105	104	1.0%
Number of Sliding area cells	27	28	3.6%
Number of noncontact area cells	36	36	0.0%

As is shown in Tab.1, the results are nearly the same, and the largest differ is about seven percent. It means our method for non-Hertzian contact is accurate enough and feasible.

1.2 RAIL WEAR MODEL

Rail wear is mainly composed of adhesives wear, abrasive wear, fatigue wear, corrosion wear and fretting wear. And abrasive wear and adhesive make up the bulk of rail wear. Only the abrasive wear and adhesive wear are considered in the model. The Archard wear model and energy dissipation model has been developed, both of them have high accuracy in solving rail wear issues, while the energy dissipation model take the effect of friction coefficient into consideration witch is seen as a large impact on rail wear. It is obvious that the energy dissipation model is more practical to calculate rail wear.

1.3 GENERY MODEL

Based on the analysis above, we use energy consumption model to estimate the total amount of wear with the help of fixed point iteration algorithm in MATLAB. Assume the contact region flat and ignore plastic deformation. Use the trace line method to analysis wheel-rail contact geometry and non-Hertzian rolling contact theory to get the relationship between rail wear and wheel-rail contact geometry with the change of wear. Thus the model was built and the relationship between wear and passing gross weigh was get. The simulation procedures are as follows:

1) Use multi-dynamic software package in modeling vehicle/rail interaction to analysis the interaction force and the creep forces/creepages of wheel/rail rolling contact.
2) Calculate the normal gap between wheel and rail with the track line method.
3) Perform wheel-rail rolling contact calculation to get friction power density with energy consumption model, then calculate the wear depth and position.
4) Work out the rail cross-section after wheel-rail wear.

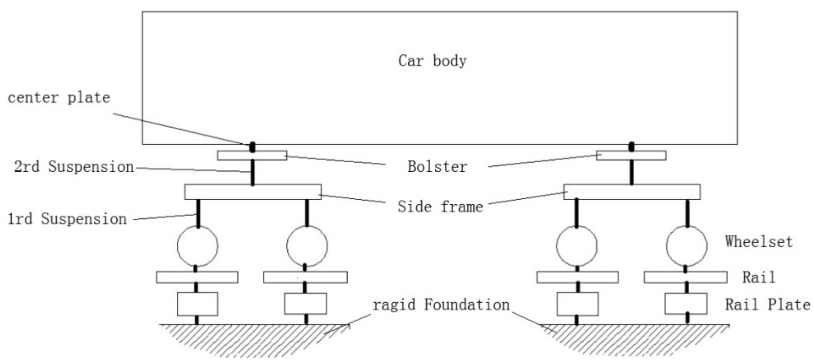

Figure 1. The topological structure of vehicle track model

2 CALCULATION RESULT

2.1 THE MODEL INPUT

The analysis example is C80 which is widely used in China. The curve is composed with straight line, transition curve, circular curve, transition curve and straight line. All of them are 200 meters long. The schematic diagram is as follows:

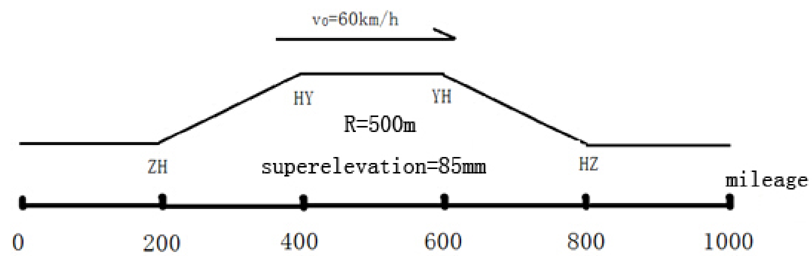

Figure 2. Rail curve schematic diagram of model

2.2 MODEL RESULT VERIFICATION

Comparison between results of numerical simulation and filed test to verify the correctness of the wear prediction. As we can see in Fig.3, the result of model is closed to the field test data except the inconsistent in the early stages. For the predicted results, the vertical wear of outer rail grows at a constant speed of 0.018mm/MGT. While the measured vertical wear grows rapidly at first, then gets steady at about 0.018mm/MGT until the passing gross weight reaches 30MGT. the decarburized layer on the surface of the new rail which is easily to wear and rail hardening phenomenon cause this to happen.

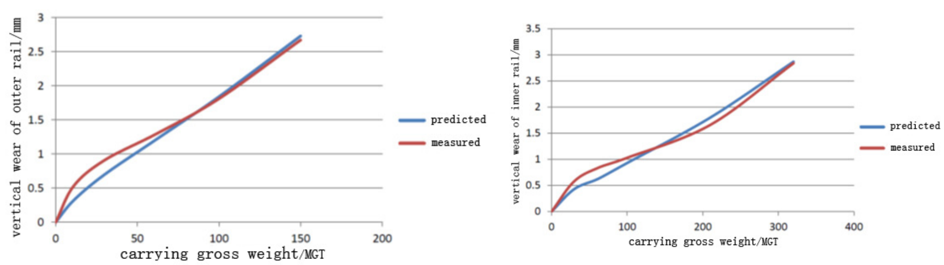

Figure 3. Model result verification outer/inner rail

2.3 WEAR AREA PREDICTION

Calculation was made to predict the rail profile change, and the chosen curve includes 30 observation points, the interval of adjacent point is 20 meter. The length of the chosen curve is 600 meters and consist of two transition curve and one circular curve. It is thought that the inner rail wear faster than the outer rail, so we reveal the wear area of the inner rail at 0-300MGT passing gross weight, and 0-150MGT of the outer one.

In Fig.4, we connect the thirty observation points with smooth curve to show the relationship between gross weight and wear area of both side of rail.

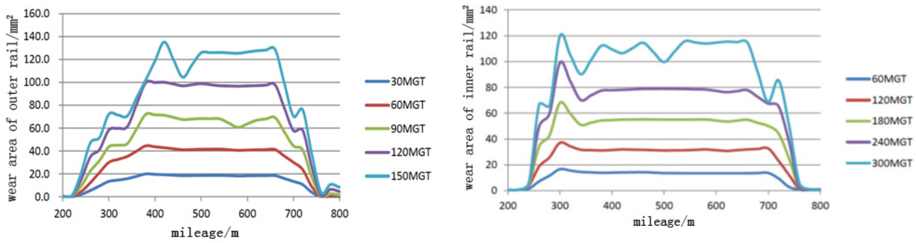

Figure 4. Predicted wear area along outer/inner rail

In the midpoint of the outer rail, the average wear area of the circular curves is about 40 percent larger than those on transition curves, while 20 percent of the inner rail. The results show positive correlation between wear area and curvature.

2.4 WEAR DEVELOPMENT ON MIDDLE POINT OF CURVE

According to the simulation results, in Fig.5, we illustrate the wear development on midpoint of rail profile The abscissa represents the arc length from wear prediction point to the center point of rail top and the working side as the negative direction

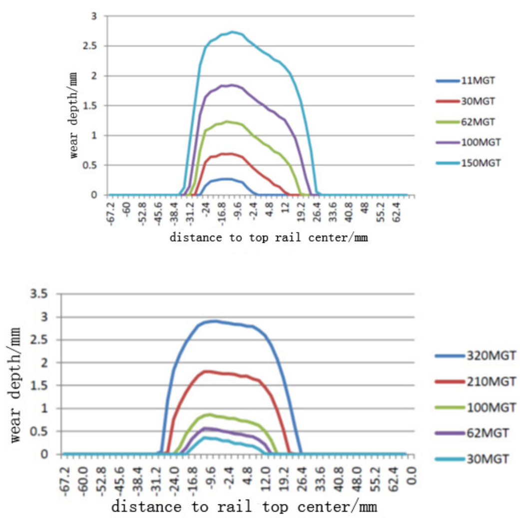

Figure 5. Abrasion loss on the midpoint of outer/inner rail

As shown in Fig.5, at the beginning, the wear area position ranges from -2mm to -23mm to rail top center, and then extends to both side of the rail top. The speed of wear zone growth on the working side is slower than the other side.

3 CONCLUSIONS

From the analysis above, our model successfully predict the relationship between rail wear and passing gross weight, which is precision enough when compared with field test data. In this model, we take profile change and the coefficient of friction into consideration and complete the calculation with high accuracy and speed. Side wear of rail and wheel wear can also be predicted. Comprehensively consider wheel-rail friction control, rail wear and grinding, a better wheel/rail maintenance and repair strategy can be established.

References

Braghin F., Lewis R, Dwyer-Joyce R.S,(2006) Bruin S.A mathematical model to predict railway wheel profile evolution due to wear. *Wear*. (261):1253-1264

De Arizon J., Verlinden O, Dehombreux P.(2007) Prediction of wheel wear in urban railway transport: comparison of existing models. *Vehicle System Dynamics*. 45(9): 849-874

Jedenl T. (2002)Prediction of wheel profile wear-comparisons with field measurements. *Wear,* 253(1):89-99

Lian S L. (2001) railway curve wear and the decrease measures. Beijing: *China Railway Publishing House*.

Jin X S, Shen Z Y. (2001) The latest progress of wheel-rail rolling fatigue research. *Journal of The China Railway Society*,23(2):92-108

Jin X. S., Zhang W H, Hu L J. (1997)Effect of lateral motion on the creep forces in wheel/rail rolling contact. *Journal of Southwest Jiaotong University*. 1997, 5:44-54

Kalker J. J.(1973) Simplified theory of rolling contact. *Delft Progress Report 1*.

Roger Enblom, Mats Berg (2005)Simulation of railway wheel profile development due to wear-influence of disc braking and contact environment. *Wear*, 258(7): 1055-1063

Roger Enblom, Mats Berg.(2008) Proposed procedure and trial simulation of rail profile evolution due to uniform wear. *Wear*, 222(1):15-25

Telliskivi T. , Olofsson U. (2004)Wheel-rail wear simulation. *Wear*,257(11)

Zhai W. M. (2003)Vehicle-track coupling dynamics. *Beijing:Science Press*.

Zhan Gang. (2011)Railway curve profile wear prediction and its prevention measles. Shanghai: Tongji University, 2011

Influence of Axle Loads on Rail Wear in Heavy Haul Railways under Different Gross Tonnage

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Abstract: In railway transportation, the rail wear decreases the sectional area, not only reduces the rail's strength, but also changes the wheel-rail contact geometric. Furthermore, rail wear affects the stability of the trains. This paper presents a rail wear prediction model. First, to know if the prediction model was credible, a circle curve center point rail wear was predicted and the results compared with the field measured value. Then, we predicted wear value under different axle loads and gross tonnages through the model. As the results shown: (1) Before the passed gross tonnage exceeds 30MGT, the wear depth increased significantly with the increase of axle load; (2) While the passed gross tonnage reached 60MGT or 90MGT, the wear depth under different axle load hasn't too much discrepancy; (3) As the gross tonnage continued to increase, reached 120MGT or 150MGT, the wear depth under 23t was the shallowest, while the wear under 21t and 25t were the same.

Keywords: Heavy haul railway; Rail wear prediction; Axle load; Gross tonnage.

1 Introduction

In China, high-speed and heavy load are the symbols of modern railway transportation. With the increase of velocity, axle load and traffic density, rail wear's increasing is inevitable. In railway transportation, the rail wear decreases the sectional area, not only reduces the rail's strength, but also changes the wheel-rail contact geometric. Furthermore, rail wear affects the stability of the trains. Analysis on the influence of axle load on rail wear contributes to perfecting the measure to reduce rail wear.

In this paper, a numerical wear prediction model was established. Then, the heavy haul rail wear was predicted through the model. Moreover, the prediction results were compared with the field measured value. At last, the rail wear under different conditions (axle load, gross tonnage) was predicted and the results were analyzed.

2 Wear Prediction Methodology

A wear prediction model consists of three main parts, (a) dynamics simulation of vehicle/track, (b) wheel/rail rolling contact analysis, (c) rail wear calculation. The wear prediction model general architecture is showed in Figure.1

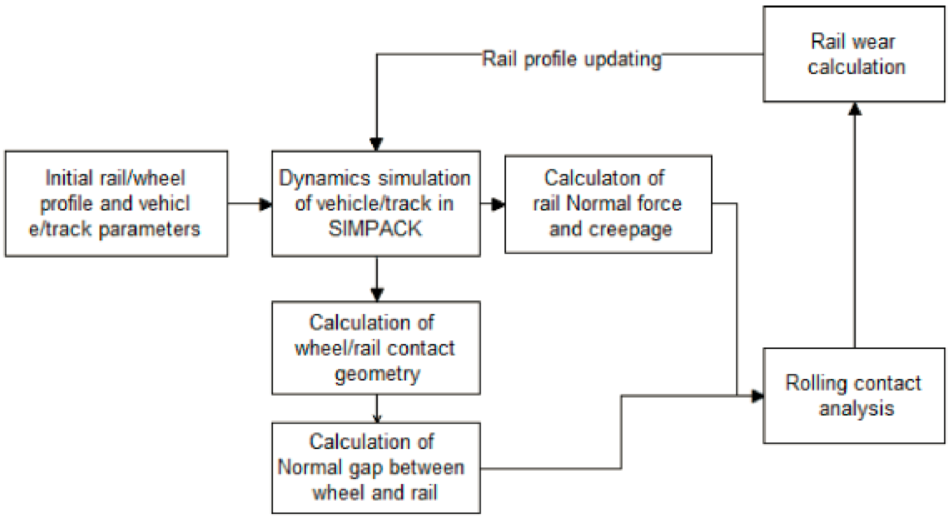

Figure 1. Process flow chart of wear prediction model

2.1 Dynamics Simulation of Vehicle/track

SIMPACK software was used to reproduce the dynamics of vehicle/ track. The vehicle model was simplified and consisted of three parts: car body, bogie and wheelset, and every part was rigid. The wheelset and the bogie were connected by primary suspension, while the car body and the bogie connected through the secondary suspension. The vehicle model in the SIMPACK is showed in Figure.2. The track model was simplified as slab track.

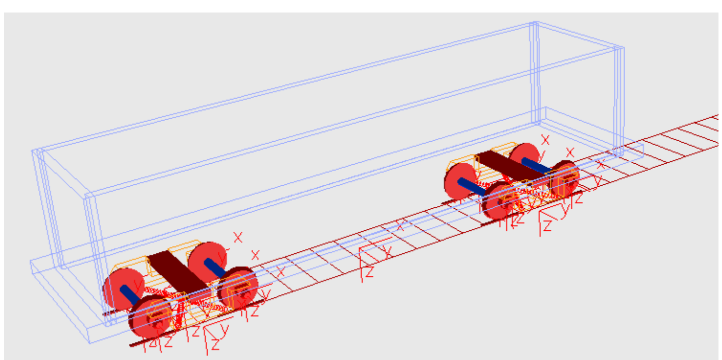

Figure 2. UIC gateway software architecture

2.2 Wheel/rail Rolling Contact Analysis

The rolling contact analysis was based on Kalker's three-dimensional elastic bodies rolling contact theory, which was very fit for wheel/rail contact analysis.

2.3 Rail Wear Calculation

Rail wear calculation was based on energy consume theory. The theory believes that wear value is proportional to the wheel/rail frictional work and inversely proportional to hardness.

2.4 Calculation Parameters of the Model

Considering that some other factors also have influence on wear value, some calculation parameters of the model are showed in Table.2.

Table 1. Calculation parameters of the model

	Calculation parameters	Value
Vehicle parameters	primary suspension longitudinal stiffness K_{px}	11MN/m
	primary suspension lateral stiffness K_{py}	13MN/m
	primary suspension vertical stiffness K_{pz}	160MN/m
	secondary suspension longitudinal stiffness K_{sx}	3MN/m
	secondary suspension lateral stiffness K_{sy}	3MN/m
	secondary suspension vertical stiffness K_{sz}	4MN/m
Track parameters	cushion layer vertical stiffness K_{bv}	187.5MN/m
	cushion layer vertical damping C_{bv}	0.03MN•s/m
	cushion layer lateral stiffness K_{bl}	39.2MN/m
	cushion layer lateral damping C_{bl}	0.04MN•s/m
	curve radius	500m
	curve superelevation	85mm
Other parameters	running speed	60Km/h
	coefficient of friction between wheel and rail	0.3

3 Wear Prediction Results and Analysis

3.1 Wear Model Valuation

To valuation the model, the wear circle curve center point which is severest was predicted. Our engineers measured the wear value in filed. The railhead midpoint wear value is showed in Table.1.

Table 2. Railhead midpoint wear value in circle curve center point

	High rail		Low rail	
gross tonnage /MGT	prediction value (mm)	measured value (mm)	prediction value (mm)	measured value (mm)
11	0.32	0.53	0.43	0.58
30	0.7	0.91	0.63	0.84
62	1.22	1.3	0.93	1.03
100	1.84	1.81	1.8	1.66
150	2.73	2.67	2.87	2.84

The prediction results and measured results were compared, shown in Figure.3 and Figure.4. The comparison showed that the prediction value was nearly consistent with the measured value, and the wear prediction model was credible.

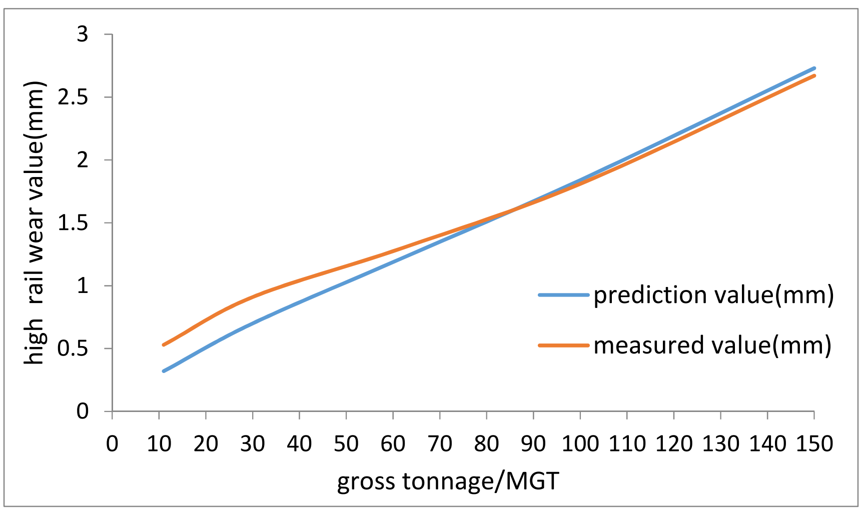

Figure 3. Railhead midpoint wear value comparison for high rail

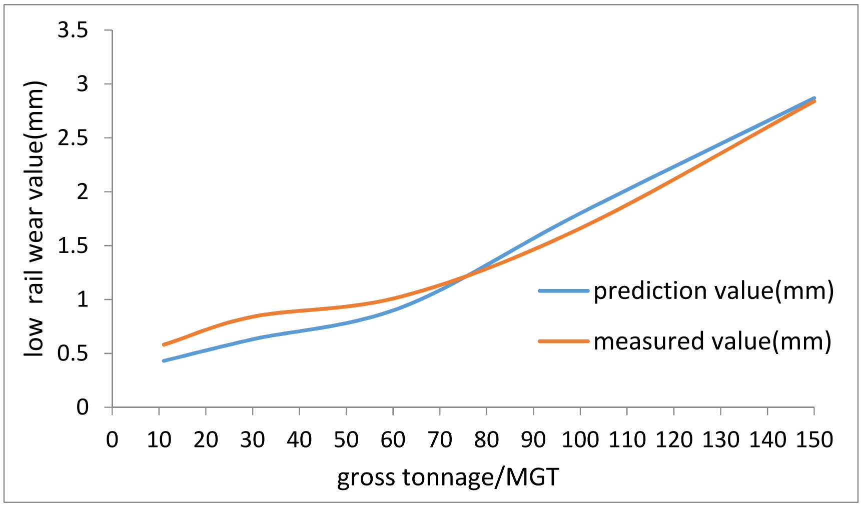

Figure 4. Railhead midpoint wear value comparison for low rail

3.2 Wear Prediction Results and Analysis

To know the influence of axle load under different gross tonnage, 21t, 23t, 25t axle loads were considered in the model. While the passed gross tonnage reaches 30MGT, 60MGT, 90MGT, 120MGT, 150MGT, wear of circle curve center point were calculated and the results were showed in Figure.5, Figure.6, Fiureg.7, Figure.8 and Figure.9 respectively.

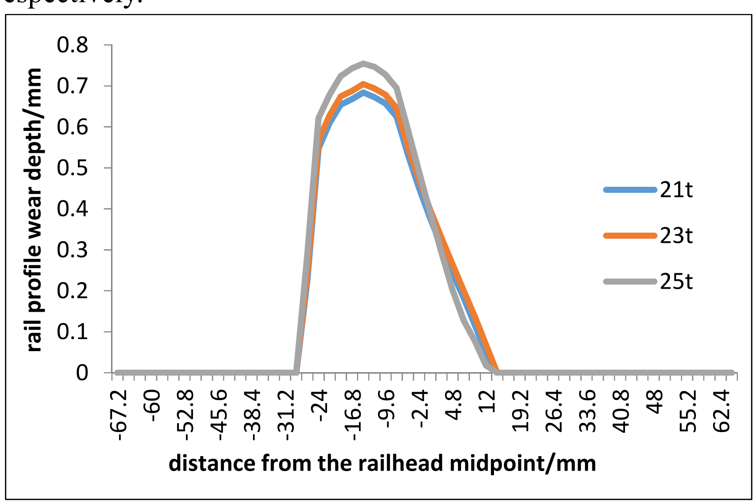

Figure 5. the rail profile wear while the gross tonnage reaches 30MGT

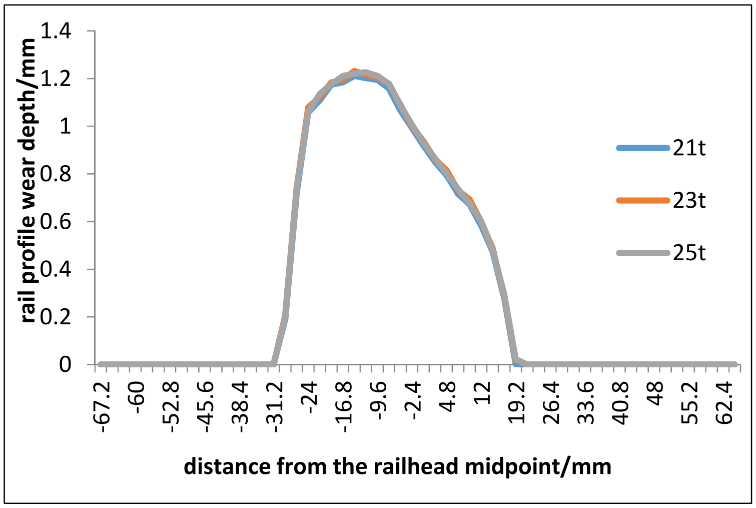

Figure 6. the rail profile wear while the gross tonnage reaches 60MGT

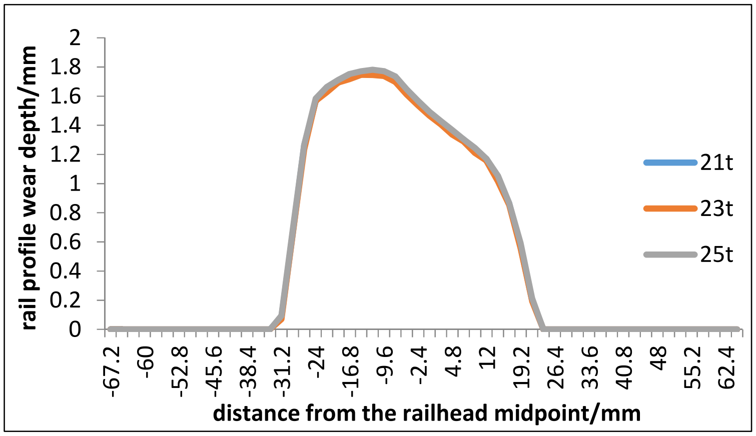

Figure 7. the rail profile wear while the gross tonnage reaches 90MGT

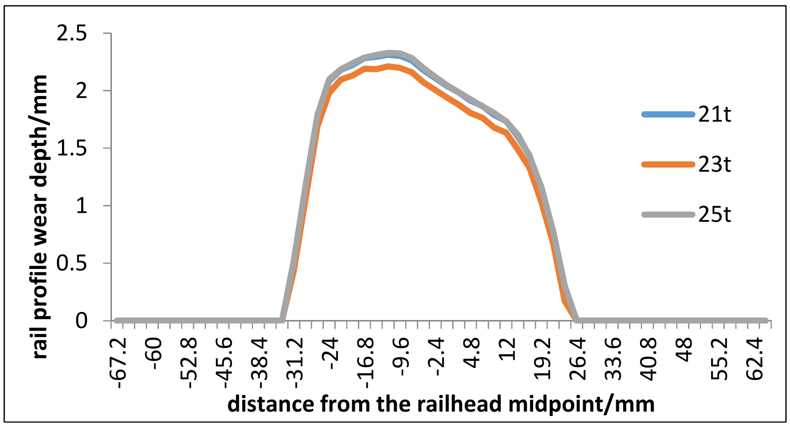

Figure 8. the rail profile wear while the gross tonnage reaches 120MGT

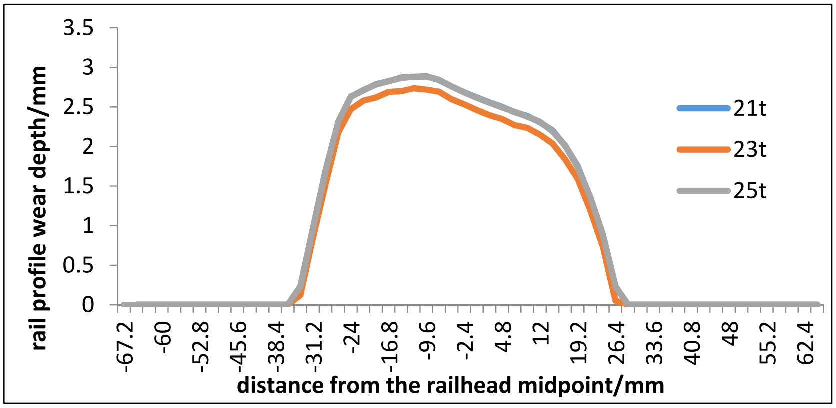

Figure 9. the rail profile wear while the gross tonnage reaches 150MGT

As the calculation results shown, before the passed gross tonnage exceeds 30MGT, as showed in Figure.5, in the left half of the rail head, the wear depth increased significantly with the increase of axle load. However, while the passed gross tonnage reached 60MGT or 90MGT, the wear depth under different axle load hasn't too much discrepancy as showed in Figure.6 and Figure.7. As the gross tonnage continued to increase, reached 120MGT or 150MGT as shown in Figure.8 and Figure.9, the wear depth under 23t was the shallowest, while the wear under 21t and 25t were the same.

4 Conclusions

In this paper, wear of a heavy haul railway circle curve center point were calculated under different conditions based on a wear prediction model. The results showed:

(1) Before the passed gross tonnage exceeds 30MGT, the wear depth increased significantly with the increase of axle load;

(2) While the passed gross tonnage reached 60MGT or 90MGT, the wear depth under different axle load hasn't too much discrepancy;

(3) As the gross tonnage continued to increase, reached 120MGT or 150MGT, the wear depth under 23t was the shallowest, while the wear under 21t and 25t were the same.

5 Recommendations for Future Research

In this paper, only three kinds of axle loads and five gross tonnages were considered. If there were more time, many conditions could be considered and calculated, and the results would be more enrich.

References

Bing-rong Miao. (2008). SIMPACK Dynamics Simulation. *Southwest Jiaotong University Press.*
Fu-tian Wang. (2009). Vehicle System Dynamics. *China Railway Press.*
Kalker J J. (1973). Simplified Theory of Rolling Contact. *Delft Progress Report.*
L. D. Landan. (1986). Theory of Elasticity. *Elsevier Butterworth-Heinemann.*
Zobory I. (1997). Prediction of Wheel/Rail Profile Wear. *Vehicle System Dynamics.*

Application of the ARMA Model in Railway Freight Volume Analysis

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Abstract: Railway freight volume is an important index in railway transportation. This paper combined ARMA model with multivariate regression model to analyze the variables that affected the rail freight volume. Ten variables are selected as explanatory variables to study their relationship with rail freight volume. The results show that the rail freight volume is affected by many factors together and we also get the rail freight regression equation. Our results can provide the support for the traffic department to develop the transport plan.
Keywords: Rail freight volume; ARMA model; Regression analysis.

1.Introduction

Railway freight reflect the transport demand of various sectors of the government. It plays an important role in formulating the national and regional economic development plan. Prediction of railway freight has attracted a lot of interest by many researchers. Previous research on this area has been diverse. From an methodological standpoint, watched fractal theory(Lin,2005), rough set theory(Zhang,2007), neural network theory(Xie,2009 and Li,2003), the complex network theory(Li,2004) et.al have been used to forecast the volume of railway freight. As rail transport system is a complex system of uncertainty, rail freight affected by many factors, previous study mainly include the following three aspects: national economic factors(Zhao et.al,2004); transport system factors(Li,2004); policies and other factors(Li,2004; Zhao et.al,2004).

This paper takes advantage of the ARMA and regression analysis at the same time, which is bebeficial to overcome the lack of single method. We make use of rail freight data from China Statistical Yearbook to verify the validity of the model. And the results and conclusions can provide references for the development of railway transport development plan and to determine the operational decisions.

2.Rail freight factors analysis and data preprocessing

Factors affecting rail freight transport is very extensive and complex. This paper will divide the related factors that affected rail freight into two categories: external factors and internal factors. External factors refer to external factors that could affect the railway freight. such as gross domestic product, total fixed asset investment, the total freight of other means, express volume and total production of primary energy. Internal factors refer to rail freight competitiveness and attractiveness of their own. Such as national railway wagon ownership, national railway mileag, transit van residence time, freight train travel speed and truck turnaround time.

The factors affected railway freight transport can be expressed as Fig.1.

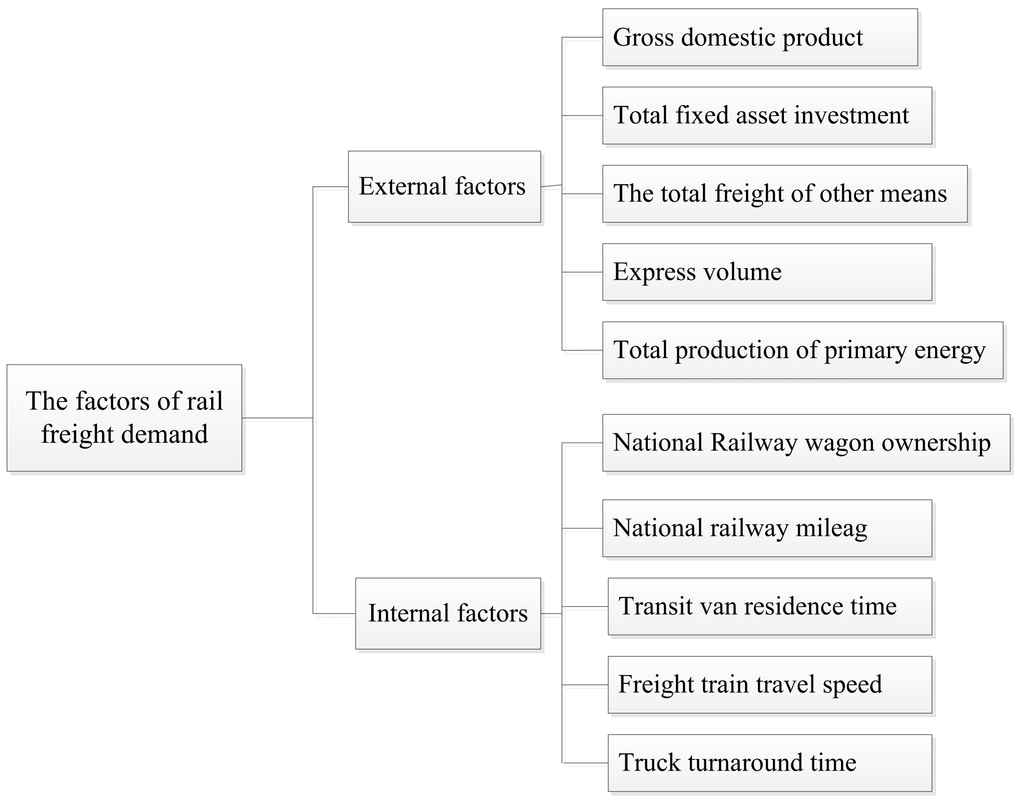

Figure1. The factors that affected rail freight volume

To facilitate the description, we give the following abbreviations of the related variables in Table 1.

Table 1. Abbreviations for variables

Symbol	Meaning	Units
X1	Gross domestic product	One hundred million yuan
X2	Total fixed asset investment	One hundred million yuan
X3	The total freight of other means	Ten thousand tons

X4	Express volume	Ten thousand tons
X5	Total production of primary energy	Ten thousand tons
X6	National Railway wagon ownership	Vehicles
X7	National railway mileag	Ten thousand km
X8	Transit van residence time	Hours
X9	Freight train travel speed	Km/h
X10	Truck turnaround time	Days
Y	Freight Volume of Railways	Ten thousand tons

In order to test the validity and usefulness of the method, we sort out rail freight data and its related factors data in China from 1998 to 2012 .fitting and testing the data use SPSS17.0 and R3.2.1, Explanatory variables includes 10 Variables and railway freight volume are selected as response variable. The raw data of factors and national rail freight data in Table 2. It is noted that all data in Table 2 come from "China Statistical Yearbook."

Table 2 Railway freight data and influencing factors data from 1998 to 2012

Year	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	Y
1998	84883.7	28406.2	1103118	7667.7	135738	439326	5.76	5	32	5	164309
1999	90187.7	29854.7	1125454	9091.3	140110	436236	5.79	4.9	32	5.5	167554
2000	99776.3	32917.7	1180101	11031.4	143046	439943	5.87	4.7	32	5.39	178581
2001	110270.4	37213.5	1208597	12652.7	154168	449921	5.91	4.6	40	5.08	193189
2002	121002	43499.9	1278491	14036.2	164752	446707	5.95	4.6	32	5.1	204956
2003	136564.6	55566.61	1340244	17237.8	196308	503868	6.04	4.5	33	5.1	224248
2004	160714.4	70477.43	1457395	19771.9	231176	520101	6.1	4.4	32	4.94	249017
2005	185895.8	88773.61	1592770	22880.3	272771	541824	6.22	4.3	32	4.9	269296
2006	217656.6	109998.2	1748836	26988	284193	558483	6.34	4.4	32	4.87	288224
2007	268019.4	137323.9	1961585	120190	309161	571078	6.36	4.3	33	4.76	314237
2008	316751.7	172828.4	2255583	151329	339260	584961	6.4	4.6	33	4.73	330354
2009	345629.2	224598.8	2491874	185786	366705	594388	6.55	4.7	33	4.68	333348
2010	408903	251683.8	2877536	233892	403777	622284	6.62	4.5	33	4.48	364271
2011	484123.5	311485.1	3303698	367311	440620	644677	6.6	4.5	34	4.45	393263
2012	534123	374694.7	3709998	568548	460578	664333	6.63	4.7	34	4.68	390438

3. Method

In the statistical analysis of time series,autogressive-moving-average(ARMA) models provide a stationary stochastic process in terms of two polynomials, one for auto-regression(AR) and the other is moving average(MA).

The AR (p) model of order p is written:

$$X_t = c + \sum_{i=1}^{p} \varphi_i X_{t-i} + \varepsilon_t \quad (1)$$

Where $\varphi_1, \cdots, \varphi_p$ are parameters, c is a constant, ε_t is the random variable.

The MA(q)model of order q is written as

$$X_t = \mu + \varepsilon_t + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i} \quad (2)$$

Where θ_i are parameters, μ is the expectation of X_t ,and ε_{t-i} are error terms.

The ARMA(p,q) model can be written as:

$$X_t = c + \varepsilon_t + \sum_{i=1}^{p} \varphi_i X_{t-i} + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i} \quad (3)$$

Regression analysis is a statistical method to determine between two or more quantitative variables interdependent relationships. Specifically, the regression analysis is Variables determined by the provisions of the causal relationship between variables, regression model, and based on the measured data to solve the various parameters of the model, and then evaluate whether the regression model can fit the measured data; can be a good fit if you can predict based on the argument further. The specific steps of regression analysis are as follows:

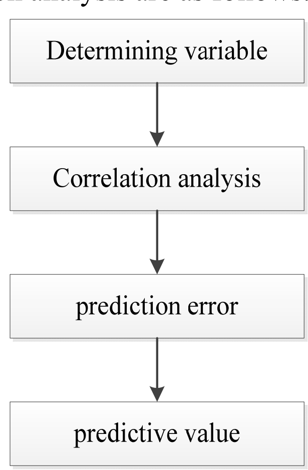

Figure 2. Steps of regression analysis

4. Results and analysis

Correlation analysis is first conducted, the results are listed in table 3, most variables have strong relationship with railway freight volume Y, and their Zero-order correlations more than o.8 basically, X_8 and X_9 have weak relationship with Y. The relationship of $X_1, \cdots, X_{10}$ with Y are presented in Table.3.

Table 3 The correlation coefficient of X with Y

	Zero-order correlations	Partial correlation		Zero-order correlations	Partial correlation
X1	.965	.904	X6	.992	.251
X2	.942	-.212	X7	.989	.524
X3	.946	-.709	X8	-.411	-.696
X4	.833	.116	X9	.069	-.368
X5	.994	.399	X10	-.908	-.469

Despite the influence of each variable on the rail freight are different, all these variables have an impact on cargo sizes. In order to learn the trend of the railway freight volume and factors, we use ARMA model to analyze the data. As the raw data have a different dimension, we first conduct logarithmic transformation for the raw data, the trend figure of the transformed data can be see in Fig.3.

It can be seen from Fig.3 that X_4 have the maximum fluctuation in all variables, as X_4 refer to express volume, in 2007, the internet experienced rapid development, which leads to a larger growth of express volume.

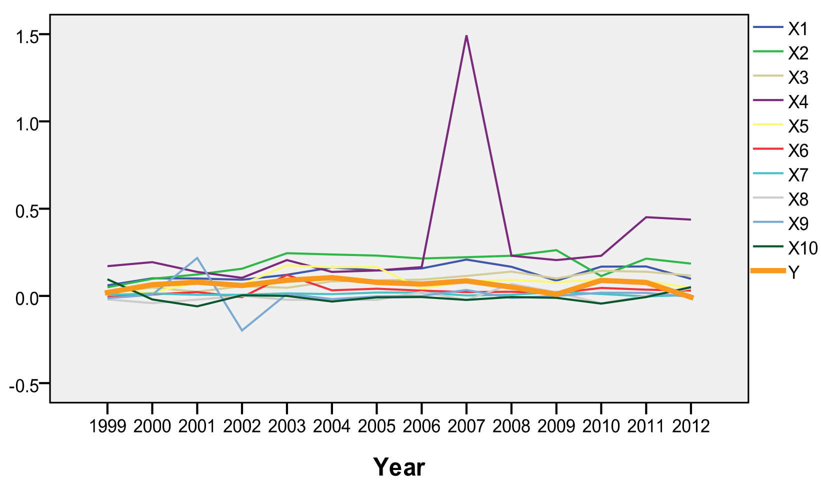

Figure 3. The trend of variables

Furthermore, we make use of R to achieve the order of the regression equation, the Fig.4 are the trend and stationary of the railway freight volume from 1998 to 2012, it shows that the rail freight volume experienced a relatively high growth in 2001, and its value back to its previous level in 2002. Overall, the growth of railway freight volume is very slow.

Figure.4 The trend of rail freight and the first order differential of rail freight

Then we can make multiple regression analysis for the explanatory variables and the response variable, the anova of the model is presented in Table 4, it shows that regression analysis for these variables are statistically significant.

Table 4 ANOVA of variables

Model	SS	df	MS	F	Sig.
Regression	9.115E10	10	9.115E9	703.686	.000
residual	5.181E7	4	1.295E7		
sum	9.120E10	14			

Table 5 Multiple regression model

	Coefficients	Std. Error	t Stat	Sig.
Intercept	95549.834	266494.642	.359	.738
X1	.895	.212	4.219	.013
X2	-.148	.342	-.434	.686
X3	-.100	.050	-2.009	.115
X4	.016	.070	.234	.826
X5	.184	.212	.869	.434
X6	.076	.146	.519	.631
X7	42935.468	34935.680	1.229	.286
X8	-26315.700	13568.263	-1.940	.124

X9	-524.832	663.183	-.791	.473
X10	-9804.594	9231.805	-1.062	.348

The results of regression analysis are presented in Table 5, we can write out the multiple regression equation as follows. And we can use this equation to analysis the relationship between Y with X_i ($i = 1, \cdots, 10$).

$$\begin{aligned} Y = 95549.834 + 0.895X_1 - 0.148X_2 - X_3 + 0.16X_4 + 0.184X_5 + 0.076X_6 \\ + 42935.468X_7 - 26315.700X_8 - 524.832X_9 - 9804.594\ X_{10} \end{aligned} \quad (4)$$

From regression equation (4), we could know that Y have positive correlation with X_1, X_4, X_5, X_6, X_7, Y have negative correlation with X_2, X_3, X_8, X_9, X_{10}. And regression equation (4) can be used to predict the short term rail freight volume if we know $X_1, \cdots, X_{10}$

5.Conclusions

Railway freight volume analysis play a fundamental role in making freight traffic plan. This paper analyzed the influence factors on rail freight volume based on ARMA model with multivariate regression model, we get the regression equation that characterized the relationship between rail freight volume and ten selected indicators. we found that rail freight volume is affected by many factors together, and gross domestic product produce a vital role on rail freight volume. For one hand, our results can be used to analysis how the ten selected variables influence the rail freight volume. For another, the regression equation can be used to predict the short term rail freight volume. In the future, we can combine the time series method with the machine learning method to analyze this question.

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References

LI, H.Q., and LIU, K.(2003)Analysis of Railway Fright Volume Based on Fractal

Theory.Journal of the China Railway Society , 25(3):19-23.

LI, H.Q.and LIU, K.(2004).Prediction of Railway Freight Volumes Based on Rough Set Theory.Journal o f the China Railway Society , 26(3):1-7.

LIN, X.Y.and CHEN Y.X. (2005) Study on Railway Freight Volume Forecast by the Gray-Mar kov Chain Method .Journal of the China Railway Society , 27(3):15-19.

XIE,J.W.and ZHANG Y.B.(2004) , WANG Zhi-wei .Railway Freight Volume Forecasting Based on Unbiased Grey-Fuzzy-Markov Chain Method.Journal of the China Railway Society , 31(1):1-7.

ZHANG, C.and ZHOU X.F.(2007) Prediction of Railway Freight Volumes Based on Gray Forecast-Markov Chain-Qua litative Analysis.Journal of the China Railway Society, 29(5):15-21 .

ZHAO, C.LIU, K., and LI, D.S. (2004) .Freig ht Volume Forecast Based on GRNN.Journal of the China Railway Society , 26(1):12-15.

Evaluation of High-Speed Railway Product Adaptability

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Abstract: Adaptability of high-speed passenger transport products is assessed from the service level and market competitiveness. Index system of service level is established and grey comprehensive evaluation method is used to calculate the service level of Wuhan-Guangzhou high-speed line. Sharing rate of high-speed railway is calculated by non-disaggregate model, and analyzed the influence of fares and travel time on the sharing rate. It is concluded transport enterprises should design products based on demand of market and itself, and then discount fares and adjust travel time to improve adaptability of high-speed passenger transport products.

Keywords: High-speed railway; Adaptability; Service level; Sharing rate.

Introduction

With the development of high-speed railway, railway transport capacity is released, and it creates conditions for improving high-speed railway services. Passenger channel gradually formed in some economically developed cities, in which high speed railway, ordinary railway, highway and other transportation ways compete with each other (BaoJingjing, 2012). Transportation market competition is becoming increasingly fierce, high-speed railway transport enterprise must evaluate on existing products, then design and optimize the transportation service to provide high quality products, which can help maximize attract traffic and strengthen the competitiveness in the transport market. Based on this, this paper firstly analyzes the internal service characteristics of high-speed railway transportation product, and calculates the share rate of high speed railway; then based on demand, paper evaluates the product from the high-speed rail competition in the transport market to analyze the suitability of high-speed railway product (Liu Dongfei, 2013).

1 Measurement index system of service level

Service level of high-speed railway transportation product reflects the extent to meet the transportation needs. The evaluation index system of service level of transportation product is shown in the figure below:

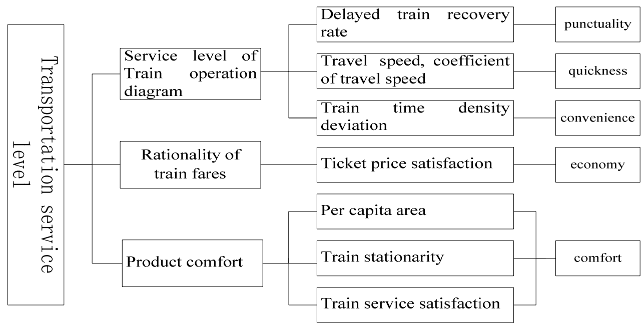


Figure 1.Evaluation index of transportation service level

1.1 Service level of train operation diagram

Service level of train diagram includes recovery rate of late trains, travel speed, coefficient of travel speed and deviation of train time-density.

Recovery rate of delayed trainrefers to the ratio of late trainsthat can be restored punctuality of total delayed trains by setting buffer time in train diagram, under the conditions of certain capacity utilization and probability distribution of delayed time.

Travel speed is referred to the average speed of train running in the segment, including stop time in intermediate stationsand additional time of start-stop. Coefficient of travel speed is the ratio of the average travel speed of running speed, which reflects the reduction degree resulted bytrain stopping on the way.

Train time density deviation R is to contrast passenger travel time preference and statistics of departuretrains from train schedules in different periods, and measures the matching degree between train departure time and passenger travel time preference.

1.2 Rationality of train fares

Economy mainly depends on the level of high-speed railway freight rate, and freight rate levels associate with income, transportation costs and competitive factors. This paper selects fares satisfaction to measure the rationality of train, it reflects satisfaction of passengerson fares from the passengers'point of view.

1.3 Product comfort

Product comfort refers to the comfort level of passengers perceived on the train, and decided by the per capita area, operation stability and to train service satisfaction.

Per capita area is calculated depending on the type of emu, and refers to the ratio of the area passengers can useof the train capacity.Running stability N is subjective feelings of passengers on the magnitude and frequency of train vibration.

Train service satisfaction refers to all the passengers' satisfaction on the train service, that will begetaccording to the questionnaire statistical analysis.

1.4 Classification standard of evaluation index

The indexes will be divided into five grades in order to get a unified evaluation results, A grade (5 points) is the best, class B (4 points) is second, and so on, each level corresponds to a certain range of parameter values. Specifically, the classification standard of each index is shown in table 1.

Table 1.The evaluation index system and grading standard

Rule layer	Index layer	A/5	B/4	C/3	D/2	E/1
punctuality	Recovery rate	≥0.95	[0.9,0.95)	[0.85,0.9)	[0.8,0.85)	<0.8
quickness	Travel speed	[240,300)	[200,240)	[160,200)	[120,160)	<120
	Coefficient of travel speed	[0.85,0.9]	[0.8,0.85) (0.9,0.95]	[0.7,0.8) >0.95	[0.6,0.7)	<0.6
economy	Fare satisfaction	≥0.9	[0.8,0.9)	[0.7,0.8)	[0.6,0.7)	<0.6
comfort	Per capita area	≥1	[0.8,1)	[0.6,0.8)	(0.3,0.6)	≤0.3
	Train stationarity	≤1	(1,2]	(2,4]	(4,5]	>5
	Service satisfaction	≥0.9	[0.8,0.9)	[0.7,0.8)	[0.6,0.7)	<0.6
convenience	Train time density deviation	≤0.2	(0.2,0.4]	(0.4,0.6]	(0.6,0.8]	>0.8

1.5 Evaluation results and conclusions

On the basis of operation data of Wuhan-Guangzhou high-speed line and passenger questionnaire survey, the calculated results and service levels of each index is determined. We issued 2000 questionnaires by face-to-face form, and effective rate is 88.2% According to passenger preference for the transport product quality, we judge the relative importance ofevaluation indexes and construct judgment matrix by Analytic Hierarchy Process, then the weights for each indicator is shown in table 2.

Table 2.Evaluation index calculation results and the weight

Rule layer	Weight	Index layer	Results	Level	Level 2 weight	Level 1 weight	Rating
punctuality	0.081	Delayed train recovery rate	0.96	A/5	0.5	0.041	5/A
quickness	0.220	Travel speed	246.3	A/5	0.67	0.147	5/A
		Coefficient of travel speed	0.852	A/5	0.33	0.073	
economy	0.116	Ticketpricesatisfaction	0.29	E/1	0.34	0.040	1/E
comfort	0.158	Per capita area	1.03	A/5	0.33	0.052	4.33/ A-B
		Train stationarity	1.19	B/4	0.33	0.052	
		Train service satisfaction	0.86	B/4	0.34	0.054	
Convenience	0.200	Train time density deviation	0.44	C/3	1	0.200	3/C

The service level evaluation result is 3.67 through grey comprehensive evaluation method based on the above results.Therefore, the service level of high-speed transportation supply in the Wu-Guang channel is between B and C grade. Among them, quickness, punctuality belongs to grade A, comfort is between class A and class B, convenience belongs to class C, and economy belongs to E grade.

Following conclusions are get: 1) Increasing the speed of train travel can make high-speed railwaymore attractive; 2) The level of high-speed railway train service process needs to be improved; 3) Train time density deviation degree is higher and should be adjusted to improve the convenience; 4) Passenger considerfares high because of fare mechanism not flexible enough. So this paper will analyze the suitability of high-speed railway passenger transport products on the basis of fares.

2 Calculation on sharing rate of high-speed railway

Based on analysis and evaluation on internal service properties of high speed railway transportation product, the market share in the channel still need to be calculated to analyze high-speed rail products adaptability from the perspective of the competition with other modes. Logit model is one of the most commonly used model of non-disaggregate model, paper will use it (Wu Wenxian, 2011).

2.1Selection and calibration of characteristic variables

According to the results of existing research and software, this paper finally choose income, travel time and cost as characteristic variables of linear utility function, specific calibration method is as follows.

The income level determines on the travel consumption desireto a certain extent, there are significant differences in main factors considered by different passengers when choosing the mode of transportation, the feature variables can be directly obtained from the questionnaire. This questionnaire takes monthly income of 4,000 or less as low-income groups; monthly income between 4000 and 8000 for income levels; monthly income of more than 8000 as high-income people.

Travel time is generally defined as passengers' travel timein transit, and is calculated as follows:

$$T_n^i = \frac{L_{od}^i}{V_i} + 2t_{nd}^i + t_{ns}^i + t_{nx}^i + t_{nw}^i \quad (1)$$

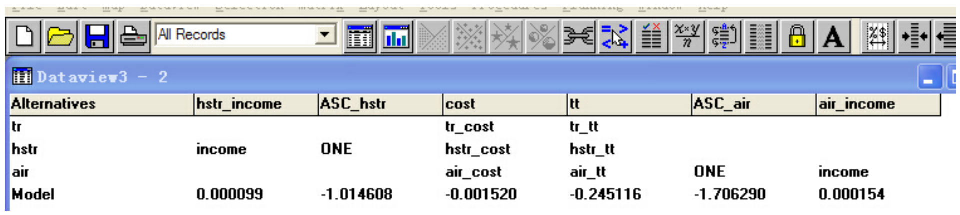
In the formula, t_{nd}^i —time needed of traveler n choose the mode i to arrive/depart the station ; t_{ns}^i 、 t_{nx}^i 、 t_{nw}^i —time required to get on、get off and wait; L_{od}^i —distance of i way; V_i —average speed of i mode of transportation.

Travel cost is determined through fare rate multiplied by the distance between each OD.Quantitative values of characteristic variables are listed in the table below.

Table 3.Service parameters of transportationmodewithinWuhan-Guangzhou channel

The mode of transportation	Operating range（km）	Freight rate （Yuan/km）	average time of city traffic（h）	average waiting time（h）
High speed train	1069	0.45	0.96（Guangzhou） 0.96（Wuhan）	0.83
Train	1069	0.16	0.46（Guangzhou） 0.60（Wuhan）	1
Air	873	0.762	1.56（Guangzhou） 1.56（Wuhan）	1.5

To model parameters are calibrated by Transcad:



Alternatives	hstr_income	ASC_hstr	cost	tt	ASC_air	air_income
tr			tr_cost	tr_tt		
hstr	income	ONE	hstr_cost	hstr_tt		
air			air_cost	air_tt	ONE	income
Model	0.000099	-1.014608	-0.001520	-0.245116	-1.706290	0.000154

Figure 2 Results of parameters calibration

Combined with average time-consuming of urban passenger traffic in cities along Wuhan-Guangzhou railway, the utility function formis shown.

$$V_{tr} = -0.001520C - 0.245116T \quad V_{hstr} = -0.001520C - 0.245116T + 0.000099inc - 1.014608 \quad V_{air} = -0.001520C - 0.245116T + 0.000154inc - 1.706290$$

In the formula, C—travel cost; T—travel time; inc—the income.

The sharing rate of existing railway, high-speed passenger railway and air three ways is shown in the table below:

Table 4.Passenger transport sharing rate of differentways in the channel

interval / mode	Wuhan-Guangzhou	Wuhan-Changsha
Train	26.92%	48.57%
Hs train	49.91%	35.86%
Air	23.17%	15.57%

For Wuhan-Guangzhou channel, railway has higher market share, which reached more than 70%.Sharing rate of high-speed railway and air passenger transport is relatively low because the distance is short and time advantage is not obvious.

2.2 Influence of high-speed railway fares on passenger sharing rate

Research about influences of high-speed railway fares on passenger sharing rate provides the basis forestablishing reasonable fares and improving the market competitiveness of high-speed railway products.

Here take Wuhan - Guangzhou section as an example,study the effects of fare for the sharing rate, the specific results as shown in the figure in figure 3.

For Wuhan-Guangzhou segment, price elasticity of share rate among income groups is a constant, with a mean of 3.36×10^{-4}.The fare is lower, the greater the share rate is.Therefore,transport companies want to increase the sharing rate of high speed railway, they can make a certain degree of reduction of ticket pricesaccording to different income groups.

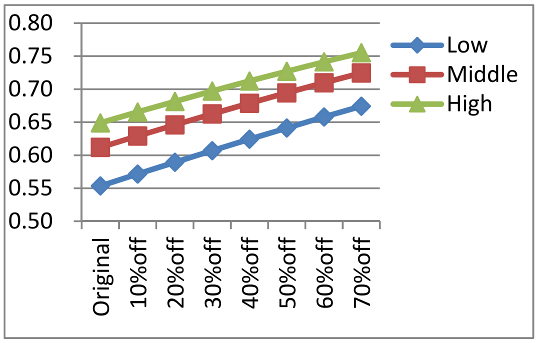


Figure 3.The influence of high-speed rail fares

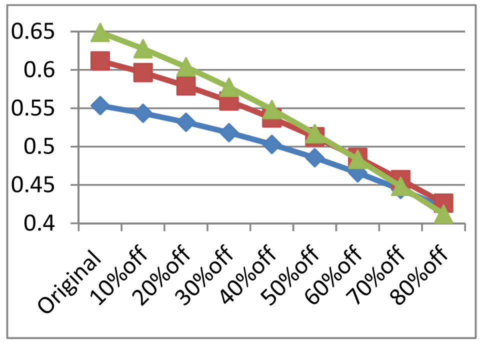


Figure 4. The influence of air fares

Air fare is lower,the sharing rate of high-speed rail is lower. Sensitivity change of income groups to air fares is not big;high-income people have greater susceptibility to airline fares; and when the air ticket discount gets to a certain degree, the sharing rate of different groups is basically the same. When air fareis down, high-speed railway transport enterprises can also make a certain degree of reductionaccording to the specific situation; when high-speed fares and air fares changes at the same time, sharing rate of high-speed railway change as shown in figure5.

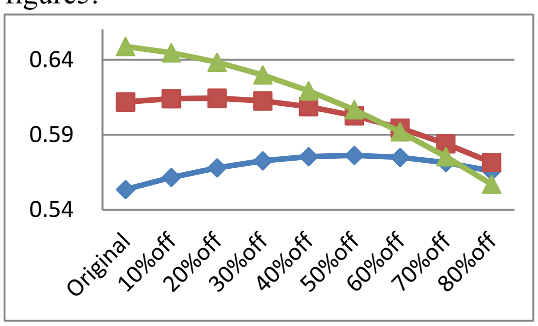


Figure 5.Influence of high-speed rail and air fares

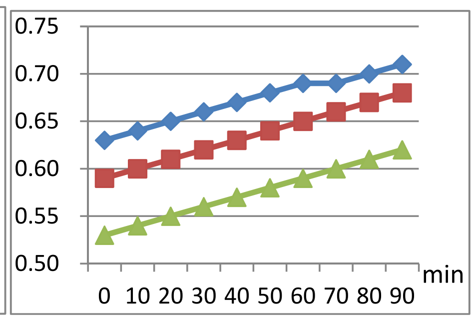


Figure 6. The influence of travel time

From the foregoing: 1) High-speed railway and air ticket prices fall at the same time, the sharing rate of high income and middle income groupsis on the decline. The sharing rate of low-income groupsrise first with ticket prices down, then itrises no longer when fare discount is 5 fold, if discount continues high-speed railway sharing rate willedcrease; 2) High income passengers have higher sensitivity to the high-speed rail and air fares.

Currently, fares developing of various modes of transport should be well adapted to the market mechanism and make different price strategy according to different consumer groups. Enterprises should raise the ticket prices of high and intermediate grade groups andreduce fares of ordinary seats at the same time; take fare difference between high and intermediateseats to compensate fares of ordinary seats.

2.3 Influence of travel time on sharing rate

Studying the influence of travel time on sharing rate can provide technical basis for designing high-speed railway transportation products and increasing the amount of visitors attracted. It can be seen from figure 6.

(1) The sensitivity of travel time to the sharing rate basically remains unchanged. Compared withthe average of price elasticity above, travel time has greater impact on the sharing ratethan the fares;

(2) High-speed sharing rate shows a trend of gradually increasing with the shortened travel time;

(3) According to the needs of enterprise itself and passengers to design high-speed passenger rail products and make a certain compression on running time, such as raising speed, which can help to improve the market competitiveness.

3 Conclusion

This paper set up index system of service level from the supply service level of railway transportation and market share; and then conducts a preliminary assessment on service level of high-speed products. Finally, it calculates the sharing rate of high-speed through non-disaggregate model, andadaptability of high-speed passenger rail products is evaluatedfrom the angle of market competitiveness. Conclusion is transport enterprisecan make a certain degree of price discounts and compress travel time according to specific market demand and the needs of itself.Based on characteristics of passengers' choice behavior, enterprise can design different products to meet the demand of passengers, improve the adaptability of the high-speed railway transportation products, and make the high speed railway transport enterprise has a stronger market competitiveness.

References

Bao Jingjing.(2012) “The Evaluation Theory and Method of High-speed Train Diagram”.Southwest Jiaotong University.

Liu Dongfei.(2013) “Comprehensive Evaluation of High-speed Railway Passenger Satisfaction”.Beijing Jiaotong University.

Wu Wenxian.(2011) “Research on the Share Rate of Passenger Flow and Tansportation Origanization Stategy in Railway Transportation Corridor”.China Railway Science,32(2):126-129.

GuoChuijiang,WangHuijing.(2011) “Model and Algorithm for Adjustment of High-speed Railway Service Properties Basd on Market Demand”. Journal of the China Railway Society, 33: 8-12.

Effects of Curve Parameters on Wheel-Rail Dynamic Characteristics of Heavy Haul Railways

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Abstract: Based on the multi-body dynamics software SIMPACK, a vehicle-track dynamics model on heavy haul railway is established. And effects of curve radius and superelevation on wheel-rail dynamics performance are analyzed by the model. The results show that wheel-rail dynamics performance is improved with the increase of curve radius of heavy haul railway, but it is improved to a lesser extent when curve radius is over 800 m. And wheel-rail dynamics performance will be decreased when the superelevation on curve is excessive or inadequate. So deficient superelevation is advantageous for improving the wheel-rail dynamics performance and the reasonable superelevation is recommended to decrease 5% to 10% of balanced superelevation.

Keywords: Curve radius; Superelevation; Wheel-rail dynamics performance; Heavy haul railway.

1 Introduction

With the development of heavy haul railway and the increase of axle load and density of heavy haul train, dynamic interaction will further enlarge between wheel and rail. More factors affect wheel-rail dynamic characteristics and there are many domestic and foreign scholars have done a lot of research on this. The effect of track stiffness on vehicle vibration is investigated by means of the theoretical method of vehicle-track coupling dynamics (ZHAI Wanming, 2000). And the impact of suspension parameters of heavy haul train on wheel-rail dynamic performance is analyzed and the lower suspension wheel-rail dynamic interaction purposes can be achieved by optimizing parameters (HAO Jianhua, 2005; WANG Kongming, 2005; YANG Chunlei, 2011). The impact of mutations on the high-speed vehicles fastener stiffness and dynamic characteristics of the track is calculated and analyzed considering different fastener stiffness mutation conditions (LIU Xueyi, 2014). Although scholars analyze the influence of different factors on wheel-rail dynamic characteristics from multiple angles, the depth analysis of relationship between railway line parameters and wheel-rail dynamic characteristics is not much from the point of railway line design. So the paper will study effects of curve parameters such as curve radius and superelevation on wheel-rail dynamic characteristics of heavy haul railway and the theoretical basis is provided for improving wheel-rail dynamics performance in railway line design.

2 Calculation model and evaluation index

A dynamics simulation model of vehicle/track system in heavy haul railway curves is made by SIMPACK. The 30t axle vehicle model is used, including rigid bodies of one body, two bolsters, four side frames, four wheelsets and so on. And many principal nonlinear factors on vehicle system are considered. The DOFs of vehicle dynamics model were 60, as shown in Table 1. The vertical and lateral DOFs of rails and the integral vertical stiffness, damping of track as well as the integral lateral stiffness, damping of track are considered in the dynamics model. In the simulation model, LM tread and 75kg/m rail of China are used. In order to study the influence of single factor of railway curves on the wheel-rail dynamic characteristics of heavy haul railway, the track irregularity is out of consideration.

Table 1. The DOFs of vehicle dynamics model

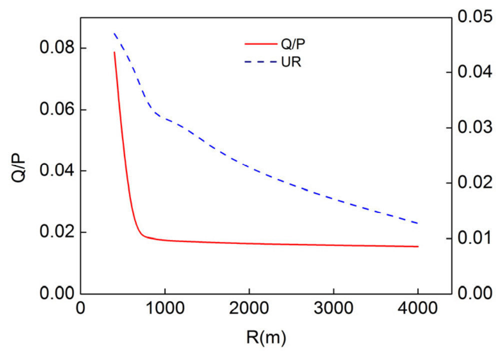
Rigid bodies	Longitudinal movement	Lateral movement	Vertical movement	Anti-roll	Pitch	Yaw	remark
Car-body	x_c	y_c	z_c	α_c	β_c	γ_c	—
Bolster	—	—	z_{bj}	α_{bj}	—	γ_{bj}	j=2
Side frame	x_{tj}	y_{tj}	z_{tj}	α_{tj}	β_{tj}	γ_{tj}	j=4
Wheelset	x_{wj}	y_{wj}	z_{wj}	α_{wj}	β_{wj}	γ_{wj}	j=4

The traditional evaluation methods (ZHAI Wanming, 2007) are used in the evaluation of the wheel-rail dynamic characteristics of heavy haul railway system. The main evaluation indexes include derailment coefficient, wheel unloading rate, lateral wheel-rail force, vertical wheel-rail force and wheel-rail wear index.

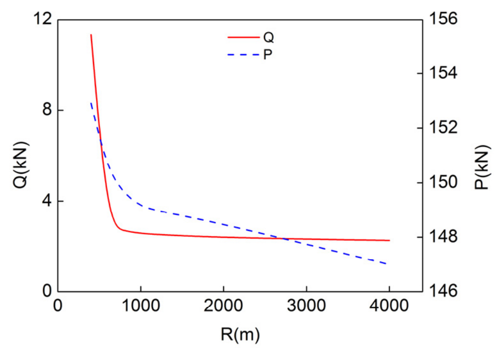
3 Results and Discussion

3.1 Influence of curve radius on wheel-rail dynamic characteristics

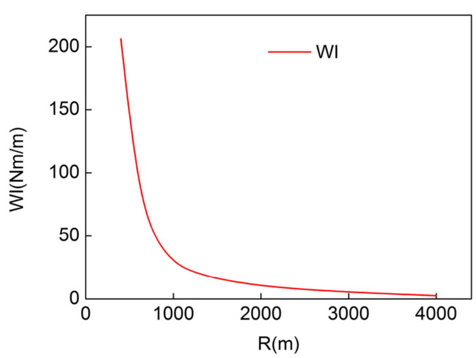
When calculating the speed of heavy vehicle on curve is 60km/h and seven kinds of operating conditions are considered according to 400 m and 600 m, 800 m, 1000 m, 1200 m and 2000 m and 4000 m on curve radius (R). And all curves of superelevation adopt balanced superelevation. Figure 1 shows influence law of wheel-rail dynamic responses in the condition of different curve radius, including derailment coefficient (Q/P), wheel unloading rate (UR), lateral wheel-rail force (Q), vertical wheel-rail force (P) and wheel-rail wear index (WI).



(a) Q/P and UR



(b) Q and P



(c) WI

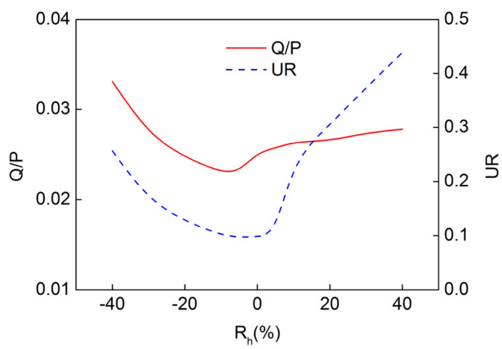
Figure 1. Influence of curve radius on wheel-rail dynamic performance

Figure 1 shows that wheel-rail dynamics performance is improved with the increase of curve radius of heavy haul railway and the values of Q/P, UR, Q, P and WI are decreased by 80.3%, 73%, 80.1%, 3.9%, 98.7% when the curve radius is increased from 400m to 4000m. The influence on wheel-rail wear index is maximum while influence on vertical wheel-rail force is minimum with change of curve radius.

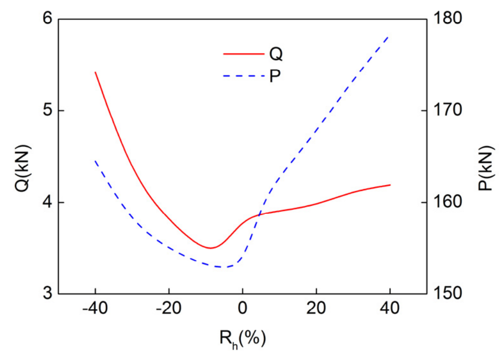
And the curve radius is less than 800m, the wheel rail dynamics performance decreases obviously with decreasing curve radius. But the curve radius is more than 800 m, they increase slower with the growth of curve radius. Therefore, curve radius should be adopted more than 800 m as far as possible in the design of heavy haul railway in order to reduce dynamic interaction between wheel and rail.

3.2 Influence of superelevation on wheel-rail dynamic characteristics

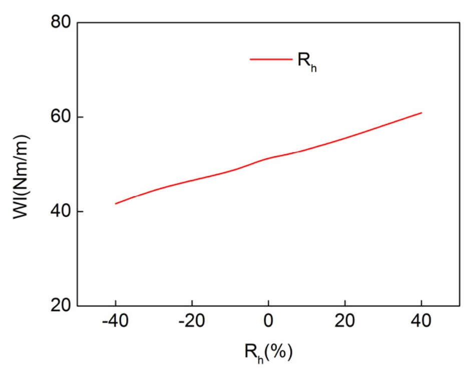
When calculating the speed of heavy vehicle on curve is 80km/h and curve radius is 800m. Superelevation value is used by superelevation change rate (R_h) that is the ratio of difference value between actual superelevation and balanced superelevation and balanced superelevation. And the range of R_h is -40%~40%. Figure 2 shows influence law of wheel-rail dynamic responses in the condition of different R_h.



(a) Q/P and UR



(b) Q and P



(c) WI

Figure 2. Influence of superelevation on wheel-rail dynamic performance

Figure 2 shows that WI grows but Q/P, UR, Q and P decrease after increasing with the increase of curve superelevation. Compared to the maximum value of dynamic response on balanced superelevation (i.e., superelevation change rate is 0), the values of Q/P, UR, Q and P increase respectively by 31.3%, 161.9%, 42.5%, 7.4% when superelevation change rate is -40%, but WI decreased 18.9%.When the superelevation change rate is 40%, the values of Q/P, UR, Q, P and WI rise respectively 10.3%, 348.7%, 10.2%, 16.5%, 18.5%. Also we can see from Figure 2 that the values of evaluation indexes except WI on wheel-rail dynamics performance will be decreased when the superelevation on curve is excessive or inadequate. And when R_h is in the -5%~-10% range, the values of Q/P, UR, Q and P reached the minimum and the largest decreasing range respectively is 30.5%, 62.6%, 36.4%, 7.1%. Therefore, the reasonable superelevation is recommended to decrease 5%~10% of balanced superelevation and deficient superelevation helps to reduce the dynamic wheel-rail interaction.

4 Conclusions

The following conclusions can be drawn from the study.

(1)When the curve radius of heavy haul railway is less than 800 m, the wheel-rail dynamics performance decrease greatly with decrease of radius curve, but the wheel-rail dynamics performance increase with a small range when the radius is more than 800 m. And the curve radius of more than 800m should be used to effectively reduce the wheel rail interaction in the design of heavy haul railway.

(2)The wheel-rail dynamics performance will be decreased when the superelevation on curve is excessive or inadequate. And it is small deficient superelevation, the better wheel-rail dynamic performance can obtain. And the reasonable superelevation of heavy haul railway is recommended for 90%~95% of balanced superelevation.

(3) It is shown through the analysis that the wheel-rail dynamics performance of heavy haul railway is enhanced accordingly with the improvement of heavy haul train speed. But the influence law of curve parameters of heavy haul railway on wheel-rail dynamic characteristics is similar under the condition of different train speed. So only calculation results for the train speed of 60 km/h are given in this paper.

(4)The curve parameters of heavy haul railway have a large influence on the wheel-rail dynamic characteristics. Only the relationship between single parameter of railway curve and wheel-rail dynamic characteristics is analyzed in the paper. Main parameters of railway curve can be matched reasonably to further improve the wheel-rail dynamic performance in the design.

References

HAO Jianhua, ZENG Jing, WU Pingbo. (2005)Vertical vibration isolation and suspension parameter optimization of railway vehicle. *Journal of Traffic and Transportation Engineering*, 5(4) : 10-14.

LIU Xueyi, ZHANG Zhongwang, WAN Zhangbo. (2014)Influence of Fastener Stiffness Mutation in Ballastless Track on Dynamic Characteristics of High speed Trains. *Journal of Railway Engineering Society*, (9): 53-58.

WANG Kongming, LI Fu BU Jiling.(2005)Research on Suspension Parameter and Performance of Freight Car Bogie. *Railway Locomotive & Car*,25(5):4-8.

YANG Chunlei, LI Fu, HUANG Yunhua.(2011) Optimization of Primary Vertical Suspension of Heavy Haul Freight Car. *Journal of Southwest Jiaotong University*, (5): 820-825.

ZHAI Wanming, CAI Chengbiao,WANG Kaiyun.(2000)Effect of track stiffness on train running behavior. *Journal of The China Railway Society*, 22(6):80-83.

ZHAI Wanming. (2007)Vehicle-Track Coupling Dynamics (Third Edition). Beijing: *Science Press*.

Analysis of Effect Parameters of Track Settlement in Heavy Haul Railways

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Abstract: Ballast bed in heavy haul railway will accumulate residual deformation and lead to track accumulative settlement under the repeatedly influence of the dynamic load of train. Studying on rule LU Ye s of track settlement of heavy haul railway is the premise of variant design and maintenance management, the effects of transportation conditions and track structure parameters on ballast settlement were analyzed by improving the existing track settlement calculation model and building track structural finite element analysis model. The results show that vehicle running speed, axle load and railway traffic are main factors of controlling track deformation; it benefits to decrease track settlement by adopting heavy rail, increasing bottom area of sleeper, reducing space of sleeper; track settlement reduces by 12.3% when thickness of ballast increases from 30cm to 40cm, and track settlement increases by 25% when elastic modulus of ballast increases from 90MPa to 150MPa, however, increasing thickness of ballast leads to more maintenance work and small elastic modulus reduces the capacity of structure, therefore, it is important to select track structural parameters reasonably.
Keywords: Heavy haul railway; Ballast bed settlement; Effect parameters; Vertical deformation.

1 Introduction

Two reasons caused settlement and deformation of line: ballast bed settlement and track bed disease. Ballast bed settlement account for 90% of total subsidence of ballasted track. Indoor and field tests (Augustin, 2003; Baessler, 2003) were conducted to study on characteristics of ballast bed accumulated settlement and the calculation formula, theoretical simulation (Indraratna, 2003; Saussine, 2006; Martin, 2012; Eric, 2012) were conducted to analyse settlement rule and influence parameters of ballast bed settlement. So existing track accumulative settlement calculation models are insufficient for heavy haul railway

This paper derive and transform the settlement model of China Academy of Railway Sciences as the calculation model, build finite element model for heavy haul railway by finite element analysis program, analyse ballast bed settlement of different ballasted track structure under different transportation conditions.

2 Building Track Settlement Calculation Model

This paper use the settlement model of China Academy of Railway Sciences(Eq. 1) for reference, transform some parameters of it and build a more reasonable model.

The model include compressive strain and vibration acceleration of ballast bed, but compressive strain of ballast bed(ε) is not convenient to simulate in the model, accumulated settlement is related to transportation conditions and track structure, especially vibration acceleration of ballast bed and stress on the surface of ballast bed is the direct factors of ballast deformation. Therefore, vibration acceleration, stress and height of ballast bed and parameter of sleeper are in the model of this paper.

$$\beta = 1.27 \times 10^{-6} (\varepsilon a_b)^{2.4} \quad (1)$$

with β: amount of ballast bed settlement under load for one time(mm/10^6 times); a_b: vibration acceleration of ballast bed (g); ε: stress of ballast bed($\mu\varepsilon$)

The relationship between pressure of sleeper and amount of compression of ballast bed can be obtained by fitting the experimental data, as shown in Eq. 2

$$\Delta y = 14.591 Q^{0.553} \quad (2)$$

Stress of ballast bed is amount of compression of ballast bed(Δy) divided by thickness of ballast bed(H), as shown in Eq. 3

$$\varepsilon = \frac{\Delta y}{H} \quad (3)$$

Fed Eq. 2 into Eq. 3,

$$\varepsilon = \frac{\Delta y}{H} = \frac{14.591 Q^{0.553}}{H} \quad (4)$$

pressure of sleeper and stress on the surface of ballast bed are in Eq. 5

$$\sigma_b = \frac{2Q}{bl} \quad (5)$$

with σ_b: stress on surface of ballast bed (kPa); Q: pressure of sleeper (kN); b: effective support width of sleeper (m); l: effective support length of sleeper (m)

Fed Eq. 4 and Eq. 5 into Eq. 1, settlement calculation model of ballast sleeper with parameters:pressure and vibration acceleration of ballast sleeper is in Eq. 6.

$$\beta = 5.854 \times 10^{-2}.\left(\frac{a_b}{H}\right)^{2.4}.(\sigma_b bl)^{1.3272} \quad (6)$$

In the following, we refer settlement to ballast bed settlemen for simplification.

3 Transportation Conditions Effect on Ballast Bed Settlement

3.1 Speed

Take speeds are 60km/h, 80km/h, 100km/h and 120km/h, axle load is 27t, type Ⅲ concrete sleeper, analyse regulation between settlement and speed.

Table1. Ballast bed settlement under different speeds

speed /km/h	60	80	100	120
maximum ballast bed settlement /×10^{-6}mm	4.904	6.104	7.708	19.743
average ballast bed settlement /×10^{-6}mm	2.551	3.753	4.912	7.907

As shown in Table 1, amount of settlement increase as speed increase. When speed increase from 60km/h to 120km/h, amount of maximum settlement increase from 4.904×10^{-6}mm to 19.743×10^{-6}mm under one time load, with the increase of speed, change rate is large. When speed is more than 100km/h, amount of settlement increase rapidly, so speed should not be too high.

3.2 Axle Load

Take axle load is 25t, 27t and 30t,speed is 80km/h. As shown in Table 2, axle load has great impact on settlement, When axle load increase from 25t to 30t, amount of maximum ballast bed settlement increased by 38.6%. Therefore, axle load become one of major parameter to control track deformation.

Table2. Ballast bed settlement under different axle loads

axle load（t）	25	27	30
maximum ballast bed settlement /×10^{-6}mm	5.339	6.104	7.398
average ballast bed settlement /×10^{-6}mm	3.246	3.753	4.620

3.3 Traffic

Amount of settlement would increase with traffic increase, due to unable to reflect influence of traffic, using times of load to reflect cumulative settlement. The relationship between carrying gross weight and number of load replication as follow.

$$N_L = \frac{10^6}{A_t \cdot N_a} \quad (7)$$

with N_L: number of load replication corresponding to 1 million tons of carrying gross weight; A_t: axle load; N_a: axle replication under one time load

Firstly, calculated the amount of settlement under one time load, used Eq. 7 to calculate the number of times, then it can calculate a amount of ballast bed settlement under certain traffic. As shown in Figure 1.

From Figure 1, amount of settlement increase along with number of loads, i.e. amount of subsidence of track structur become large when the traffic increase.

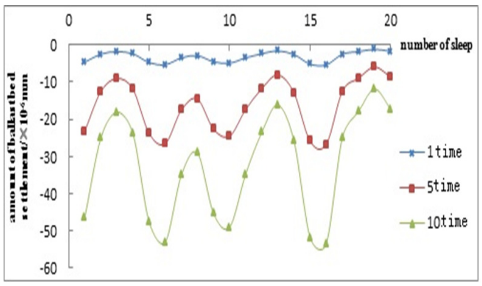

Figure1. Amount of maximum ballast bed settlement under different loads

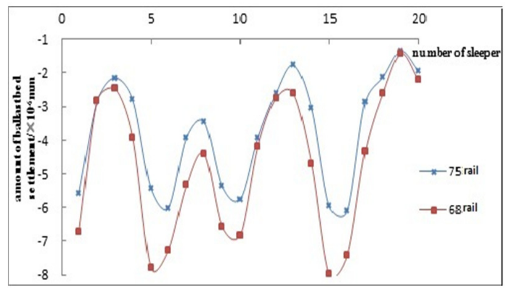

Figure2. Maximum ballast bed settlement under different type of rails

4 Track Structure Effect on Ballast Bed Settlement

4.1 Rail

This paper calculated amount of settlement when the type of rails are 68 rail and 75 rail, axle load is 27t, speed is 80km/h and type Ⅲ concrete sleeper.

Table3. Ballast bed settlement under different type of rails

type of rails	68 rail	75 rail
maximum ballast bed settlement /$\times10^{-6}$mm	7.977	6.104
average ballast bed settlement /$\times10^{-6}$mm	4.721	3.753

From Figure 2, maximum settlement decrease when quality of rail is enlarged, amount of settlement decrease by 23.5% if use 75 rail rather than 68 rail, therefore, type of rails have strong effect on settlement.

4.2 Sleeper

Calculated amount of settlement when sleepers are type III concrete sleeper and type Ⅱ concrete sleeper, axle load is 27t, 80km/h speed and 75 rail.

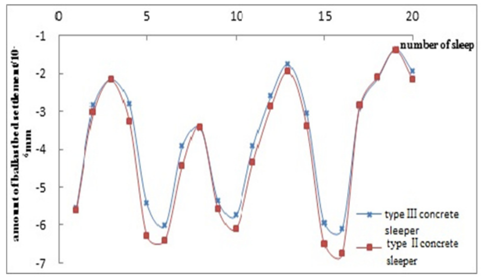

Figure3. Maximum ballast bed settlement under different type of sleeps

Table4. Ballast bed settlement under different type of sleeps

sleeper	type Ⅱ concrete sleeper	type Ⅲ concrete sleeper
maximum ballast bed settlement /$\times 10^{-6}$mm	6.766	6.104
average ballast bed settlement /$\times 10^{-6}$mm	4.031	3.753

From the above, amount of settlement under type Ⅲ is 10% lower than type Ⅱ, increase area size of sleeper bottom can reduce amount of settlement, for increasing contact area of sleeper will reduce stress of the surface of ballast bed.

4.2 Sleeper Span

There are 1667 sleepers in per kilometer in heavy haul railway, calculate amount of settlement under 1760 sleepers and1840 sleepers in per kilometer, corresponding to sleeper span of 0.600m, 0.568m and 0.545m. Axle load is 27t, speed is 80km/h,75 rail and type Ⅲ concrete sleeper, results are shown in Table 5.

Table5. Ballast bed settlement under different spaces of sleeps

sleeper span（m）	0.600	0.568	0.545
maximum ballast bed settlement /$\times 10^{-6}$mm	6.104	5.367	4.846
average ballast bed settlement /$\times 10^{-6}$mm	3.753	3.532	3.315

Amount of settlement increase with the increase of sleeper space, amount of settlement increase by 25.9% when sleeper space increase from 0.545m to 0.600m. Therefore, rational sleepers should be configured to control settlement.

4.4 Elastic Modulus of Ballast Bed

Calculated amount of settlement when elastic modulus are 90, 110, 130 and 150MPa.Results are shown in Table 6.

Table6. Ballast bed settlement under different elastic modulus

elastic modulus（MPa）	90	110	130	150
maximum ballast bed settlement /$\times10^{-6}$mm	4.867	5.345	5.806	6.104
average ballast bed settlement /$\times10^{-6}$mm	3.149	3.305	3.559	3.753

From table 6, the greater of elastic modulus,the stronger of track structure vibration, this increase amount of settlement, amount of settlement increased by 25% when elastic modulus increased from 90MPa to 150MPa, thus, different elastic modulus have different effect on settlement. Too small elastic modulus can decrease settlement but also decrease the bearing capacity of track structure.

4.5 Thickness of Ballast Bed

Calculating amount of settlement when thickness of ballast bed are 30cm, 35cm and 40cm. Results are shown in Table 7.

Table7. Maximum ballast bed settlement under different thickness of ballast

thickness of ballast bed（cm）	30	35	40
amount of ballast bed settlement /$\times10^{-6}$mm	3.753	3.485	3.292

Amount of settlement decrease with the increase of thickness, and the influence to settlement of thickness is larger. Amount of settlement decreased by 12.3% when thickness increased from 30cm to 40cm. The greater thickness of ballast bed can be advantageous to the dispersion of train load, but increase maintenance workload.

5 Conclusions

(1)Transportation conditions have a large effect on ballast bed settlement. Amount of settlement will increase with the increase of speed, amount of settlement increases about 3 times when speed increases from 60km/h to 120km/h, and amount of settlement increases rapidly when speed is more than 100km/h; amount of settlement increases by 38.6% as axle load increases from 25t to 30t, with increasing traffic, there is a linear relationship between amount of settlement and traffic.

(2)Track structure also have effect on ballast bed settlement. Amount of settlement decreases by 23.5% by using 75 rail; type III concrete sleeper and type Ⅱ concrete sleeper are almost the same; amount of settlement increases by 26.9% when sleeper space increases from 0.545m to 0.6m; amount of settlement increases by 25% when elastic modulus increases from 90MPa to 150MPa; the thicker of ballast bed, the smaller vibration acceleration of ballast bed, amount of settlement decreases by 12.3% when thickness increases from 30cm to 40cm; Therefore, comprehensive consideration should be taken during selecting the track structure in view of each track structure parameter have different effect on settlement.

References

Augustin S, Gudehus G, Huber G, et.a1. (2003). "Numerical model and laboratory tests on settlement of ballast track." *System dynamics and long-term behaviour of railway vehicles，track and subgrade*，Berlin：Springer, 317-336.

Baessler M, Ruecker W. (2003). "Track settlement due to cyclic loading with low minimum pressure and vibrations." *System dynamics and long—term behaviour of railway vehicles, track and subgrade*, Berlin: Springer, 337-356.

Eric G. Berggren, Martin X.D. Li, Jan Spannar.(2012). "A new approach to the analysis and presentation of vertical track geometry quality and rail roughness." *Wear*,265,1488-1496.

Indraratna Buddhima, Salim Wadud.(2003). "Deformation and degradation mechanics of recycled ballast stabilized with geosynthetics." *Soils and Foundations*, 43(4), 35-46．

Martin Li, Ingemar Persson, Jan Spännar & Mats Berg (2012). "On the use of second-order derivatives of track irregularity for assessing vertical track geometry quality." *Vehicle System Dynamics*, 50, 389-401.

Saussine G,Cholet C,et.al.(2006). "Modelling ballast behavior under dynamic loading.Partl:A 2D Polygonal discrete element method approach." *Computer methods in applied mechanics and engineering*, (195), 2841-2859

Reconstruction and Modeling Method for Rail Head Checks in Heavy-Haul Railways Based on X-Ray Computed Tomography and the Extended Finite Element Method

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Abstract: To understand the characteristics of head check (HC) propagation, the methods for reconstruction and modelling HCs in the rail were presented by realizing the geometry morphology and spatial position of HCs with the help of some creative technologies: X-ray computed tomography (CT) was applied to detect the rail specimens taken from a curve in a heavy-haul railway and the three dimensional (3D) internal information of HC was extracted and digitalized to the point cloud data with 3D coordinate by thresholding of the grey level. For splicing HCs in different rail specimens, removing the abnormal points, extracting and fitting the edges of HCs, the algorithms for investigating the geometry characteristics, including geometry morphology and spatial angle were designed and programmed. Therefore, the reconstruction of 3D HCs in rail was realized by reconfiguration of geometry morphology and spatial position. By defining the contact property, the fitted 3D HCs were assembled and coupled with a 3D rail model for further crack propagation analysis with the eXtended finite element method (XFEM). The reconstruction results can provide an accurate method for reconstruct HC and a reliable model for study the HCs propagation in the rails of the heavy-haul railway.
Keywords: Heavy-haul railway; HCs; X-ray CT; 3D reconstruction; XFEM.

1 Introduction

With the application of the alloy rail and heat-treated rail with high hardness and good wear-resistance in China heavy-haul railway, rolling contact fatigue (RCF) cracks came to be one of the main defects to rail lifetime. Head Check (HC), one kind of RCF cracks, initiated at rail gauge corner and shoulder at the early stage after new rail installation and propagated rapidly while it could not be worn away easily. To investigate the characteristics of HCs propagation, a model with information about the geometry morphology and spatial position of HCs should be built and analyzed for simulating further. The traditional destructive examinations only allowed to observe the crack from the cross-section along the longitudinal or transverse direction of the rail by cutting, of which only the projection of the crack in the longitudinal or transverse planes were observed and the true morphologies of HCs were damaged (Zhou, 2014) since the HCs often took an orientation of a certain angle with respect to the longitudinal or transverse direction of the rail, and it was hard to reconstruct HCs. Thus, the shape of the HCs were often assumed as standard semi-circular or semi-elliptical in traditional models (Bogdanski, 2002). As HC was micro-scale and distributed densely, 3D image software had the limitation on the precision of reconstruction the geometry and spatial position automatically, while error was larger if dealt with by manual operation, e.g., defining the value of HC in size and spatial position.

In this paper, X-ray computed tomography (CT) was applied for examining the three dimensional (3D) shape of the HCs inside the rails. 3D rendering of the HCs shape were obtained by thresholding of the grey level, and the 3D internal information of the HCs were extracted from the surrounding rail microstructure and digitalized to the point clouds data with 3D coordinate, by which the geometry and spatial position of HC was defined. Considering wheel-rail interaction and with the help of eXtended finite element method (XFEM) (Ding, 2007), 3D rail finite element (FE) model coupling with reconstruction 3D HC was built, which provided a reliable model for study the HCs propagation.

2 Extraction of point cloud data of 3D HCs

A 500m radius curve in a dedicated coal heavy-haul railway was chosen as field test line. The samples were 75 kg/m U75V heat-treated rails. As shown in Figure 1, samples were cut to specimens by the size of 5mm high, 10mm wide, and 50mm long along the longitudinal direction of rail. HCs in specimen 1 and 2 were chosen to CT scan because it located 12 mm away from the gauge face where HCs were first observed at this location in field tests.

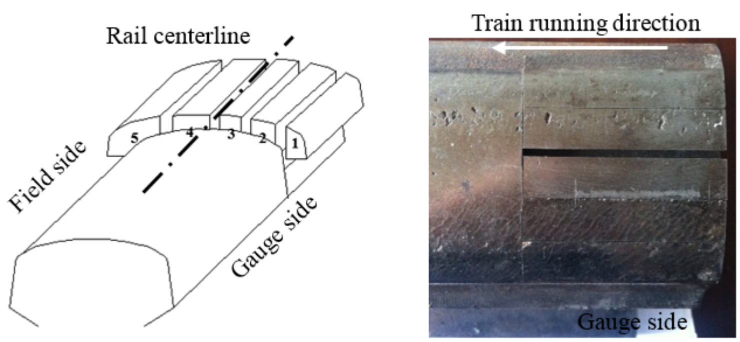


Figure 1. Schematic diagram and actual specimens

CT scan devices scanned the rail specimens by X-ray. The reflected energy was converted into 3D grey value, forming the original RAW format data; the images of scanned specimen with HCs could be shown in 3D image software, shown as figure 2. Because of different grey values of rail and HCs, the STereo Lithography (STL) file of HCs which contained point cloud data, could be exported by thresholding of the appropriate grey value.

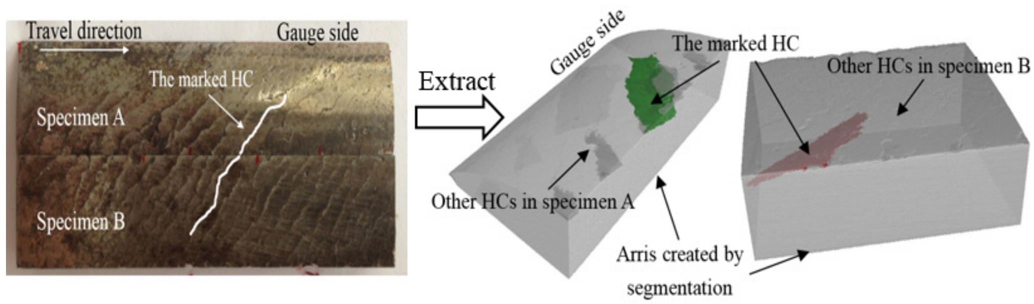


Figure 2. Process of extraction of HCs data

By numerical calculation, the complicated STL file was simplified to points represented by 3D coordinate. As a result, the spatial position and geometry shape of HCs could be obtained.

3 3D reconstruction of HCs

The specimen A and B were examined respectively and the marked HC in Figure 2 were segmented. As HC was micro-scale and distributed densely, 3D image software could not guarantee the precision of the reconstructed geometry and spatial position by automating, while it had larger error by manual aligning. Thus, a several algorithms were used to ensure the accuracy of reconstruction of HCs.

3.1 Splicing HCs in different rail specimens

Because the same HC were segmented in specimen A and B, they should be spliced to ensure the integrity of geometry. The procedure was shown as figure 3. Point M, N, O' and P were the boundary points in the bottom.

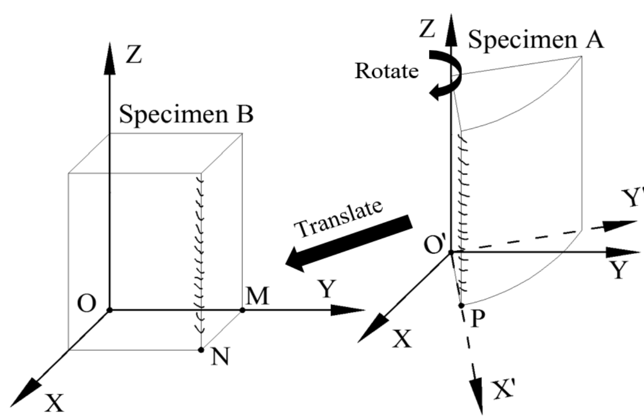


Figure 3. The translation and rotation of HCs in two specimens

Considering the two specimens were an integral part, point M and point O' should coincide, point N and point P as well. There were one rotational degree of freedom (about z axes) and three translational degrees of freedom (about x axes, y axes and z axes) as the two specimens were parallel when scanned. The algorithms of translation and rotation are shown as follow:

$$\begin{bmatrix} x'_{Ai} \\ y'_{Ai} \\ z'_{Ai} \end{bmatrix} = \begin{bmatrix} x_{Ai} \\ y_{Ai} \\ z_{Ai} \end{bmatrix} + \begin{bmatrix} \Delta x_{MO'} \\ \Delta y_{MO'} \\ 0 \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} x_2 & y_2 & z_2 \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} x_1 & y_1 & z_1 \end{bmatrix} \quad (2)$$

In formula (1), x'_{Ai}, y'_{Ai} and z'_{Ai} are the coordinate of HC after translation; x_{Ai}, y_{Ai} and z_{Ai} are the original coordinate; $\Delta x_{MO'}$ and $\Delta y_{MO'}$ are the difference between point M and O'. In formula (2), (x_2, y_2, z_2) are the coordinate of HCs after rotation; (x_1, y_1, z_1) are the original coordinate; θ is the angel between vector $\overrightarrow{MN}$ and vector $\overrightarrow{O'P}$, with $cos\theta = (\overrightarrow{MN} \cdot \overrightarrow{O'P}) / (|\overrightarrow{MN}| \times |\overrightarrow{O'P}|)$.

3.2 The shape definition of HCs

(1) Rotating projection in 3D spherical coordinate system

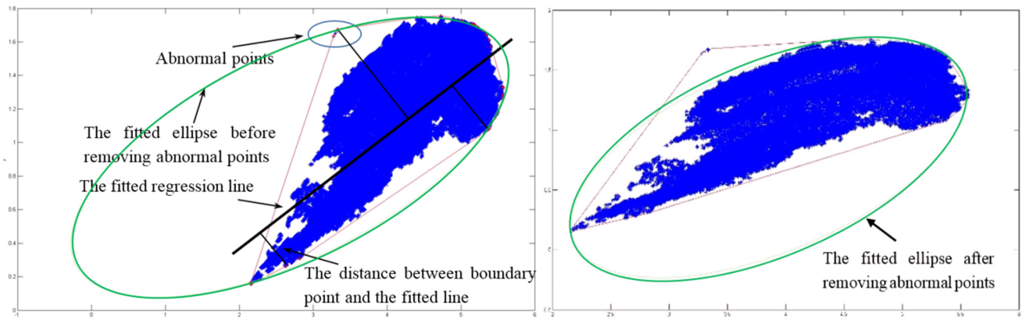
As the HCs point cloud data were curved surface instead of plane, it would be smaller than actual size by vertical projective operation. Therefore, 3D spherical coordinate was adopted for rotating projection. In order to calculate effectively, all the data were projected to XOY-plane by rotating projection, ensuring original size of HC. Transformation matrix of projection to XOY-plane was as follows:

$$\begin{cases} x'_i = x_i + (\sqrt{x_i^2 + y_i^2 + z_i^2} - \sqrt{x_i^2 + y_i^2}) \cdot \cos\theta \\ y'_i = y_i + (\sqrt{x_i^2 + y_i^2 + z_i^2} - \sqrt{x_i^2 + y_i^2}) \cdot \sin\theta \\ z'_i = 0 \end{cases} \quad (3)$$

Where $\cos\theta = x_i / \sqrt{x_i^2 + y_i^2}$, $\sin\theta = y_i / \sqrt{x_i^2 + y_i^2}$.

(2) Removing the abnormal points and fitting the shape of HC

The outline shape of HC was decided by its boundary points, and the boundary information could be obtained by computing the point set of the convex hull (Liu, 2007). However, abnormal boundary points seriously affected the accuracy of the fitted shape of HC, shown as figure 5(a). Thus, PauTa criterion was applied to remove the abnormal points (Zeng, 1988).



(a) The original fitted ellipse (b) The amended fitted ellipse

Figure 4. The comparison of fitted ellipse after removing abnormal points

By the least square method, the fitted regression line of HC points was obtained. The distance of all the boundary points to the fitted regression line could be calculated and PauTa criterion was applied if they obeyed the normal distribution:

$$P\left(\left|x-\bar{x}\right|\leq 3\sigma\right)=0.9974 \tag{4}$$

After removing the abnormal points, the direct least square fitting of ellipse method (Andrew, 1999) was taken to fit the shape of HC. The length of semi-major axis and semi-minor axis could be shown as

$$\begin{cases} a^2 = 2(AXc^2+CYc^2+BXcYc-1)/(A+C+\sqrt{(A-C)^2+B^2}) \\ b^2 = 2(AXc^2+CYc^2+BXcYc-1)/(A+C-\sqrt{(A-C)^2+B^2}) \end{cases} \tag{5}$$

Where, Xc and Yc are the coordinate of ellipse center; A, B, C are coefficients of normalized ellipse $AX^2+BXY+CY^2+DX+EY+1=0$ in XOY-plane.

After that, the crack tip (i.e., HC edge inside the rail) was fitted with the calculated ellipse shape, while the crack mouth (i.e., HC edge bordering on the rail top or gauge corner) was fitted with rail profile of the corresponding position to make the fitted HC shape be consistent with the actual case as much as possible.

3.3 Definition of HC's spatial position by plane fitting

The spatial plane where point cloud data of HC located could be defined through the least square plane fitting method, by which the spatial position could be obtained. Assuming that $Ax+By+Cz+1=0$ represented a spatial plane which did not pass through the origin, the transfer matrix can be seen in formula (6) and the matrix of coefficient was calculation in formula (7), according to the least square method.

$$\begin{bmatrix} x_1 & y_1 & z_1 \\ x_2 & y_2 & z_2 \\ \vdots & \vdots & \vdots \\ x_i & y_i & z_i \end{bmatrix} \begin{bmatrix} A \\ B \\ C \end{bmatrix} = \begin{bmatrix} -1 \\ -1 \\ -1 \end{bmatrix} \tag{6}$$

$$\begin{bmatrix} A \\ B \\ C \end{bmatrix} = \begin{bmatrix} \sum x_i^2 & \sum x_i y_i & \sum x_i z_i \\ \sum x_i y_i & \sum y_i^2 & \sum y_i z_i \\ \sum x_i z_i & \sum y_i z_i & \sum z_i^2 \end{bmatrix}^{-1} \begin{bmatrix} -\sum x_i \\ -\sum y_i \\ -\sum z_i \end{bmatrix} \tag{7}$$

By rotating the fitting shape of HC (in XOY-plane) to the position where were perpendicular to the normal vector ($\vec{n}$=(A,B,C)) of the plane, the spatial position of HC could be defined.

4 XFEM model of rail assembling with HC

4.1 Discrete equation

Considering the actual propagation of the HCs, the more effective method XFEM was applied, which had the advantages of allowing modeling of complex shaped cracks in 3D media by the level set method, easy intersecting them in the elements by the enriched finite element and considering the stress singularity, which could provide reasonable meshes and calculation time. Like FEM, the discrete equation of each element could be shown:

$$K^e d^e = F^e \tag{8}$$

Where K^e is the element stiffness matrix, F^e is the equivalent nodal force and d^e is the element node displacement. Each direction component of d^e could be expressed by (Xiao, 2012)

$$u(x) = \sum_{i \in N} N_i(x) u_i + \sum_{j \in N^{disc}} N_j(x) H(f(x)) a_j + \sum_{k \in N^{asy}} N_k(x) \sum_{a=1}^{4} \phi_t(x) b_k^t \tag{9}$$

To explain the stress singularity of crack tip, $\phi_t(x)$ is used with

$$\phi_t(x) = [\sqrt{r}\sin\frac{\theta}{2}, \sqrt{r}\cos\frac{\theta}{2}, \sqrt{r}\sin\frac{\theta}{2}\cos\theta, \sqrt{r}\cos\frac{\theta}{2}\cos\theta] \tag{10}$$

4.2 FE rail model with the constructed HC

The fitted ellipse was imported into CAD software, in which the ellipse was modified by combining with the rail profile around gauge corner to correspond to the actual geometry. Then, the fitted HC was transferred into finite element (FE) sketch data (Yang, 2011) and 3D HC shell was created. 3D rail solid model was built by assembling and coupling with the fitted 3D HC shell, it was shown in figure 5. As under the wheel-rail force, hard contact property with a penalty function was defined in case of penetration (Jim, 2014).

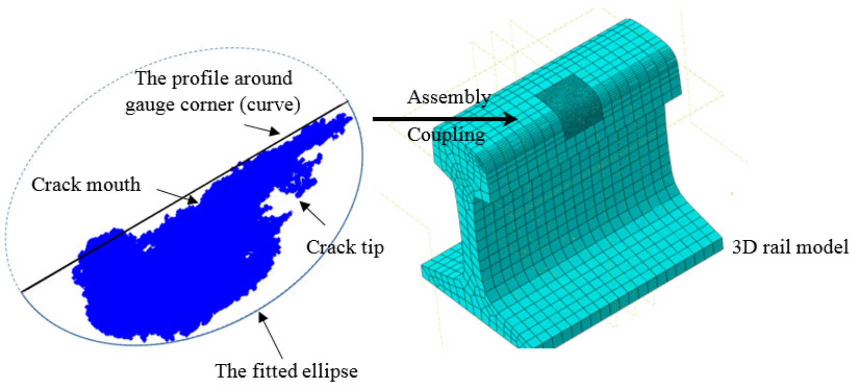


Figure 5. Finite element model of HC coupling with 3D rail model

For simulating the effect of wheel-rail interaction, moving Hertz contact normal pressure and creep force was applied on the rail, which made the stress and strain result close to the actual case.

5 Conclusions

Reconstruction and modeling method for HC in heavy-haul railway based on CT scan technology could implements the following features:

(1) With CT scan technology, 3D point cloud data of HCs could be precisely distinguished and extracted by thresholding of the grey level; the integrity of geometry was insured by splicing, which could restore the actual geometry of HCs more accuracy.

(2) By rotating in 3D spherical coordinate system, removing the abnormal boundary points by the least square method and PauTa criterion, the outline shape and size of HC could be obtained; the spatial position of HC in rails was defined by the least square plane fitting method, which guaranteed the reliability of the fitted HC.

(3) 3D HCs reconstruction could be realized by the definition of HC geometry and spatial position, which provided a more realistic basic for FE model; XFEM provided a more effective and accurate way to FE calculation.

It was shown that the 3D reconstruction and modeling method for HCs based on CT had a good applicability for crack propagation simulation, which could provide reliable model for study the HCs propagation in heavy-haul railway. By this method, further work, such as the propagation of HC in rails at different traffic and the relationship between HC propagation and wear growth can be investigated.

Acknowledgement

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References

Andrew, F., Maurizio, P., and Robert B. F. (1999). "Direct Least Square Fitting of Ellipses", *J. The IEEE Transactions on Pattern Analysis and Machine Intelligence,* 21(5), 476-480.

Bogdanski, S., Brown, M. W. (2002). "Modelling the three-dimensional behaviour of shallow rolling contact fatigue cracks in rails." *J. Wear*, 253(1-2): 17-25.

Ding, J. (2007). "Application of the Extend Finite Element Method to Fracture Mechanics". Hohai University.

Liu, G. H., Chen, C. B. (2007). "New algorithms for computing the convex hulls of a simple polygon and a planar point set." *J. Computer Science*, 34(12), 222-226.

Jim, B. (2014). "Wear impact on rolling contact fatigue crack growth in rails." *J. Wear*, 314, 13-19.

Xiao, Q. (2012). "The elasto-plastic analysis and fatigue damage research of wheel/rail rolling contact". China Academy of Railway Sciences.

Yang, Q., Sun, C., Zhu, Y. (2011). "Research of interactive converting technique from Pro/E drawing to AutoCAD drawing." *J. Machinery Design & Manufacture,* 8, 251-253.

Zeng, S. G. (1988). *Railway track dynamic testing technology*, China Railway Press, Beijing, 231-236.

Zhou, Y., Wang, S. F., Wang, T. Y. (2014). "Field and laboratory investigation of the relationship between rail head check and wear in a heavy-haul railway." *J. Wear*, 315, 68-77.

Operation Scheme Optimization Model of Heavy-Haul Train Loading Area

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Abstract: heavy-haul loading transportation can improve efficiency, greatly reduce the transportation cost in shipping bulk cargo. This article discussed the organization mode of heavy-haul loading transportation, comprehensively consider the operation condition of heavy-haul loading train and its economic benefits, use the running time consumption minimum and operation benefit maximization as objective function, use the uniqueness of operation scheme and Loading and unloading capacity as the constraint condition, built the 0-1 nonlinear optimization model of heavy-haul loading operation plan. For the convenience of the model solution, use the Linear weighted method to change the model objective function into single objective function. Design the genetic algorithm to acquire the prioritization scheme of heavy-haul loading train plan.
Keywords: Heavy-haul train; Loading area; Train operation scheme; Genetic algorithm.

Heavy haul transportation has put forward higher requirements to the traffic organization and technology station reorganization work in order to play the advantages of heavy haul transportation, we need improve train marshalling and traffic organization scheme, rationally adjust the labor division of marshalling station, solve the successive problem of supply, freight and transport capacity. Finally improve the formation of the network in the whole region.

1 The construction of model

Organizing the wagon flow into heavy haul train can speed up the delivery of the goods, improve the section carrying capacity, but the grouping of heavy haul train needs more centralized supply and adequate supply of empty car, put forward higher requirements for marshalling capacity of loading area technology station. Therefore we cannot simply organize the wagon flow into heavy haul train form. we need consider the station line operation capacity and transport organization form. use the train plan benefit maximization as the goal to determine the optimal train operation plan. Freight train need loading, adaptation and truck operations in the way, use M as the total time cost, then the formula of the objective function is:

$$\min M = M_H + M_{NH}$$

Use M_H indicate the consumption of heavy haul train technical operation time, use M_{NH} indicate non heavy haul train time consumption.

Defined the decision variables:

$$X_{st}^{H} = \begin{cases} 1 \text{ if there is heavy haul train in the } N_{st} \\ 0 \; others \end{cases} \qquad X_{st}^{H(k)} = \begin{cases} 1 \; marshalling \text{ heavy haul train in the first marshalling station} \\ 0 \text{ others} \end{cases}$$

$$X_{st}^{k} = \begin{cases} 1 \text{ if the first marshalling station of non heavy haul train is k} \\ 0 \text{ others} \end{cases} \qquad X_{st}^{H(k)} = \begin{cases} 1 \text{ marshalling heavy haul train in the last marshalling station} \\ 0 \; others \end{cases}$$

$$X_{st} = \begin{cases} 1 \text{ if there is non heavy haul train in the } N_{st} \\ 0 \; others \end{cases}$$

use c_{st}^{H} as heavy haul train assembling parameter from s to t, use c_{sk}^{NH} as heavy haul train assembling parameter from s to k. use m_{st}^{H} as numbers of heavy haul train from s to t, use m_{sk}^{H} for numbers of heavy haul train from s to k. use t_{k}^{H} for technical operation time consumption of heavy haul train at technical station, use o_{st}^{H} for time consumption of heavy haul train in indirect way, use v_{st}^{H} for time consumption of heavy haul train in direct way, use c_{st}/c_{sk} for non-heavy haul train assembling parameter, use m_{sk}/m_{st} for numbers of non-heavy haul train, use t_k for technical operation time consumption of non-heavy haul train at technical station, use

o_{st} for time consumption of heavy haul train in indirect way, use v_{st} for time consumption of non-heavy haul train in direct way.

If there is no coding work in the way at marshalling station, the consumption of Nst in the loading area and unloading area can be divided into the following three kinds of circumstances.

(1) if marshalling heavy haul train in the first mashalling station, the consumption in the loading area, first marshalling station and unloading area is:

$$E_1^H = N_{st}(w_{st} + t_k^H + o_{st}^H)\ x_{st}^{H(k)},\ k \in v(s)$$

(2) Send the heavy haul train to the final collapse from loading area, the consumption in the loading area, technology station and unloading station is:

$$E_2^H = \left[c_{sk}^H m_{sk}^H + N_{st}(t_k^H + o_{st}^H)\right] x_{st}^{H(k)},\ k \notin V(s), k \in V(t)$$

(3) Directly send Nst to the unloading area from loading area, the consumption in the loading area and unloading area is:

$$E_3^H = (c_{sk}^H m_{st}^H + N_{st} v_{st}^H)\ x_{st}^H$$

If there is non heavy haul train in the Nst, the consumption in the loading area, way and unloading area can be divided in to following three circumstances:

(1) the traffic were sent to the front technology station as technical traffic, the consumption in the loading area and unloading area is:

$$E_1^{NH} = N_{st}(w_{st} + o_{st}) x_{st}^k, k \in V(s)$$

(2) the traffic was centred in loading area and sent to technology station k, the consumption in the loading area and unloading area is:

$$E_2^{NH} = (c_{sk} m_{st} + N_{st} o_{st}) x_{st}^k, k \notin V(s)$$

(3) Directly send Nst to unloading area from loading area, the consumption in the loading area and unloading area is:

$$E_3^{NH} = (c_{sk} m_{st} + N_{st} v_{st}) x_{st}$$

(4) as long as there is no through train from loading area to unloading area ,then there will be marshalling consumption in the technology station. if wagon flow's last marshalling station is j, wagon flow Nst were marshalled in the k station, then V (k, t) represents a collection that wagon flow need to be marshalled in the way. and V (k, t) includes k station. then the consumption of wagon flow Nstin the way is:

$$E_4^{NH} = N_{st} \sum_{k \in \rho(s,t)} \sum_{i \in V(k,t)} t_i x_{st}^k$$

The total consumption of wagon flow is:

$$E_{\mathrm{st}}^{C} = E_{H} + E_{NH}$$

Heavy haul train can improve the transportation efficiency, it has higher economic profit. when calculating the income, we only need to compare the two different parts of the organization form's save and loss. because the gain of heavy-duty train is currency as the unit.so it needs to be converted to consume hours of car in the optimization model. Set operation 1 column heavy-duty train to unload area, the increase transportation income in relative to the heavy-duty train is W_c, in order to conversion the yield to hours car consumption, introduce the conversion factor, the revenue calculation formula of heavy-duty train is:

$$E_{H}^{C} = \beta N_{\mathrm{st}}^{H} / \mathrm{m}_{\mathrm{st}}^{H} W_{C}^{\mathrm{s\text{-}t}} (x_{\mathrm{st}}^{H} + x_{st}^{H(\mathrm{k})})$$

The goals of the mode require to minimum car hour consumption and maximum returns of heavy-duty train, the objective function of the model is:

$$E = \min E_{st}^{C} + \max E_{H}^{S}$$

Traffic into heavy-duty train or heavy-duty train, there are three ways can be used, we can organize through train to unload area, or we can send it to the technical station, then incorporate it into the corresponding technical traffic. either assemble with shaft in the loading area, then organize through train to unload area. There is only one kind of the operation mode, namely operation scheme has uniqueness.

$$x_{st} + \sum_{k \in \rho(s,t)} x_{st}^{k} + x_{st}^{H} + \sum_{k \in V(s) \cup V(t)} x_{st}^{H(k)} = 1$$

if organize heavy-duty train or non heavy-duty train, we must satisfy the conditions of loading and unloading area, calculating formula of allowed intensive number of loading and unloading car from loading area to unloading area is:

$$m_{st} = \min(m_{st}^{l}, m_{st}^{u})$$

If we organize through train to k station, we must meet the following requirements:

$$\sum_{t \in D(k)} m_{st} \geq m_{sk}$$

Use m_{sk} for number of car directly from s to k, D (k) for the collection of station that attract traffic.

When marshalling heavy-duty train from loading area to a fulcrum station k, allowable dense number of car attracted by the direct traffic needs to satisfy the following requirements:

$$m_{st}^{H} I \left(\sum_{t \in Q(s)} x_{st}^{H(k)} \right) - \sum_{t \in Q(s)} m_{st} x_{st}^{H(k)} \leq 0$$

I (x) is a step function, defined as

$$I(x)=\begin{cases}1 & x\rangle 0\\ 0 & x\le 0\end{cases}$$

When marshalling non heavy-duty train from loading area to a fulcrum station k, allowed intensive number of train that attracted by the through traffic need to satisfy the following requirements.

$$m_{st}I(\sum_{t\in Q(s)} x_{st}^{k})-\sum_{t\in Q(s)} m_{st}x_{st}^{k}\le 0$$

Organize heavy-duty train or non heavy-duty train, if it is through traffic from loading area to unloading area, whether single or more, its operation must meet that the car hours saving on the way without adaptation through technical station ≥ car time consumption in loading area, otherwise, it should not be commonly is divided into separate marshalling. For a single traffic, it meet the necessary conditions for:

$$\sum_{j\in\rho(s,t)} t_j^H N_{st} x_{st}^H \ge c_s^H m_{st}^H$$

$$\sum_{j\in\rho(s,t)} t_j N_{st} x_{st} \ge c_s m_{st}$$

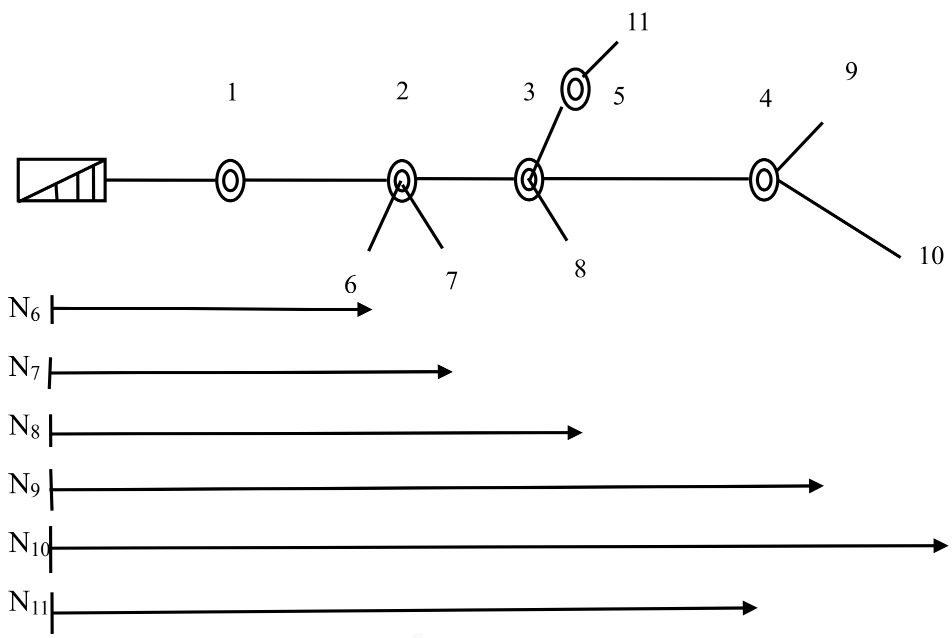

Figure 1. Loading area train diagram

L for loading area, label 1-5 for technical station that can marshall heavy-duty train,6-11 for unloading station, a simplified road network structure and the flow diagram is shown in figure 1. a simplified road network structure and the flow diagram is shown in figure 1. There are 6 direct traffic,, if loading flow respectively N6=75, N7=35, N8=20, N9=70. N10=40 and N11=45, cost parameters respectively wt = 10, ot= 10, vt = 7, ot= 8 and vt= 5, average plait bought for heavy-duty train mt= 70, average plait bought for direct train to reach the unloading point mt = 40,, and parameter ck/ct= 12, ck/ct= 10, $\lambda 1=\lambda 2= 0.5$。The average conversion consumption of heavy-duty train at technical station is 8,the average conversion consumption of non heavy-duty train at the technical station is 4,assume organize 1 column heavy haul train that has 60 cars, its earnings 350, 450, 550, 500, use MATAlab software to design genetic algorithm, get the following loading heavy-duty train operation plan:

The traffic N6 and N11 organize the direct train from loading area to unloading area.

The traffic N7and N8 does not meet the condition of overloading and direct train, use rolling off the train to send to the front technology stand into the site traffic.

The traffic N9,N10 organize the direct heavy-duty train to unloading area when gather full shaft.

2 Conclusion

Built the nonlinear 0-1 programming model of loading area heavy-duty train, the objective function is the sum of time consumption at loading area, unloading area and on the way and heavy-duty train economic benefit. The model can comprehensive describe various combination of loading area heavy-duty train and guarantee the maximum benefits of operation scheme. Numerical example verifies the various traffic combination scheme in loading area, use maximum benefits of operation plan to confirm the rationality and validity of the operation plan .At the same time, building loading area heavy-duty train operation plan should also be coordinated with technical train stations on the way very well, so as to ensure normal execution. of operation plan .

Reference

Xue-ming Cao, Bo-liang Lin, He-xiang Yan. (2006). Loading area direct train operation plan optimization model. *Journal of railway* 28 (8) : 6-11.

Bo-liang Lin. (1994). *nonlinear 0-1 programming optimization model of marshalling plan and simulated annealing algorithm*. Journal of railway, (2) : 61-66

Yan-feng Sun, Zhong-tuo Wang. (1994). *genetic algorithm of multi-objective 0-1 programming problem*. Journal of systems engineering and electronics, (10) : 57-61.

Bo-liang Lin, Zhu Songnian Shi Deyao, etc. (1995). *optimization model of loading area direct train marshalling plan* . China railway science, 26 (6) : 108-114.

Li-xin Qian. (2000). *economic benefit and contribution of Daqin line overload transportation in 10 years*. Journal of China railway, (1) : 10-11

Li-xin Qian. (2002). *International railway heavy-load transportation development*, (12) railway transportation and economy.

Feng Bin. (2007). *Research on loading area overloading transportation organization and issues related*. Southwest jiaotong university,
Yanping wang, Qiao Yanhong, zhou xh. (2008). Xing Cun Liang. *Railway heavy-load transportation benefit evaluation study*. Journal of China railway.
Tang Baogang. (2009). *Overloading transportation loading area traffic organization study and discussion*. Beijing jiaotong university.
Qi-yuan peng, (2005). YanYong haifeng Yan *transport corridor and reasonable division of labor model after the completion of passenger dedicated railway*. Journal of southwest jiaotong university.

Network Assignment Model of Passenger Train Scheme on a High-Speed Railway

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Abstract: Passenger flow assignment has a direct influence on optimization of the high-speed railway train operation plan, thus the rational assignment passengers is a basic link and an important role. Considering the level of passengers demand and the impact of passenger product attribution on the passenger assignment, this paper classifies passengers and trains into different category, and shows the cost conversion coefficients of between each passenger set and train set. During the construction of distribution network, this paper divides network into 4 types of nodes and 6 directed arcs: running arc, accumulation arc, transfer arc, stop arc, getting on arc and getting off arc, according to the train arrival and departure time and passenger getting on and off procedure. Every arc has its calibration parameters. Research shows that the essence of assignment under this network is the problem of maximum flow with minimal fare, the assignment process has characteristics of self-driven, the getting on and getting off arc is only used to limit capacity and with no assignment cost produced. The assignment process can be achieved by looking for OD node circuits of corresponding passenger flow from the assignment network. Corresponding algorithm is designed by the use of the properties and the algorithm steps are present-ed.
Keywords: High-speed railway; Train operation plan; Assignment network; Maximum flow with minimal fare.

1 Introduction

Although the high-speed railway transportation is taking the social responsibility of passenger transport, the economic benefit should be considered. Meanwhile, high-speed railway should also try to improve service, expand market share, cut costs, and improve profitability, while meeting the transport needs of the community.

The key problem of passenger transportation organization is high-speed railway train operation plan [1]. It’s the foundation of computerized train graph and train-set scheduling, which directly reflects the management strategy and service quality of railway passenger transportation. A rational high-speed railway train operation plan not only contributes to improve the operational efficiency of railway passenger transportation, which represents competitive ability compared with other transport, but relates to the ability to provide a consistently high level of service and to get the expected economic returns [2]. Therefore, the key demanding prompt solution problem is that how to compute a rational high-speed railway train operation plan or how to optimize train operation plan [3].

Optimization of high-speed trains is a large and complex system optimization problem, with the numerous influence factors and optimizing the links. Determining the train plan of passenger service information is a key to solve the optimization of high-speed train problem, as passenger flow information is the basic principle of operation scheme[1]. Although many studies, no matter in China or international, have already carried out a more in-depth study and achieved a certain theoretical results, most studies were directed at a single speed and does not take into account differences in passenger levels in practical situation. Chinese high-speed passenger transport organization mode is trains in different speed rating sharing the same line, and the delivery of passenger flow structure is not uniform. Therefore, the key problem is to optimize passenger flow at different levels, such as in the high and medium speed train, operation scheme reasonable distribution.

This paper focuses on how to turn a reasonable distribution of passenger flow in the train involving on operation plan, so that provide the basis principles and specified direction for the further optimization train operation plan, rather studying on computing train operation plan.

2 Assumptions

(1) Fixed passenger flow

Assume all the relevant passenger flow data, which is divided into middle and upper levels in accordance with a specific principle, have been fixed. In other word, passenger flow of different levels in any OD is fixed.

(2) Fixed train path

Assume there is a completed train operation plan. In this plan, two speed rating trains (i.e. high-speed and mid-speed) correspond to two level passenger flows (i.e. high level and middle level); and the transport capacity is over the transport demand. Moreover, the object of this study focuses on one single direction trains. This is because, in reality, the train is usually symmetrical opening lines in pairs, and thus, the results of the plan in one direction can be applied to the reverse trains.

(3) Classified train in different speed

In order to corresponding the level of trains with the level of passengers, this study classifies the train not only according to the initial, final and intermediate stops, but also according to the level of passenger flow on trains, due to the high speed railway served different level passengers. To take train's speed level into account, the initial train operation plan contains the high-speed and medium-speed train, and any type of train contains only one speed-level train. In other words, two trains are classified into different levels as long as they have different speeds, though these two trains have same the initial, final and intermediate stops.

(4) Fixed sensitivity of traveler time and money

The sensitivity of passengers for components of the generalized travel cost (includes payments for time and money) is different, because the impact of factors for passengers, such as the travel purposes, the economic capacity, is different. For instance, the high level passengers have relatively low sensitivity for money, because of their high time value; the low level passengers have high sensitivity for the money (i.e. they prefer to spend more time to save money), because of their relatively poor economic conditions. Although, the sensitivity of the time and money is an important criterion to classify the travelers' level, it's hard to quantify, due to it involves traveling behavior, economic capacity, consumption habits and values. Therefore, this study assumes passengers' sensitivity of time and money is fixed.

(5) Fixed train seating capacity

China's CRH series are mainly used on high-speed railway motor train, there are several different models and the seating capacity of every model is different. Sometimes, the seating capacity is changed even in the same model motor train, as the marshalling mode is different. Therefore, in order to facilitate the study and description of the nature of the problem, while reducing model size, this study assumes the train seating capacity is fixed in the train operation plan.

(6) Fixed the additional time for starting and stopping

Additional time for starting and stopping, whose proportion of value is very small in the train running time, depends on motor train performance, railroad track condition, speed, etc. To facilitate this research, this study treats the additional time for starting and stopping as a part of the stopping time, which won't bring an obvious error. This means this study assumes the stopping time has included the additional time for the starting and stopping, which produces by train stopping. What's more, this study assumes the stopping time is related to the station nature, which means if the station nature is the same, the stopping time is the same.

3 The Model

3.1 The objective of the passenger flow distribution

Rational distribution of passenger flow is the basis for optimization of high-speed trains and an important part. To improve the social benefit and marketing efficiency of high-speed railway by optimizing the train operation plan, the passenger travel demand and travel costs should be considered during the distributing the passenger flow. On the premise of meeting the whole passengers need, the passengers total travel cost, which includes the travel fare, travel time and travel expenditure [4], is the objective of the passenger flow distribution. That is：

$$\min z = \sum_{i=1}^{m} T_i N_i + \varepsilon \qquad (1)$$

Where

T_i is passengers' average travel cost of the i^{th} passenger flow;

N_i is the total number of passengers of the i^{th} passenger flow;

m is the total number of passengers flow in initial train plan of high-speed railway;

ε is penalty values variables, if there are some passengers outside the service train at the end of passenger flow distribution process, ε is infinity, which means this distribution plan cannot meet the need of passenger flow; if there is no passenger outside the service train at the end of passenger flow distribution process, ε =0, which means this distribution plan can be applied.

3.2 Passengers' travel cost analysis

T_i is mainly composed of passengers' travel fare and time consumption. Travel fare makes up of the urban traffic fare for arriving railway station, the urban traffic fare for leaving railway station and the fare for railway ticket. Time consumption consists of the time for arriving railway station, waiting railway time, train running time, stopping time, the time for leaving railway station and transfer time.

（1）This study only focuses on the travel cost caused by the high-speed railway, rather those travel cost outside the railway, which have no effect on the passenger flow distribution in the train operation plan, such as the time and fare for the arriving and leaving railway station.

（2）The accumulation time can be calculated by the method in reference [1]. But the accumulation time will change with the train's number and frequency of some level passengers, due to the level of trains and passengers. However, the passengers' stopping time is irrelated to the passengers' level, then, the passengers' stopping time consumption can be fixed in the train operation plan, if some level passenger's is distributed to the l^{th} level train.

（3）The travel cost T_g (i.e. travel ticket fee and the running time) of the g^{th} train can calculate:

$$T_g = \frac{L}{v_g} + \frac{L\rho_g}{\omega_g} \qquad (2)$$

Where

L is the train's running time;

v_g is the velocity of the g^{th} train;

ρ_g is the fare rate of the g^{th} train;

ω_g is the time cost of the g^{th} passenger.

If a high level passenger is sent to a medium-speed train, he may be unsatisfied, because he cares more about the time compared with money. Similarly, it is unsatisfied to send a middle level passenger to a high-speed train, because middle level passengers have high sensitive to the money. Therefore, it is necessary to conversion travel cost T_g from the two aspects: time and price, for the above situation. That is, the scaling factor η :

$$\eta = \left(\gamma_{ti}\frac{v_{pa}}{v_{tr}} + \gamma_f \frac{\rho_{tr}}{\rho_{pa}}\right) \quad (\gamma_{ti} + \gamma_f = 1) \qquad (3)$$

Where

γ_{ti} is the sensitivity to the time of every specific level passengers;

γ_f is the sensitivity to the fare of every specific level passengers;

v_{pa} is the train's running speed which every specific level passengers should have;

ρ_{pa} is the train's fare rate which every specific level passengers should have;

v_{tr} is the train's running speed which passenger stake in reality;

ρ_{tr} is the train's fare rate which passengers take in reality;

$\eta=1$ when the passengers' level equals to the trains' level which they take.

3.3 Network setting up

To research a high speed railway corridor, the stations in the research direction are defined as set $St = \{1,2,...,N\}$, and then set $\overline{St} = St - \{1\}$ and set $\underline{St} = St - \{N\}$

are defined. Set $St = \{1,2,\ldots,N\}$ is defined as the train operation plan of the n kinds of trains in origin stop order, and the corresponding train network is defined as Net=(V,E), where, V is the network point set which includes subset V_i(i=1,2,3,4) , E is the network arc set which includes subset E_i(i=1,2,3,4,5,6). The subsets are defined as in table 1.

Table 1. The definition of subsets

Name	Subset	Constraint Condition	Explanation	Nature	Operation
Point Set	$V_1=\{v_{1j}\}$	$j\in St$	The station for dispatching passengers	Getting on node	Dispatching passengers
	$V_2=\{v_{2j}\}$	$j\in St$	The station for arriving passengers	Getting off node	Arriving passengers
	$V_3=\{v^l_{3j}\}$	$j\in St\bigcap l\in Sh$	The station for the l^{th} train dispatching	Dispatched train node	Dispatching trains
	$V_4=\{v^l_{4j}\}$	$j\in St\bigcap l\in Sh$	The station for the l^{th} train arriving	Arrived train node	Arriving trains
Arc Set	$E_1=\{e^l_{FD}\}$	$l\in Sh$; $F,D\in St\,\&\,F\prec D$	The l^{th} train from F station to D station	Running are	Train running process
	$E_2=\{e^g_{ZS}\}$	$g=midium,$ high ; $Z,S\in St\,\&\,S\prec Z$	S-Zorigin station passengers take g level train	Accumulation arc	Train accumulating process
	$E_3=\{e^l_j\}$	$l\in Sh; j\in\overline{St}\cap\underline{St}$	The $l$level train stopping by j station	Stopping arc	Train stopping process
	$E_4=\{e^j_{QH}\}$	$j\in\overline{St}\cap\underline{St}$; $Q,H\in Sh\,\&\,Q\neq H$	Passengers transfer from Qlevel train to H level train at $j$station	Transfer arc	Passenger's transfer process
	$E_5=\{e^C_{jl}\}$	$j\in\underline{St}; l\in Sh$	Passenger taking l level train at j station	Getting on arc	Passenger's getting on process
	$E_6=\{e^X_{jl}\}$	$j\in\overline{St}; l\in Sh$	Passenger taking l level train getting off at j station	Getting off arc	Passenger's getting off process

The steps of setting up network are as follows:

(1) Setting up the getting on and getting off node at each station according to the

corridor station order;

(2) Setting up the getting on node and getting off node at each origin station, intermediate station and terminal station of each level train in the train running direction;

(3) Setting up the running arc for the each level train from the dispatched node to the arrived node;

(4) Setting up the stopping arc for the each level train between the dispatched node and the arrived node;

(5) Setting up the transferred arc between the dispatched node and the arrived node, according to the possible transfer plan.

(6) Setting up the accumulation arc between the getting off node and getting on node of each *g* level passenger flow in the OD;

(7) Setting up the getting on arc and getting off arc between the getting on node and getting off node and *l* level train's dispatched node and arrived node, according to the OD passenger flow and intermediate station in the train operation plan;

(8) Deleting the isolated node.

Following the above steps, the train running network of given OD passenger flow and initial operation plan is finished. This network is a simple connective directed network without parameter.

3.4 Network Parameters

In order to solve the passenger flow distribution problem, the parameters will be set up in the network, which should involve in all the information about the factors of passenger flow distribution. The parameters are named in the table 2 to table 6.

Table 2. Arc Parameters

e^l_{FD} parameter	The meaning of parameter	Parameter's value	The set of parameter
g	The grade of the l^{th} level train	The grade of the train	{g, T_g, H, f_h^l, f_m^l, C^l}
T_g	The ticket and train running time of the g^{th} grade train from F station to D station	T_g	
H	The scaling factor caused by the level of passengers no match with grade of the l^{th} level train	$\eta \cdot T_g$	
f_h^l	The passenger flow of the high level passengers in the l^{th} level train	Variable, initial value equals 0	
f_m^l	The passenger flow of the medium level passengers in the l^{th} level train		
C^l	The capacity of the l^{th} level train	$l_n \cdot S_l$	

*l_n is the number of the train in reality

S_l is the seating capacity of the l^{th} level train

Table 3. The Accumulation Arc Parameters

e^{g}_{ZS} parameter	The meaning of parameter	The value of parameter	The set of parameter
J^{h}_{j}	The accumulation time, if the grades of passengers and trains are high	Accumulation time	{ J^{h}_{j} , J^{m}_{j} , J_{j} , f^{h}_{SZ} , f^{m}_{SZ} , A^{h}_{SZ} , A^{m}_{SZ} }
J^{m}_{j}	The accumulation time, if the grades of passengers and trains are medium		
J_{j}	The accumulation time, if the level of passengers no match with grade of the train		
f^{h}_{SZ}	The number of the distributed high level passengers between S and Z station	Variable, initial value equals 0	
f^{m}_{SZ}	The number of the distributed medium level passengers between S and Z station		
A^{h}_{SZ}	The high level passenger flow between S station and Z station	The passenger flow data between S station and Z station	
A^{m}_{SZ}	The medium level passenger flow between S station and Z station		

Table 4. Getting on and Getting off Arc Parameter

e^{C}_{jl} (e^{X}_{jl}) parameter	The meaning of parameter	Parameter value	The set of parameter
g	The grade of the l^{th} level train	The grade of the train	{ g , U^{l}_{j} , D^{l}_{j} , C^{l} }
U^{l}_{j}	The number of passengers in the l^{th} level train who is getting on at j station	Variable, initial value equals 0	
D^{l}_{j}	The number of passengers in the l^{th} level train who is getting off at j station	Variable, initial value equals 0	
C^{l}	The capacity of the l^{th} level train	$l_{n} \cdot S_{l}$	

Table 5. The Stop Arc Parameter

e^{l}_{j} parameter	The meaning of parameter	Parameter value	The set of parameter
g	The grade of the l^{th} level train	The grade of the train	{g , T^{t}_{jl} , P^{t}_{jl} , C^{l} }
T^{t}_{jl}	The stopping time at j station of the l^{th} level train	The standard of stopping time	

P^{t}_{jl}	The total number of passenger l^{th} level train who pass by j station	Variable, initial value equals 0	
C^{l}	The capacity of the l^{th} level train	$l_n \cdot S_l$	

Table 6. The Transfer Arc Parameter

e^{j}_{QH} parameter	The meaning of parameter	Parameter value	The set of parameter
Th^{QH}_{j}	The transfer time from the Q^{th} level train to the H^{th} level train at j station	The reference [1]	$\{Th^{QH}_{j}, Ph^{QH}_{j}, Ch^{QH}_{j}\}$
Ph^{QH}_{j}	The number of passenger transfer from the Q^{th} level train to the H^{th} level train at j station	Variable, initial value equals 0	
Ch^{QH}_{j}	The capacity of transfer from the Q^{th} level train to the H^{th} level train at j station	$\min\{C^{j}_{Q}, C^{j}_{H}\}$	

* C^{j}_{Q} （C^{j}_{H}） means the rest capacity of the Q^{th} level train after it arriving j station and then departure from j station

3.5 The application of network

The nature of this built distribution network above is as follows:

(1) In this network, the distribution problem is a min-cost max-flownetwork optimization problem, actually.

(2) The sets of getting on arc and getting off arc parameters $\{g, U^{l}_{j}, D^{l}_{j}, C^{l}\}$, only including the grade of the train, passenger flow and the train capacity, are direction arcs and the constraint conditions of the passenger flow without any fare.

(3) This distribution network is a self-driven network because it can be finished by calculating the named parameter, without any other data involved.

(4) This distribution network is a loop network because for some level passengers it connected the getting off node with getting on node by accumulation arc.

(5) As a loop network, when distributing the passenger flow from S to D, the trains' level of passenger flow $A_{SZ}(S \in \underline{St}; Z \in \overline{St};$ 且 $S \prec Z)$ can be inferred by finding the minimum distance between the S station node（$S \in V_1$）and Z station node（$Z \in V_2$） in the network.

Therefore, this network distribution problem is changed to a minimum distance problem of any pair of getting on node and getting off node with given passenger flow. The constriction conditions are network structure and passenger travel demand, as the distribution loop network has to include the pair of passenger's getting on node and getting off node. The objective function is the minimum total cost at the entire direction arc.

$$\min z = \sum_{i=1}^{4} F_i + \varepsilon \qquad (4)$$

$$\begin{cases} F_1 = \sum_{e_{FD}^l \in E_1} (F_{e_{FD}^l}(f_g^l) \cdot F_{e_{FD}^l}(T_g) + F_{e_{FD}^l}(f_{!g}^l) \cdot F_{e_{FD}^l}(H)) \\ F_2 = \sum_{e_{ZS}^g \in E_2} (F_{e_{ZS}^g}(J_j^g) \cdot F_{e_{ZS}^g}(f_{SZ}^g) + F_{e_{ZS}^g}(J_j) \cdot F_{e_{ZS}^g}(f_{SZ}^{!g})) \\ F_3 = \sum_{e_j^l \in E_3} F_{e_j^l}(P_{jl}^t) \cdot F_{e_j^l}(T_{jl}^t) \\ F_4 = \sum_{e_{QH}^j \in E_4} F_{e_{QH}^j}(Ph_j^{QH}) \cdot F_{e_{QH}^j}(Th_j^{QH}) \end{cases} \tag{5}$$

In the equation (5), $F_e(K)$ is self-defining function. Its return value is element k values belonging to arc-e parameter. $!g$ means the grade of train no match with the level of passengers.

The penalty values variables ε depends on the residual passenger number at the end of passenger flow distribution process. The function of ε is

$$\varepsilon = M \cdot \left[\sum_{e_{ZS}^g \in E_2} (F_{e_{ZS}^g}(A_{SZ}^h) + F_{e_{ZS}^g}(A_{SZ}^m) - F_{e_{ZS}^g}(f_{SZ}^h) - F_{e_{ZS}^g}(f_{SZ}^m)) \right] \tag{6}$$

In the equation (6), M is a sufficiently large positive number.

4 The Algorithm

4.1 The principle of distribution flow

The principle of distribution is based on the traveler transport demand and the railway transportation company's benefit, so the principle is:

(1) To meet the transportation market diversity demand and to improve passenger satisfaction, the level of passenger should match with the grade of train, so that the market capitation can be increased.

(2) The high level passenger as the main service object of high-speed railway should have the priority.

(3) In order to expending the attendance rate and increasing the enterprise profit, the long distance passenger should be distributed in advance.

4.2 The step of algorithm

According to the principle mentioned above, the steps of the distribution algorithm are:

Step1: Set up the distribution network according to the initial train operation plan and set down all parameters depending on the related data.

Step2: Sort passenger flow by the distance of OD.

Step3: Find the same level loop path which includes the getting on node and getting off node corresponding to the passenger's OD in the passenger flow priority order. Then distribute the maximum passenger flow for the each loop path from the minimum cost loop. At the same time write down the trains' information of passenger service and the parameters of network update.

Step4: If the network gets the maximum passenger flow, then go to step 6; if not, then go to step 5.

Step5: Find the entire loop path which includes the getting on node and getting off node corresponding to the rest passenger's OD in the passenger's distance and passenger's level order. Then distribute the maximum passenger flow for the each loop path from the minimum cost loop. At the same time write down the trains' information of passenger service and the parameters of network update. Go to step 4.

Step6: Calculate the distribution plan's minimum total cost according to the function (4) to function (6).

5 Conclusions

The network passenger flow distribution model and algorithm in this paper are the solution only for the passenger flow distribution problem of the initial train's operation plan or the train given the operation plan. In order to optimize the passenger flow, the distribution result in this solution need a further adjustment according to the matching information of passenger flow and the train's information. Finally, adjust the operation plan depending on the situation, and repeating iteration to get an optimal operation plan. In these whole process, there are three core problem, network passenger flow distribution optimization, passenger flow transport plan optimization, and train operation plan optimization. The optimization process shows in Figure 1.

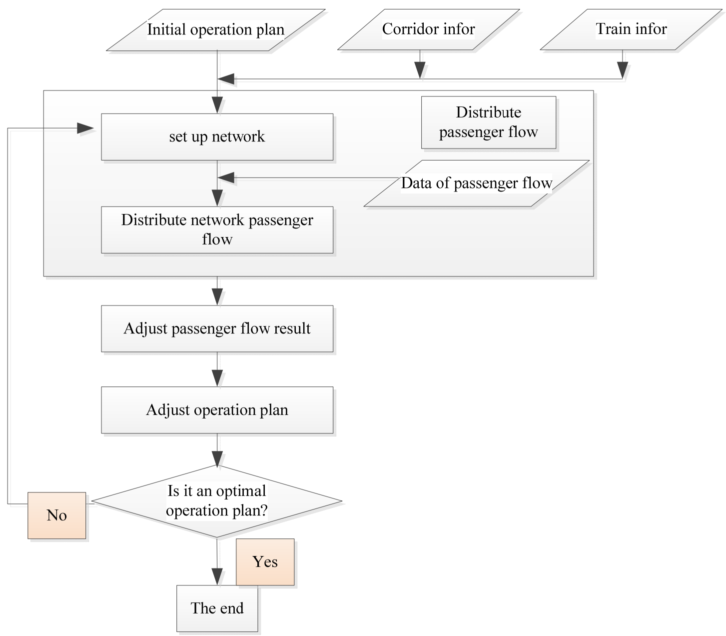

Figure 1. The Process of Optimizing Operation Plan

As a basic link in the high-speed railway transportation operation plan, a reasonable passenger flow distribution has a directly influence on the optimization result. The method in this paper applies to the Beijing- Shanghai high-speed railway corridor in 2005 operation plan and passenger flow data. The network passenger flow distribution is optimized with computer programming technique. And the optimization result has arrived at the aim expected by comparing the initial plan to the optimized plan.

Reference

Shen Qingyan，Lang maoxiang. Research on passenger train scheme of jinghu high speed railway. China Academy of Railway Sciences，beijing：1993.

Yan Haifeng.Passenger train plan optimal reference on passenger special lines. Southwest Jiaotong University Press，Chengdu：2012.

Zha weixiong，Fuzhuo. Research on the optimization method of through passenger train plan.Journal of the china railway society. 2000，22（5）：1-5.

Analysis of Local Vibration Characteristics and Influencing Factors of a High-Speed Railway Box Beam

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Abstract: In the study of high-speed railway viaduct, structural noise is becoming a hot issue, the root cause is the local vibration which is generated when the trains pass the bridge, the vibration frequency is between 20-200 Hz. Based on the vehicle - track coupling dynamics, the local vibration of the box girder is analyzed by the Finite Element Method (FEM) in detailed. Six representative sensitive points were selected to analyze the vibration response under various conditions. Different section forms are analyzed, including different thickness, dip angle of the web plate, and so were the double room beam. The results show the local vibration can be controlled effectively by the improvement of the cross-sectional form in the practical engineering, in particular changing the thickness of the top plate, and the thickness inclination web plate, at the same time the form must meet other precondition. At last the effects of local vibration on double room box girder beam are discussed. The vibration response of double room box girder is lower than single room box girder.
Keywords: Local vibrations; Box girder; Section forms; Double room.

1 Introduction

The structural noise is caused by the local vibration which is generated when the trains pass the bridge, the vibration frequency is between 20-200Hz. The vibration is affected by many factors, so it will be discussed in this paper to find the mainly factors influencing the local vibration.

Several factors on local vibration characteristics of the box girder form is analyzed in this article, including the thickness of the each plate, dip angle of the web plate and the chamber of beam. First, the different finite element models of box girder are established, and then its time domain characteristics and frequency domain characteristics are analyzed. The previously methods (Luo wenjun, 2013, 2014) to analysis local vibration are used in this paper. The details of each analysis are as follows.

2 The effects of different forms of cross-sectional dimensions on the local vibration

The box girder is divided into the top, web, bottom and flange plate, then changing the thickness of the each part to solve, analyze the impact of each plate thickness on the bridge of local vibration. The variation in thickness of flange plate is not considered. Because flange plate is located in the edge of the beam and the effect of the variation on other parts are very little.

2.1 Thickness of top plate

Four kinds of conditions of the thickness were used to analysis—290mm, 340mm, 390mm, 440mm. The RMS curve of vibration acceleration of each sensitive points of different top thickness is shown in the figure:

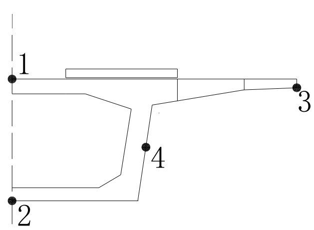


Figure 1. The sensitive point layout two kinds of box beam

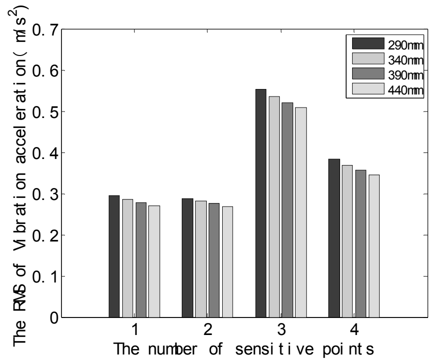
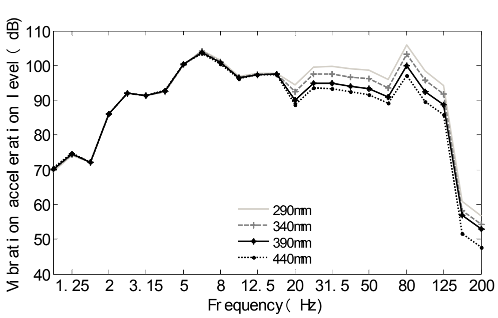
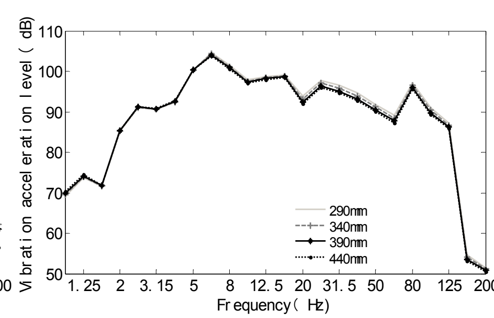


Figure 2. Vibration acceleration RMS of different thickness of top plate

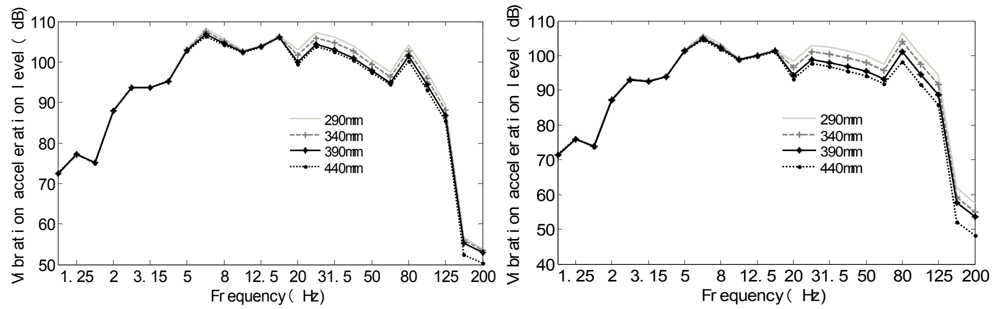
As can be seen from the figure, the acceleration RMS of all sensitive points has been reduced as the thickness from 290mm to 440mm. The reduce magnitude of each point are similar, but this cannot reflect impact of the local vibration on the points are the same, the impact on the high frequency local vibrations need to be determined through the spectrum analysis.



Point one



Point two



Point three Point four

Figure 3. The 1/3 octave of vibration acceleration

Based on the spectrum, the impact of changing the thickness on low frequency vibration 0-20Hz is relatively small, vibration level curve of the points are coincided. Between 20-200Hz, it has a more significant impact on local vibration response of point one and four, the impact on point one is the greatest. As the top become thicker, vibration level is smaller and these points are mainly located in the top and around the adjacent position. And for point three, the influence is relatively small. There is no effect on the point two. It may because these points are far away the top plate.

2.2 Bottom thickness

Four kinds of conditions of the bottom thickness were used to analyzed—250mm,250mm,300mm,350mm. The RMS bar charts of each sensitive point about different bottom thicknesses are shown in the figure:

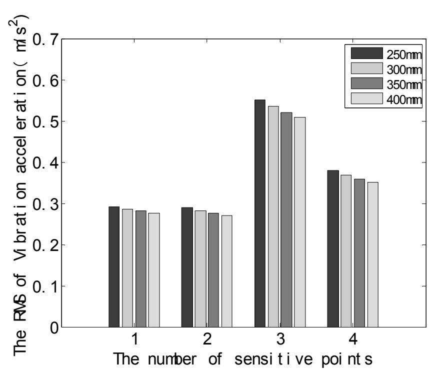


Figure 4. Vibration acceleration RMS variation

The figure shows the RMS of acceleration of all sensitive points has been reduced by the top thickness increasing and the point one decreases relatively small.

Spectrum analysis of vibration acceleration of each point is shown below. Here the expression is same with the top plate.

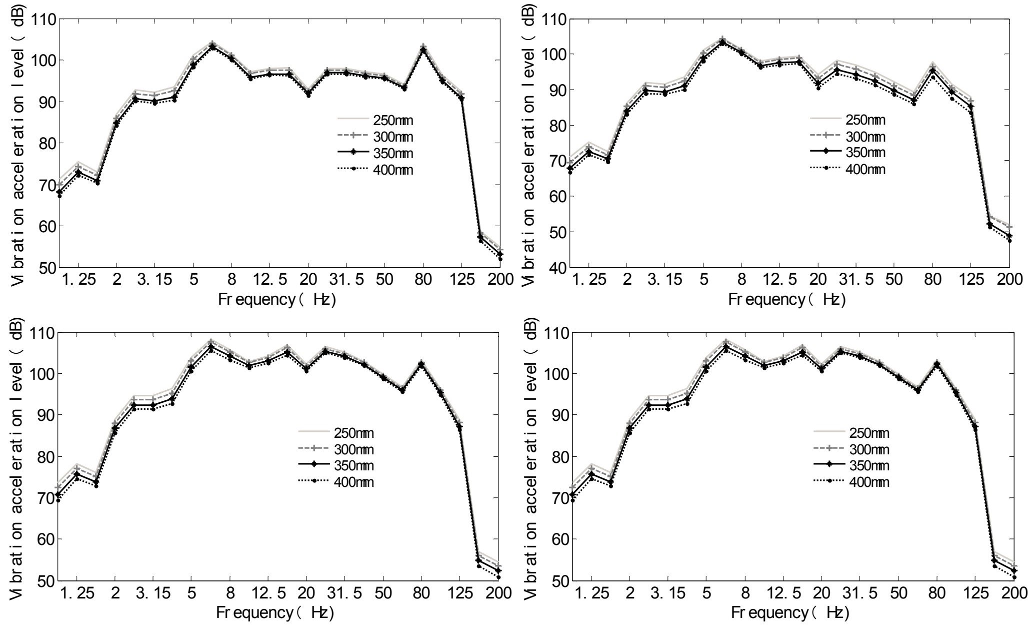


Figure 5. The 1/3 octave of vibration acceleration

According the one-third octave curve, bottom thickness of the points have little influence on each point at low frequency 0-20Hz. The situation is different from the change of the top plate; vibration level curve of four points has no too obvious differences between 20-200Hz except point two. Taken together, by changing the thickness of the bottom to control the local vibration has general effect.

2.3 Web thickness

Four different web thickness were used to be analysis—370mm, 420mm, 470mm, 520mm. The RMS curve of variation acceleration of each sensitive points of different web thickness is shown in the figure:

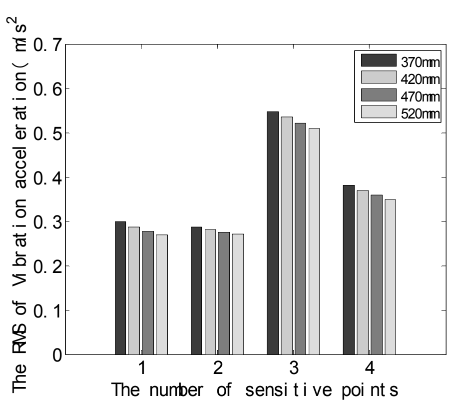
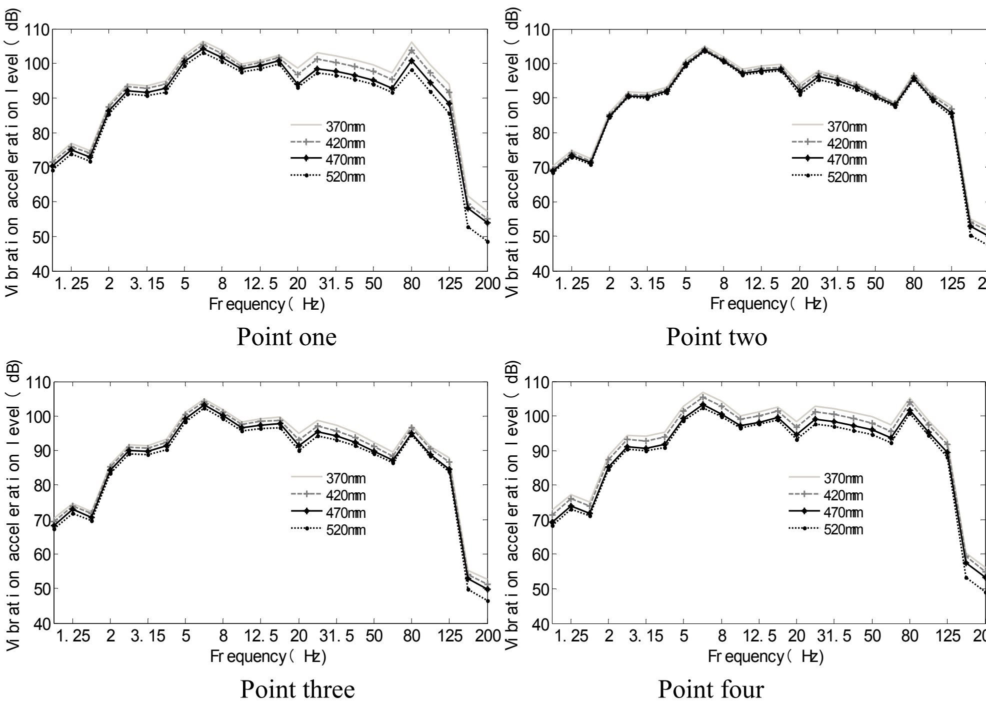


Figure 6. Vibration acceleration RMS variation

This case is similar with the above content. The difference of vibration acceleration RMS of the points is little. Now analyze the points of local vibration by discussing one-third octave curve.



Point one Point two

Point three Point four

Figure 7. The 1/3 octave of vibration acceleration

As the changing of the web thickness, the most obvious influence is on point one which located at the top plate and the point four followed. And point five which located in the middle of the web is very sensitive to the changes of web thickness at the entire band (0-200Hz). Point three which located in flange plate is not sensitive particularly. And it has no effect on the sensitive point two basically.

In summary, the changes of the top and the web thickness control the local vibration effectively.

3 Analysis of different webs inclination

The original design angle of the web plate is about 9 °. Now we analyze the influence on local vibration of the web inclination. The model diagram of 18 and 0 degrees are listed below.

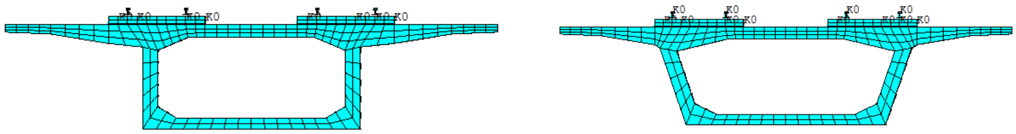


Figure 8. The model of different web inclination

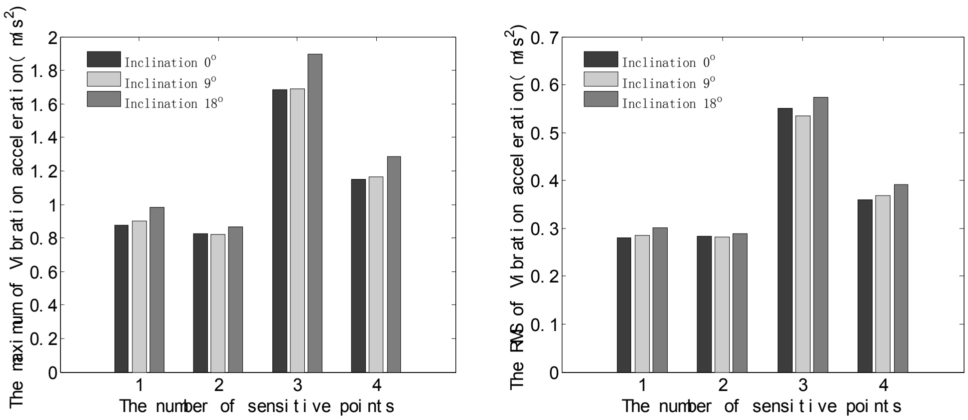
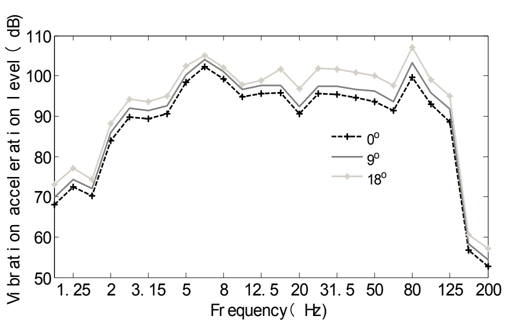


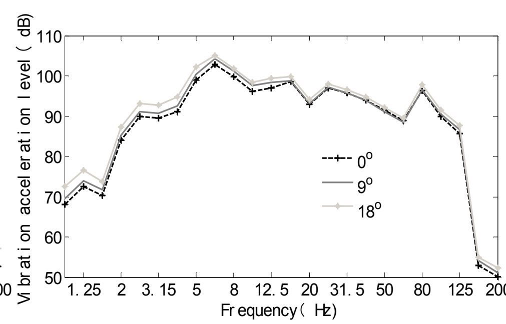
Figure 9. The maximum value and RMS of sensitive points

Through transient dynamic analysis of the three beams, maximum and RMS acceleration of three different inclinations are shown in the figure.9. As can be seen from the figures, vibration acceleration of each point is the largest as the inclination is 18 °, it is followed at 9 ° and it is least at 0°. However the difference between the three cases is not a simple linear. The numerical difference between 9 ° and 0 °is much smaller than the difference between 9 ° and 18 °.

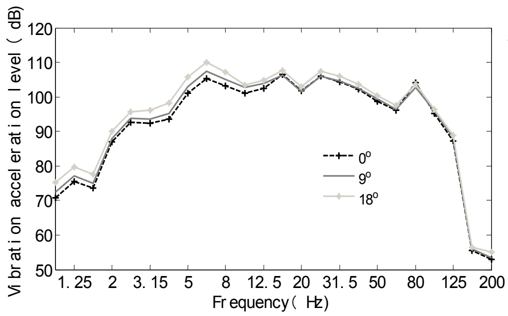
Now analyze the points of local vibration by discussing one-third octave curve:



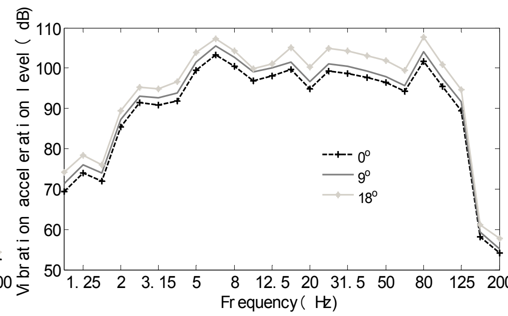
Point one



Point two



Point three



Point four

Figure 10. The 1/3 octave of vibration acceleration

The vibration level of each point in the conditions of inclination 18° were significantly larger than the other conditions, the maximum difference is about 2dB. And the difference of the inclination of 0 ° and 9 ° (design inclination) in the entire frequency band is very small. In most frequency interval, the vibration level of inclination 0 ° is smaller than it is 9°.Theoretically, it is appropriate if we can use a smaller inclination, but it does not necessarily mean it is best to set the dip to be 0 ° (Zhang xun,2012).

4 Analysis of the changing of girder chamber

This section focus on comparative study of local vibration characteristic between double-chamber girder and single room girder.

4.1 Natural vibration analysis of girder chamber

The method to establish model of double-chamber girder is similar to the single chamber beam; The model is shown in Figure 11. First the natural vibration of the girders are contrasted and it is shown in table 1.

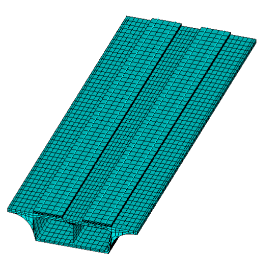


Figure 11. Double chamber beam model

Table 1. Contrast of natural vibration

Mode order	*Natural vibration frequency（Hz）*	
	Single room girder	*Double room girder*
1	*5.6113*	*5.8203*
2	*5.8784*	*5.9431*
3	*10.584*	*15.535*
4	*12.67*	*15.956*
5	*14.707*	*16.853*
6	*17.544*	*19.258*

Natural vibration characteristics of single chamber are slightly different with double room beams. The first two natural frequencies of them are similar, but the modes are contrary.

4.2 Analysis of local vibration

The dynamic analysis method of dual-chamber box is used the same with the single-chamber girder. Layout of sensitive point on double chamber beam is as follows:

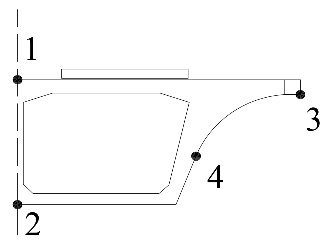


Figure 12. The contrast point layout two kinds of box beam

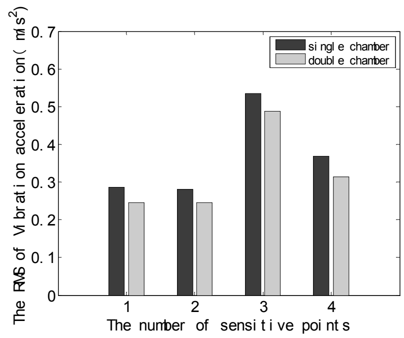
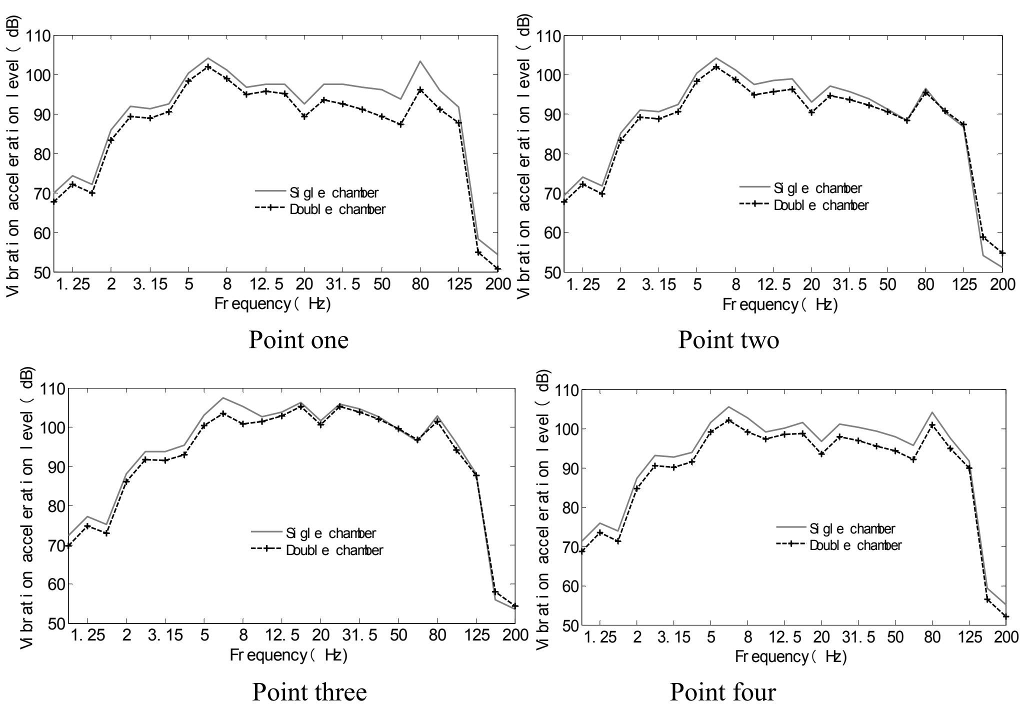


Figure13. Vibration acceleration RMS of the two types of beam

From the figure we can know that the double room in exchange for a substantial reducing of the vibration at a very low weight; The one-third octave curve are below:



Point one Point two

Point three Point four

Figure 14. Each sensitive vibration acceleration

As can be seen in the figure changes of the local vibration from 20 to 200Hz, the sensitive point one, two and four of double-chamber are significantly higher than the single-chamber, the difference of point three is not very obvious. That is, selecting the dual-chamber beam to control top and bottom plates of local vibration has obvious effect between 20 to 200Hz.

5 Conclusions

(1) Establish the models of different plate thicknesses to analysis. In a word, good effect on controlling the local vibration by changing the thickness of top web plate .

(2) Small angle has certain effect on local vibration control of structure. However, the best angle is not set to 0, other factors also need to be considered, take the most appropriate web inclination.

(3) Compared the single chamber with double chamber beam, the local vibration response of the latter is significantly weaker. In engineering selecting the double chamber beam at the corresponding position can reduce the structure noise radiation.

Acknowledgement

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References

Li Qi, (2008) "Analysis and application of Vehicle Bridge coupling vibration theory of the track system . Shanghai: Tongji University

Li Qi, (2011) "The local vibration of the box girder cantilever plate and its influence on the train running performance" .Chinese Railway Science

Li Xiaozhen, Zhang Xun, Li Yadong(2011)."Journal of boundary element method, noise of high-speed railway simply supported box girder structure in civil engineering" ,Journal of Civil Engineering, 2011, 44: 95-101.

Luo Wenjun, Lei Xiaoyan, Lian Songliang(2013). "Analysis of the new model of vehicle track coupling system of viaduct". Journal of East China Jiaotong University.

Luo Wenjun, Zhang Xinyuan(2014), "High speed railway box girder finite element analysis."Noise and Vibration control .

Zhang Xun; Li Xiaozhen(2012) , "Study on radiation characteristics of 32m simply supported box beams on high speed railway sound". Journal of the China Railway Society.

Calculation Method for High-Speed Railway Running Cost under the Conditions of Mixed Passenger and Cargo Marshalling

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Abstract: Chinese high-speed railway got a fast development in recent years, several new lines have been put into operation. After analyzing the mixed passenger and cargo marshalling modes in foreign countries, the high-speed train operation cost quantitative analysis and the calculation formula was given, which was suitable for Chinese actual practice. Using the operation cost method to calculate basic work and operational work between the existing railway line and the high-speed railway passenger-dedicated line. By apportioning the single carriage single cost to calculate the equivalent under the condition of high-speed train mixed passenger and cargo marshalling into operation costs.
Keywords: Mixed passenger and cargo marshalling; High-speed train operation costs; Quantitative analysis.

1 Introduction

High-speed railway in our country in terms of passenger transportation, and domestic high-speed railway cargo has just started; the research is not deep enough. Nowadays, Wuhan-Guangzhou high-speed railway confirming train has been used to develop mass transport of ordinary express, but mixed marshalling high-speed railway has not came true.

(Gerhard Troche, 2010) for high-speed rail transport of goods to the definition, in Sweden, Denmark, France and other countries of the high-speed rail freight handling, transit and train vehicle technology, such as the train operation are summarized. (Seung-Ju, 2007) considers the transportation cost, the influence of the transit time to cost, operation plan compiling model is established.

(Lin zhonghong, 2012) analyze the feasibility of high-speed railway to carry out the fast freight, suggest should be as soon as possible to carry out the research. (Wu yunyun, 2010) studies on the pros and cons of the overseas high-speed railway freight transportation mode, analyzes the feasibility of using this mode. (Zhao chen,2009) using the activity cost method to passenger and cargo transportation costs for research. However, the domestic most of activity cost method for cost calculation is macro qualitative analysis, lack of quantitative analysis. Mixed transportation potential market of high-speed railway, the feasibility of the train operation, and the researching mode of operation is less. This paper is mainly considering different marshalling modes and under the influence of running speed, combined with the cost of high-speed railway passenger dedicated line and existing lines freight cost by the activity cost method ,using the influence coefficient of high-speed railway passenger and cargo mixed into the running cost of the train.

2 Transportation cost allocation

2.1 The high-speed railway passenger dedicated line transportation cost allocation

According to the characteristics of the high-speed railway transportation production organization, combined with the requirements of the activity cost method calculate principle of railway transportation, the high-speed railway passenger transport production process is divided into operation and basis two parts. The passenger dedicated line operation cost allocation is divided into sending activity, operating activity and maintenance activity. In order to analyze the structure of high-speed railway passenger dedicated line operation cost, divided the high-speed railway operation cost into wages, power, material, depreciation, capital costs and other expenses six parts by economic nature.

High-speed railway passenger dedicated line operation assignments, operating index and corresponding allocation of spending grouped collection, the collection summary as shown in figure1.

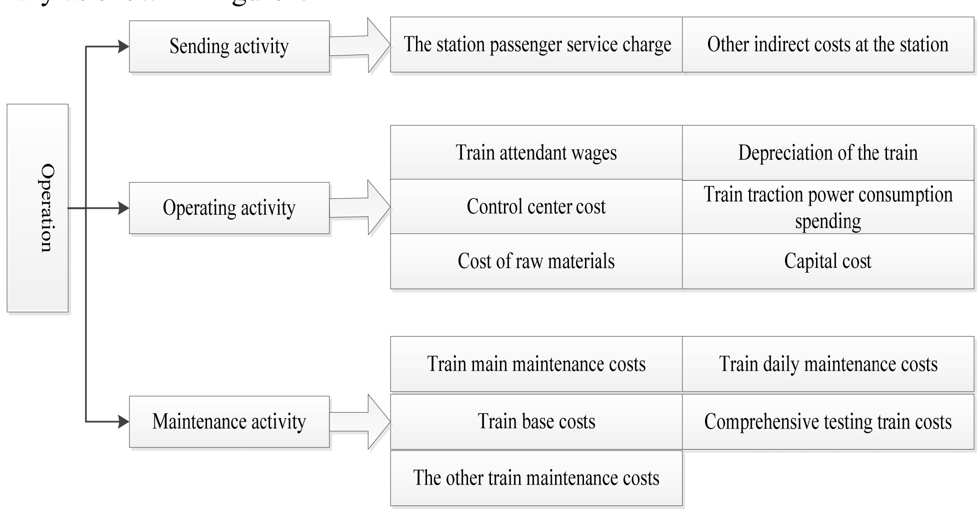

Figure1. Summary of passenger dedicated line operation assignments

The above mentioned can determine the dedicated line which has the certain starting station and a high-speed railway passengers , then every carriage daily produced in the process of train running average operating costs C_{Y_1} computation formula is as follows.

$$C_{Y_1} = (\sum \text{ Operating expenditure project} \times \text{The single running operating indexes})/T_1 \quad , \quad T_1 = 16\mu + 8(1-\mu) \qquad (1)$$

In the (1) formula, T_1 is passenger railway marshalling carriage number, General Chinese high-speed railway marshalling for 8 or 16 carriages. μ is a 0-1 variables, $\mu = 0$, shows the marshalling train running, but $\mu = 1$, shows the marshalling train is not running.

High speed railway passenger dedicated line's basic assignments, operating index and corresponding allocation of spending grouped collection and the collection summary as shown in figure2.

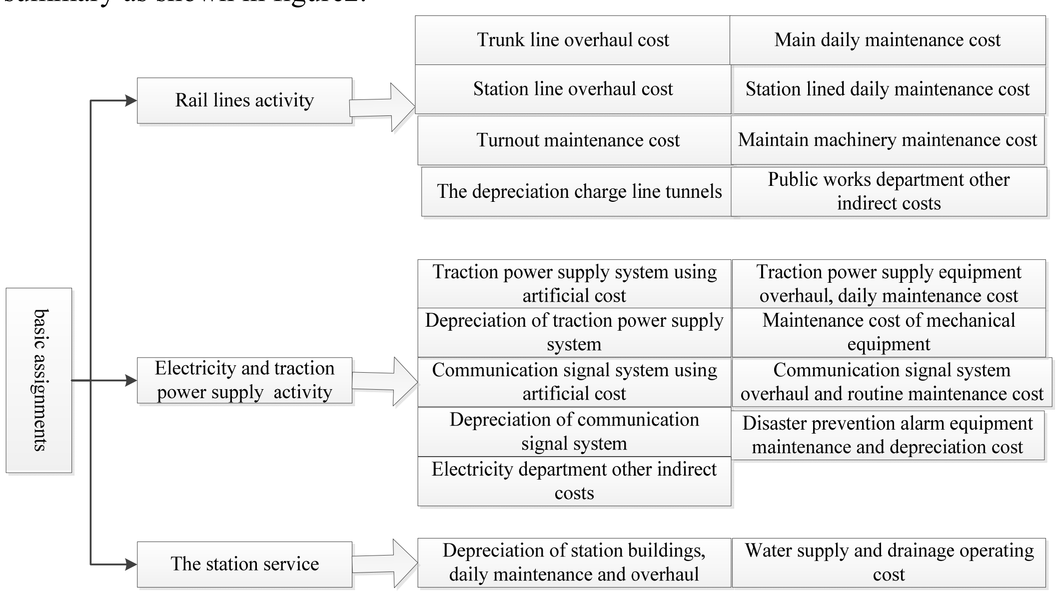

Figure2. Summary of passenger dedicated line basic assignments

By the above-mentioned can be in determining the starting station and a high-speed railway passenger dedicated line determined, every carriage daily produced in the process of train running average basic assignments C_{Z_1} computation formula is as follows.

$$C_{Z_1} = (\sum \text{ Basic assignment expenditure project} \times \text{Basic assignment index})/T_2 \quad ,$$

$$T_2 = W_1 \times 365 \times (16n_1 + 8n_2) \quad (2)$$

In the (2) formula, W_1 is the maximum operating life of high-speed railway lines, n_1 is the number of daily operation class of high-speed railway passenger dedicated line to 16 carriages marshalling. n_2 is the number of daily operation class of high-speed railway passenger dedicated line to 8 carriages marshalling.

2.2 Existing railway cargo transportation costs

Also existing railway cargo transport operations can be divided into the cost of cargo operations assignments and foundational assignments.

2.2.1 Cargo transport operations assignments cost allocation

Cargo transport operations are divided into sending assignment, transit assignment, operating assignment. The rail cargo operations indexes and cost range as shown in figure3.

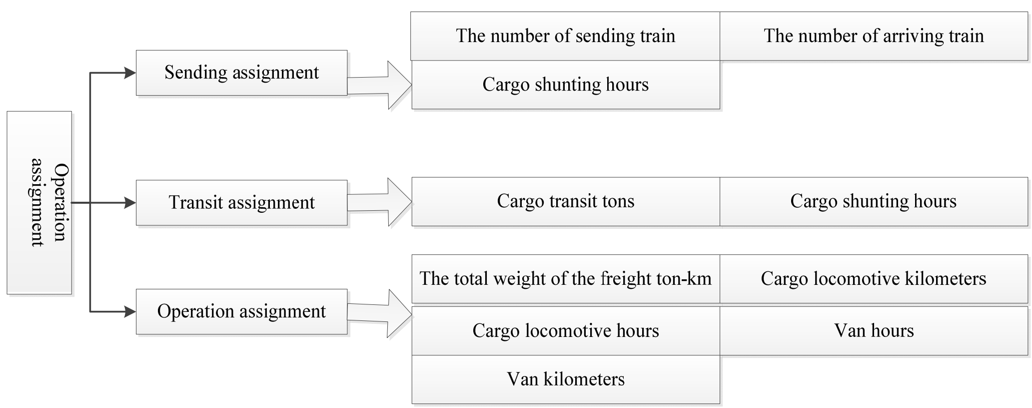

Figure3. Summary of cargo operation assignments

By the above can be in determining the starting station and arriving station into an existing railway to transport goods, every carriage daily produced in the process of train running average operating assignment costs C_{Y_2} computation formula is as follows.

$$C_{Y_2} = (\sum \text{The operational indexes} \times \text{The single running operating costs}) / T_3 \quad (3)$$

In the (3) formula, T_3 is the marshalling freight carriage number of existing railway cargo trains.

2.2.2 Existing railways mixed running cost allocation proportion

Li Daian by applying the method of railway line engineering model system research and calculation analysis concluded that the cargo on the basic assignments cost ratio of the railway line is 68.72%, passenger is 28.32%.To determine the existing lines and passenger, cargo cost allocation proportion is 28.32% and 68.72% respectively, roughly 3:7. So the proportion of existing railway passenger and cargo basic assignment costs allocation is 3:7.

2.2.3 Carriage of goods by basic assignment costs

Existing railway basic assignments cost calculation, the operating indexes and cost range summary as shown in table1.

Table1.Summary of basic assignments cost

Assignment		The index of transportation activities	Corresponding to the cost
Basic assignment	Line based assignments	The past total weight of ton kilometer	Public works department cost
	Train operation signal	Freight train kilometer	The communication signal cost
	Station operation	The number of sending goods	The cost of the maintenance, depreciation, etc.

By the above can be in determining the starting station and arriving station into an existing railway to transport goods, every carriage daily produced in the process of train running average basic assignment costs C_{Z_2} computation formula is as follows.

$$C_{Z_2} = 0.7\times(\sum \text{The operational indexes} \times \text{Corresponding to the cost}) / T_4$$

$$T_4 = W_2 \times 365 \times n_3 \times T_3 \qquad (4)$$

In the (4) formula, W_2 is the largest operating life of existing railway lines, n_3 is the number of daily operation class of existing cargo railway line marshalling with T_3.

2.3 Mixed marshalling modes

On the marshalling modes, from abroad to carry out high-speed railway passenger and cargo mixed into the model, there has been passenger and cargo coexist in a high-speed train. In theory, it is suitable for the high-speed railway in passenger and cargo mixed marshalling can be divided into the following two modes, as shown in figure 4.

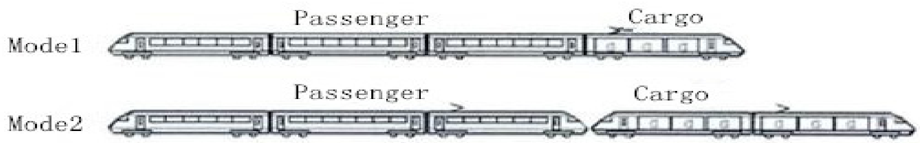

Figure4. Mixed marshalling mode of the high-speed railway

The first is passenger carriages and cargo carriages coexist in the same model of high-speed train, which is the highest degree in mixed mode.

The second is the goods and passengers in different train transportation respectively. In this mode, the cargo train and passenger train on the same line can united together to run from the different starting and end point. From the above figure 4 we can know that mode 1 and mode 2 on the number of passenger and cargo carriages ratio is 3:1, 3:2 respectively. General Chinese high-speed railway marshalling is 8 or 16 carriages marshalling. To choose different marshalling mode with the number of passenger and cargo carriages（$N_1 : N_2$） that show in table2.

Table2. Mixed carriages number of different marshalling modes

Carriages number（N_1:N_2）	8 marshalling	16 marshalling
Mode 1	6:2	12:4
Mode 2	5:3	10:6

2.4 The influence coefficient of running speed under mixed marshalling

In terms of speed, the high-speed railway passenger dedicated line and cargo train of existing lines in the process of transport of the two speeds is different, and there is a certain gap. For mixed marshalling operation, passenger and freight coordinated transport makes for reasonable running under the same speed. For passenger transport, due to the change of speed, consider the influence of mixed marshalling for the passenger transportation costs into an influence coefficient λ_1.

$$\lambda_1 = \frac{\overline{V}_2}{\overline{V}_1 + \overline{V}_2} \times \frac{2V_3}{\overline{V}_1 + \overline{V}_2} \quad , \quad \overline{V}_2 \le V_3 \le \overline{V}_1 \tag{5}$$

In the (5) formula, $\overline{V}_1$ is the high-speed railway passenger dedicated line average running speed, $\overline{V}_2$ is existing railway cargo train average running speed, V_3 is mixed marshalling high-speed train running speed under the condition of mixed marshalling, $\frac{2V_3}{\overline{V}_1 + \overline{V}_2}$ is mixed marshalling under the condition of high-speed railway running speed of passenger and cargo operation speed impact factors as a whole. Because of the influence of the speed of the operation of the passenger is mixed into relative decline, it should also multiply $\frac{\overline{V}_2}{\overline{V}_1+\overline{V}_2}$ as the cost ratio.

Due to the change in the speed of the effect of the cargo costs it should into an influence coefficient λ_2.

$$\lambda_2 = \frac{\overline{V}_1}{\overline{V}_1+\overline{V}_2} \times \frac{2V_3}{\overline{V}_1+\overline{V}_2} \quad , \quad \overline{V}_2 \le V_3 \le \overline{V}_1 \tag{6}$$

$\frac{\overline{V}_1}{\overline{V}_1+\overline{V}_2}$ is as mixed into the running speed of cargo relatively increase, the operation cost of the cargo ratio should be increased.

3 The running cost calculation model of high-speed railway mixed marshalling

After determining the departure point and the end, considering the same starting and arriving station to the same line of existing railway with high-speed railway passenger dedicated line running average allocation cost in each compartment, calculating mixed cycling times daily high-speed railway marshalling produced in the process of car running cost as flows.

$$C_W = \lambda_1 \times N_1 \times C_P + \lambda_2 \times N_2 \times C_g \quad , \quad C_P = C_{Z_1} + C_{Y_1} \quad , \quad C_g = C_{Z_2} + C_{Y_2} ,$$

$$\lambda_1 + \lambda_2 = \frac{2V_3}{\overline{V}_1+\overline{V}_2} \quad , \quad \overline{V}_2 \le V_3 \le \overline{V}_1 \tag{7}$$

In the (7) formula, C_W is a certain passenger and mixed marshalling under the condition of high-speed railway running costs, C_P is high-speed railway passenger dedicated line single carriage single running costs, C_g is existing railway single cargo carriage single running costs, N_1、N_2 is the number of passenger and cargo carriage of different mode mixed marshalling respectively. It is shown from table 2.

4 Conclusions

For the current situation of high-speed railway in our country, this paper is based on one of the same station, same line, application of operate cost method, respectively, calculated existing lines and high-speed railway passenger dedicated line in the basic assignment and operation assignment, by using single carriage single cost to calculate the equivalent under the condition of high-speed railway passenger and mixed marshalling of running costs. Utilization of equivalent existing line freight and high-speed railway passenger dedicated line operation cost, considering both the difference between average running speeds, under the condition of passenger and cargo mixed into the unity of the running speed of the impact of different types carriages cost allocation, introduced changes in the rate of correction effect coefficient will affect in operating costs, it is more convenient to use quantitative method of cost calculation.

5 Recommendations for Future Research

High-speed railway passenger and cargo mixed marshalling mode mentioned in this paper was suitable for bulk transport, this paper is based on the alignment of the proposed model will send stations between mixed into all the way, also need to consider in the process of the actual intermediate stop stations to exchange passengers, unloading streamline cross interference on running cost impact on each other and there is some differences between the high- speed railway operation cost of the existing railways. This is the ongoing work of the next.

References

Lin chonghong, Xu qiaofeng (2012). “High-speed railway to carry out the fast transport of goods". *Railway Economics Research*, 2012(04), 1-5.

Li daian ,etc. (2002). "Research on engineering model of railway track cost shared by passenger and freight car". *Journal of Railway*, 2002(04), 12-16

Seung-Ju, Jeong (2007). "The European freight railway system as a hub-and-spoke network ", *Transportation Research Part A*, 1(41), 523-536.

TROCHE, G (2010). "High-speed rail freight Sub-report in Efficient train systems for freight transport", *Swedish National Road and Transport Research Institute*. (Jun 7, 2010).

Wu yunyun (2010). "High speed railway freight development abroad". *China Railway*, 2010(09), 72-74.

Zhao chen and Lv chengwei (2009). "Railway passenger and cargo transportation operation cost calculation method". *Railway Economics Research,* 2009(01), 42-45.

Exploration of Night Train Plans and Window Settings for High-Speed Railways

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Abstract: Night train is a form of adapting to development of high-speed railway and passenger transport demand in China. High-speed rail train operation at night exist such as waiting for line, transferring line and “a line of maintenance, a line of traffic” three modes, corresponding respectively the way of two line totally closed maintenance and one line closed maintenance. Through comparative analysis, it can be found that high-speed rail window setting should adopt fully closed mode. Based on summary analysis of traditional rectangular window feature, this paper proposes the set form of two-day segmenting rectangle window, and it can effectively avoid the disadvantages of traditional segmenting rectangle window. Finally, taking the Beijing-Shanghai high-speed railway as an example, the paper analyzes the set of two-day segmenting rectangle window.
Keywords: High-speed railway; Trains operating in night (night trains); Comprehensive maintenance window; Sectional rectangular window.

1 Introduction

So far, China has opened the Beijing-Guangzhou, Beijing-Shanghai, Beijing-Harbin high-speed railway having the length of more than 500 km, which basically have communicated with each other, with the conditions for running across the line. High-speed long distance trains run across the line, the operation time of which is significantly longer, having a great impact on the setting of window. At the same time, with the development of social economy and improvement of people's living standard, the public per capita trip time becomes more and more, and travel ways also become more and more diverse; the main service object of the high-speed railway is the business flow, high level commuter passenger flow and tourist flow, who have higher sensitivity to the travel comfort and time. To attract more passenger groups, China’s railway sector needs provide more diverse high-speed railway transport products to socialization. Therefore, it is necessary to consider opening the high-speed train at night, which will also generate conflict between operation and maintenance.

2 Night train operation mode analysis of high-speed railway

2.1 Types of driving mode at window time

At present, the vast majority of worldwide high speed railway adopts the mode of transportation driving during the day and comprehensively maintaining at night. While the mode of driving at night is associated with the maintenance mode of window, generally divided into the following two categories:

(1)Line full closed mode at window time

As lines are full closed in window time, high-speed trains entering the window time have only two choices:

① Waiting for line mode : Stop waiting in the front station before the window opens, then the trains continue to run on high-speed lines after the closure of the window.

②Transferring line mode: In front of the station within the range of window, the high-speed trains run down to the existing line, running again up to the high-speed line after the closure of the window.

Compared to the transferring line mode, the waiting for line mode has higher requirements to the ability of window station equipment, and not conductive to the repair work at night. There night trains should use the transferring line mode.

(2)The mode of "a line of maintenance, a line of traffic" in the window time

When working on comprehensive repair at night, only a line is repaired, however another line organizes bidirectional train operation.

2.2 Driving mode comparison of window time

(1) The full closed mode uses complete closure of service sector, and external factors influencing the repair work are less, requiring shorter window time; because the mode of "a line of maintenance, a line of traffic" is affected by the train operation of adjacent lines, part of repairing work can be performed under certain conditions, requiring longer window time.

(2) The full closed mode does not provide capacity in the window time; while the mode of "a line of maintenance, a line of traffic" has certain driving conditions in the window time.

(3) Under the full closed mode, because of less factors of influencing repair work, repair efficiency is high; the mode of " a line of maintenance, a line of traffic" both influence each other in train's running and maintenance, so repair efficiency is low. According to the above comparative analysis, the window of high-speed railway should be set to the full closed mode.

3 Analysis of high-speed railway window setting

3.1 Traditional segmenting rectangle window

Rectangle window can realize fully closed repair of lines, is the comprehensive repair window way commonly adopted by the national high-speed railway. It is divided into vertical rectangle and segmenting rectangle, and the vertical rectangle is a special form of segmenting rectangle window. Traditional segmenting rectangle window, refers to take the daily (24h) as the cycle, between 0:00 and 6:00, respectively open rectangle window according to the window sublevel, none of which has the same opening time, as shown in figure1. It has the following characteristics:

(1) Has great flexibility, namely can choose the right time, tilt direction, inclination angles across the line according to the need of actual traffic, opening in a variety of ways such as segmentation, combination and continuation.

(2) By adjusting the opening time of each segmentation window, it can provide certain night operation conditions for trains of the slope direction in a smaller range.

(3) Full consecutive set will produce great influence area, even can affect daytime departure; it has greater influence on the train in the opposite direction to the window sloping direction. Therefore, the window should not be continuously opened across the line.

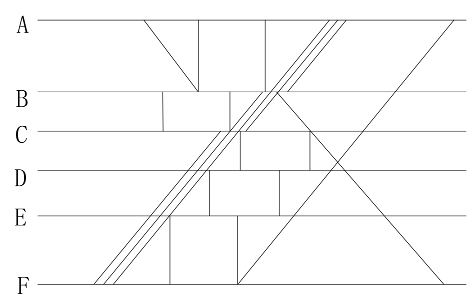

Fig.1 Schematic diagram of sectional rectangular window

3.2 Two-day segmenting rectangle window

Two-day segmenting rectangle window, refers to take the two days (48h) as the cycle, between 0:00 and 6:00, respectively open rectangle window according to the window sublevel. Thus, segmentation rectangular window will be opened in two different ways in a cycle, to ensure the capacity balance between the uplink and downlink, as shown in figure 2.

Fig.2 Schematic diagram of two-day segmenting rectangle window

Based on the adjustment of opening period of segmenting rectangle window, and in harmony with train running chart drawing, two-day segmenting rectangle window has not only the characteristics of traditional segmenting rectangle window, but also can effectively avoid the disadvantages:

(1) The line can be integrated maintenance by taking the full closed mode;

(2) Having the same capacity with traditional segmenting rectangle window, it can achieve balance of the train operation between the uplink and downlink;

(3) It can reduce the efficiency of traditional segmentation rectangular window due to limited capacity of motor train-set and be uneven;

(4) The deficiency is that part of night train need to organize the next day trip.

4 Case study

Taking the Beijing-Shanghai high-speed railway as an example, 4 hours two-day segmenting rectangle window is opened between 0:00 and 6:00, the train running speed is 200km/h in the period of time, and the night train adopts referring line mode in Ji'nan-Xuzhou section. According to the above description, the Beijing-Shanghai high-speed railway window is set, as shown in figure 3(the shaded areas in figure 3 indicate the running time of the night train).

Through the figure 3 as you can see, opening two-day segmenting rectangle window can increase night capacity of the line section; within two days, the capacity of the uplink and downlink balances, also ensuring the efficiency of the bottom of the train.

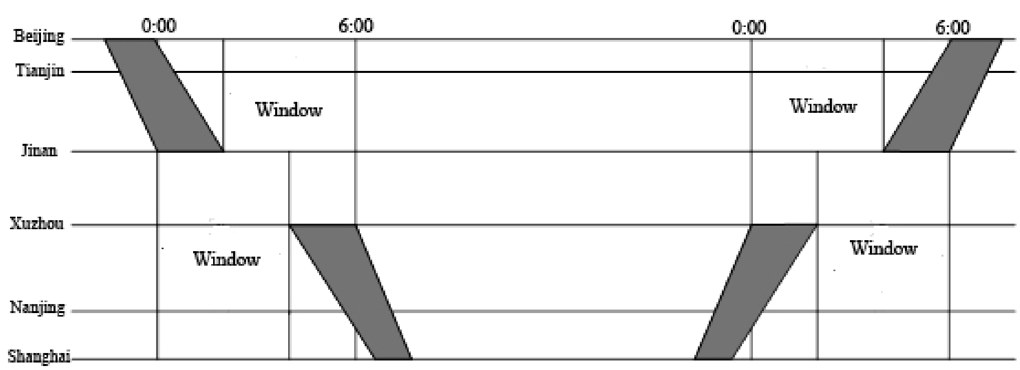

Fig.3 The window set of night operation plan of Beijing-Shanghai high-speed railway

5 Conclusions

The operation of high-speed railway night train, not only conforms the characteristics of long line and train operation time of China's high-speed railway, also accords with the requirement of mining the potential of high-speed railway in the greatest efficiency.By analyzing of night train plans for high-speed railway, on the basis of the traditional segmentation rectangular window, this paper puts forward two-day segmenting rectangle window suitable for long-distance high-speed railway train operation at night, providing certain reference for opening night train of our country high-speed in the future. However, this pattern is only a kind of discussion, these related contents coordinate with train plans and running chart drawing for the process of implementation still need further research.

Acknowledgement

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References

DONG Shouqing(2005). "Study on all-around maintaining sky-light scheme of Chinese passenger special line." *Southwest Jiaotong University Master Degree Thesis. Chengdu.*

FAHG Tianbin(2011). "A research on the scheme of comprehensive maintenance Window for passenger dedicated lines." Tsinghua University Master Degree Thesis. Beijing.

PENG Qiyuan, LUO Jian(2006). " Research on operation of sunset-departure and sunrise-arrival trains on dedicated passenger lines." Journal of Southwest Jiaotong University, 41(5): 626-630.

ZHU Wenting(2011). " Research on transport operation of sunset-departure and sunrise-arrival trains on dedicated passenger lines." South Jiaotong University Master Degree Thesis. Chengdu.

Reasonable Matching Train Speed of Chinese High-Speed Railways

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Abstract: From 4 aspects of technical condition of fixed equipment, running speed of middle-speed trains, passing capacity of high-speed railway and technical condition of mobile equipment, this paper studies the reasonable matching program of high-speed railway by using mixed operation of two speed types of trains, then the allowable speed matching programs under each condition were achieved. Combining with each factor, the paper suggests that during mixed operation of two speed types of trains on high-speed railways, 3 speed matching programs shall applied, which including 300/200 km/h and above, 250/200 km/h and above as well as 200/140 km/h and above.
Keywords: High-speed railway; Train speed; Reasonable matching.

1 Introduction

The differences of passenger transportation products in High-speed railway mainly reflected on the train speed. Because the train speed is different, its operating costs and the time value of passenger are different. Because of different high-speed railway operation speed of trains, it will cause economic war of freight rate and time saving between railway enterprises and passengers. And reasonable matching speed of high-speed trains needs to consider fixed equipment condition, mobile devices, and transport organization.

2 The status about reasonable matching speed of high-speed trains in China

The speed matching situation is shown as table 1.

Table 1. The speed matching situation about line and cross-line trains

Railway line	Line train speed/(km/h)		Cross-line train speed/(km/h)	
	High-speed train	Motor train	High-speed train	Motor train
Beijing-Shanghai	300	250	300	250
Wuhan-Guangzhou	300	250	300	—
Guangzhou-Shenzhen-Hong Kong	200	—	200	—
Zhengzhou-Xian	300	250	—	250

Shanghai-Nanjing	300	—	300	250
Shanghai-Hangzhou	300	—	—	250
Hefei-Nanjing	—	—	—	250、200
Hefei-Wuhan	—	200	—	200
Qingdao-Jinan	—	200	200	200
Ningbo-Taizhou-Wenzhou	—	—	—	200
Wenzhou-Fuzhou	—	200	—	200
Fuzhou-Xiamen	—	200	—	200
Hefei-Bengbu	300	—	300	—
Zhengzhou-Wuhan	300	250	300	250
Beijing-Zhengzhou	300	250	300	250
Harbin-Dalian	200	200	—	200

As shown in the table 1, there are following three kinds of situations about high-speed railway operation of train speed matching in China.

(1) Use 300 km/h high-speed trains match more than 250 km/h emu trains.

(2) Use 250 km/h high-speed trains match more than 200 km/h emu train.

(3) Use only one kind speed of above 200 km/h emu trains.

3 Technical condition of fixed equipment

3.1 Basic technical condition

Reasonable matching speed between line train and cross-line train need to consider technical condition of this line and the adjacent lines.

(1) When different speed trains collinear run, maximum speed and minimum speed are limited by technical condition of high outer rail and minimum radius of curve(The Ministry of Railways,2008). The lowest speed matching of different speed trains operation in high-speed railway is: 200/120 km/h, 250/140 km/h and 300/160 km/h.

(2) Existing railway and high-speed railway in China widely used CTCS train control system, and there are five levels now: CTCS-0, CTCS-1, CTCS-2, CTCS-3 and CTCS-4.

3.2 The condition of train control system

(1) The existing lines whose speed is no more than 160km/h generally use CTCS-0 or CTCS-1 train control system.

(2) The existing lines of transformation whose speed is 200km/h and the passenger special line whose speed is 200~250km/h generally use CTCS-2 train control system.

(3) The high-speed railway whose speed is no less than 300km/h generally use CTCS-3 train control system.

(4) CTCS-0 and CTCS-1 can switch with CTCS-2; CTCS-3 can switch with CTCS-2, but CTCS-3 can't switch with CTCS-0 and CTCS-1.

If collinear trains don't slow down to run, it should promise that the train control system match each other. Therefore, the minimum matching speed of different trains in high-speed railway is 200/120km/h, 250/120km/h and 300/200km/h.

4 Travelling speed of middle-speed trains

When the high-speed trains and middle-speed trains run collinear, the influence for middle-speed trains is the basis of reasonable matching speed. The coefficient of travelling speed for middle-speed trains is estimated by formula 1(PENG Qiyuan,2008).

$$\beta_B = \frac{v_{Bl}}{v_{By}} = \frac{T_B}{T_B + T_{Be} + [T_B(1-\Delta B)]/1\,440 \times n_A[0.5(1-\Delta \mathrm{B})t_y + 2I + t_q]} \quad (1)$$

From formula 1: v_{Bl} (v_{By}) is travelling speed for middle-speed trains; T_B (T_{Be}) is running time (station time for passengers taking down); ΔB is the speed ratio of middle-speed trains and high-speed trains; n_A is the number of railway traffic of high-speed trains; t_y (t_q) is the running time in section of middle-speed train (Additional parking time is 4 min); I is the average tracking interval time of middle-speed train (5 min).

According to the reference of Wuhan-Guangzhou, Zhengzhou-Xian, Shanghai-Nanjing, Shanghai-Hangzhou, Beijing-Shanghai and Hefei-Nanjing passenger special lines, determine the relevant parameter value (As shown in table 2). Base on formula 1, compute speed factor of middle-speed train in different speed matching programs, as shown in the figure 1.

Table 2. Travelling speed calculation parameters of middle-speed trains

Train speed/(km/h)	Line length /km	Average station distance /km	T_{Be} /min	n_A /double
300	600	60	15	50
250	300	35	15	50
200	300	35	15	50

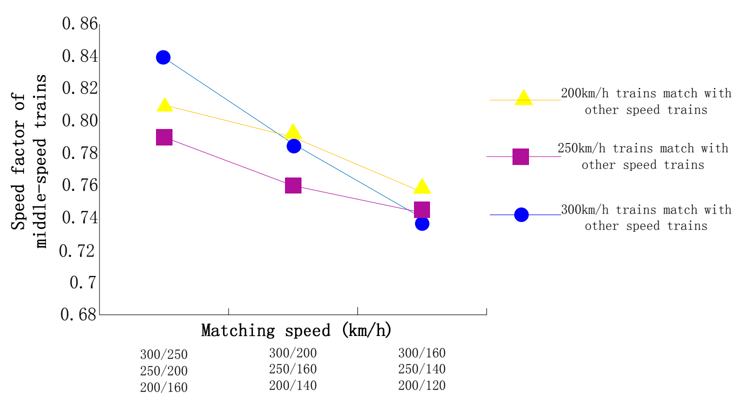

Figure 1. Speed factor curve of middle-speed trains in matching programs

The figure 1 shows that the bigger of speed difference, the smaller the speed factor of low level train. When high-speed and middle-speed trains matching speed are above 200/120km/h, 250/160km/h and 300/200km/h, the speed factor of middle-speed trains are all more than 0.75. This shows that the speed difference of high-speed and middle-speed trains is no more than 100km/h.

5 Passing capacity of high-speed railway

Most high-speed railway in China are passenger special lines, so it will must take place that high-speed trains overtake middle-speed trains when the train runs collinear. Therefore, determining the speed of the train operation plan must consider the impact of speed difference for passing capacity. When use coefficient of train removal to calculate passing capacity of high-speed railway, determine the average coefficient of train removal is the key.

5.1 The determination of coefficient of train removal

(1) Coefficient of high-speed train removal. High-speed train stopping will have to deduct for passing capacity of railway line. When high-speed trains stop at a rate of 20%, and stopping time is between 1 min and 5 min, coefficient of high-speed train removal ε can be valued between 1.4 and 1.6(LIU Xiaoqing,2008).

(2) Coefficient of middle-speed train removal. When the number of railway traffic of high-speed trains is a, and the number of railway traffic of middle-speed trains is b, the probability of train running by automatic block signals between overtaking stations is b/(a＋b), and the probability of single train running is a/(a＋b). Base on whether the train is parking, middle-speed train formation of the train operation can be set is divided into 8, and calculate coefficient of train removal, as the table 3. When the distance between two overtaking stations is 100 km, calculate the probability of 6 kinds (As shown in the table 3). The average coefficient of middle -speed train removal is the weighted average of 6 kinds.

Table 3. Coefficient of middle -speed train removal and occurrence probability

<table>
<tr><th>NO.</th><th colspan="2">Trains in front</th><th colspan="2">Trains in after</th><th>Coefficient of train removal</th><th>probability</th></tr>
<tr><td>1</td><td>High-speed</td><td>Don't stop</td><td>Middle -speed</td><td>Don't stop</td><td>$\varepsilon_1 = 1 + \Delta t / I$</td><td>$\omega_1 = 2a/5(a+b)$</td></tr>
<tr><td>2</td><td>High-speed</td><td>Don't stop</td><td>Middle -speed</td><td>Stop at station</td><td>$\varepsilon_2 = 1 + (\Delta t + t_q) / I$</td><td>$\omega_2 = 2a/5(a+b)$</td></tr>
<tr><td>3</td><td>High-speed</td><td>Stop at station</td><td>Middle -speed</td><td>Don't stop</td><td>$\varepsilon_3 = 1 + \Delta t / 2I$</td><td>$\omega_3 = a/10(a+b)$</td></tr>
<tr><td>4</td><td>High-speed</td><td>Stop at station</td><td>Middle -speed</td><td>Stop at station</td><td>$\varepsilon_4 = 1 + (\Delta t + t_m - t_h + t_q) / I$</td><td>$\omega_4 = a/10(a+b)$</td></tr>
<tr><td rowspan="3">5</td><td rowspan="3">Middle-speed</td><td>Don't stop</td><td rowspan="3">Middle -speed</td><td>Don't stop</td><td rowspan="3">$\varepsilon_5 = 1$</td><td rowspan="3">$\omega_5 = 3b/4(a+b)$</td></tr>
<tr><td rowspan="2">Stop at station</td><td>Stop at station</td></tr>
<tr><td>Don't stop</td></tr>
<tr><td>6</td><td>Middle-speed</td><td>Don't stop</td><td>Middle -speed</td><td>Stop at station</td><td>$\varepsilon_6 = 1 + (t_m + t_q) / I$</td><td>$\omega_6 = b/4(a+b)$</td></tr>
</table>

Note: The stopping proportion of high-speed trains is 20%, the stopping proportion of middle-speed trains is 50%, and average distance between stations is 50 km; t_h (t_m) is stopping time in the station of high-speed (middle-speed) trains; Δt is the running difference time of high-speed train and middle-speed train at the overtaking point.

5.2 The calculation of passing capacity

From the above, the passing capacity of high-speed railway in different overtaking distance and different matching speed. When L=100 km, coefficient of train removal for 300km/h high-speed trains is 1.5, coefficient of train removal for 200～250km/h high-speed trains is 1.4(The Ministry of Railways,2008). Passing capacity of high-speed railway in different matching speed is as shown in table 4.

Tab. 4. Passing capacity of high-speed railway in different matching speed

Matching situation		b=5	b=10	b=15	b=20	b=25	b=30	b=35	b=40
300/250 km/h	$\varepsilon_{parallel}$	3.11	3.05	2.99	2.92	2.85	2.78	2.70	2.62
	a	166	156	146	136	126	117	108	99
300/200 km/h	$\varepsilon_{parallel}$	4.95	4.82	4.67	4.50	4.31	4.11	3.89	3.67
	a	160	144	129	115	101	89	79	69
300/160 km/h	$\varepsilon_{parallel}$	7.24	7.00	6.69	6.32	5.88	5.42	4.95	4.50
	a	152	130	109	90	74	62	52	44
250/200 km/h	$\varepsilon_{parallel}$	3.73	3.65	3.57	3.48	3.38	3.27	3.16	3.03
	a	175	162	149	137	125	114	103	93
250/160 km/h	$\varepsilon_{parallel}$	6.03	5.86	5.65	5.41	5.13	4.82	4.50	4.16
	a	167	146	127	109	93	79	68	58
250/140 km/h	$\varepsilon_{parallel}$	7.67	7.42	7.09	6.67	6.19	5.67	5.14	4.64
	a	161	135	111	91	73	60	50	42
200/160 km/h	$\varepsilon_{parallel}$	4.19	4.09	3.99	3.87	3.74	3.61	3.46	3.30
	a	172	158	144	130	118	106	94	84
200/140 km/h	$\varepsilon_{parallel}$	5.83	5.67	5.48	5.25	4.99	4.70	4.39	4.08
	a	167	147	128	110	95	81	69	60
200/120 km/h	$\varepsilon_{parallel}$	8.02	7.74	7.38	6.92	6.37	5.79	5.22	4.69
	a	159	132	107	86	69	56	46	39

Note: $t_h = t_m = 3\min$, I=3min, $t_q = 3\min$

The table 4 shows that the larger the speed difference is, the smaller the passing capacity is. The passing capacity difference of train speeding matching plan (300/160 km/h, 250/140 km/h and 200/120 km/h) is increasing with increased number of middle-speed trains. When the number of middle-speed trains is more than 20, decrease in the number of passing capacity is more than 50%. So those three train speed matching plan is not recommended. Base on passing capacity, the minimum of train speed matching are 200/140 km/h, 250/160 km/h and 300/200 km/h.

6 Technical condition of mobile equipment

6.1 The matching condition of different speed emu trains

When the doors and windows of train are closed, the time of indoor pressure changes from 3600 Pa to 1350 Pa should be more than 18 s. When the train speed is more than 200 km/h, the train must meet the requirements of air tightness, but some of CRH_1 emu trains don't meet the requirements. As a result, the emu trains can achieve more than 300/250km/h, 300/200km/h and 250/200km/h speed matching.

6.2 Matching conditions of ordinary speed trains and emu trains

According to the relevant provisions, track design live load concentration of passenger special line whose speed are 300~350 km/h and 350~250 km/h is not more than 20 t; Track design live load concentration of passenger special line whose speed is 200 km/h is not more than 22 t; Ordinary speed train driving by locomotive should keep less than 200km/h speed when they run in high-speed railway. At present, ordinary speed trains don't reach conditions of running in passenger special line, and only reach conditions of running in 200km/h passenger and goods collinear.

7 Conclusions

At present, matching speed of Chinese high-speed trains in operation are 300/250 km/h, 250/200 km/h or 200 km/h.This paper studies the reasonable matching program of high-speed railway by using mixed operation of two speed types of trains, and gets the following conclusions.

(1) In the condition that maximum speed and minimum speed are limited by technical condition of high outer rail and minimum radius of curve, the lowest speed matching is: 200/120 km/h, 250/140 km/h and 300/160 km/h.

(2) In the condition of train control system the lowest speed matching of train is: 200/120 km/h, 250/120 km/h and 300/200 km/h.

(3) In the condition of train mobile equipment the lowest speed matching of train is: 200/120 km/h, 250/200 km/h and 300/200 km/h.

(4) From the point of travelling speed of middle-speed trains, reasonable matching train speed is not less than 200/120km/h, 250/160km/h and 300/200km/h.

(5) From the point of passing capacity of high-speed railway, reasonable matching train speed is not less than 200/140km/h, 250/160km/h and 300/200km/h.

Integrate the above five aspects, it is recommended that during mixed operation of two speed types of trains on high-speed railways, 3 speed matching programs shall applied, which including 300/200 km/h and above, 250/200 km/h and above as well as 200/140 km/h and above. At present the actual speed matching program of high-speed railway in China is reasonable.

References

Liu Xiaoqing. (2008). “The research about passing capacity of high-speed railway.” Chengdu: Southwest Jiaotong University.

Peng Qiyuan. (2008). Passenger special line railway transport organization. *Science Press*, Beijing.

The Ministry of Railways. (2008). Provisional rules of passenger special railway design. *China Railway Publishing House,* Beijing.

Operation Mode and Rational Travelling Distance of Overnight Trains in Chinese High-Speed Railways

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Abstract: With great-leap-forward development in the last decade, the operation of high speed railway in China has entered into network era from single line. With expanded service area and long traveling time, the high speed railway in China is qualified for overnight operation in net structure and time space, which is significantly different from that of high speed railway in other countries and areas. The overnight operation of high speed railway is of significance for capacity utilization improvement, besides diverse travelling demand in time horizon. Waiting, transferring, running and maintenance in adjacent lines meanwhile, and periodic operation are the alternative modes for overnight operation. The technical condition, operation feature and applicability are presented, respectively. With rational range of departure time from original station and arrival time at destination, spatial span of network in vertical and horizontal direction, maintenance demand taken into consideration, the rational travelling distance of overnight high speed train are calculated with different operation mode and travelling speed. The work in this paper on operation mode and rational travelling distance is salutary and leading, which provides particular supports for night operation in Chinese high speed railway, in theory and technique.
Keywords: High speed railway in China; Overnight operation mode; Technical conditions; Maintenance; Rational travelling distance.

1 Introduction

By the end of 2014, the revenue kilometers of high speed railway in China have reached to 16,000, over 50% of total kilometers worldwide. With large-scale network, advanced technology and busy operation, the high speed railway system in China has good performances in safety, speed and economy. As an important part of comprehensive system of transport, the high speed railway system markedly shortens the journey time and promotes economic and social developments. In the past 5 decades, the transport service of high speed railway is available only in daytime, and the nighttime (generally from 0:00~6:00) is arranged as railway curfew for infrastructure maintenance. With small national territorial area, besides short travelling distance and time, the high speed railway system in countries and areas except China, is not qualified in practice for overnight operation in network condition and travelling demand. The operation and infrastructure maintenance are staggered in time, leads to interactive influence avoidance and efficiency improvement.

With vast territory, the travelling time by taking high speed train between major cities in China, is much more than that in other developed countries and cities in high speed railway worldwide. More than 1000 passenger flow ODs are formed by the major node cities in China, in which the amount of passenger flow ODs with travelling distance over 2,000 km reaches to 328 , and travelling time more than 7h, about 500. With large scale in network and spatial span, besides long distance of single backbone line in vertical and horizontal direction, the network operation of high speed railway in China is characterized by extensive high speed train and their long travelling time and wide service range. The overnight operation of high speed railway can provide much more diverse transport service, and expand the time horizon of travelling, leading to improvement in temporal accessibility, especially with long travelling distance. Besides, the overnight operation can upgrade capacity utilization in network, and expand efficient service areas, with prominent effects on attractions promotion compared to airline and long road transport. Based on national and railway conditions in practice, it is imperative for overnight operation in Chinese high speed railway, with qualified conditions in network, space and time. The overnight operation is the joint demand from passenger and enterprise. However, as an emerging operation in high speed railway, it is pressing and valuable to work on overnight operation mode and rational travelling distance, based on prior operation experience.

There are very few academic papers published on overnight operation in developed countries and areas in high speed railway except China, due to the little or no demand for overnight operation. However, the dusk-to-dawn train (departing from original station between 18:00 and 23:00, besides arriving at destination station between 6:00 and 9:00) in traditional rail lines, is a popular transport product promoted from 1997. Many efforts are taken on the dusk-to-dawn train in Chinese high speed railway, and they generally took the high speed railway from Beijing to Shanghai as instance. The joint optimization with both overnight train and track maintenance, the operation mode and technical conditions were studied (Peng et al. 2006). The different situations were presented, besides the travelling distances with different curfew time for maintenance were calculated, respectively. The feasibility of dusk-to-dawn train in high speed railway with rectangle curfew was discussed (WANG et al. 2007). The effects of vertical rectangle curfew and inclined rectangle curfew on operation were analyzed, and the specific organization method was proposed by taking the high speed railway from Beijing to Shanghai as instance.

The rational departing time horizon of dusk-to-dawn train was calculated by congruence strategy (LUO et al. 2007). The joint optimization model between train plan and maintenance curfew was established, and the optimal time for maintenance curfew was obtained. Based on the interaction effects between vertical rectangle curfew and overnight train, the mathematical model was established and the corresponding algorithm was designed, for the optimal time of maintenance curfew

(NIE et al. 2010). To minimize the number of affected train by curfew was set as the objective in the optimization model, besides the rational time horizon, as constraints. Three organization modes (waiting, transferring to adjacent parallel traditional rail line, transferring and back to high speed line) were proposed for dusk-to-dawn train in high speed railway (ZHANG et al. 2014). The indexes and rules were presented by establishing candidate scheme generation model and analyzing the solution process. The conclusion was made that the transferring mode is prior for medium and long travelling distance and the waiting mode, for long travelling distance. Based on the previous achievements, running in one direction, transferring twice, transferring once and waiting were the four alternative modes for overnight operation, and the adaptability and security were analyzed respectively(SUN et al. 2014). The train plan was obtained by optimization model, which took operation safety, running time and stop demand as constraints, besides the optimal travelling time as objective.

Based on the achievement on dusk-to-dawn train in high speed railway, five different overnight operation modes are defined and described. The overnight operation modes are avoidance, waiting, transferring to adjacent parallel traditional line, running and maintenance in adjacent lines meanwhile and passenger transferring, and their technical conditions, organization features and adaptability are presented. Finally, the rational travelling distances with different operation mode and travelling speed, are calculated based on the complete operation process of overnight train in Chinese high speed railway.

2 Overnight Operation Modes in High Speed Rail Line

The technical equipment are dispersive, used frequently and continuously, thus the routine maintenance and recondition are necessary for safety and comfort. The maintenance curfew is scheduled at night in advance and large-scale maintenance machinery is adopted, which is the tradition in practice worldwide. However, as essential technical measurement keep equipment in sharp, the maintenance curfew occupies the section exclusively, which leads to negative effects on operation process of overnight train in high speed railway. Under the influence from maintenance curfew, avoidance, waiting, transferring to adjacent parallel traditional line, running and maintenance in adjacent lines meanwhile, passenger transferring are the feasible alternatives for overnight operation mode. The technical conditions, organization features and adaptability are different.

2.1 Avoidance Mode

Avoidance is defined as a particular operation mode for overnight train in high speed railway, in which high speed train plan and maintenance curfew are disperse in time-space. With avoidance mode adopted, the running process of high speed train and maintenance are not interactive, which leads to improvement in safety and efficiency. Avoidance mode is the best overnight operation mode, without particular demands for technical conditions. With avoidance mode, the operation environment, method and process are uninfluenced, the same as that in daytime. The avoid mode is illustrated in figure 1. Maintenance curfews with short duration in different sections are set respectively, and certain idle time interval is reserved for overnight train in 1（a）. Besides, the overnight operation is not affected without maintenance curfew, as shown in 1（b）.

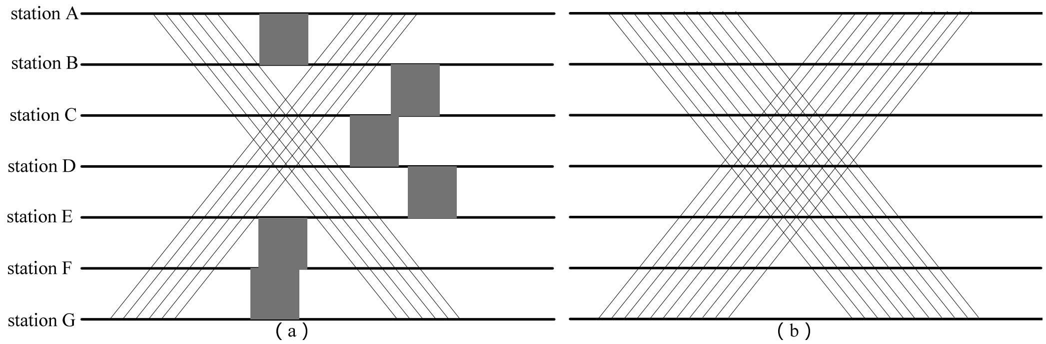

Figure 1. Avoidance mode illustration for overnight operation in high speed railway

As for single section in high speed railway, the avoidance mode is particularly adaptable for maintenance curfew with short duration or no maintenance curfew. However, the implementation of avoidance mode in network is a complex mathematical programming problem, with constraints in time and space. In practice, it is very difficult for overnight train in high speed railway to avoid negative influence from maintenance curfew in its every section. Thus the number of overnight train in high speed railway without influence from maintenance, is extremely limited.

2.2 Waiting Mode

Waiting mode is defined as an overnight operation mode of high speed train, in which the overnight train moves forward as far as possible, suspends at right station prior to maintenance curfew, and restores running to destination station after curfew in high speed line. The waiting mode is illustrated in figure 2(a) and 2(b), in the form of graph and network respectively.

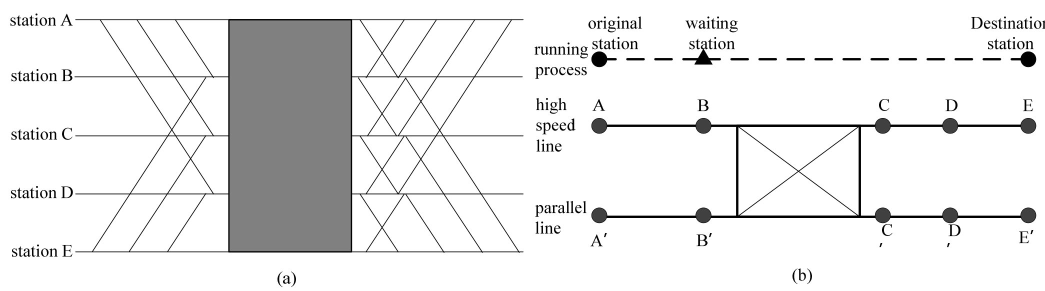

Figure 2. Waiting mode illustration for overnight operation in high speed railway

With waiting operation mode, the running environment (track, signal and control system, power supply et al.) keeps constant in its whole process. The operations in high speed railway and its adjacent parallel traditional rail line, are staggered and not interactive. However, overnight train suspends at station, and occupies arrival-departure track in waiting duration. Idle track resource and routine life power supply are necessary assurance conditions for waiting mode. Thus the technical conditions are listed as:(1)enough arrival-departure available tracks in every station involved with overnight operation; (2)effective power supply equipment for routine life need in waiting process.

The organization method is relatively not complex in all alternatives. However, the continuity and equilibrium of operation in time horizon are affected seriously, and increment of travelling time is the most salient. Constrained by boundary of power supply section, the waiting duration is definitely more than that of maintenance curfew, and is the biggest in all modes under equal conditions. The waiting mode is adaptable for high speed railway with capacity defect or without parallel line. Certain advantages emerge when duration of maintenance is small and the travelling distance of overnight train is long.

2.3 Transferring to Adjacent Parallel Line

Transferring mode is defined as an overnight operation mode of high speed train, in which the overnight train transfers to adjacent parallel line prior to maintenance curfew, moves forward in parallel line in curfew duration, and continues moving ahead or return back to high speed railway after curfew, to destination station. The transferring mode to adjacent parallel line is illustrated in figure 3(a) and 3(b), in the form of graph and network respectively.

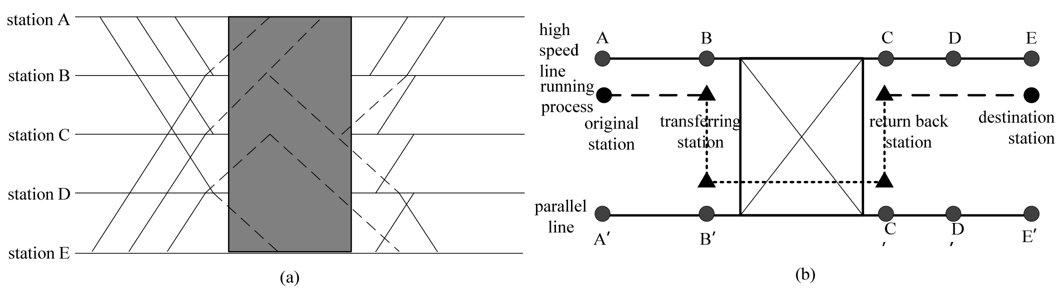

Figure 3. Transferring to adjacent parallel line mode illustration for overnight operation in high speed railway

When transferring mode to adjacent parallel line is adopted, the high speed train transfers to adjacent parallel line by link rail line, prior to maintenance curfew. The train moves forward in parallel line in curfew duration, and continues moving ahead or return back to high speed railway after curfew, to destination station. Its basic technical conditions are presented as: (1) rail line linking high speed rail line and its adjacent parallel line; (2) satisfied track conditions of paradise line for safety and comfort; (3) compatible communication and control system in parallel line with high speed train; (4) affluent capacity in parallel line.

Constrained by rational time horizon for original departure and destination arrival, the transferring section and time may be various for different trains. The number of transferring train and travelling time in transferring process may be also various in different transferring sections. The capacity is occupied by transferring train in parallel line, and the imbalance of remaining available capacity will leads to utilization efficiency of whole capacity. According to the detailed transferring process, the increment of travelling time is small, which results in particular advantage with long maintenance curfew. However, the operation of transferring train is interactive with that of trains in parallel line. The higher requirement for on-schedule rate is needed, otherwise it is difficult to transfer to parallel line prior to maintenance curfew or return back to high speed line after maintenance curfew.

2.4 Running and Maintenance in Adjacent Lines Meanwhile

Running and maintenance in adjacent lines meanwhile is defined as an overnight operation mode, in which one line is occupied by maintenance and the adjacent line is available for overnight train. The overnight operation in maintenance curfew can be organized in the way of multi-train tracking or running in pairs. The running and maintenance in adjacent lines mode is illustrated in figure 4(a) and 4(b), in the form of graph and network respectively.

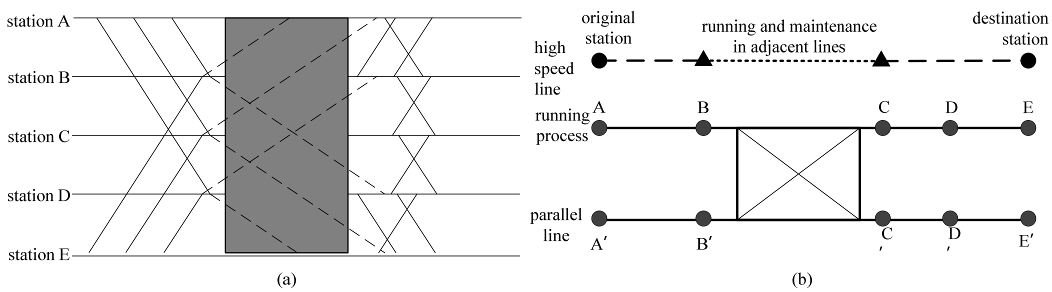

Figure 4. Running and maintenance in adjacent lines mode illustration for overnight operation in high speed railway

Operation in one-direction line will reduce the available capacity greatly, and the temporary capacity bottleneck may lead to part of trains waiting at stations, at both end of maintenance section. The technical conditions for running and maintenance in adjacent lines are listed as: (1) matching maintenance curfew plan; (2) operation conditions in converse direction; (3) running speed lower than 160km/h; (4)necessary safeguard measures for maintenance operator; (5)the same conditions as that of waiting mode.

An available line in single direction is left for overnight train in this operation mode. However, the it is complex in transport organization, and necessary to transfer between two organization methods in short time. Meanwhile, particular maintenance works cant be carried out in this mode, such as the maintenance on junction line or overhead line system. The overnight train on adjacent line may rise risk of maintenance safety and increase time of auxiliary operation, which leads to great potential negative influence on efficiency and safety.

2.5 Passenger Transferring Mode

Passenger transferring mode is defined as an overnight operation mode, in which high speed train moves forward as far as possible prior to maintenance curfew, and passengers are transferred to another train running on adjacent line to destination station when suffering curfew. Passenger transferring mode is illustrated in figure 5(a) and 5(b), in the form of graph and network respectively.

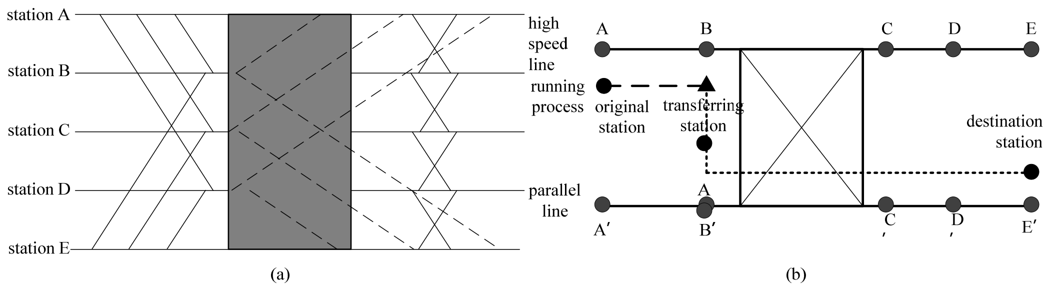

Figure 5. Passenger transferring mode illustration for overnight operation in high speed railway

With passenger transferring mode, the transport service is provided jointly by trains in high speed railway and its adjacent parallel line in nature. The transferring station is the destination station for overnight train in high speed railway, and the original station for following train in its adjacent parallel line. The basic technical conditions are presented as: (1) adjacent line and the linking line with high speed railway; (2) capable of technical operation for original and destination train; (3) sufficient arrival-departure track; (4) good conditions for transferring in same platform or station hall; (5) good coordination in passenger flow and time.

The passenger transport organization is complex and brings inconvenience to transferring passengers. When the high speed line is introduced into traditional rail station directly, passengers can transfer to the following train in platform. Otherwise, the transferring operation can be carried out by linking line between high speed rail station and traditional station. Besides, the fixed number of passenger may be not matched between high speed rail train and traditional train. Only a part of passengers in the high speed train transfer to the following traditional train, and the latter undertakes the routine task in traditional line. It is adaptable for overnight passenger transport in long high speed rail line, and is obviously preferable when the transferring time is earlier than midnight.

As for single overnight train, the negative influence is limited almost in one section, and the operation mode is just one of the previous alternatives. Based on the dynamic interaction between maintenance curfew and train, the avoidance mode owns the highest priority. When the avoidance is not feasible, transferring to adjacent line is the following choice, with long duration of maintenance, and waiting mode, with short duration. As for passenger transport in long high speed rail line, passenger transferring is an alternative to be considered. Finally, the Running and maintenance in adjacent lines meanwhile is the last choice. As for the network of high speed rail line, the overnight operation mode is a combination for the previous 5 alternatives. The operation modes may be various for different trains or in different sections. The operation mode and corresponding train plan are determined by taking operation and maintenance curfew into consideration, to minimize the total negative influence of maintenance curfew on overnight trains in high speed rail line.

3. Rational Travelling Distance

From the perspective of overnight passenger, the overnight train is expected to depart from original station before midnight, and to arrive at destination station after 6:00 in next day. The total travelling time is more than six hours, which is the basic basis for the down bound of travelling distance. With high travelling speed, the upper bound of travelling time is constrained by the space span in vertical and horizontal direction. Taking the high speed rail network in China as instance, the travelling time is less than 16h definitely, and the down bound of travelling time is the only issue need to consider for rational travelling distance. The comparison with traditional transport product in travelling speed is necessary to determine the rational travelling distance. The overnight high speed train is preferable when its travelling speed is higher than that of train in traditional train.

3.1 Parameter Definition

v_1 and v_2 are defined as the top speed in high speed railway and parallel traditional rail line, respectively. β_1 and β_2 are the coefficients of travelling speed in high speed railway and parallel traditional rail line. According to operation practice, β_1 is valued as 0.9 when top speed is higher than 250km/h, and 0.85, otherwise. S_1 and S_2 are the travelling distances in high speed rail line and parallel traditional rail line respectively. S_0 and t_0 mean the down bounds of total travelling distance and time, and $t_0 = 360\,\text{min}$. t_1, t_2 and t_3 are the travelling time in various operation stage, prior to maintenance curfew, in duration of maintenance curfew and after maintenance curfew. t_1' and t_2' are defined as the transferring time from high speed rail line to parallel traditional rail line and reversely, respectively. T is the duration of maintenance curfew. I_b means the minimum interval between high speed train and the beginning of maintenance curfew, and I_e, between the end of maintenance curfew and high speed train. $I_{\min}$ is the minimum tracking interval between adjacent train in the same direction and section.

3.2 Rational Travelling Distance with Various Overnight Operation Modes

（1）Rational travelling distance with avoidance mode

With avoidance mode adopted for overnight operation in high speed railway, the overnight train is not influenced from maintenance curfew in its travelling process. The down bound of travelling distance S_0 can be calculated by formula (1).

$$S_0 = \frac{\beta_1 v_1 t_0}{60} = \begin{cases} 1620km & (v_1 = 300km/h) \\ 1275km & (v_1 = 250km/h) \end{cases} \tag{1}$$

（2）Rational travelling distance with waiting mode

With waiting as overnight operation mode, the waiting time of single train includes three different parts at least, the duration of maintenance curfew, the time interval between high speed train and the beginning of maintenance curfew, and that between the end of maintenance curfew and the high speed train. With more than one train in the same direction scheduled to wait at the same station, the waiting time increases with the increase of the number of waiting trains. The waiting time increases by $(n-1)I_{\min}$ due to the minimum tracking interval, in which n is the number of train in the same direction scheduled to wait at the same station. The rational down bound of travelling can be calculated as formula (2).

$$S_0 = \beta_1 v_1 (t_0 - T - I_b - I_e - (n-1) I_{\min}) / 60) \qquad (2)$$

In formula (2), the values of I_b, I_e, n and $I_{\min}$ are determined by rail network and train plan, and S' is determined by v_1 and T. I_b is valued as 10 min and I_e is valued as 20 min according to operation practice. n is determined by detailed train plan and valued as one in the following calculation. The down bounds of rational travelling distance are changed as shown in figure 6, with top travelling speed as 250 km/h and 300 km/h, respectively. With top travelling speed in traditional rail line as 160 km/h, the farthest reachable distance is about 820 km in six hours, which is necessary to be considered as the down bound of travelling distance for overnight high speed train.

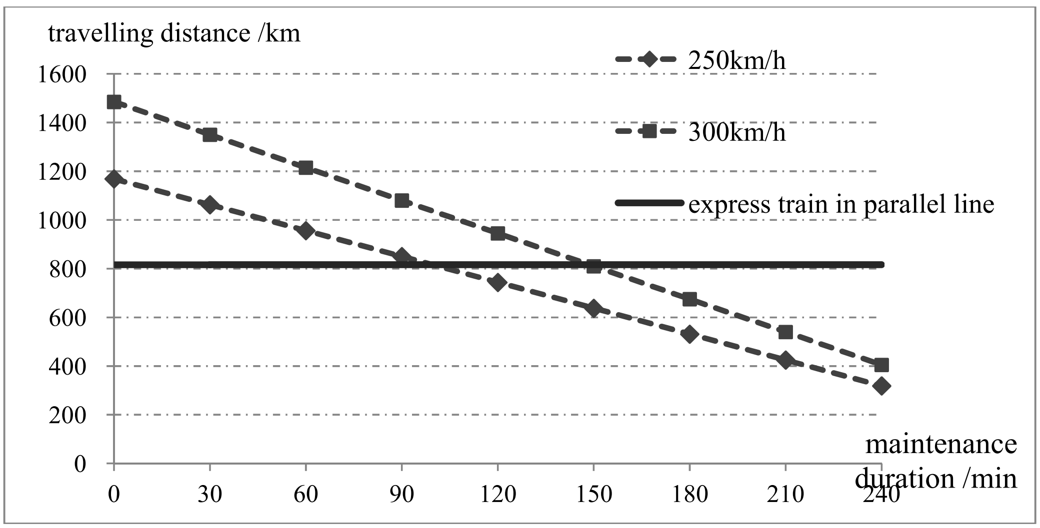

Figure 6. the variation tendency of down bound of overnight travelling distance with the duration of maintenance curfew, in waiting mode

The down bound of rational overnight travelling distance inclines with the increase of maintenance duration. With [120,240] as the maintenance curfew duration range, the down bound of travelling distance is 816 km when 250 km/h is considered as the top travelling speed, and the down bound of distance is in the range [816,945].

（3）Rational travelling distance with transferring to adjacent parallel line mode

The complete operation process includes three stages: (1) the first stage in high speed rail line prior to maintenance curfew; (2) the second stage in adjacent parallel rail line in the duration of maintenance curfew; (3) the last stage to return back to high speed rail line. According to the previous introduction, the transferring time is more than the sum of duration of maintenance and the minimum interval time. The first kind of transferring mode is defined when the previous three stages are involved, and the second is defined when the first stage and the second stage are involved.

In the first transferring mode, the transferring time condition can be presented as $t_2 + t_1' + t_2' \geq T + I_b + I_e$. In the second transferring mode, the transferring time condition can be presented as $t_2 + t_1' \geq T + I_b$. The down bounds of rational travelling distance in the first transferring mode can be calculated by formula (3), and that in the second transferring mode, by formula (4).

$$S_0 = (\beta_2 v_2 t_2 + \beta_1 v_1 (t_0 - t_1' - t_2' - t_2)) / 60 \\ = (\beta_2 v_2 (T + I_b + I_e - t_1' - t_2') + \beta_1 v_1 (t_0 - T - I_b - I_e)) / 60 \quad (3)$$

$$S_0 = (\beta_2 v_2 t_2 + \beta_1 v_1 (t_0 - t_2 - t_1')) / 60 \\ = (\beta_2 v_2 (T + I_b - t_1') + \beta_1 v_1 (t_0 - T - I_b)) / 60 \quad (4)$$

Set $I_b = 10\,\text{min}$, $I_e = 20\,\text{min}$ and $t_1' = t_2' = 15\,\text{min}$, the down bounds of rational travelling distance are changed with the duration of maintenance curfew, as shown in figure 7.

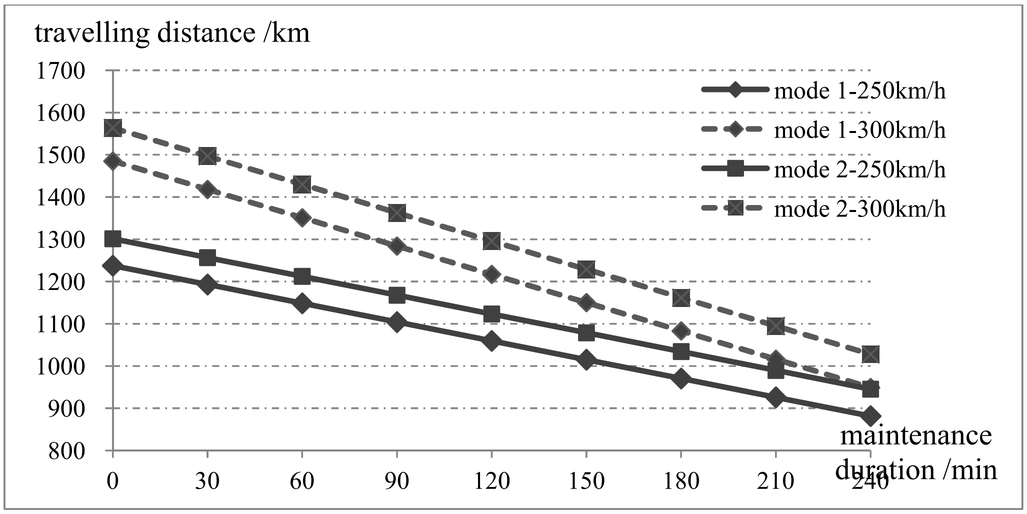

Figure 7. the variation tendency of down bound of overnight travelling distance with the duration of maintenance curfew, in transferring to adjacent parallel line mode

With transferring to adjacent parallel line mode, the down bound of rational overnight travelling distance inclines with the increase of maintenance duration. With [120,240] as the maintenance curfew duration range, the down bounds of travelling distance in first transferring mode are distributed in [882, 1238] and [949, 1485], with 250km/h and 300km/h as top travelling speed respectively. And the corresponding ranges are [945, 1301] and [1028, 1564] in second transferring mode.

（4）Rational travelling distance when running and maintenance are carried out in adjacent lines meanwhile

When running and maintenance are carried out in adjacent lines meanwhile, the duration for operation in single line mode is definitely not less than $T + I_b + I_e$, and the top travelling speed is limited to be less than 160km/h. Without regard to the increase of waiting time due to temporary capacity deficiency, the down bound of overnight travelling distance is calculated by formula (5). The down bounds of rational travelling distance are changed with the duration of maintenance curfew, as shown in figure 8.

$$S_0 = (\beta_2 v_3 t_3 + \beta_1 v_1 (t_0 - t_3)) / 60 \quad (5)$$

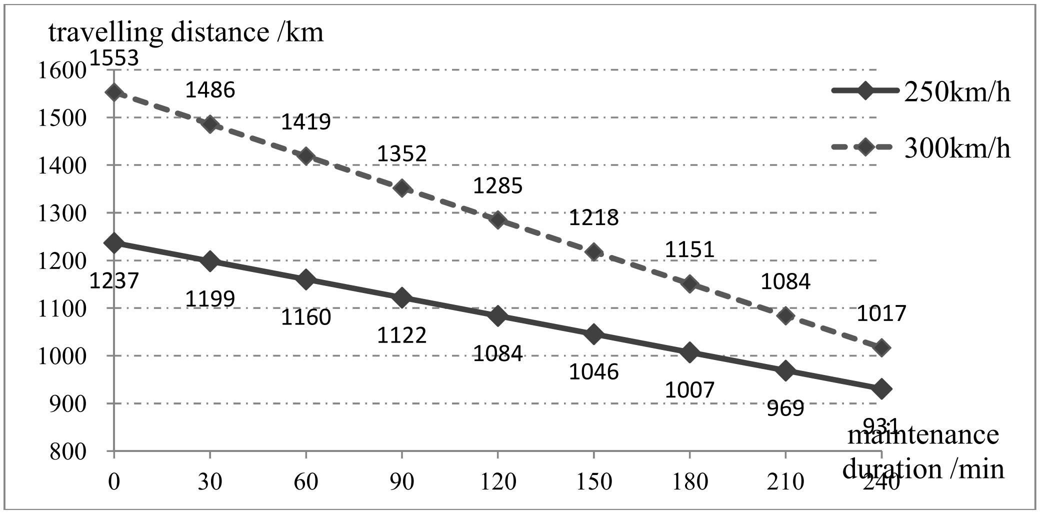

Figure 8. the variation tendency of down bound of overnight travelling distance with the duration of maintenance curfew, when running and maintenance are carried out in adjacent lines meanwhile.

When running and maintenance are carried out in adjacent lines meanwhile, the down bound of rational overnight travelling distance inclines with the increase of maintenance duration. With [120,240] as the maintenance curfew duration range, the down bounds of travelling distance in first transferring mode are distributed in [931, 1238] and [1017, 1553], with 250km/h and 300km/h as top travelling speed respectively.

（5）Rational travelling distance with passenger transferring mode

With passenger transferring mode, the transport service is provided jointly by trains in high speed railway and its adjacent parallel line in nature. For passengers' convenience, transferring before midnight is preferable, and the running time in traditional rail line is at least 6h. Due to the necessary time consumption in transferring process, the passenger transferring mode may be attractive when its whole travelling time is not more than the average travelling time between the same original and destination stations. The critical condition is presented as formula (6).

$$\beta_1 v_1 t_1 = \beta_1 v_2 (t_1 + t_h) \quad (6)$$

According to previous practical experience, set $t_h = 60$ min, and the value of parameter t_1 are approximately 120min and 90min, with 250km/h and 300km/h as top travelling speed respectively. With the travelling distance in parallel traditional rail line, the down bound of travelling distance in passenger transferring mode can be calculated as following:

$$S_0 = (\beta_2 v_2 t_2 + \beta_1 v_1 t_1)/60 = \begin{cases} 1119km & (v_1 = 250km/h) \\ 1221km & (v_1 = 300km/h) \end{cases} \quad (7)$$

The rational travelling distances of overnight train in different operation modes, are calculated by the previous formulas, which is helpful decision-making for overnight train plan. In practice, the mismatching between running section and the shortest increase of travelling time will increase the whole travelling time, which leads to further reduction of rational travelling distance. These factors are uncertain and their effect is limited, so they are not taken into consideration in calculations.

4 Conclusions

Under the influence from maintenance curfew, avoidance, waiting, transferring to adjacent parallel traditional line, running and maintenance in adjacent lines meanwhile, passenger transferring are the feasible alternatives for overnight operation mode. The technical conditions, organization features and adaptability are different. Based on the dynamic interaction between maintenance curfew and train, the avoidance mode owns the highest priority. When the avoidance is not feasible, transferring to adjacent line is the following choice, with long duration of maintenance, and waiting mode, with short duration. As for passenger transport in long high speed rail line, passenger transferring is an alternative to be considered. Finally, the Running and maintenance in adjacent lines meanwhile is the last choice. As for the network of high speed rail line, the overnight operation mode is a combination for the previous 5 alternatives. The operation modes may be various for different trains or in different sections. The operation mode and corresponding train plan are determined by taking operation and maintenance curfew into consideration, to minimize the total negative influence of maintenance curfew on overnight trains in high speed rail line.

With high travelling speed, the upper bound of travelling time is constrained by the space span in vertical and horizontal direction. In Chinese high speed rail network, the travelling time is less than 16h definitely, and the down bound of travelling time is the only issue need to consider for rational travelling distance. The down bound of rational travelling distance are calculated at various speeds and in different operation modes. It is the same that the down bound of rational overnight travelling distance reduces with the increase of maintenance duration. In practical scheduling process to determine the overnight train plan, the travelling demand and its temporal and spatial characteristics, the technical conditions and section capacity are the factors of significance.

References

LUO Jian， PENG Qi-yuan(2007). Study on Collaboratively Optimizing the Coordination Between Train Running Schedule and the Comprehensive Maintenance Gap. Railway Transport and Economy, 29(8):65-67

NIELei, HU Bi-song, FUHui-ling, et al(2010). Interaction Analysis between Night Train Operation and Maintenance Time on Passenger Dedicated Railway Line. Journal of Transportation Systems Engineering and Information Technology, 10(5): 66-72.

PENG Qiyuan, LUO Jian(2006). Research on Operation of Sunset-Departure and Sunrise-Arrival Trains on Dedicated Passenger Lines. Journal of Southwest Jiaotong University,41(5):626-629+640.

QIANG Lixia, YAN Yin(2006). The Difference on transport demand of high speed railway in the world. Railway Transport and Economy, 28(9):18-21.

SUN Jie-ping, ZHANG Chi, ZHANG Tian-wei(2014). The optimization of operation plan of sunset-departure and sunrise-arrival train on high-speed railway based

on operation safety. Journal of Safety Science and Technology, 07:5-10.
WANG Xiangping, HUA Wei, LI Bo, etl(2007). The feasibility for dusk-to-dawn train in high speed railway with rectangular skynight. Railway Transport and Economy, 29(11):16-17+48.
ZHANG Tian-wei,NIE Lei,LU Jin(2014). Comprehensive Comparison and Selection of Operation Modes of Sunset-departure and Sunrise-arrival Train on High-speed Railway. Journal of Transportation Systems Engineering and Information Technology,04:209-216.
ZHAO Lizhen, ZHAO Yinglian, YANG Yueqin, et al(2002). Ways of Opening Comprehensive Maintenance“Window” and Its Coordination with Traffic Organization for High-speed Railway. China Railway Science, 23(2):127-131.

Prediction of High-Speed Railway Passenger Demand Volume Based on Grey Relational Analysis

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Abstract: The prediction of high speed railway passenger demand volume is important for not only development of railway but also meeting the passenger transport demand. Because of the volatility and uncertainty of the passenger transport demand, this paper puts forward a regression forecasting model based on Grey Relational Analysis (GRA). The correlation between passenger demand and its influencing factors is worked out by using GRA. A multivariate nonlinear regression equation is established to predict high speed railway passenger demand volume. Base on the method, a more reasonable transportation plan and marketing strategy can be developed to meet passenger transport demand better.
Keywords: High speed railway; Passenger demand; Grey relational analysis; Regression forecasting.

1 Introduction

Transportation demand volume means the amount of transportation products purchased by transportation consumers who are willing and able to purchase them at different prices during a certain period of time (Liu, 2010).

The uncertainty of the transport demand determines the complexity of forecasting methods. The methods of Grey Relational Analysis (Liu, 1999), Grey prediction model and exponential smoothing (Huang, 2011) are used in the past research. However, Grey Rational Analysis method cannot provide a reliable prediction. Both Grey prediction model and exponential smoothing method all need the information of historical data. As we known, there is no historical data can be used in demand prediction.

2 Method Analysis

There are many factors that can affect passenger transportation demand. The macro factors include social economic development level, resident income and consumption level, population size and structure, tourism development, substitutability of transportation, national policy, and so on. The direct influencing factors include velocity (travel time), density (departure frequency), fares, comfort, and so on. Since passenger transportation demand is influenced by various factors comprehensively, it is reasonable to determine the importance of influencing factors using the method of GRA.

2.1 Passenger demand and its influencing factors

Through the investigation of factors influencing the passenger demand, we can set up a data sequence of passenger demand. On the conditions of analyzing the transport demand, the data of passenger demand volume can be replaced with passenger volume.

2.2 Data transformation

After transforming the original survey data, it can be compared easily. Data transformation also needs certain principles and methods.

A sequence is $x=(x_1,x_2,\cdots,x_n)$, then, the data transformation from sequence x to sequence y is

$$f:\ x\rightarrow y\ f_{(x_k)}=y_k \quad k=1,2,3,\cdots,n \tag{1}$$

Transformation principle:

① $x_k>0$, $y_k\geq 0$, $k=1,2,3,\cdots,n$;

② $x_i<x_j$, $y_i<y_j$; $x_i>x_j$, $y_i>y_j$;

③For any i, t, k, j: $\frac{x_i-x_t}{x_k-x_j}=\frac{y_i-y_t}{y_k-y_j}$.

Transformation method:

① Initial-value transformation

$$f_{(x_k)}=\frac{x_1}{x_k}=y_k,\quad x_1\neq 0 \tag{2}$$

where, x_1 is the first original data of a sequence; x_k is the original data of the same sequence.

② Mean transformation

$$\bar{x}=\frac{1}{n}\sum_{k=1}^{n}x_k \tag{3}$$

where, x_k is the original data of the same sequence; $\bar{x}$ is the average of each sequence.

③ Normalized transformation

$$f_{(x_k)} = \frac{x_k}{x_0} = y_k, \quad x_0 > 0 \tag{4}$$

2.3 Determining the connection coefficients

Setting the reference sequence as $x_{0(k)} = (x_{0(1)}, x_{0(2)}, x_{0(3)}, \cdots, x_{0(n)})$.

The comparison sequence is $x_{i(k)} = (x_{i(1)}, x_{i(2)}, x_{i(3)}, \cdots, x_{i(n)})$.

When $t = k$, the correlation coefficients of $\{x_{0(t)}\}$ and $\{x_{i(k)}\}$ is $\xi_{0i(k)}$,

$$\xi_{0i(k)} = \frac{\Delta \min + \rho \Delta \max}{\Delta_{0i(k)} + \rho \Delta \max} \tag{5}$$

where, $\Delta_{0i(k)} = \left| x_{0(k)} - x_{i(k)} \right|$ is the absolute difference between the two sequences;

$\Delta \min = \min_i \min_k \Delta_{0i(k)}$ are two level minimum differences;

$\Delta \max = \max_i \max_k \Delta_{0i(k)}$ are two level maximum differences;

ρ is distinguishing coefficient, which is used to improve the significant difference between the correlation coefficient, $\rho \in (0,1)$, usually values 0.1-0.5.

2.4 Determining the correlation

When $t = k$, the correlation between the two sequences $\{x_{0(t)}\}$ and $\{x_{i(k)}\}$ is $\gamma(x_0, x_i)$ as:

$$\gamma(x_0, x_i) = \sum_{k=1}^{n} \omega_k \cdot \xi_{0i(k)} \tag{6}$$

where, ω_k is the weight of index k, $\omega_k \in [0,1]$, and $\sum_{k=1}^{n} \omega_k = 1$; $\xi_{0i(k)}$ is the correlation coefficient.

By using the method of GRA, all the impacts on passenger transport demand caused by influencing factors can be determined.

3. Model Establish

The correlation between passenger demand and influencing factors can be worked out by using GRA, and the primary and secondary factors influencing high speed railway passenger demand are also worked out. Based on the main factors as independent variables, and the passenger volume as dependent variable, a multivariate nonlinear regression equation is established to forecast the passenger demand, which is a multiple regression equation based on grey rational grade analysis.

Regression analysis prediction method utilizes causal relationship between the factors, by establishing regression equation to forecast. This method is known for high forecast precision, easy to use, and suitable for long-term forecast. Because the factors influencing the passenger demand are a lot, and the influencing relationship is complex, a multivariate nonlinear regression equation is needed.

3.1 Determining the main factors influencing the passenger demand

Calculating the correlation - $\gamma(x_0, x_i)$ between the factors influencing high speed railway passenger demand and the passenger demand by GRA, and then, identifying the main influencing factors.

3.2 Establishing the regression equation

Suppose that predictor variable y is in linear dependence relation with a group of variables $x_1, x_2, x_3, \cdots x_m$:

$$y = a + b_1 x_1 + b_2 x_2 + \cdots + b_m x_m + e \tag{7}$$

where, e is random error term;

a, b_i are unknown parameters, $i = 1,2,3,\cdots,m$;

m is the number of variables.

3.3 Test of the regression effect

Solving the regression model and calculating the test statistics to test the regression effect.

Test statistic F is as:

$$F = \frac{RSS / m}{ESS / (n - m - 1)} \tag{8}$$

where, RSS is the regression sum of squares, that is the sum of squares of the differences between estimate value $\hat{y}_i$ and the average value; ESS is the residual sum of square, that is the sum of squares of the differences between observed value y_i and estimate value $\hat{y}_i$.

Comparing the value of F with $F_\alpha(m, n-m-1)$. If $F > F_\alpha$, the regression equation is significant, otherwise, the regression equation is not significant.

3.4 Accuracy test

Comparing the predicted data in regression model with real data, the relative error can be worked out to determine the accuracy of regression model.

4. Data Analysis and Discussion

Dalian North Railway Station at the end of Harbin-Dalian high speed railway is selected as an example.

4.1 Data selection

It is invested that the transport capacity of Dalian North Railway Station can satisfy the demand of passengers since its opening. So the passenger volume, fares, velocity, departure density, marked capacity of passenger train seating, days of the holiday in the station are investigated to analyze the relationship between the passenger demand and influencing factors. The data in the first half of 2014 is selected as Table 1.

Table 1. Outcomes in Dalian North Railway Station in the first half of 2014

Month	Passenger volume (Ten thousand)	Velocity (km/h)	Departure density (train)	Fares (yuan/ km)	Marked capacity of passenger train seating (Ten thousand)	Days of the holiday (day)
Jan	24.08	166.17	1085	0.45	61.59	3
Feb	25.06	166.17	980	0.45	58.16	7
Mar	21.08	166.17	1085	0.45	64.89	0
Apr	24.56	191.25	1050	0.50	60.70	5
May	23.68	216.33	1085	0.60	59.95	1
Jun	24.13	216.33	1050	0.65	58.12	3

4.2 Calculation and analysis of correlation

Using GRA and according to formula (6), the correlation between all the factors and passenger volume can be calculated as following:

$$\gamma_{(x_0,x_1)}=\frac{1}{6}\times 4.96=0.83 \tag{9}$$

$$\gamma_{(x_0,x_2)}=\frac{1}{6}\times 5.51=0.92 \tag{10}$$

$$\gamma_{(x_0,x_3)}=\frac{1}{6}\times 4.90=0.82 \tag{11}$$

$$\gamma_{(x_0,x_4)}=\frac{1}{6}\times 5.51=0.92 \tag{12}$$

$$\gamma_{(x_0,x_5)}=\frac{1}{6}\times 3.75=0.63 \tag{13}$$

The results show that the rank of correlation of influencing factors is $\gamma_2=\gamma_4>\gamma_1>\gamma_3>\gamma_5$.

The largest correlation is departure density and marked capacity of passenger train seating, and secondly is velocity, and then is fares, the final is the days of the holiday. This illustrates that departure density and marked capacity of passenger train seating affected the most during the first half of 2014 in many influencing factors.

4.3 Passenger demand forecasting

According to the results of the grey correlation analysis, multivariate nonlinear regression prediction model is established to forecast the passenger demand.

According to the results of the grey rational grade analysis, setting the passenger demand as the predicted target y, and setting departure density and marked capacity of passenger train seating as influencing factors x_1, x_2, and then regression equation is established based on formula (7) and Table 1.

$$y = 0.023017x_1 + 0.506515x_2 + 17.85523 \tag{14}$$

When significance level is $\alpha = 0.10$, then $F_\alpha(2,3) = 5.46$, $F > F_\alpha$, it shows that regression effect is significant under the lever of $\alpha = 0.10$.

Comparing the predicted data in regression model with real data in Table 2. It is shown that the error is about $\pm 4\%$, and the accuracy of the regression model remains high.

Table 2. Analysis of the error between the actual and the predicted data

Month	The actual data (Ten thousand)	The predicted data (Ten thousand)	Error %
Jan	24.08	23.21	3.66
Feb	25.06	25.23	-0.66
Mar	21.08	21.68	-2.77
Apr	24.56	24.79	-0.93
May	23.68	23.34	1.43
Jun	24.13	24.35	-0.92

When the departure density and marked capacity of passenger train seating are known, passenger demand of Dalian north station can be predict with the help of the formula (14).

5. Conclusions

This paper uses the regression forecast method based on GRA, without considering the numbers of the sample and the typical distribution or not. The main factors influencing the passenger demand can be dig out, especially when the information is poor, relevant materials and data are shortage, statistics gray is high. The method is so effective, and can greatly reduce the analysis time of selecting variables, that the convenient prediction and high precision overcome the insufficient short-term prediction and too much dependence of the data in the quantitative prediction method. The method is also suitable for medium and long-term prediction.

If regression effect established by regression prediction model is not very ideal, reselecting factors and analyzing correlation can establish prediction model with high regression effect and prediction accuracy.

References

Huang Yongli (2011). “Grey model and exponential smoothing method in transportation demand forecasting comparison-a case study of passenger demand in Guangxi.” Equipment Manufacturing Technology, Nanning, China, 5(2), 106-108.

Liu Qi (1999). “The influencing factors of railway passenger flow and correlation analysis.” Journal of Shanghai railway university, Shanghai, China, 20(2), 41-44.

Liu Zuoyi, Zhao Yu (2010). “Transportation Marketing.” China Railway Press, Beijing, China.

A Particular Waiting Mode for Overnight Operation of the Chinese Beijing-Guanghzou High-Speed Railway

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Abstract: With great development in the last decade, the operation of high speed railway in China has entered into network era from single line era. With expanded service area and long traveling time, the high speed railway in China is qualified for overnight operation in net structure and time space, which is significantly different from that of high speed railway in other countries and areas. The overnight operation of high speed railway is of significance for capacity utilization improvement, besides diverse travelling demand. The service area and operation demand of high speed railway from Beijing to Guangzhou were analyzed. The alternatives of overnight operation mode are waiting, transferring to adjacent parallel traditional line, running and maintenance in adjacent lines meanwhile and passenger transferring, and their technical conditions, organization features and adaptability are presented respectively. With the basic information of high speed railway from Beijing to Guangzhou, the waiting mode was selected as the preferable overnight operation mode, and the optimized maintenance curfew scheme was proposed to increase the travelling speed. The work in this paper on operation mode and rational travelling distance is salutary and leading, which provides particular supports for overnight operation in Chinese high speed railway.
Keywords: Beijing-Guangzhou high speed railway; Overnight operation; Waiting mode; Maintenance curfew.

1 Introduction

By the end of 2014, the revenue kilometers of high speed railway in China have reached 16,000km, over 50% of total kilometers worldwide. With large-scale network, advanced technology and busy operation, the high speed railway system in China has good performances in safety, speed and economy. As an important part of comprehensive system of transport, the high speed railway system markedly shortens the journey time and promotes economic and social developments. In the past 5 decades, the transport service of high speed railway has been available only in daytime, and the nighttime(generally from 0:00~6:00) is arranged as railway curfew for infrastructure maintenance. Due to small national territorial area, short travelling distance and time, the high speed railway system in countries and areas excluding China, is basically not qualified in practice for overnight operation in network condition and travelling demand. The daily operation and infrastructure maintenance are staggered in time or space, leading to interactive influence avoidance and efficiency improvement.

With vast territory, the travelling time by high speed train between major cities in China, is much longer than that in other developed countries and cities in high speed railway worldwide. With large scale in network and spatial span, as well as long distance of single backbone rail line in vertical and horizontal direction, the network operation of high speed railway in China is characterized by extensive high speed trains, besides their long travelling time and wide service range. The high speed railway from Beijing to Guangzhou is the most typical high speed railway in the world, with long travelling distance and busy daily operation.

The overnight operation in Chinese high speed railway is the joint demand from passenger and enterprise. It provides much more diverse transport service, and expands the travelling time horizon, leading to in temporal accessibility improvement, especially with long travelling distance such as the line from Beijing to Guangzhou. Besides, it upgrades capacity utilization in network, and expands efficient service areas, with prominent effects on attractions promotion compared to airline and long road transport. Based on national and railway conditions in practice, it is imperative for overnight operation in Chinese high speed railway, especially from Beijing to Guangzhou, with qualification in network, space and time. However, as an emerging operation mode in high speed railway, it is pressing and valuable to research on overnight operation mode in Beijing-Guangzhou high speed, based on the prior literature and operation experience.

There are very few academic papers published on overnight operation in developed countries and areas in high speed railway except China, due to the little even definitely no demand for overnight operation. However, the dusk-to-dawn train (departing from original station between 18:00 and 23:00, and arriving at destination station between 6:00 and 9:00) in traditional rail lines, is a popular transport product promoted from 1997. Many efforts are taken on the dusk-to-dawn train in Chinese high speed railway, and they generally took the high speed railway from Beijing to Shanghai as instance. The joint optimization with both overnight train and track maintenance, the operation mode and technical conditions were studied (Peng et al. 2006). The different situations were presented, besides the travelling distances with different curfew time for maintenance were calculated, respectively. The feasibility of dusk-to-dawn train in high speed railway with rectangle curfew was discussed (WANG et al. 2007). The effects of vertical rectangle curfew and inclined rectangle curfew on operation were analyzed, and the specific organization method was proposed by taking the high speed railway from Beijing to Shanghai as an instance.

The rational departing time horizon of dusk-to-dawn train was calculated by congruence strategy (LUO et al. 2007). The joint optimization model between train plan and maintenance curfew was established, and the optimal time for maintenance curfew was obtained. Based on the interaction effects between vertical rectangle curfew and overnight train, the mathematical model was established and the corresponding algorithm was designed to obtain the optimal time of maintenance curfew (NIE et al. 2010). To minimize the number of affected train by curfew was set as the objective in the optimization model, besides the rational time horizon, as constraints. Three organization modes (waiting, transferring to adjacent parallel traditional rail line, transferring and back to high speed line) were proposed for dusk-to-dawn train in high speed railway (ZHANG et al. 2014). The indexes and rules were presented by establishing candidate scheme generation model and analyzing the solution process. The conclusion was drawn that the transferring mode is prior for medium and long travelling distance and the waiting mode, prior for long travelling distance. Based on the previous achievements, running in one direction, transferring twice, transferring once and waiting were the four alternative modes for overnight operation, and the adaptability and security were analyzed respectively(SUN et al. 2014). The train plan was obtained by optimization model, which took operation safety, running time and stop demand as constraints, the optimal travelling time as objective.

Based on the achievement on dusk-to-dawn train in high speed railway, the service area and operation demand of high speed railway from Beijing to Guangzhou were analyzed. The alternatives of overnight operation mode are waiting, transferring to adjacent parallel traditional line, running and maintenance in adjacent lines meanwhile and passenger transferring, and their technical conditions, organization features and adaptability are presented respectively. With the basic information of high speed railway from Beijing to Guangzhou, the waiting mode was selected as the satisfied overnight operation mode, and the optimized maintenance curfew scheme was proposed to increase the travelling speed.

2 The Service Area and Overnight Operation Demand of Beijing-Guangzhou High Speed Railway

2.1 The Service Area of Beijing-Guangzhou High Speed Railway

Beijing-Guangzhou high speed railway, with the longest running mileages

(2118km) in the world and 36 stations, starts from Beijing West Railway Station, and ends at Guangzhou South Station, through Beijing, Hebei, Henan, Hubei, Hunan and Guangdong province. Operated from December 26, 2012, as a parallel rail line to the traditional Beijing-Guangzhou railway, the particular high speed railway is developing into a "economic broadband” to connect the Bohai Economic Rim, Central Plains Economic Zone, Wuhan city circle, Changsha-Zhuzhou-Xiangtan metropolis, Pearl River Delta and other developed and densely-populated regions.

Its designed operation speed is up to 350km/h and the maximum speed in daily operation is up to 310km/h. In current net operation mode, the daily timetable, weekend timetable and peak timetable are designed respectively, based on the passengers flow characteristics. In the initial operation stage, 155 pairs trains are scheduled in Beijing-Guangzhou high speed railway, among which 58 pairs are transferring trains with Shijiazhuang-Taiyuan Passenger Dedicated Line, Zhengzhou-Xi an high speed railway and the Guangzhou-Shenzhen-HongKong high speed railway. Beijing-Guangzhou high speed railway has connected Hefei-Wuhan high speed railway at Wuhan Station since July 2013, connected Beijing-Shanghai high speed railway in Shandong province. The service range, line mileage and operating speed of Beijing-Guangzhou high speed railway are shown in figure 1.

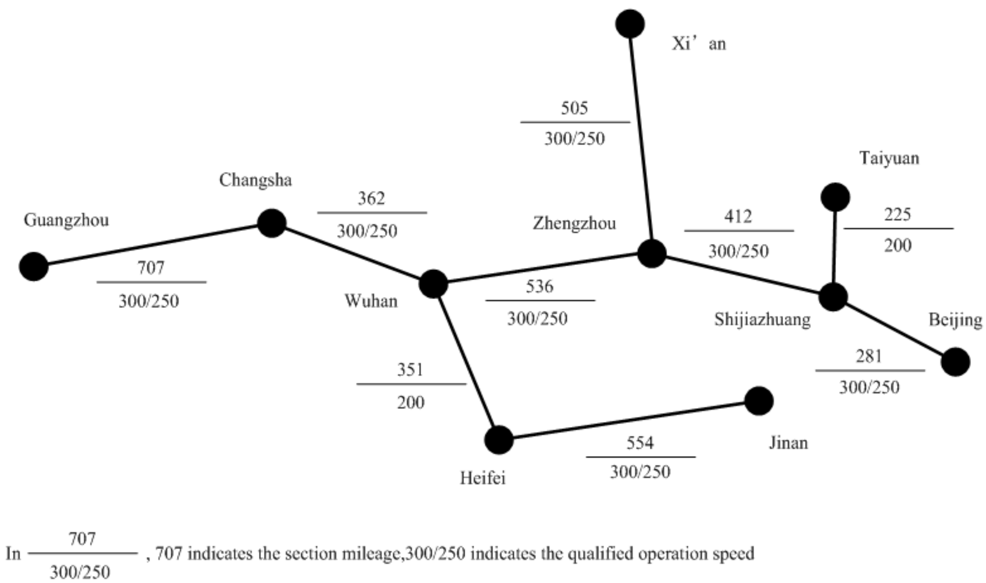

Figure1. Train service area, line mileage and operation speed in Beijing-Guangzhou high speed railway

Based on the previous field experience, the coefficients of high speed train are 0.9 and 0.85, responding to the operation speed 300km/h and 250km/h, respectively. The access time between two important cities in service area of Beijing-Guangzhou high speed railway is listed in table 1.

Table 1. The access time between important cities in Beijing-Guangzhou high speed railway service area (unit:min)

	BJ	SJZ	ZZ	WH	CS	GZ	TY	XA	HF	JN
Beijing(BJ)	-	63	155	275	356	514	143	290	-	-
Shijiazhuang(SJZ)	63	-	92	212	293	451	80	227	336	-
Zhengzhou(ZZ)	155	92	-	120	201	359	172	135	244	-
Wuhan(WH)	275	212	120	-	81	239	292	255	124	248
Changsha(CS)	356	293	201	81	-	158	373	336	205	329
Guangzhou(GZ)	514	451	359	239	158	-	531	494	363	487
Taiyuan(TY)	143	80	172	292	373	531	-	307	416	-
Xi'an(XA)	290	227	135	255	336	494	307	-	379	-
Hefei(HF)	-	336	244	124	205	363	416	379	-	124
Jinan(JN)	-	-	-	248	329	487	-	-	124	-

1.2 Overnight Operation Demand in Beijing-Guangzhou High Speed Railway

Under the daytime-only mode, the daily operation is limited definitely in daytime, generally from 7:00am to 11:00pm. The longer the travelling time is, the narrower the time horizon of train departure is. If the overnight operation is unavailable, The departure and arrival time ranges from Beijing to Guangzhou is about [8:00,13:00] and [17:40,22:30], which is definitely inconvenient for rail passengers. The overnight operation in Beijing-guangzhou high speed railway is the joint demand from passenger and enterprise. It provides much more diverse transport service, and expands the travelling time horizon, leading to in temporal accessibility improvement, especially with long travelling distance such as the line from Beijing to Guangzhou.

The overnight passenger flow is mainly soured from the dusk-dawn travelling demand between important cities. It is generally bidirectional between original and terminal stations, with great quantity. The departure and arrival time ranges are [17:00, 24:00] and [6:00, 9:00], respectively. The whole travelling time is from 6h to 16h. Based on the above OD cities and their access time, 11 OD cities illustrated in figure 2, are qualified for overnight operation in the service area of Beijing-Guangzhou high speed railway.

3 Alternative Operation Modes in High Speed Railway

The technical infrastructures in high speed railway are dispersive, used frequently and continuously, thus the routine maintenance and recondition are necessary for safety and comfort. The maintenance curfew is scheduled at night in advance and large-scale maintenance machinery is adopted, which is the tradition in practice worldwide. However, as essential technical measurement keeping equipment in sharp, the maintenance curfew occupies rail section exclusively, which leads to negative effects on operation process of overnight train in high speed railway.

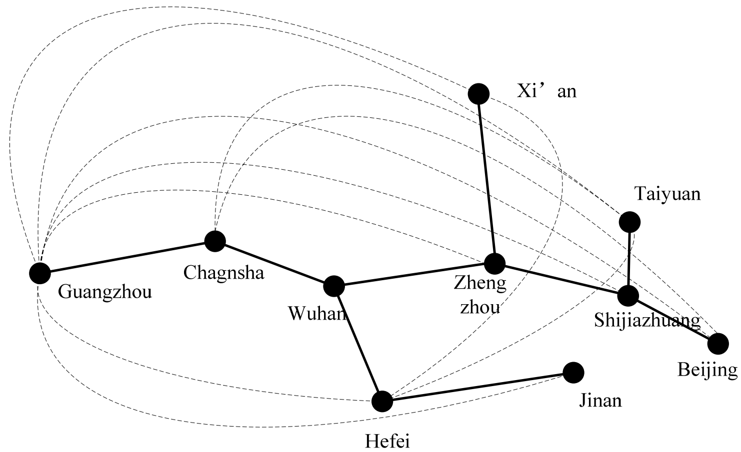

Figure 2.The overnight operation qualified OD cities in the service area of Beijing-Guangzhou high speed rail line

3.1 Alternative Operation Modes

In spite of the type of maintenance curfew, a dynamic interactional relationship exists between the maintenance curfew schedule and overnight high speed train plan, due to the resource assignment in the same duration. Good coordination means better operation conditions for overnight train, while satisfying the necessary maintenance need. Under the effects from maintenance curfew, waiting at station, transferring to adjacent parallel traditional line, running & maintenance in adjacent lines meanwhile, passenger transferring are the feasible alternative modes for overnight operation in high speed railway. The operation alternatives are different in technical conditions, organization features and adaptabilities.

Waiting mode is an operation mode of high speed train, in which the overnight train moves forward as far as possible, suspends at right station prior to maintenance curfew, and restores running to destination station after curfew in high speed line. Transferring mode is defined as an overnight operation mode of high speed train, in which the overnight train transfers to adjacent parallel line prior to maintenance curfew, moves forward in parallel line in curfew duration, and continues to move ahead or return back to high speed railway after curfew, to destination station. Running and maintenance in adjacent lines meanwhile is an overnight operation mode, in which one line is occupied by maintenance and the adjacent line is available for overnight train. The overnight operation in maintenance curfew can be organized in the way of multi-train tracking or running in pairs. Passenger transferring mode is defined as an overnight operation mode, in which high speed train moves forward as far as possible prior to maintenance curfew, and passengers are transferred to another train running on adjacent line to destination station when suffering curfew.

The operation modes are illustrated in figure 3, in which the imaginary lines in (b), (c) and (d) mean the operation in single direction, through transferring train and segmented transferring train in adjacent parallel line, respectively.

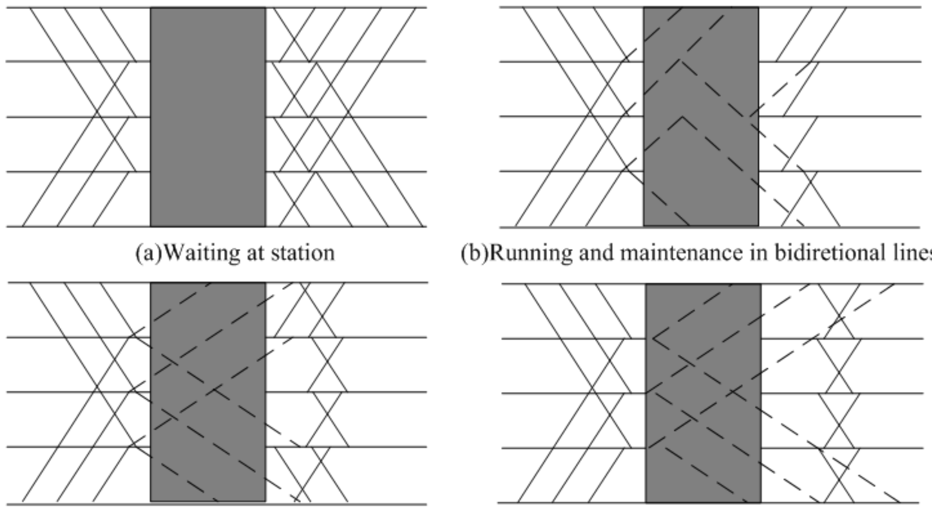

Figure 3. The overnight operation modes illustration in high speed railway

3.2 Technical conditions, features and adaptability

The operation mode for overnight high speed train is featured by its particular operation process, and the corresponding technical conditions are the basic premises. Besides, the organization features and adaptability are diverse for different operation modes. The technical conditions and organization features are listed by operation mode in table 2.

Table 2. The technical conditions and features for overnight operation

	Technical conditions	Organization features
Waiting at station	**(a)** sufficient arrival-departure track at waiting station; **(b)**household power assurance for waiting train	**(a)**uncomplicated organizations, but great negative effects on continuity and balance of operation; **(b)g**reat increment in travelling time and prominent reduction in travelling speed
Operation and maintenance in bidirectional lines	**(a)**matching maintenance curfew plan;**(b)** operation qualification in reverse direction;**(c)**necessary reinforce in safety protection;**(d)**operation speed not more than 160km/h	**(a)**complicated organizations and twice mode transformations; **(b)**available passage way in single direction, with limited reduced capacity; **(c)** increased maintenance risk and declined efficiency; **(d)**incapable of maintenance for

		certain equipments, such as switch
Transferring to parallel adjacent line	**(a)**adjacent parallel line and corresponding linking rail line; **(b)**safety and comfort qualification in technical conditions of parallel line; **(c)**compatible communication and control system in parallel line; **(d)**affluent capacity at night in parallel line.	**(a)**complicated organizations and interaction between transferring train and existing train in parallel line, **(b)**less increment in travelling time and less reduction in travelling speed. **(c)**unbalance in capacity utilization leads to declined available capability in parallel line, **(d)**high demand for punctuality of transferring train
Passenger transferring mode	**(a)**adjacent parallel line and corresponding linking rail line, **(b)**sufficient arrival-departure track in transferring station, **(c)**sufficient multiple unit train or motor coach train	**(a)c**omplicated passenger organization **(b)** short travelling distance and time for each segmented train, **(c)**less utilization ratio of multiple unit train or motor coach train

The waiting mode is adaptable for high speed railway with capacity deficiency or without parallel rail line. Particular advantages emerge when duration of maintenance is short and the travelling distance of overnight train is long, in which the travelling speed can be achieved at a certain high level. Operation and maintenance in bidirectional lines is adaptive to high speed line qualified for operation in reverse direction, with limited reduced capacity. However, the mode is incapable of maintenance for certain equipments, such as switch. Transferring to parallel adjacent line is adaptive for the high speed with parallel adjacent line with capacity deficiency. The linking line between high speed and its parallel line is necessary, besides the sufficient capacity in its parallel line. Passenger transferring mode is adaptable for overnight passenger transport in long high speed rail line, and is preferable especially when the transferring time is earlier than midnight.

As for single overnight train, the negative influence is limited almost in one section, and the operation mode is just one of the previous alternatives. As for passenger transport in long high speed rail line, passenger transferring is an alternative to be considered. Finally, the Running and maintenance in adjacent lines meanwhile is the last choice. As for the network of high speed rail line, the overnight operation mode is a combination for the previous alternatives. The operation modes may be various for different trains or in different sections. The operation mode and corresponding train plan are determined by taking operation and maintenance curfew into consideration, to minimize the total negative influence of maintenance curfew on overnight trains in high speed rail line.

4 Overnight Operation Method in Beijing-Guangzhou High Speed Railway

4.1 The optimal overnight operation mode

In order to keep operation safety and travelling comfort in high speed railway, the necessary maintenance scheme is reserved in advance, and generally scheduled at night, in the duration with least travelling demand. Due to difference in equipment and operation, the maintenance curfew plan (type, duration and beginning time, etc.) is made based on the practical demand in maintenance and operation.

Without overnight operation in high speed railway, the vertical rectangle type of maintenance curfew is preferred worldwide, with long duration for maintenance. It involves good maintenance performance in efficiency and quality, without negative effects on daily operation in daytime. The maintenance curfew scheme for Beijing-Guangzhou high speed railway, without overnight operation is illustrated in figure 4. Under the daytime-only mode, the operation is limited definitely in daytime, generally from 7:00am to 11:00pm. The longer the travelling time is, the narrower the time horizon of train departure is. If the overnight operation is not available, the latest departure time of high speed train from Beijing to Guangzhou is about 13:00, and the later high speed rail service between the two cities is not available

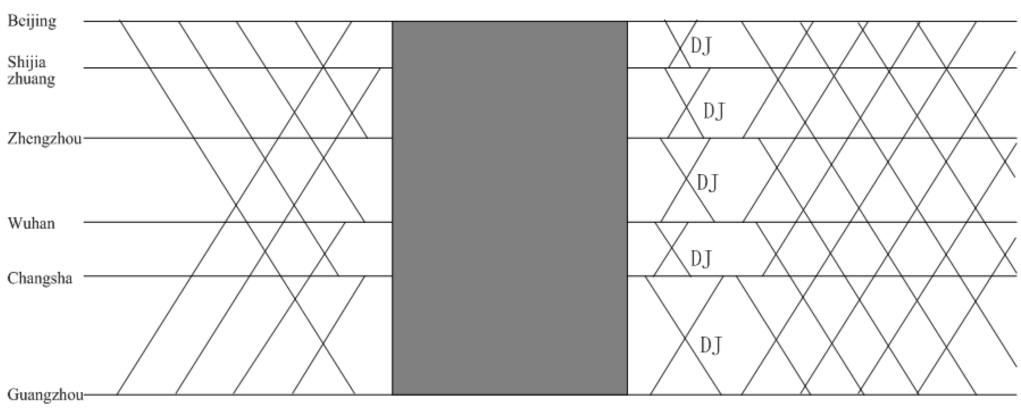

Figure 4. Illustration for passenger train plan and maintenance curfew without overnight operation in Beijing-Guanghzou high speed railway

With long travelling distance and huge passenger flow, the overnight operation in Beijing-Guangzhou high speed railway is valuable, people-beneficial and urgent. However, the negative effects on travelling speed and organization from maintenance curfew is unavailable, in spite of its type, duration and beginning time of maintenance curfew. With organization complexity, maintenance demand, travelling speed decline and mode adaptation taken into consideration, the waiting mode and transferring to parallel rail line are the better mode alternatives for overnight operation in high speed railway, compared with the other two modes.

The linking lines between the high speed railway with the traditional rail line are designed and constructed in significant stations respectively, such as Wuhan, Changsha, etc. The linking lines make it to be qualified for transferring mode. However, the Beijing-Guangzhou high speed railway was designed and operated especially in order to relieve the great capacity deficiency in the traditional Beijing-Guangzhou rail line. After the operation of Beijing-Guanghzou high speed line, most passenger trains are scheduled in the high speed railway, and the rest capacity of traditional rail line is reserved particularly for freight train. Due to the capacity deficiency in traditional Beijing-Guangzhou rail line, the waiting mode takes certain advantages for the overnight operation in Beijing-Guangzhou high speed railway, compared with the transferring to parallel rail line.

4.2 Particular Organization method in Waiting Mode

The waiting mode is featured with long waiting time at station, uncomplicated organization, the obvious reduction in continuity and balance. Under waiting mode, the waiting train is qualified to departure after the end of maintenance both at waiting station and the following section. The waiting at station leads to travelling time increase, and travelling speed decline. The waiting time at station is determined by maintenance duration, the number of waiting train in the same direction, and minimum tracking interval and the necessary interval between maintenance curfew and train operation. Define T , I_b and I_e as the duration of maintenance curfew, the necessary interval between maintenance curfew and train operation before the beginning of maintenance and after the end of maintenance. n and $I_{\min}$ indicate the number of waiting train in same direction, and the minimum tracking interval, respectively. T_l and T_l' mean the travelling time in ordinary case and in overnight waiting mode, respectively. With first-arrival first-departure rule, the waiting time T_d can be calculated by formula (1) and (2).

$$T_d = T + I_b + I_e + (n-1)I_{\min} \qquad (1)$$

$$T_l' = T_l + T_d \qquad (2)$$

Determined by the operation mileage, the highest operation speed and maintenance duration, the travelling speed can be calculated by formula (3). In formula (3), β_1 indicates the travelling speed coefficient of high speed train, and is valued as 0.9 based on previous practice. With 300km/h as the highest operation speed, the travelling speeds with different operation mileage and maintenance duration are listed in table 3.

$$v' = \frac{L}{T_l'} = \frac{L}{L/(\beta_1 v_1) + T_d} \tag{3}$$

Table 3. The travelling speed with different operation conditions（km/h）

L /km \ T /min	500	1000	1500	2000	2500	3000	3500	4000
120	119	166	190	205	216	223	229	233
180	96	142	169	186	199	208	215	220
240	81	124	152	170	184	194	202	209

With the above calculation, the travelling speed changes based on the rule that, at certain operation speed, shorter maintenance duration and longer travelling distance is corresponding to higher travelling speed and thus weaker negative effects. And long travelling distance assures travelling speed at a higher level, and reduces the negative effects.

In practice, certain technical measures can be adopted to improve the travelling speed, with maintenance demand satisfaction and basic operation conditions as premise. The available measures can be concluded as:(1)Make different maintenance curfew schemes for adjacent sections to improve the operation conditions; (2)Increase the number of maintenance worker and strengthen the maintenance operation, to shorten the auxiliary operation time and improve maintenance efficiency;(3)Optimize the waiting scheme to assign the trains to wait at different station and to reduce the waiting time.

Based on the technical features of power supply and the maintenance and operation demand, the high speed railway from Beijing to Guangzhou can be divided into several maintenance sections. The divided maintenance section is the fundamental unit of maintenance curfew, and their curfew plans constitute the whole maintenance curfew plan of the high speed rail line. With the same duration, the only difference between the different maintenance curfews is in their beginning times. With overnight operation demands and their features into consideration, the beginning time of maintenance curfew in different sections are scheduled differently to decrease the waiting time at station, besides the negative effects from maintenance curfew. A segmented maintenance curfew plan in Beijing-Guangzhou high speed railway is illustrated in figure 4.

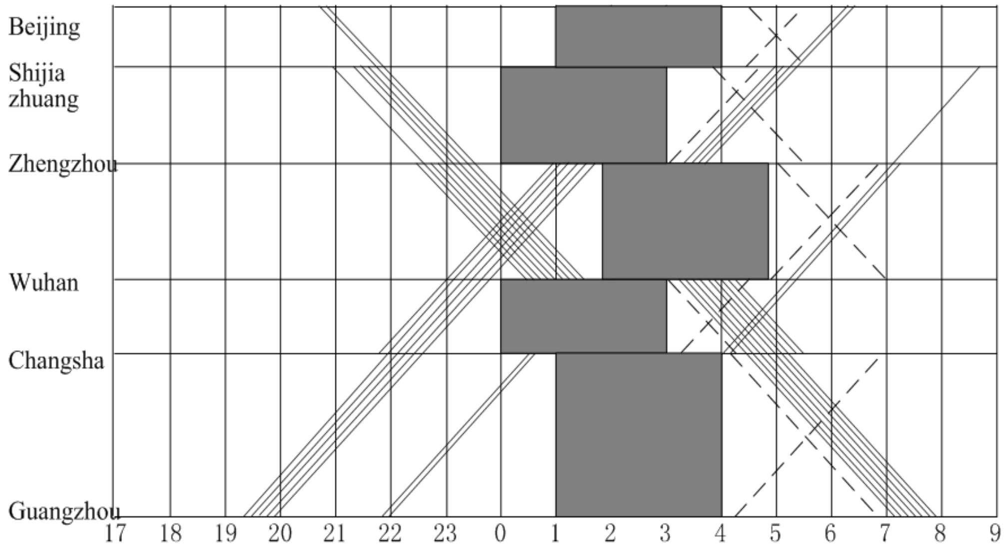

Figure 5. illustration for segmented maintenance curfew to increase the travelling speed in Beijing-Guanghzou high speed railway

The overnight operation in Beijing-Guanghzou high speed railway provide more travelling choices for medium-long distance, with sleeping time as travelling time. Due to the decline of travelling speed, the operation mileage is preferred more than the certain threshold to keep the travelling speed at certain higher level. With targeted travelling speed v_0 as objective, the mileage threshold can be calculated by formula (4). The mileage thresholds under different situations are listed in table 4 . It is concluded that the longer the maintenance duration is, the lower the operation speed is, and the higher targeted travelling speed, the longer the mileage threshold is. The average travelling speed of through express passenger train in traditional rail line is about 130km/h, and the minimum distance of overnight train reaches as high as 1400km, to obtain higher travelling speed.

$$L_0 = \frac{T_d}{(1/v_0 - 1/(\beta_1 v_1))} \quad (4)$$

Table 4. The mileage threshold with targeted travelling speed

Threshold /km; T /min	Highest operation speed /average travelling speed（km/h）				
	300/200	300/160	300/130	250/160	250/130
120	1800	920	585	1510	780
180	2570	1310	836	2160	1120
240	3340	1700	1086	2810	1450

5 Conclusions

With expanded service area and long traveling time, the high speed railway in China is qualified for overnight operation in net structure and time space, which is significantly different from that of high speed railway in other countries and areas. The overnight operation of high speed railway is of significance for capacity utilization improvement, besides diverse travelling demand in time horizon. The service area and operation demand of high speed railway from Beijing to Guangzhou were analyzed. The alternatives of overnight operation mode are waiting, transferring to adjacent parallel traditional line, running and maintenance in adjacent lines meanwhile and passenger transferring, and their technical conditions, organization features and adaptability are presented respectively. With the basic information of high speed railway from Beijing to Guangzhou, the waiting mode was selected as the satisfied overnight operation mode, and the optimized maintenance curfew scheme was proposed to increase the travelling speed. The work in this paper on operation mode and rational travelling distance is salutary and leading, which provides particular supports for overnight operation in Chinese high speed railway.

References

LUO Jian，PENG Qi-yuan. Study on Collaboratively Optimizing the Coordination Between Train Running Schedule and the Comprehensive Maintenance Gap. Railway Transport and Economy，2007，29(8):65-67

NIELei，HU Bi-song，FUHui-ling, et al. Interaction Analysis between Night Train Operation and Maintenance Time on Passenger Dedicated Railway Line. Journal of Transportation Systems Engineering and Information Technology, 2010,10(5): 66-72.

PENG Qiyuan， LUO Jian. Research on Operation of Sunset-Departure and Sunrise-Arrival Trains on Dedicated Passenger Lines. Journal of Southwest Jiaotong University, 2006, 41(5):626-629+640.

QIANG Lixia, YAN Yin. The Difference on transport demand of high speed railway in the world[J]. Railway Transport and Economy, 2006,28(9):18-21.

SUN Jie-ping, ZHANG Chi, ZHANG Tian-wei. The optimization of operation plan of sunset-departure and sunrise-arrival train on high-speed railway based on operation safety. Journal of Safety Science and Technology,2014,07:5-10.

WANG Xiangping, HUA Wei, LI Bo, etl. The feasibility for dusk-to-dawn train in high speed railway with rectangular skynight. Railway Transport and Economy ,2007,29(11):16-17+48.

ZHANG Tian-wei,NIE Lei,LU Jin. Comprehensive Comparison and Selection of Operation Modes of Sunset-departure and Sunrise-arrival Train on High-speed Railway. Journal of Transportation Systems Engineering and Information Technology, 2014,04:209-216.

ZHAO Lizhen，ZHAO Yinglian，YANG Yueqin， et al. Ways of Opening Comprehensive Maintenance“Window” and Its Coordination with Traffic

Organization for High-speed Railway. China Railway Science， 2002，
23(2):127-131.

Transport Organization Modes under a High-Speed Railway Network

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Abstract: High-speed railway Transport Organization Mode is very important for transport operation plan formulation, the improvement of transport efficiency, economic and social benefits. The determination of Transport Organization Mode under high-speed railway network has become a urgent problem need to be addressed with the high-speed railway network gradually constituting in China. This paper gives the definition of Transport Organization Mode based on analyzing the connotation of high-speed railway network Transport Organization Mode. And this paper introduces the influence factors and basic principles of Transport Organization Mode under high-speed railway network. Analyzing the types and characteristics of domestic and foreign high-speed railway Transport Organization Mode, putting forward four types of Transport Organization Mode under high-speed railway network, which are "various speed trains share the same line, one-line and over-line trains share the same line, trains with different stop schedule plans share the same line, trains with various characters share the same line".

Keywords: Network; Transport organization mode; Cooperation on the same line.

1 The connotation of Transport Organization Mode under high-speed railway network and the train combinations

Mode is the standard style of stuff, which is abstracted from concrete complex phenomenon. It describes the evolution law of object through the summary of the system, obtains logical structure and the method to solve problem via the deductive method which carries the strict reasoning (LIU Hua, 2005). Transport Organization Mode under high-speed railway network is referred to the train organization form and method of high-speed railway under certain operating management system, a certain level of social economy and science and technology development, under the condition of a certain network function structure. In particular, it is a comprehensive description of the train properties, types, running speed and the cross line train running (cross line passenger transportation) under the condition of joining each other between the high speed railway lines or between high-speed railway lines and existing lines.

According to the analysis of Transport Organization Mode under high-speed railway network, we can get the following different train combinations, as shown in *table 1*:

Table1. Train combinations of high-speed railway in different Transport Organization Modes

Classification standard	type	characteristic	Train combination
Train property	Mixed passenger and freight train	Mixed passenger trains and freight trains run in high-speed railway	Mixed passenger and freight trains;passenger trains and freight trains run in different period of time but in the same line
	Passenger dedicated line	Only Passenger trains run in high-speed railway	Only dedicated train;mixed dedicated trains and over-line trains;trains run at the same speed;trains run in the same line at different speed
Train speed	Same speed train in the same line	Train run at the Same speed	Dedicated trains run；mixed dedicated trains and over-trains run; trains run at the same speed
	Different speed train in the same line	Trains run at the different speed	Dedicated trains run at different speed;passenger trains and freight trains run at different speed;dedicated trains and over-line trains run at different speed;dedicated line trains、over-train and freight trains run
Over-line train operation	Dedicated train transfer	No over-line train	Dedicated trains run at same speed；dedicated trains run at different speed
	Over-line train go on line	Over-line train and dedicated train in the same line	Over-line trains and dedicated trains run at same speed；Over-line trains and dedicated trains run at different speed；Passenger trains and freight trains run
	Over-line train off line	Over-line train and dedicated train in the same line	Over-line trains and dedicated trains run at same speed；Over-line trains and dedicated trains run at different speed；Passenger trains and freight trains run
	Over-line train go on and off line	Over-line train and dedicated train in the same line	Over-line trains and dedicated trains run at same speed；Over-line trains and dedicated trains run at different speed；Passenger trains and freight trains run

2 The influence factors of Transport Organization Mode under high-speed railway network

The influence factors of Transport Organization Mode under high-speed railway network are complex. The main influence factors are as following:

(1)The properties and characteristics of passenger flow

The nature and characteristics of the passenger flow are the core influence factor of the high-speed railway Transport Organization Mode. High-speed railway Transport Organization Mode should be consist with the properties and characteristics of passenger flow. Passenger flow is divided into the line passenger flow and cross line passenger flow. The line flow is divided into big station passenger flowand passenger flow along the merge (XU Xingfang,2010). Across line can be divided into two parts, passenger flow from other line to the line or set off from this line to other line of passenger flow through the line of the passenger flow. Analyzing the characteristics of passenger flow is to analyse the line passenger flow, cross the line passenger flow, passenger flow of the shape and size. In addition, the demand characteristics of passenger flow should be researched from ticket costs, travel time, convenience and so on.

(2)Railway network structure and scale

Network structures mainly contain the situation of railway network joining and each line of joining compatible. Therefore, network under the condition of high speed railway is mainly divided into two kinds: one is the railway network system, separating the existing lines to form a single high-speed rail network structure. Another is connecting with existing lines to form a high-speed rail network and complex network structure of existing railway network combination. With the advancement of the high-speed railway construction in china, the railway network structure is clear, a high-speed line between the big nodes to join each other, and join the existing lines, thus form between highway system, the high railway system between the existing network and complex network structure.

(3) Macroscopic environment

Macroscopic environment mainly includes railway situation, human geography, economic environment, cultural tradition, passenger travel habits, policies and regulations and so on. When the macroscopic environment changes, high-speed railway Transport Organization Mode should also be changed accordingly. On a world scale, high-speed railway Transport Organization Mode is different from country to country. Macroscopic environment have influence on the determination of Transport Organization Mode.

(4)The train types and their mutual relations

The research of high speed railway Transport Organization Mode is bound to involve in the process of the type of the train, a single or multiple. If there are many types of trains, it inevitably involves the interaction relationship between different types of trains. From the world of high speed railway operation management, they involves different types of trains and the influence of relationship, just different from concrete manifestation.

(5)Safety and reliability of system and equipment (HU Siji,1996)

Safe system and reliable equipment are prerequisite condition to research and determine the Transport Organization Mode. No matter what kind of Transport Organization Mode, it must be based on system and equipment to ensure its security. System mainly includes the hardware and software system, equipment mainly includes fixed devices and mobile devices. System and equipment mainly includes train command system, control system, adjusting system, train control system, lines, locomotive, vehicle and so on.

（6）Carrying Capacity

Different Transport Organization Modes have different influence on carrying capacity. The loss of carrying capacity in high-speed railway is mainly caused by the different train stops and different train speeds. In addition, it is also affected by interval length, train combinations, the influence of different levels of speed train number, and many other factors, grasping these factors in a correct way will help planners formulate reasonable solution (ZHENG Jinzi,2012). Therefore, determine the Transport Organization Mode must consider its effect on the capacity.

(7)Transportation service quality

Important advantage of high speed railway is the high quality of service and mainly reflected in the rapid, on time and comfort. Determining high-speed railway Transport Organization Mode should try to improve transport service quality. In the condition of meeting the demand of passenger flow, achieve rapid, on time and comfortable goal.

3 Basic principles of Transport Organization Mode under the high-speed railway network

The way to choose the Transport Organization Mode of high-speed railway is based on starting point and foothold.

(1)Making the best use of high-speed railway's capacity

The starting points to ensure the Transport Organization Mode of high-speed railway are based on three aspects: understanding the connotation of high-speed railway deeply, seizing the essence exactly and making the best use of the capacity. As the high-speed railway forming into network, there are both existing line and high-speed railway coexisting between the same corridor. Based on the connotation and essence of the high-speed railway of our country, we should organize and encourage passengers to choose the high-speed railway, improve passenger trains operation speed, decrease the quantity of trains on the existing line to increase the quantity of freight trains and make the best use of high-speed railway's capacity. These methods would make a best use of the synthetical capacity of the transportation corridor.

(2) Acquiring the maximization of both passenger satisfaction degree and performance of enterprises

The foothold to ensure the Transport Organization Modes of high-speed railway is to acquire the maximization of both passenger satisfaction degree and performance of enterprises. To improve the passenger satisfaction degree, we should satisfy the demand of different kinds of passengers, try the best to make the passengers feel convenient and decrease the travel time. As for the performance of enterprises, we could try the best to reduce transportation costs, enhance the attractiveness, improve enterprises' competitiveness and increase scale of passenger flows. The two aspects have complex relationship for being in conflict and being accelerate. The scale of passenger flows is the link of the two aspects. The choice of Transport Organization Modes has to coordinate the two parts and achieve a win-win relationship of them.

4 The Transport Organization Modes of high-speed railway at home and abroad

4.1 The Transport Organization Modes of high-speed railway abroad

The realized time of Transport Organization Modes of high-speed railway abroad is earlier, their modes have many characteristics as following *table 2*.

Table 2. The Transport Organization Mode of high-speed railway abroad

Country	*Mode*	*Remark*
Japan	High-speed railway of whole journey	Japanese Railway Company achieves the over-line transportation between the existing line and high-speed railway through technical transformation. The East Japan Railway implements the over-line transportation between different Shinkansen.
France	Trains use both the high-speed railway and exiting line	Using the over-line transportation between different.
Germany	Passenger trains and freight trains share the same line	Passenger trains and freight trains share the same line in different time bucket.
Italy	Passenger trains and freight trains share the same line	High-speed and medium-speed passenger trains and the high-speed freight trains share the same line.
Spanish	High-speed and medium-speed passenger trains use the same line.	The dedicated train AVE (300km/h) and the over-line train Talgo (200km/h) share the same line.
Sweden	Passenger trains and freight trains share the same line	Using the tilting trains to achieve a speed of 200km/h through the transformation of a part of the existing line.

4.2 The Transport Organization Modes of high-speed railway in china

According to the Long-term Planning of Chinese Railway in 2004, the "four vertical and four horizontal" high-speed railway network begin to take shape and has basic formation after ten years of construction, the mileage has reached 16,000 kilometers which is the longest mileage in the world.

Overall considering the practical operation condition of high-speed railway, passenger transport line and interurban railway and the intension of Transport Organization Mode, the Transport Organization Modes of our country are summed up as the following *table 3*.

Table 3 The different Transport Organization Modes in china

Type of line		*Transport Organization Mode*
300km/h and over		Over-line trains could use the high-speed railway line and different speed trains share the same line
200km/h-250km/h	New line	Passenger dedicated train only
	Reconstructive line	Passenger trains and freight trains share the same line
Interurban passenger transport line		Operating the one-line high speed train only

5 The types and characteristics of Transport Organization Modes

5.1 The types of Transport Organization Modes

Overall referencing the related studying achievements, this paper summarizes the modes into four types which are as follows:

(1)High-speed line with over-line train mode: The high-speed railways are only offered for the high speed trains, while the high speed train could operate on both high-speed line and the existing lines. This mode satisfy the need of both one-line and over-line passenger flows. Specifically, there are three modes: trains operate on a high-speed line and transferring to an existing line; trains operate on an existing line and then transferring to high-speed line; train operate on an existing line and transferring to a high-speed line then down to an existing line again.

(2)High-speed line with transference: The high-speed railways are only offered for the high speed trains. The high speed trains operate only on the high-speed lines. This mode asks the over-line passenger flow to transfer to the existing line on the transfer station.

(3) High-speed passenger trains with medium-speed passenger trains mode: There are different speed levels on the high-speed line, including high speed trains and ordinary speed trains. This mode achieves the transportation task of the one-line and over-line passenger flows. In this mode, there are two methods to transport the over-line passengers. One is to use the ordinary speed trains, the other is to use both the high speed trains and ordinary speed trains.

(4) Passenger trains and freight trains sharing the same lines mode: The high-speed railways are offered for the passenger trains and freight trains to accomplish the whole transportation task.

5.2 Characteristics of different Transport Organization Modes

Different Transport Organization Modes are referred to meeting the demand of passenger flow, the level of train on high speed railway, the operating range of high-speed railway train and the type of train, the different specific forms include. The characteristics of four different kinds of modes are listed as *table 4*.

Table 4 The characteristic of different Transport Organization Modes

Type	*Advantage*	*Disadvantage*
High-speed line with over-line train mode	High travelling speed, short travelling time for one-line passenger flows, high service level for one-line passenger flows, large transportation capability, simple transportation organization, easy to manage	Over-line passenger flows have to transfer to another line; the service level for over-line passenger flows is low; the attraction for over-line passenger flows is lacked.
High-speed line with transference	Decreasing the transference of Over-line passenger flows, higher service level, more attractive, high capacity use	The demands of motor train units are large, adjoining line have to use high standard and are mutually compatible, Maintenance amount of the motor train units is large, complex operation
Mixed high-speed passenger trains and medium-speed passenger trains	Satisfying different levels of passenger flows' demands	Lower transportation capability
Mixed passenger trains and freight trains share the same line	Less over-line passenger flow transference, high service level, high capacity, high line's capacity factor, attracting more freight transportation	Operation of freight trains would influence the whole line operation, adjoining line have to use high standard and are mutually compatible, Maintenance amount of the motor train units is large, lower capacity factor for passenger trains, complex operation

5.3 Limitations of different Transport Organization Modes

The various development histories of countries and multiple social economic statuses lead to a lot of operation forms and various Transport Organization Modes. According to the characteristics of our country, complete adoption of any mode would have certain limitations (such as *table 5*).

Table 5 The limitation of different Transport Organization Modes

Mode	*Limitation in our country*
High-speed line with over-line train mode	The design of station in our country is lack of transference which increases the cost of transference and causes loss of passenger flow.
High-speed line with transference	The huge demand of motor train units would take a large cost. The existing line are not completely electrified which doesn't match the high speed trains. The speed standard of the existing line is low. The operation of over-line freight trains is complex.
Mixed high-speed passenger trains and medium-speed passenger trains	This mode would decrease the capacity of high-speed railway, and reduce the influence of it.
Mixed passenger trains and freight trains share the same line	The construction standard is different. The axle load standard of high-speed line and ordinary line are diffetrent. This mode does not fit the goal of our country, which is separating the passenger trains and freight trains into different lines.

According to the analysis of table 4 and table 5, it's not hard to know that whichever mode our country chooses, it would have some limitation. But we could summarize some enlightenments.

(1) When the benefits reach a certain extent, we could reform the line network, let the high-speed train operate on the existing line and improve the high quality of high-speed railway.

(2) We could use the high-speed line to transport the freights and attract some fixed high-value freight sources.

(3)Separating the passenger trains and freight trains into different lines would crease the transference cost of passengers while save the transforming cost.

(4) We could adopt the passenger trains and freight trains sharing the same lines mode on the high-speed lines which have lower design standard and less transportation tasks. These methods could delay constructing second-line.

(5)Using the high-speed passenger trains with medium-speed passenger trains mode could attract different consumption levels passengers and extend volume growth of high-speed railways.

6 Determination of Transport Organization Modes under the high-speed railway network

The high-speed trains in our country have their own characteristics and they are much more complex than other countries. We have to find out the basic principles of Transport Organization Modes under the high-speed railway network, analyze the relevant factors about the Transport Organization Modes comprehensively and take the construction original intentions into considered. The original intentions are as follows: High-speed lines in our country have to undertake the most medium-term and long-term one-line and over-line passenger flows while the existing lines undertake the freight transportation and some passenger flows with lower speed. According to the railway situation in our country, the most amounts of high-speed railways have to be used as passenger transport lines. Meanwhile, the construction and operation of them are divided into several stages. Thus, determine the Transport Organization Modes under the high-speed railway network needs systematic planning and have to be divided into several parts. The stage of today is called “four operation trains sharing same line”.

(1) Various speed trains share the same line: There are two and more speeds of trains operating on the high-speed railway lines.

(2) One-line and over-line trains share the same line: There are one-line and over-line trains operating on the high-speed railway lines.

(3)Trains with different stop schedule plans share the same line: There are trains with different stop schedule plans operating on the high-speed railway lines.

(4)Trains with various characters share the same line: There are high-speed trains, ordinary-speed passenger trains and freight trains operating on the high-speed railway lines.

The “four operation trains sharing same line” is the most suitable high-speed Transport Organization Mode of our country. The reasons are as follows:

(1) This mode has the advantages of “Trains use both the high-speed line and exiting line” and solving the problem of the lack of capacity on existing lines.

(2) In these years, the manufacture of locomotives and vehicles grows quickly. Homebred motor train units account for a very great proportion. These backgrounds offer a strong technology support for using motor train units for over-line trains.

(3) After the raising of speed in Chinese railway, the technology and equipment conditions of existing lines improve a lot. Ordinary passenger and freight trains have less speed differences of the high-speed trains. This condition makes an advantage for trains using both the high-speed lines and exiting lines.

(4) Trains with different stop schedule plans guarantee the nonstop of high-speed trains and satisfy the service frequency of high-ranking stations. It’s the embody of high-speed railway satisfying various kinds of transportation demands and the important guarantees of transportation quality.

(5) This mode matches the functional orientation and passenger flows of high-speed line in the railway network which could improve the railway service quality and market competitiveness.

(6) Although the high-speed railway network initially formed at this stage, it is not perfect about the operation areas. The over-line trains could increase the operation areas of high-speed trains and improve the availability of high-speed lines.

(7) The high-speed lines which are transformed from existing line could operate the freight trains. And most of these lines do not have double lines between the same origin and destination. Using “passenger trains and freight trains sharing the same lines mode” could play a bigger role.

7 Conclusions

Based on the analysis of intensions and influence factors about Transport Organization Mode, this paper discusses the types and characteristics of Transport Organization Modes at home and abroad and proposes the Transport Organization Mode of our country under the high-speed railway network, namely "four operation trains sharing same line". With the developments of the high-speed railway network, it is important to increase the quantity and operation areas of high-speed trains and to decrease the quantity of over-line trains to achieve a goal of high-speed lines running high-speed and high-level trains.

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References

HU Siji(1996). The mode of "High-speed railway of whole journey" is the best choice for Beijing-Shanghai High speed railway. Journal of the China Railway Society, 18(supplement):90-96.

LIU Hua(2005). Study on organization of train operation on the line for mixed freight and passenger traffic with max. speed of 200km/h. Chengdu: Southwest Jiaotong University.

XU Xingfang , YANG Xuejun(2010). Study on problem of transport organization on high speed railway .Traffic & Transportation, 12:83-87.

ZHENG Jinzi, LIU Jun(2012). Carrying capacity of Beijing-Shanghai high-speed railway by different transport organization patterns. Journal of Transportation Systems Engineering and Information Technology, 12(4):22-28.

Calculation Methods of Minimal Headway for High-Speed Railways

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Abstract: This paper analyzes the interaction process of the running trains associated with the minimal headway for high-speed railway in a more reasonable and sophisticated way after systemically investigating previous researches. A set of new formulas are proposed to improve the calculation accuracy of minimal headway. In the case study section, the proposed methods are tested to calculate the minimal headway of the running trains of different speeds range from 250 km/h to 350 km/h with the calculation step of 10 km/h. The case study results show that with the increase of the maximal allowed speed, the headway between two trains running in one section, the headway between two arrival trains and the minimal headway of the high-speed railway increase, while the headway between two departing trains is a constant. The main conclusions can be drew from the case study results: (1) Headway between two arrival trains is always the bottle neck to narrow down minimal headway of high-speed railway no matter how the maximal allowed speed of the train changes from 250 km/h to 350 km/h. (2) The minimal headway of high-speed railway is always greater than 180s with the maximal allowed speed of the train ranges from 250 km/h to 350 km/h, which means that some improvement measures should be taken to accomplish the goal of reducing minimal headway to 3min. (3) The improvement of braking performance of the train can reduce the minimal headway of high-speed railway.

Keywords: High-speed railway; Minimal headway; Maximal allowed speed.

1 Introduction

The minimal headway is the minimal time interval that is needed for the station to accomplish necessary train receiving and departure operations, which is also the key to ensure the safety of trains running in the section (Li et al., 2008). Many studies have been implemented on calculation of the minimal headway for high-speed railway. Shi (2005) calculated the minimal headway of high-speed railway at the speed of 350km/h and analyzed the relationship between minimal headway and train acceleration, train deceleration, length of the station throat and switch number etc. Liu et al. (2006) proposed new methods to calculate the minimal headway of high-speed railway and come up with some measures to narrow down the minimal headway. Wu et al. (2007) built section and station train headway model under the condition of high-speed railway signal system to calculate the minimal headway. Li et al. (2008) applied computer simulation technology to simulate running process of the train while the train runs in the section, arrives at the station and departs the station to calculate the minimal headway of high-speed railway. Huang (2009) designed an optimization process to optimize minimal headway of high-speed railway after analyzing formation mechanism of the headway between two arrival trains. Li et al. (2013) analyzed the train headway of high-speed railway with speed restriction and used opentrack simulation software to verify the calculation results. However, after systematically investigating previous studies, it is found that previous studies do not have consistent analysis method for interaction process of the running train when calculating the headway between two trains running in one section, arriving at the station and departing the station which are three kinds of headway and this difference has made the calculation results of minimal headway for high-speed railway vary greatly. Most important, analysis of most studies on the interaction process of the running train are very rough, which has made it harder to calculate the throughput capacity of passenger dedicated line accurately.

This paper mainly have the following three contributions to the calculation of minimal headway for high-speed railway compared with previous studies. First, calculation method of every parameter in the calculation formulas of this paper is introduced in detail which makes it easier for the proposed calculation methods of this paper to be applied in practical situations by practitioners, and calculation methods of those parameters are determined by considering both the actual situation of high-speed railway and other relevant studies which makes values of those parameters more reasonable. Second, this paper assumes that final position of arrival trains and starting position of departing trains within the station are at the centerline of station arrival and departing track which is not considered by other studies and this assumption has great influence on calculation result of minimal headway. Third, running processes of trains approaching the station and trains departing the station are very complicated and many studies merely assumes those running processes as uniformly accelerated motion or uniformly retarded motion which is not reasonable, and this paper assumes those processes as a combination of uniform motion and uniform variable motion instead. The structure of this paper are arranged as below. Firstly, this paper analyzes basic principle of one-brake control mode curve. Then this paper introduces the deduction process of calculation formulas for minimal headway in detail. Finally, the proposed methods are tested to calculate minimal headway of high-speed railway.

2 One-brake control mode curve

One-brake control mode curve is the most commonly used train control method in Chinese high-speed railways. As shown in figure 1, the safe distance L_x between two trains in the section equals to the sum of L_{g1}, L_{g2}, L_{g3}, L_{g4} and L_{g5} (Liu et al., 2006). L_{g1} is the additional train running distance during the response time of equipment and train driver; L_{g2} is the total braking distance of the train; L_{g3} is the safety protection distance considering operation tolerance of equipment and operator of the train; L_{g4} is the distance considered under the worst tracing situation; L_{g5} is the length of the train.

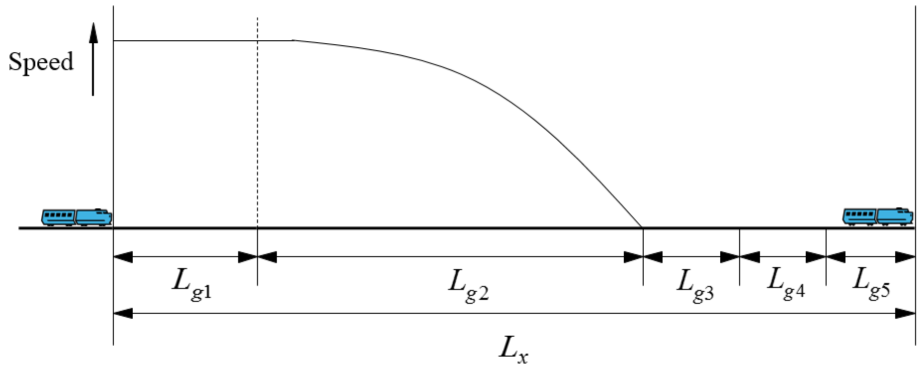

Figure 1. Principle of one-time braking mode curve train control method

3 Minimal headway of high-speed railway

The minimal headway of high-speed railway I equals to the maximal value among the headway between two trains running in one section I_z, the headway between two arrival trains I_d and the headway between two departing trains I_f as shown in formula (1) (Shi, 2005; Su et al., 2008; Li et al., 2008), that is because only the maximal headway can ensure that two adjacent trains run safely on the same railway line at the same time.

$$I = \max\{I_z, I_d, I_f\} \quad (1)$$

3.1 Headway between two trains running in one section

The distance between two trains running in one section L_x is shown in Figure 1, the formula to calculate L_x is shown below:

$$L_x = L_{g1} + L_{g2} + L_{g3} + L_{g4} + L_{g5} \quad (2)$$

L_{g1} can be calculated according to the formula bellow:

$$L_{g1} = t_g v_{\max} / 3.6 \quad (3)$$

Where t_g is the response time of equipment and train driver, t_g consists of section clear inspection time, response time of train control center, response time of on-board equipment and the time a driver needs to acknowledge the signal, t_g usually equals to 15s (Liu et al., 2006); $v_{\max}$ is the maximal speed of the train, km/h.

L_{g2} is the total braking distance of the train and L'_{g2} is the emergency braking distance. L'_{g2} can be calculated according to the formula bellow (Yang, 2008):

$$L'_{g2} = v_1 t_k / 3.6 + 4.17 \times (v_1^2 - v_2^2) / (1000 \vartheta_h \varphi_h + \omega_0 + i_j) \qquad (4)$$

Where t_k is the idling braking time, t_k usually equals to 1.5s for emergency braking (Yang, 2008); v_1 is the initial braking speed of the train, km/h; v_2 is the final braking speed of the train, km/h; ϑ_h is the train conversion braking rate, ϑ_h usually equals to 0.277 (Ma et al., 1998).

φ_h is the disc braking fraction coefficient, it can be calculated according to the formula bellow (Ma, 2011):

$$\varphi_h = 0.358 \times (2v + 150) / (3v + 150) \qquad (5)$$

Where v is the speed of the train, km/h.

ω_0 is the train unit basic resistance, it can be calculated according to the formula bellow (Ma et al., 1998):

$$\omega_0 = 0.608 + 0.008v + 0.000136v^2 (\text{N} \bullet \text{KN}^{-1}) \qquad (6)$$

i_j is the track gradient resistance, this paper doesn't consider track gradient resistance, then i_j equals to 0 N•KN^{-1}.

To ensure safety of the train and consider that the tolerance of disc braking fraction coefficient is controlled within 10%, then:

$$L_{g2} = L'_{g2} \times (1 + 10\%) \qquad (7)$$

The value of L_{g3} is related to the precision of the speed and distance measurement system, train speed and accuracy of the train braking rate. L_{g3} can be calculated according to the formula bellow (Ning, 1995):

$$L_{g3} = \beta(c + a \cdot v_{\max} + \sum_{j=1}^{n} \Delta s_j) \qquad (8)$$

Where β is the reservation coefficient and its value range is 1.1~1.4, this paper lets β equal to 1.4; c is the experience base number and its value range is 40~100m, this paper lets c equal to 100m; a is the experience constant and its value range is 0.4~0.6m, this paper lets a equal to 0.6m; $\sum_{j=1}^{n}\Delta s_j$ is the distance tolerance caused by the tolerance of braking rate as well as the tolerance of speed and distance measurement system, it usually equals to 50m.

L_{g4} usually equals to the length of the block section of high-speed railway, this paper lets L_{g4} equal to 1300m.

L_{g5} is the length of the train, the paper assumes that the train is made up of 16 coaches, then L_{g5} equals to 410m (Shi, 2005).

After L_{g1}, L_{g2}, L_{g3}, L_{g4} and L_{g5} are determined, the headway between two trains running in one section I_z can be calculated according to the formula below:

$$I_z = 2\times 3.6\frac{(L_{g2} - 1.1\times t_k v_{\max}/3.6 + L_{g3} + L_{g4} + L_{g5})}{v_{\max}} + 1.1\times t_k + t_g (s) \tag{9}$$

3.2 Headway between two arrival trains

The principle of determining the headway between two arrival trains is to ensure that the latter train will not slow down or even stop at the outside the station because the station has not prepared the receiving route. The distance between two arrival trains L_z is shown in Figure 2 and L_z can be calculated according to formula (10) (Wu et al., 2007; Yang, 2008; Huang, 2009; Li et al., 2013).

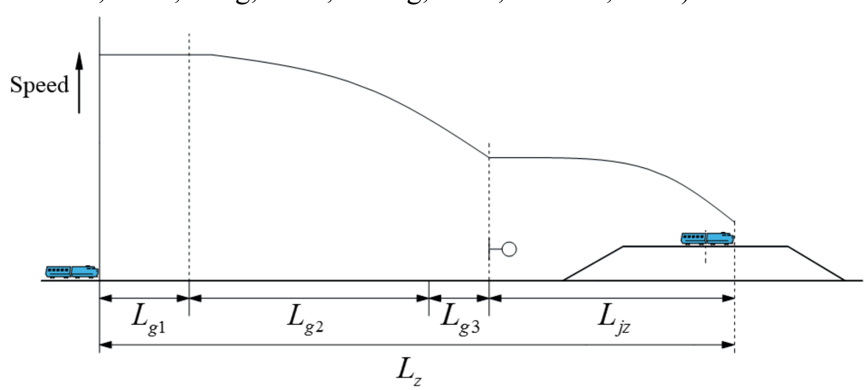

Figure 2. Distance between two arrival trains

$$L_z = L_{g1} + L_{g2} + L_{g3} + L_{jz} \tag{10}$$

L_{g1} is the additional distance produced during the period of train arrival operation and driver operation, L_{g1} can be calculated according to the formula bellow:

$$L_{g1} = \frac{(t_{dz} + t_s) \times v_{\max}}{3.6} \tag{11}$$

Where t_{dz} is the station receiving operation time, t_{dz} usually equals to 27s (Liu et al., 2006); t_s is the time that a train driver needs to acknowledge the signal, t_s usually equals to 6s (Liu et al., 2006).

L_{g2} is the total braking distance of the train, it can be calculated according to the formula bellow (Yang, 2008):

$$L_{g2} = (v_{\max} t_k / 3.6 + 4.17(v_{\max}^2 - v_y^2) / (1000\vartheta_h \varphi_h + \omega_0 + i_j)) \times (1 + 10\%) \tag{12}$$

Where v_y is the maximal allowed speed of the train while passing through switch side direction of the station, this paper lets v_y equal to 75km/h (Li et al., 2008); the meaning of other parameters are same as those in section 3.1.

L_{g3} is same as the L_{g3} in section 3.1.

L_{jz} is the running distance of the train while coming into the station, it can be calculated according to the formula bellow:

$$L_{jz} = L_n + 0.5 \times L_c + 0.5 \times L_u \tag{13}$$

Where L_n is the length of the station throat, L_n usually equals to 850m (Huang, 2009); L_c is the length of the train, this paper lets L_c equal to 410m (Shi, 2005); L_u is the length of the station effective track length, L_u usually equals to 700m (Li et al., 2008).

After L_{g1}, L_{g2}, L_{g3} and L_{jz} are determined, headway between two arrival trains I_d can be calculated according to the formula below:

$$I_d = 2\times 3.6\frac{(L_{g2} - 1.1\times t_k v_{\max} / 3.6 + L_{g3})}{v_{\max} + v_y} + 3.6\frac{\max\{(L_{jz} - L_{z0}), 0\}}{v_y} + \frac{2\times 3.6\times L_{z0}}{v_y} + t_{dz} + t_s + 1.1\times t_k \quad (14)$$

Where L_{z0} is the running distance of the train within the station while its speed reduces from v_y to 0 km/h. L_{z0} can be calculated according to the formula bellow:

$$L_{z0} = v_y t_k / 3.6 + 4.17(v_y^2 - 0^2) / (1000\vartheta_h \varphi_h + \omega_0 + i_j) \quad (15)$$

3.3 Headway between two departing trains

The principle of determining the headway between two departing trains is to ensure that the latter train will not slow down, which means that starting signal can only be opened until the former train has left the second departure section. The distance between two departing trains is shown in Figure 3 (Li et al., 2008; Yang, 2008; Li et al., 2013).

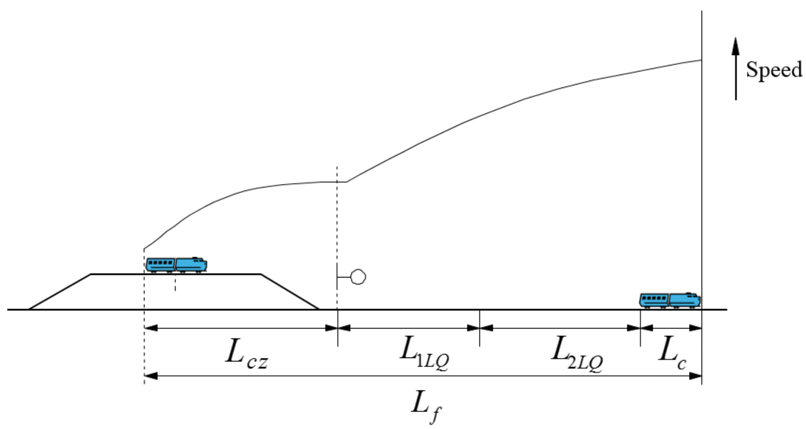

Figure 3. Distance between two arrival trains

The distance between two arrival trains L_f can be calculated according to the formula bellow:

$$L_f = \max\{L_{cz}, L_j\} + \max\{(L_{1LQ} + L_{2LQ}), L_{yb}\} + L_c \quad (16)$$

L_{cz} is the running distance of the train while departing the station, it also can be calculated according to formula (13).

L_j is the running distance of the train while it's speed reaches to v_y from 0 km/h, L_j can be calculated according to the formula bellow:

$$L_j = ((v_y / 3.6)^2 - 0^2) / 2a \tag{17}$$

Where v_y is the maximal allowed speed of the train while passing through switch side direction of the station, this paper lets v_y equal to 75km/h (Li et al., 2008); a is the acceleration of the train, this paper lets a equal to 0.35 m•s^{-2} (Shi, 2005).

L_{1LQ} and L_{2LQ} is the length of the first departure section and second departure section respectively, L_{1LQ} usually equals to 800m, L_{2LQ} usually equals to 1300m.

L_{yb} is the running distance of the former train during the period while the station is preparing the departure route for the latter train, it can be calculated according to the formula bellow:

$$L_{yb} = (v_y / 3.6) \times (t_{yb} - t_x) + 0.5a \times (t_{yb} - t_x)^2 + (v_y / 3.6) \times t_x \tag{18}$$

Where t_{yb} is the time that a station needs to handle departure route, this paper lets t_{yb} equal to 13s (Liu et al., 2006); t_x is the time interval from the moment when train comes into the first departure section to the moment when train starts to accelerate, this paper lets t_x equal to 9.5s (Liu et al., 2006).

After checking in advance, it is found that $L_{cz} > L_j$ and $L_{1LQ} + L_{2LQ} > L_{yb}$, then the headway between two departing trains I_f can be calculated according to the formula bellow:

$$\begin{aligned} I_f = t_{fz} + t_s + \frac{v_y}{3.6a} + 3.6\frac{L_{cz} - L_j}{v_y} + t_x + \frac{-2v_y / 3.6 + \sqrt{(2v_y / 3.6)^2 + 8a\min\{s, s_1\}}}{2a} \\ + 3.6\frac{\max\{(s - s_1), 0\}}{v_{\max}} \end{aligned} \tag{19}$$

Where t_{fz} is the station departure operation time, this paper lets t_{fz} equal to 11s (Liu et al., 2006); t_s is the time a driver needs to acknowledge the signal, this paper lets t_s equal to 6s (Liu et al., 2006); s_1 is the running distance of the train while its speed increase from v_y to $v_{\max}$, it can be calculated according to the formula bellow:

$$s_1 = \frac{(v_{\max}/3.6)^2 - (v_y/3.6)^2}{2a} \tag{20}$$

s can be calculated according to the formula bellow:

$$s = L_{1LQ} + L_{2LQ} + L_c - v_y t_x / 3.6 \tag{21}$$

4 Case study

The speed of the busy railway passenger dedicated line usually ranges from 250km/h to 350km/h, then this paper uses the proposed calculation methods to calculate the minimal headway of high-speed railway of different speeds range from 250km/h to 350km/h with calculation step of 10km/h. The calculation results are shown in Table 1.

Table 1. Calculation of the minimal tracing time interval

Speed(km/h) / Time Interval(s)	250	260	270	280	290	300	310	320	330	340	350
I_z	178	179	180	181	183	184	185	186	188	189	190
I_d	197	200	203	207	210	213	216	219	221	224	227
I_f	194	194	194	194	194	194	194	194	194	194	194
I	197	200	203	207	210	213	216	219	221	224	227

It is shown in Table 1 that with the increase of the maximal allowed speed, the headway between two trains running in one section I_z, the headway between two arrival trains I_d and the minimal headway I increase, while the headway between two departing trains I_f is a constant. The main conclusions can be drew from Table 1 as shown below:

(1) Because I_d is always greater than I_z and I_f, then minimal headway I is determined by I_d, which means that I_d is the bottle neck to narrow down minimal headway I no matter how the speed of the train changes from 250km/h to 350km/h. This finding is consistent with other researches' results (Liu et al., 2006; Wu et al., 2007; Li et al., 2008).

(2) Minimal headway of high-speed railway I is always greater than 180s with the maximal allowed speed of the train ranges from 250km/h to 350km/h, which means that some improvement measures should be taken to accomplish the goal of reducing minimal headway to 3min.

(3) After analyzing calculation formulas of headway between two arrival trains I_d, it is found that improvement of braking performance of the train will reduce the minimal headway of high-speed railway.

5 Recommendations for Future Research

Our future research will focus on designing parameters of the station yard, railway track and the train to narrow down the minimal headway of high-speed railway by analyzing calculation formulas of the proposed methods. We will be testing how I_z, I_d and I_f changes if some of the parameters in these formulas increase or decrease. Different combination of those parameters will lead to different construction costs and corresponding minimal headway, we will try to find out the best combination of those parameters to make a balance between construction cost and minimal headway to maximize the economy and social benefit of the railway.

References

Huang, C. (2009). "Preliminary Study on Calculating Method about Tracing Time Interval of High-speed Trains Arriving at Station." *Railway Transport and Economy,* 29(7), 85-88.

Liu, L., Wei, D. Y., Yin, Y., Wei, F. H. (2006). "Mechanism and Calculation of Speed-Interval Control of High-Speed Passenger Trains." *Journal of Southwest Jiaotong University,* 41(5):575-581.

Li, L., Peng, Q. Y., Li, X. (2008). "Analysis on Influence Factors of Minimum Train Time Interval based on CTCS Level 2.".*Railway Transport and Economy,* 31(4):90-93.

Li, B., Yang, X. (2013). "Study on Tracing Interval Time of High-speed Railway Trains under Speed Restriction." *Railway Transport and Economy,* 35(10), 12-17+31.

Ma, D. W., Lin, T. P. (1998). "Study on the Braking Distance of High Speed trains." *China Railway Science,* 19(1), 41-47.

Ma, G. Z., Mao, J. M. (2011). *Carrier of Rail Transit and Train Traction Calculation,* Southwest Jiaotong University Press, Chengdu.

Ning, B. (1995). "Braking Accuracy and Safety Protection Distance of the Train Overspeed Protection System." *Journal of Northern Jiaotong University,* 19(1), 10-14.

Shi, X. M. (2005). "Study on Train Headway of Chinese Passenger Dedicated Railway." *Chinese Railways,* 19(1), 10-14.

Su, S. H., Tian, C. H., Chen, Z. Y. (2008). "Calculation and Analysis on Throughput Capacity of Passenger Dedicated Railway." *China Railway Science,* 29(5):119-124.

Wu, L., Gao, J. Q., Mu, J. C. (2007). "Tracing Headway Control Model and Calculation of Passenger Dedicated Railway." *Computer Applications,* 27(11), 2643-2645.

Yang, C. H. (2008). "Discussion of Shortening Train Headway Under One-brake Control Mode." *Journal of Transportation Engineering and Information,* 6(1), 20-24+30.

Method of Cross-Line Timetable Optimization Based on a Single Depot for Cluster Scheduling

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Abstract: Public transportation companies generally establish a scheduling command center, and gradually develop the mode of cluster scheduling in large-sized and medium-sized cities in China. Realizing the mode of "multiple lines and a scheduling center" is one of the advantages of cluster scheduling so that it can improve the utilization of transport capacity resources. Based on the background, the paper studies a method of cross-line timetable coordinated optimization under cross-line buses with single depot, the synchronization timetable model of which not only considers the decrease of the total passengers' time cost, including the time cost of cross-line transfer passengers and non-cross-line waiting passengers, but also optimizes the buses' arriving time and buses' departure time in order to facilitate to link up the different trips. In addition, the paper established a model of seamless transfer timetable, which effectively reduces the waiting time and the cross-line transfer walking distance of cross-line transfer passengers.
Keywords: Cluster scheduling; Single depot; Cross-line operation; Synchronization timetable optimization; Seamless transfer timetable optimization.

1 Introduction

Vehicle-scheduling plan is an important production plan for transit agency as it is the key part of vehicle operation scheduling and has a great effect on operation cost and service level. The book of "Public Transit Planning and Operation-Theory, Modelling and Practice" introduces that vehicle operation scheduling has four parts: Network route design, timetable development, vehicle scheduling and crew scheduling (Ceder, 2007). Among, timetable development is an important factor of the vehicle scheduling problem (VSP) in the bus operation plan, which measures of bus punctuality and reliability. Thus, reasonable optimization of the bus departure interval and frequency is crucial to improve the punctuality of bus stations. In order to better use the bus traffic capacity and human resources, and be able to better serve the passengers, it is often to fix the timetable through adjusting the vehicle departure intervals based on passenger waiting time and vehicle operating time.

There are some researches about bus schedule coordination under the regional cross-line. Ceder (1987) proposed a method of forming variety kinds of bus schedule timetable based on passenger volume. It contained six goals: timetable change under the new integration; adjusting the departure interval of each line in the transfer nodes to make each line bus arriving most vehicles at the same time based on passengers service demand; offering a variety of schedules for the use of operators under different situations; adjusting the arrangement of different bus operation patterns to respond to the emergency; schedules ensuring the departure interval smoothness as far as possible; compiling schedule under collaborative departure. Ceder (2001) made a schedule optimization model under collaborative departure for each line based on the maximum bus approaching times online in the network. The purpose is to achieve synchronization of the schedules for each bus line. Then, Ceder (2007) put forward an optimization model to adjust the departure intervals on transit network level by minimizing passengers' transfer time through the synchronization of bus arrival. He also discussed that the synergy mainly depends on the real time bus control. Therefore, the reliability and punctuality of the timetable are very important. Liu (2007) reduced the passengers' waiting time through establishing a timetable synchronization of bus departure of multiple lines. The problem was classified as a 0-1 knapsack problem without capacity constraint of and defined the collaborative coefficient. A corresponding nested tabu search algorithm was set up to solve the model. Song (2013) proposed a timetable optimization model based on single line passengers demand and the benefit of the bus agency. This model achieved the optimized schedules which could reduce the waiting time of the cross-line transfer passengers. A particle swarm optimization (PSO) algorithm was used to solve the model. The result showed that this model could reduce the waiting time sharply.

To better meet the demand of bus service, this paper establishes a model of synchronization timetable to decrease the time cost of all passengers, including the waiting time cost of cross-line transfer passengers and the waiting time cost of non-cross-line passengers. In addition, in view of the bus lines with large cross-line transfer passenger flow in the peak hours, the model need consider the convenience of the cross-line passengers and to reduce their waiting time and walking distance. Then this paper establishes a seamless transfer timetable optimization model based on the vehicle under cross-line operation.

2 Problem Description

Figure 1 shows the cross-line operation mode based on a terminal in this paper.

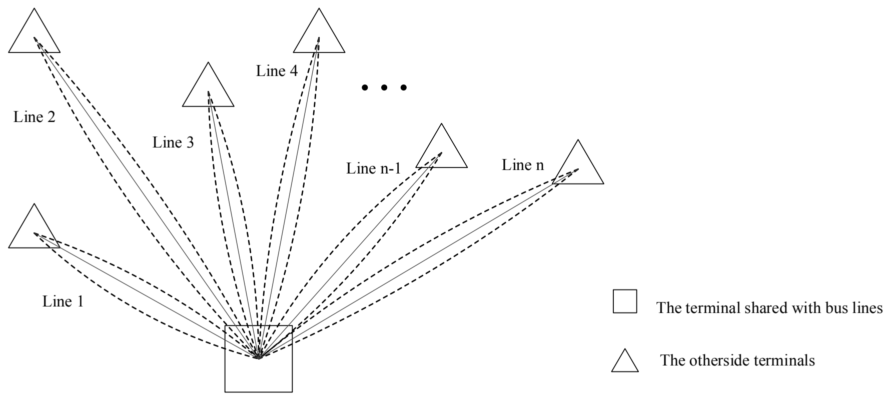

Figure 1.The cross-line operation mode based a terminal

The background of this operation mode are as follows:

(1) There are many bus terminals or intermodal transit terminals established or being planned in big cities, especially Transit-oriented Development based on terminals has become one tendency of urban planning in developing countries, such as China;

(2) Laying out bus transit network based on terminals is beneficial for fleet management and maintenance, and is also convenient for transferring organization of passenger flow;

(3) Many terminals are located among functional areas to exchange passengers. Some of lines could connect residential zones, and some could connect commercial zones or industrial zones. The peak time of the passenger volume of these lines are staggered. The transport capabilities required for these lines are complementary;

(4) It is much easier for crew-scheduling based on the SDVS vehicle-scheduling than based on MDVS.

With the widespread technology adoption of AVL, APC, RFID, wireless communication technology and other kinds of equipment in the public transportation industry, the transit agencies have the ability of information collection, processing and application. Many bus enterprises have set up scheduling command center, which provides implementation condition of bus multi-lines centralized scheduling. The condition to conduct the cross-line dispatching is mature. Therefore, it is a pressing problem to build regional dispatching timetable based on passenger service demand.

Comprehensive above, it is necessary to think over how to develop the detailed, practical and feasible regional cross-line dispatching timetables in order to guide public transport intelligent dispatching. Timetable is a connecting link between transit agency companies and passengers. And building favorable timetable is an important measure to improve the operational efficiency, increase bus service level and reduce operational costs.

3 The model building of synchronization timetable

3.1 Optimizing goal

Timetables for single line mainly meet the basic traveling demand of passengers, which do not consider transfer cost of the cross-line transfer passengers. On the basis of meeting each line passengers flow volume, this paper decreases the transfer waiting time and transfer cost of the cross-line transfer passengers. Therefore, there are three main optimization goals in timetable model with synchronization, such as the minimal difference value of departure intervals compared with timetables for single line, the minimal cross-line transfer waiting time and the minimal waiting time of the non-cross-line passengers of original line. As multi-objective optimization model, it is suitable for the heuristic algorithm to solve the optimal model.

3.2 Premise assumption

There are some premises to be stated before proposing the model:

(1) Passenger flow rule is same in optimized time range in minutes;
(2) The number of the cross-line transfer passengers is known and its arrival pattern is complied with uniform distribution because of the unknown timetable distribution;
(3) Vehicle type of each line is same, which has the same rated capacity;
(4) The cross-line transfer passengers and the non-cross-line waiting passengers of original line would get on the first coming bus, and they would not wait the later bus no matter what happened;
(5) The number of the non-cross-line waiting passengers of original line is known and its arrival pattern is complied with poisson distribution because of the known timetable distribution.

3.3 The mathematical symbol

Let $\overline{L} = \{L_j \mid j = 1,2\ldots\ldots n\}$ be the set of cross-lines departed from the identical terminal, in which j is the serial number and n is the number of lines satisfied regional scheduling.

Let $\overline{D} = \{D_{jt} \mid j = 1,2\ldots\ldots n,\ \ t = 1,2\ldots\ldots y_j\}$ be the set of the whole trips departed from the identical terminal. Let D_{jt} mean the trip t of the bus line j. Let y_j be the trips of bus line j.

Let $\overline{K}=\{K_{jt}\mid j=1,2\ldots\ldots n,\ \ t=1,2\ldots\ldots y_j\}$ be the set of the vehicles departed from the identical terminal. Let K_{jt} mean the vehicle to conduct the trip t of the line j. Let y_j be the trips of bus line j.

Let t_{djt} be the departure time from the identical terminal and t_{ajt} be the arrival time (the time back the identical terminal).

Let h_{jt} be the departure interval of the trip t of the line j.

Let $t_{jt}^{'}$, $t_{jt}^{''}$ be the running time for up and down.

Let $tt_{jt}^{'}$, $tt_{jt}^{''}$ be the stop time of the other terminal relative to the same terminal.

Let P_{jt} be the number of the non-cross-line passengers of the trip D_{is}.

Let $P_{jt,is}$ be the number of the cross-line transfer passengers from D_{jt} to D_{is}.

Let λ be the arrival rate of non-cross-line passengers per unit time.

Let β be the rate of passengers to get on the bus.

3.4 The model building

With the above mathematical symbol, the model of synchronization timetable would be built in this section.

(1) The difference value of departure intervals compared with timetables for single line:

$$\Delta t_l=\sum_{i=1}^{l}\sum_{s=1}^{y_i}(\left|h_{is}-h_{is}^{'}\right|) \quad (1)$$

(2) The transfer waiting time:

Supposing that line L_j and line L_i are from the identical terminal, the arrival times of the trips D_{jt} and D_{is} are as follows:

$$\begin{cases} t_{ajt} = t_{djt} + t_{jt}^{'} + tt_{jt}^{'} + t_{jt}^{"} = t_{dj1} + (t-1)h_j + t_{jt}^{'} + tt_{jt}^{'} + t_{jt}^{"} \\ t_{ais} = t_{dis} + t_{is}^{'} + tt_{is}^{'} + t_{is}^{"} = t_{di1} + (s-1)h_i + t_{is}^{'} + tt_{is}^{'} + t_{is}^{"} \end{cases} \quad (2)$$

And the departure times of the trips D_{jt+1} and D_{is+1} are as follows:

$$\begin{cases} t_{d,jt+1} = t_{djt} + h_j = t_{dj1} + th_j \\ t_{d,is+1} = t_{dis} + h_i = t_{di1} + sh_i \end{cases} \quad (3)$$

Assume that the arrival time of the trip D_{jt} is earlier than the departure time of the trip D_{is}, $P_{jt,is}$ means the number of the cross-line transfer passengers from D_{jt} to D_{is}; On the contrary, the number of the cross-line transfer passengers from D_{is} to D_{jt} is represented by $P_{is,jt}$.

Therefore, the transfer time of the cross-line transfer passengers is as follows:

$$\Delta T_{j,i} = \left[\sum_{t=1}^{y_j} \sum_{s=1}^{y_i} P_{jt,is}(t_{dis} - t_{ajt}) \right] + \beta_{i,j} \left[\sum_{t=1}^{y_j} \sum_{s=1}^{y_i} P_{is,jt+1}(t_{d,jt+1} - t_{ais}) \right] \quad (4)$$

Among, $\beta_{i,j}$ is logic variable.

$$\beta_{i,j} = \begin{cases} 1, 0 \le (t_{dis} - t_{ajt}) \le \min(h_{jt}, h_{is}); \\ 0, otherwise \end{cases} \quad (5)$$

If there are more than two lines from the identical terminal, the total transfer time of the cross-line transfer passengers is as follows:

$$\Delta T_l = \sum_{i=1}^{l} \sum_{j=1}^{l} \Delta T_{j,i} \quad (6)$$

(3) The waiting time of the non-cross-line passengers of original line:

Supposing that the arrival number of the non-cross-line waiting passengers of original line is complied with poisson distribution per unit time, probability density function is as follows:

$$p(x) = \frac{\lambda^x e^{-\lambda}}{x!} \tag{7}$$

Among, $p(x)$ is the arrival probability per unit time when there are x passengers arriving. Therefore, the number of the arrival passengers is $p_{is} = \lambda_i h_{is}$ in the departure interval h_{is}. And the waiting time of the non-cross-line passengers of original line is as follows:

$$\Delta T_i = \sum_{s=1}^{b_i} \frac{(\lambda_i h_{is})^2}{2} \tag{8}$$

Among, $h_{is} = t_{dis} - t_{d,is-1}$.

The total waiting time of all kinds of lines is as follows:

$$\Delta T_{ll} = \sum_{i=1}^{l} \sum_{j=1}^{l} \Delta T_i = \sum_{i=1}^{l} \sum_{j=1}^{l} \sum_{s=1}^{y_i} \frac{(\lambda_i h_{is})^2}{2} \tag{9}$$

(4) The model of synchronization timetable

Based on above three aspects, this paper builds the model of synchronization timetable. Because of multi objective optimization problem, this paper makes use of the linear weighted method to convert the model. As considering two lines synchronized to depart from the identical terminal, the model is as follows:

$$\min(\alpha_1 z_1 + \alpha_2 z_2 + \alpha_3 z_3) = \min\left\{ \begin{array}{l} \alpha_1 \sum_{i=1}^{l} \sum_{s=1}^{y_i} (|h_{is} - h_{is}^{'}|) \\ +\alpha_2 \left\{ \left[\sum_{t=1}^{y_j} \sum_{s=1}^{y_i} P_{jt,is} (t_{dis} - t_{ajt}) \right] + \beta_{i,j} \left[\sum_{t=1}^{y_j} \sum_{s=1}^{y_i} P_{is,jt+1} (t_{d,jt+1} - t_{ais}) \right] \right\} \\ +\alpha_3 \left[\sum_{s=1}^{y_i} \frac{(\lambda_i h_{is})^2}{2} + \sum_{t=1}^{y_j} \frac{(\lambda_j h_{jt})^2}{2} \right] \end{array} \right\} \quad (10)$$

Among, z_1, z_2, z_3 respectively represent the deviation cost compared with timetables for single line, the cross-line waiting cost and the waiting cost of the non-cross-line passengers of original line. $\alpha_1, \alpha_2, \alpha_3$ respectively represent the weights of the three optimization goals. What's more, $\alpha_1 + \alpha_2 + \alpha_3 = 1$ and $0 < \alpha_1, \alpha_2, \alpha_3 < 1$. According to the importance of the three optimization goals, we could give values of $\alpha_1, \alpha_2, \alpha_3$.

Generated from the above mathematical model, if there are more than two lines from the identical terminal, the model of synchronization timetable is as follows:

$$\min(\alpha_1 z_1 + \alpha_2 z_2 + \alpha_3 z_3) = \min\left\{ \begin{array}{l} \alpha_1 \sum_{i=1}^{l} \sum_{s=1}^{y_i} (|h_{is} - h_{is}^{'}|) \\ +\alpha_2 \left\{ \sum_{i=1}^{l} \sum_{j=1}^{l} \left\{ \left[\sum_{t=1}^{y_j} \sum_{s=1}^{y_i} P_{jt,is} (t_{dis} - t_{ajt}) \right] + \beta_{i,j} \left[\sum_{t=1}^{y_j} \sum_{s=1}^{y_i} P_{is,jt+1} (t_{d,jt+1} - t_{ais}) \right] \right\} \right\} \\ +\alpha_3 \sum_{i=1}^{l} \sum_{j=1}^{l} \sum_{s=1}^{y_i} \frac{(\lambda_i h_{is})^2}{2} \end{array} \right\} \quad (11)$$

4 The model building of seamless transfer timetable

4.1 The model building

The model with synchronization timetable has three optimization goals, which are the minimal difference value of departure intervals compared with timetables for single line, the minimal transfer waiting time and the minimal waiting time of the non-cross-line passengers of original line. However, for some cross-line transfer passengers, not only would they like to reduce transfer waiting time, but also want to reduce cross-line walking distance. Therefore, this section would build the model of seamless transfer timetable to improve passenger perception service requirements, which is suitable for some lines having lots of cross-line transfer passengers or some lines having intensive passengers flow during the peak. Seamless transfer timetable is a cross-line timetable suited for vehicles cross-line operation, which means a vehicle can continue conducting another line's trip after conducting one line's trip in order to improve passenger transfer convenience, reduce the cross-line transfer passenger walking distance and reduce the transfer waiting time.

Assume that the arrival time of the vehicle K_{jt} is earlier than the departure time of the trip K_{is}, and let the vehicle K_{jt} continue conducting the trip D_{is} after conducting the trip D_{jt}. Then for the cross-line transfer passengers from D_{jt} to D_{is}, the identical terminal is a middle station, in which the dwell time of the vehicle K_{jt} should be diminished as soon as possible. When all the passengers get on the bus, the vehicle could be departed. Therefore, a constraint of dwell time should be added up in the model of seamless transfer timetable. Because the cross-line transfer passengers do not get off the bus, the dwell time is proportional to the non-cross-line waiting passengers.

Let β be the rate of passengers getting on the bus. Then the time to getting on the bus is the departure interval, which is as follows:

$$\begin{cases} h_{is} = \beta P_{\text{other},is} + \beta P_{is} \\ \quad = \beta \sum_{j=1}^{l} \sum_{t=1}^{y_i} P_{jt,is} - \beta P_{jt,is} + \beta P_{is} \\ \quad = \beta \sum_{j=1}^{l} \sum_{t=1}^{y_i} P_{jt,is} - 0 + \beta P_{is} \\ \quad = \beta \sum_{j=1}^{l} \sum_{t=1}^{y_i} P_{jt,is} + \beta P_{is} \\ \quad = \beta \sum_{j=1}^{l} \sum_{t=1}^{y_i} P_{jt,is} + \beta \lambda_i h_{is} \end{cases} \Rightarrow h_{is} = \frac{\sum_{j=1}^{l} \sum_{t=1}^{y_i} P_{jt,is}}{\frac{1}{\beta} - \lambda_i} \tag{12}$$

According to the departure intervals of connecting trips, seamless transfer timetable can be developed.

4.2 The solution domain

Through solving out the model with seamless transfer timetable, we could get the departure intervals of all kinds of lines. Based on the premise that the departure time of first trip is known, the timetable for each line could be set out as follows:

$$\begin{bmatrix} t_{11} & t_{11}+h_{12} & \dots & t_{1,s-1}+h_{1s} & \dots & t_{1,y_i-1}+h_{1y_i} \\ \vdots & \vdots & \dots & \vdots & \dots & \vdots \\ t_{i1} & t_{i1}+h_{i2} & \dots & t_{i,s-1}+h_{is} & \dots & t_{i,y_i-1}+h_{iy_i} \\ \vdots & \vdots & \dots & \vdots & \dots & \vdots \\ t_{n1} & t_{n1}+h_{n2} & \dots & t_{n,s-1}+h_{ns} & \dots & t_{n,y_i-1}+h_{ny_i} \end{bmatrix} \quad (13)$$

5 Conclusions

This paper studied the model of synchronization timetable and the model of seamless transfer timetable for single-depot based on vehicle capacity sharing. The optimization goals of the two models are to decrease the waiting time cost of the whole passengers, reduce the transfer waiting time and cross-line walking distance of the cross-line transfer passengers.

Future research will focus on two aspects:

- To find out the suitable algorithms to solve the two models;
- To find out applicability of the two models and to calculate through cases.

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References

Ceder, A. (1987). Methods for Creating Bus Timetables. *Transportation Research Part A, 21(1),* 59-83.

Ceder, A., Golany, B. and Tal., O. (2001). Creating Bus Time Tables with Maximal Synchronization. *Transportation Research Part A, 35,* 913-928.

Ceder, A. (2007). Public Transit Planning and Operation- Theory, Modelling and Practice. *Butterworth-Heinemann,* UK.

Liu, Z.G., Shen, J.S., Wang, H.X. and Yang, W. (2007). Regional Public Transportation Timetabling Model with Synchronization. *Journal of transportation System Engineering and Information Technology, 7(2),* 109-113.

Song, T.Y. (2013). Research on Regional Bus Timetable Scheduling Optimization. *Huazhong University of Science and Technology.*

Feasibility of Mixed Marshalling of Passenger and Cargo Transportation on a High-Speed Railway

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Abstract: With the comprehensive construction of high-speed railway and deepening reform of the railway freight transportation, high-speed railway is labeled with safe, fast, punctual and other features, which will bring infinite possibility for the railway freight transportation, therefore the research of fast freight trains on high-speed railway is a meaningful exploration. Combining with the current situation of the development of high-speed railway freight transportation in China and abroad, six modes of high-speed railway freight transportation in theory is put forward in this paper. By analyzing the operation conditions of all aspects of the six modes, the suitable mode of China in the short term is the mode of the high-speed train with the mixed marshalling of passenger and cargo. Then this paper prove the feasibility of the mixed marshalling of passenger and cargo transportation on the high-speed railway through selecting and transforming the appropriate freight train, constructing the freight line and platform in the stations on the high-speed railway, analyzing the transport organization technology and the economic operation conditions. In the end, the further research work and the operation mode of the high-speed railway freight transportation in the future are put forward.

Keywords: High-speed railway; Freight transportation; Operation mode; Mixed marshalling of passenger and cargo; Feasibility.

1 Introduction

Since the 1990s, high-speed railway developed rapidly in China, passenger dedicated line network has been initially formed, and the construction large-scale high-speed railway construction has begun. At the same time, the reform of railway freight also begun along with the founded of the railway corporation. Railway freight transportation participated in market competition actively in order to adapt to market requirements. And the development of high-speed railway provides a good condition for the freight reform, because the characteristics of high transport speed, high punctuality rate, security and environmental protection can effectively meet the various demands of today's freight transportation. However, at the beginning of the design of high-speed railway, the possibility of the transport of cargos didn’t be taken into consideration. This paper seeks the suitable high-speed railway freight operation mode for China in the short term from six possible high-speed railway freight operation modes, and discusses its feasibility.

2 The development of high-speed railway freight

France is the earliest country that developed high-speed railway freight transportation, with the opening southeast of Paris TGV line in Paris – Lyon, two TGV passenger train were transformed to transport letters , packages and other small freight transportation at the speed of 270 km/h on the line. It is generally known that Germany and Italy are the countries that use the operation mode of high-speed freight train. In 2000, the German railway company transformed a kind of special container train to the high-speed freight train which shipped intercity packages. And Italy transport fresh, perishable cargos on the high-speed railway. The speed of high-speed freight train is controlled within 160 km/h in Germany and Italy (Wu Yunyun, 2010).

With the establishment of China Railway Corporation and improvement of the freight organization reform, high-speed express products are planned to develop. At present there are two main types of high-speed railway express train in China, one is the first train which is used to check the situation of line in the morning every day, without picking up passengers; another is the passenger train which loads part expresses and parcels. However, the possibility of the transport of cargos wasn't considered in the original design of high-speed railway, therefore, freight lines and the corresponding platforms weren't built in the plans. Furthermore, the limited stop time of high-speed trains in the along high-speed railway station and the lack of special high-speed railway freight train in China, will lead to the limitation on the size and number of freight. So the research on finding the right high-speed railway freight transportation operation mode is urgent and important.

3 The selection of high-speed railway freight operation mode

Combining with present situation in China and abroad, freight traffic transport capacity and technical conditions, there are six modes of high-speed railway freight operation mode in theory: transport freight on the high-speed passenger train, the high-speed railway confirm train, the high-speed freight train, the high-speed train with the mixed marshalling of passenger and cargo, the coupling train of passenger and cargo and high-speed freight railway (Wu Yunyun, 2010).

The comparison results of six modes is showed in Table 1.Among them, the mode of transport freight on the high-speed passenger train and the high-speed railway confirm train are used in China, but high-speed freight transportation can't be developed on the basis of the two modes because of the small transport capacity. Although the mode of high-speed freight railway has the largest transportation capacity without the crossover operation of passenger and cargo, it needs a set of high-speed freight railway equipment which includes lines, vehicles and stations, requiring a huge construction cost and a long construction cycle. The mode of the coupling train of passenger and cargo can solve the shortage of high-speed railway freight station equipment and freight line. But at the same time the link of shunting operation is increased, and the speed of the passenger train operation will be reduced. The operation of loading and unloading is handled in the station on existing lines, hence the signal equipments on the existing line should be connected with the ones on high-speed railway, so the implementation of the mode is also difficult to achieve in the short term.

Table 1. The contrast table of operation modes

Operation mode	Transport capacity	The impact on the passenger capacity	Vehicle equipment requirements	The station requirement	The technical requirements	The instance
Transport freight on the high-speed passenger train	Small	No	Rack with slightly modified	No special requirements	No special requirements	CRE
The high-speed railway confirm train	The relatively small	No	No special requirements	No special requirements	No special requirements	Wuhan-Guangzhou high-speed railway
The high-speed freight train	Big	Yes	Design special freight trains	Special freight base	The modified signal equipment on existing lines; Increased freight organization	TGV
The high-speed train with the mixed marshalling of passenger and cargo	The relatively big	Yes	Existing freight trains with modified	Special station platform; The corresponding handling equipment	Increased freight organization	Talgo XXl type tilting train in the United States
The coupling train of passenger and cargo	Big	Yes	Design special freight trains	No special requirements	The modified signal equipment on existing lines; Increase the shunting operation	No
The high-speed freight railway	Big	No	Design special freight trains	Special high-speed freight railway station	Special high-speed freight railway	No

The mode of the high-speed freight train is used in France, Germany and Italy. But in China, firstly, vehicle equipment of dedicated freight train is the problem which is still unsolved. In addition, because of the shortage of the freight line and freight platform, special freight base is required to be built in China. Moreover, the connected signal equipment is needed on the existing lines and high-speed railway. Therefore, although the operation of high-speed freight train in short term is unlikely in China, the high-speed freight train is the trend of high-speed railway freight transportation in the long run.

The transport capacity of the mode of the high-speed train with the mixed marshalling of passenger and cargo is relatively big, the existing freight trains can be reformed in order to reach the standard of high-speed railway, and the problem of signal equipment can be solved through increasing the freight line and platform in high-speed railway station. It's a suitable mode in short term in China, we can open the market of high-speed railway freight transportation through this mode and prepare for the later development of the high-speed freight train.

4 The feasibility of the high-speed train with the mixed marshalling of passenger and cargo

4.1 The feasibility of trains

At present, there are two kinds of fast freight train which are operated in China. One is the dedicated mail train whose speed reaches 160km/h and the other is the dedicated package train whose speed reaches 120km/h for the reason of the different weights of the cargos. The representative of dedicated mail train is the 25T package train developed by China CNR Corporation, using the passenger train bogie. The dedicated package train is mainly remolded from the P65 and PB freight train, using the freight train bogie. The mode of the high-speed train with the mixed marshalling of passenger and cargo is the pattern which mix passenger motor train unit with freight train into an integrated train, therefore the speed, transportation organization and structure of the freight train should be close to the passenger motor train unit.

Table 2. The contrast table of trains

Train model	Axle load（t）	Speed（km/h）	Bogie
CRH5	≤17	200	Passenger
25T package train	≤16.5	160	Passenger
P65 freight train	18	120	Freight

The table above is the comparison between CRH5, 25T package train and P65 freight train on the axle load, speed and bogie type. It shows that 25T package train, which uses the passenger train bogie and has the closely speed and axle load, is more close to the passenger motor train unit. Therefore, 25T package train is selected to be remolded as follow. Firstly, the boundary dimension of the freight train should be consistent with passenger motor train unit due to the mixed grouping of them. In addition, the handling operation of the passenger and cargo is proceeded in the high-speed railway station, thus the operation should be safe, efficient and convenient. The delivered cargos mainly consist of expresses and postal parcels hence the inner structure should be designed in the form of cargos warehouse in order to use interior space adequately, and the cargos should satisfy the standardization of the size and weight at the same time to achieve the requirements of rapid, balanced and reasonable loading. Moreover, the door should be designed to be wide enough for easy access and have the function of automatic switch as passenger motor train unit to accelerate the degree of automation.

4.2The feasibility of station

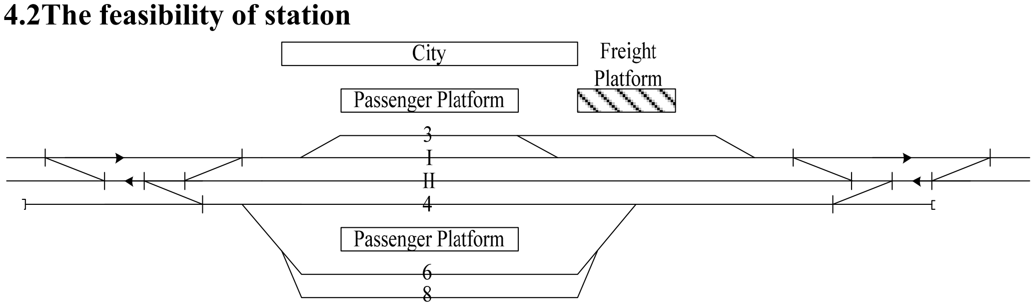

Figure 1. Modified figure of intermediate station

The station stoppage time in the intermediate station of high-speed railway is short, and the corresponding city is small, thus the cargo quantity handled in the station is relatively confined. Therefore, the situation can be solved by setting through-type freight yard in the intermediate station of high-speed railway, and lengthening the existing arrival-departure lines and constructing another freight line and corresponding freight platform. Considering the convenience for picking up and delivering the cargos, the through-type freight yard should be set by the side near the city.

In the operation process of high-speed railway freight train, the junction center station is responsible for loading and unloading of cargos, maintenance and marshaling of the vehicle. Therefore, the requirement of massive handled cargos cannot be satisfied by the through-type freight yard, thus end-type freight yard should be set on the side of the maintenance base line and maintenance of the mixed train will be convenient, and handling operation time of the cargos can be satisfied as well.

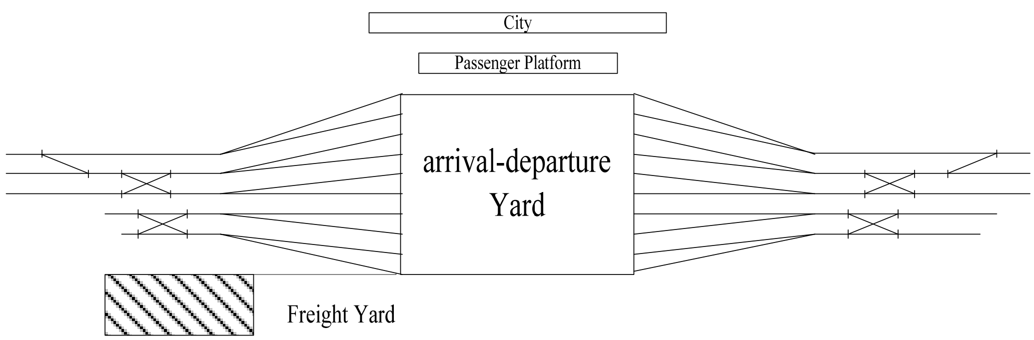

Figure 2. Modified figure of junction center station

4.3 The feasibility of transportation organization

For the mode of the high-speed train with the mixed marshalling of passenger and cargo, loading and unloading operations can be done in high-speed railway stations which are remolded in the short term. Therefore, trains can use the existing signal equipments of high-speed railway instead of switching to the existing lines. High-speed railway station should be equipped with corresponding handling equipment. According to the standard specification and weight, the cargos should be handled with corresponding handling equipment as the plans in the station stoppage time.

Furthermore, operation situations of passenger trains which have been opened at present are shown in table 3 (Gu Xuejing, 2014). From the table, operation situation of the Beijing-Shanghai passenger dedicated line is the best, and the daily operation numbers are approximate to the largest traffic capacity. The remains of traffic capacity and the low attendance opportunely provide the technical conditions for the operation of the high-speed railway freight transportation. It should be pointed out that the operation of the high-speed railway freight transportation will increase the stop time and influence the passenger service, the loading and unloading of passengers and cargos will be operated on the same platform in intermediate station, the above problems will be the focus in further research.

Table 3 Operation table of high-speed railway

High-speed railway line	Daily operation log	Attendance
The Beijing-Tianjin inter-city	90	70%
Shijiazhuang-Taiyuan	17	90%
Wenzhou-Fuzhou	31.5	-
Ningbo-Wenzhou	35	160%
Wuhan-Guangzhou	70	105%
Zhengzhou-Xi'an	15	-
Fuzhou-Xiamen	37	-
Chengdu-Dujiangyan	20	-
Shanghai-Nanjing	80	121.7%
The Nanchang-Jiujiang inter-city	9	85%
Shanghai-Hangzhou	93	80%
Nanjing-Hangzhou	86	70%
Beijing-Shanghai	112.5	107%
Beijing-Guangzhou	3	-

4.4 The feasibility of economy

At present, high-speed railway network with the longest operation mileage and fastest speed has been built in China. According to the long-term schemes of railway network, until 2020, operation mileage at the speed of 200km/h will reach 3000 kilometers. In recent years, the prosperity of electronic commerce and online shopping market prompted the rapid development of express industry in China.

The advantages of large capacity, high speed, high on-schedule rate and less influence of the climate make the high-speed railway freight occupy the advantageous position in competition of the express industries. Such a massive network of high-speed railway and the express industry with great increments provide excellent economic conditions for the rapid development of the high-speed railway freight and the cooperation between express companies and Railways Corporation.

5 Conclusions

According to analysis on the merits and demerits of six kinds of high-speed railway freight operation modes, the mode of the high-speed train with the mixed marshalling of passenger and cargo which is suitable for China's high-speed railway freight operation mode in the short term is summed up in this paper. The mode is feasible by proof in vehicle equipment, transformation of high-speed railway station, organizational technology and economy of transportation in the short term. Especially, the viable solutions are put forward to the selection and renovation of vehicle equipment and maintenance of the station freight line.

The present research works are in the primary phase, in order to realize the freight transport of high-speed railway further, specific operation lines and schemes of the mode of the high-speed train with the mixed marshalling of passenger and cargo should be researched in the further work. In addition, through the future research and renovation of the infrastructure, China's freight operation mode of high-speed railway should be the mode of high-speed freight train.

References

Wu Yunyun(2010). "Development of high-speed railway freight abroad." *Chinese railways,* Dec, 71-74.

Gu Xuejing(2014). "Study on High-speed Rail Freight Market Demand and Operation Mode in China." *School of Transport and Logistics, Beijing Jiaotong University*, Beijing, China.

Liu Qibin and Ma Guizhen(1994). "Railway station and terminal." *China railway publishing house*, Beijing, China, 36-42.

3D Model of Seaplane Domain during Takeoff and Landing Based on Ship Domain Theory

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Abstract: As the civil seaplane is an emerging industry in China, its navigation safety needs to be studied. The research on the three-dimensional model of seaplane domain provides the site supervision with technical support during taking-off and landing, and also helps to improve the safety and efficiency of navigation in the operation area. Fujii and Goodwin ship domain model are analyzed by comparison in between. Combined with the navigational characteristics and the safety requirements of seaplane during taking-off and landing, the basic theory of seaplane domain is proposed. On the basis of ship following model, the safety distance between seaplane and ship in encounter is calculated, and a two-dimensional seaplane domain model is established. Additionally, the third vertical dimension model of seaplane domain is determined by its requirements on headroom clearance to prevent collision with the superstructure of ships around. Finally, the developed three-dimensional model is applied in the case in Sanya, China.

Keywords: Seaplane; Taking-off and landing; Ship domain; Three-dimensional model.

1 Introduction

The civil seaplane is one of the important members of general aviation. Currently, the civil seaplane industry is in the initial stage in China. According to the risk factors of seaplane-vessel collision by *Weng et al. (2013)*, it stated the first civil seaplane project had settled in Sanya City, Hainan Province in 2012.

Seaplane, as a new means of marine transport in China, its navigation safety is urgent to be studied. Despite the impact of environmental factors, the navigation safety of seaplane is also strongly affected by the disturbance from small vessels around. Guaranteeing a basic seaplane domain provides the seaplanes with a safe operation during taking-off and landing, and gives the vessels around a reference of collision avoidance with the moving seaplane.

2 Seaplane characteristics

2.1 Property of seaplane as a ship

According to COLREGs by *IMO (2012)*, the third article 'General Definitions' defines 'seaplane' including any aircraft designed to be able to maneuver on the water. When the seaplane is contacting with the surface of the water, it is seen as a vessel and COLREGs apply. While it leaves the water surface, seaplane is taken as aircraft and suitable for *Aviation Rules*. According to *People's Republic of China Maritime Traffic Safety Law*, seaplanes are regarded as ships.

2.2 Features of seaplane comparing to general ships

(1) Faster speed

Compared to general ships, the speed of seaplane is significantly higher during taking-off and landing. For instance, the highest flight speed of 'SH-5' is 556km/h, and 'US2' 560km/h. Similar to the civil aircrafts on land, the first phase for taking-off is taxiing to the operation area. Upon arrival, the seaplane accelerates and takes off after the speed reaching 200 km/h or so. Generally speaking, the speed during landing is slightly lower than for taking-off.

(2) Larger taking-off and landing waters

Before taking off and after landing, the seaplanes need a long time to taxi between the berth and the operation area. Since the speed for taking-off and before landing is rather high, the seaplanes need a larger area to accelerate or decelerate. For instance, the water length for taking-off of 'SH-5' is 482m, and the landing area is 653m long. As for 'US2' from Japan, the taking-off distance is 280m, and the landing distance is 330m.

(3) More flexible maneuverability

Seaplanes have flexible maneuverability. Despite operating on the open water area, they also can take off or land on the rivers, lakes and reservoirs with the depth of 2.5m, length is 1500m and width is 200m. Some seaplanes can also use the land for taking-off and landing. *Lu et al. (2011)* have simulated the process of aircraft landing. Due to the unique structure of seaplanes, they are designed with good turning ability, anti-wave performance and flexible maneuverability.

2.3 Movements for taking-off and landing of seaplane

As shown in (Figure1) the seaplanes take off and land in a defined operation area, e.g. a circle with diameter 1000m in port of Sanya in China. After leaving the berth, seaplanes taxi to the operation area and accelerate to take off.

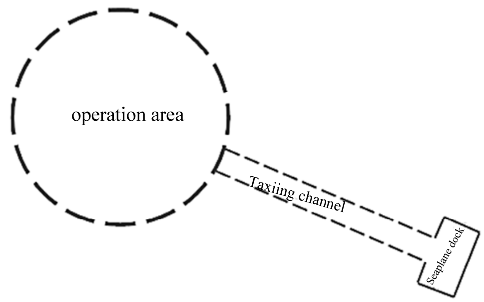


Figure 1. The operation waters of seaplane

The process of seaplane leaving the berth to taking off, the changes in speed and movement of seaplane can be divided into three phases.

(1) Taxiing

After leaving the berth, seaplanes taxi to the operation area at an average speed of 5 to 6 knots, which is similar to the sailing ships in port. In this phase, the seaplane can be regarded as a general ship and COLREGs apply.

(2) Accelerating

Upon arrival at the operation area, the pilot determines the taking-off direction according to the current meteorological and hydrological information. Normally, a direction against the wind is preferred. After receiving the order from the Aviation Control Center, the seaplane begins to accelerate and takes off when the required speed is reached. It is easy to collide with vessels around in this phase.

(3) Aerial adjusting

After taking off, the seaplane will adjust its flight direction. At this moment, the seaplane is seen as an aircraft totally.

3 Safety distance calculation based on the following theory

3.1 Safety distance between sailing seaplane and ships around

For any vehicle in movement, it will keep a certain distance with the others around to guarantee its safety. To a seaplane, it also needs to keep such a safety distance with the ships around during taking-off and landing. The distance is required to guarantee enough time for a seaplane to stop or pass with each other at a safe distance when encountering with a ship. In this way, there is a safety distance around the seaplane, which is called the seaplane domain. It is a quantitative scope of the seaplane rather than a particle, which describes the minimum distance for the safe navigation of seaplane.

3.2 Following model of seaplanes

The following theory was firstly proposed in the road traffic research. *Chen (2011)* has stated the main point of the following theory is to simulate the macroscopic traffic flow in a single lane. In such a circumstance, the cars ahead cannot be overtaken, and the behavior of the cars behind is restricted by the former one.

The ship following theory is developed on the basis of the following theory of vehicles, which simulates the vessels sailing in a one-direction channel. Since the seaplanes move in a determined direction during taking-off or landing, and the ships will be in the front or at the rear, the following theory can apply. By the analysis on the original ship following model, if a seaplane encounters with a vessel, the biggest safety distance can be obtained when the speed of vessel is lowest, and it is namely for the stationary state of the vessel. In order to ensure the largest navigation safety of ships, the revised following model of encounter between a seaplane and a vessel is shown in (Figure.2).

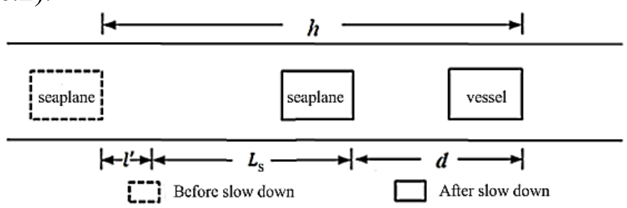


Figure 2.The following model of seaplane and veseel

According to Fig. 2, the minimum safety distance between seaplane and ship is calculated as Equation (1).

$$h = l' + L_S + d = d + Vt_r + \frac{V^2}{2a} \tag{1}$$

In which

h is the minimum safety distance between ship and seaplane; d is the safety distance between the ship's bow and the seaplane's head, l' is the sailing distance within the response time of the pilot; t_r is the response time of seaplane pilot; L_S is the stopping distance of seaplane; V is the speed of the seaplane, a is the maximum braking acceleration of the seaplane.

4 2D seaplane domain development

4.1 Applicability analysis of ship domain theory

Ship domain refers to the scope existing around the sailing vessel, which describes the distance for safe navigation. The studies on the statistical analysis of the relative positions between the ships are to obtain the shape and size of the ship domain. The most representative ship domain models are the Fujii model and Goodwin model.

According to comparative study on ship domain models by *Liu et al. (2009)*, Fujii defined the ship domain as the field around the navigating ship, in which the following ships should avoid entering into. In this way, the ship domain model is an oval.

Inspired by Fujii, Goodwin developed an asymmetrical ship domain model by the means of radar simulator, considering the impacts of COLREGs on ships' behavior for collision avoidance. According to the display range of ship's lights, the model consists of three sectors, as shown in Figure 3.

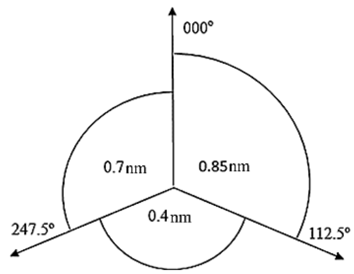


Figure 3. Ship domain model of Goodwin

Fujii determined the size and boundary of ship domain by considering the traffic capacity and the risk of collision in a channel, while the model of Goodwin considers the risk level of marine traffic, the latter is more accurate in open waters.

The core of the above two models are similar, but each of them also has its own characteristics. The research on the encountering situation in the operation area of seaplane is similar to the basic conditions of Goodwin model. Therefore, the seaplane domain model is developed according to the theory of Goodwin.

4.2 Development of 2D model for seaplane domain in operation area

Referring to the analysis of the seaplane characteristics by *Zhong et al. (1989)*, due to the flexible maneuverability of seaplanes in the operation area, the capability of collision avoidance for turning port or starboard are almost the same. Therefore, the left and right part of the seaplane domain can be seen as symmetrical.

When the seaplane is taking off and landing, the speed of the seaplane is much larger than the following ships. There is almost no following ship can overtake a seaplane. Hence, the rear part of the seaplane domain can refer to the theoretical values of the Fujii model.

Combined with the movement characteristics of the seaplane, the preliminary seaplane domain model is developed based on the theory of Goodwin as Figure 4.

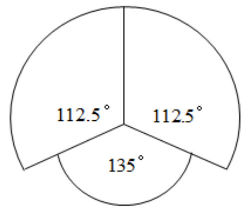


Figure 4. Preliminary seaplane domain model

The size of the two-dimensional (2D) seaplane domain is determined by the speed of seaplane. According to the analysis of the safety distance, within the range of 225 ° in front of the seaplane, the safety distance is *h*, while within the range of 135° in the rear, the safety distance is valued by half of the long axis of Fujii model, which is three times the length of seaplane.

The seaplane domain is a revision of the Goodwin model. Due to three different encounter situations between ships, the safety distance varies in different directions. In order to avoid a sharp change in the safety distance, the preliminary model is further modified. The connecting points of the lines locate at 22.5 degrees both at the left and right sides, and the radian of each arc is 45 degrees. Then a coordinate system is built up with the seaplane at the center point, as shown in Figure 5.

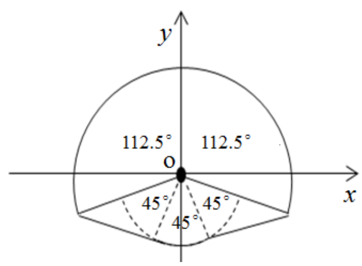


Figure 5.Coordinate system of 2D seaplane domain

In the coordinate system, the scope of the seaplane's ship domain is respectively introduced in a sectional function.

In the range of 0° to 202.5° and 337.5° to 0°, the function formula is as Equation (2).

$$x^2 + y^2 = h^2 \tag{2}$$

In the range of 202.5° to 247.5°, the function formula is as Equation (3).

$$y = -\frac{(\sqrt{2}-1)h - 3(\sqrt{2}+1)L}{(\sqrt{2}+1)h - 3(\sqrt{2}-1)L}x + \frac{\sqrt{2}h^2 - 3(\sqrt{2}+1)hL}{(\sqrt{2}+1)h - 3(\sqrt{2}-1)L} - \frac{2-\sqrt{2}}{4}h \tag{3}$$

In the range of 247.5° to 292.5°, the function formula is as Equation (4).

$$x^2 + y^2 = 9L^2 \quad (4)$$

In the range of 202.5° to 247.5°, which is symmetrical with the second situation, the function formula is as Equation (5).

$$y = \frac{(\sqrt{2}-1)h - 3(\sqrt{2}+1)L}{(\sqrt{2}+1)h - 3(\sqrt{2}-1)L}x + \frac{\sqrt{2}h^2 - 3(\sqrt{2}+1)hL}{(\sqrt{2}+1)h - 3(\sqrt{2}-1)L} - \frac{2-\sqrt{2}}{4}h \quad (5)$$

Based on the above calculation, the size and shape of the seaplane domain is determined as in Figure 6. Since the shape of the model is similar to 'scallops', the seaplane domain model is named as 'scallops model' in this paper.

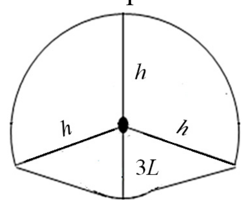


Figure 6. 2D scallops seaplane domain model

5 3D seaplane domain development

The development of s three-dimensional (3D) seaplane domain model is to avoid collision with the superstructures of ships during the climbing phase of the seaplane. The 3D seaplane domain model is developed from the 2D seaplane domain model by considering its requirement of headroom clearance after the seaplane leaving the water surface.

According to characteristics of seaplane during taking-off, set the climbing angle of seaplane as α (usually about 10°), the height above the water of the ship as *H*, and the distance which will cause collision between seaplane and ship as *d* , which is the minimum safety distance analyzed above. The parameters can be shown in Figure 7.

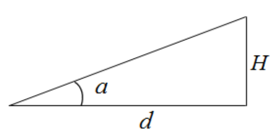


Figure 7. Trigonometry relationship between seaplane ane ship in headroom

The relation between the horizontal and the vertical distance is as Equation (6).

$$d = \frac{H}{\tan a} \quad (6)$$

The 3D coordinate system for seaplane is established as shown in Figure 8.

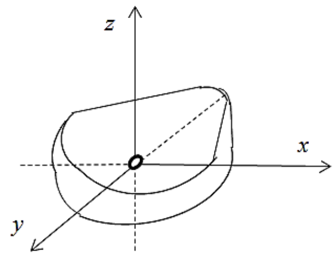


Figure 8.3D coordinate system of seaplane domain

In the 3D coordinate system, headroom requirement z varies with change in x and y as in Equation (7).

$$z=\begin{cases}\frac{H}{h}\sqrt{x^2+y^2}, & z>G\\ G, & z\le G\end{cases} \qquad (7)$$

In which, G is the height of seaplane.

According to the relations between variables in the coordinate system, a 3D seaplane domain model can be developed. The maximum length of the model is the length of 'scallops', which is the safety distance h plus three times of L the length of seaplane. The maximum width of is $2h$, which is double of the safety distance. The height of the model is the headroom for safety navigation of seaplanes. The 3D seaplane domain model is finally developed as shown in Figure9. And the orthographic views of the model are shown in Figure10.

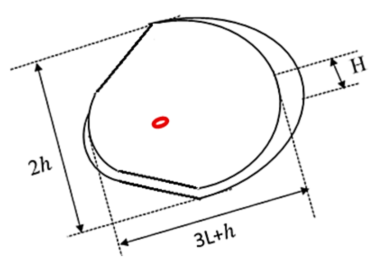
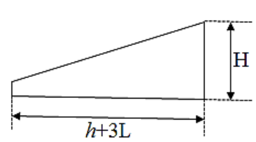
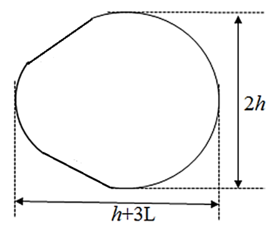


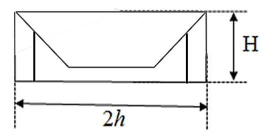
Figure 9. 3D seaplane domain model



(a) Front view of the model



(b) Top view of the model



(c) Left view of the model

Figure 10. Orthographic views of the model

The shape and size of the 3D seaplane domain is related to the parameters of both the seaplane and the ship. In this way, the length, width, and height of the model are different to different participants. According to the acquired statistics of ships and seaplanes, the size of the model can be determined. In the different phases of taking-off and landing, the 3D seaplane domain model also varies dynamically.

6 Case study

A case study is performed choosing a particular seaplane model in port of Sanya, China by *Pan et al. (2014)*. The seaplane is named VIKING DHC-6/400 (Twin Otter) with its performance parameters listed in Table 1：

Table 1.Performance parameters of VIKING DHC-6/400

Taking-off distance	Landing distance	Length	Height	Taking-off speed
374m	337m	15.77m	2.95m	180km/h

According to the study on the response time of pilots by *Xu et al. (2007)*, 0.6s is the statistical results. And the value of the seaplane pilot's response time t_r is set as 0.6s. The safety distance between the bow of the ship and the seaplane d can be obtained when the height above the water of the ship H is confirmed. In this paper H is set as 10m. The calculation results are shown in the follow Table 2:

Table 2.Parameters calculation of 3D seaplane domain model

Parameter	Value	Paramete r	Value
V	50m/s	a	43.3m/s^2
t_r	0.6s	Ls	374m

H	10m	**α**	10°
d	57m	***L***	15.77m
Parameter	***h***	**Value**	461m

On the basis of the above calculation results, when the seaplane encounters with a ship whose superstructure is 10m, the minimum safety distance is 461m. Within this distance the seaplane can avoid the collision with the ship and take off safely. Comparing the size of the 3D ship domain model designed for seaplane to the diameter of operation area 1000m (vessels are forbidden to sail in or through) set in Sanya currently, the size of the model is considerably smaller. If the exclusive area for seaplane is set according to the 3D seaplane domain, the navigation efficiency in this area is expected to increase.

Acknowledgement

The navigation safety of seaplane is affected by many factors, by the study on the process of seaplane during taking-off and landing, the three-dimensional seaplane domain model is established. The developed 3D seaplane domain model can be used as reference to set the exclusive water area for taking-off and landing of seaplane. After implementing efficient methods and means for site supervision, the safety of both seaplanes and ships can be guaranteed at a least decrease of the navigation efficiency in the area.

References

Gou, Z., Chen, Q. (2011). Influence of Safety Interval between Ships on Throughput Capacity of Coastal Fairway. Dalian University of Technology.

IMO (2012). The International Regulations for Preventing Collisions at Sea 1972 with amendments adopted from April 2012.

Liu, M., Deng, S. (2009). Comparative Study on Ship Domain Models. China Water Transport, 6.

Lu, J., Wu, G., and Wu, Y. (2011). Simulation Based on Optimized CMAC-PID Control in Process of Aircraft Landing. Computer Simulation, 4.

Weng, J., Zhou, Y. (2013a). Analysis of Risk Factors of Seaplane-vessel Collision Based on the Integration of DEMATEL and ISM. Navigation of China, 9.

Weng, J., Zhou, Y. (2013b). Analysis of Risk Factors and Safety Countermeasures of Collision between Seaplanes and Vessels Based on ISM Theory. Proceedings of the Second International Conference on Transportation Information and Safety. American Society of Civil Engineers, 2282-2288.

Pan, Z., Liu, W. (2014). Explorations and practice in the project of temporary seaplane landing field at Sanya Bay. General Aviation, 3.

Xu, X., Tian, H. (2007). The Determination of Driver's Reaction Time on Expressway. Information Technology and Information, 5.

Zhong, G. (1989). The Comprehensive Test for Take-off and Landing Characteristics of Free Flight Model of a Seaplane. Aerodynamic Experiment and Measurement & Control, 6.

Benefits of the Tram System in Zhuhai, Guangdong Province, China

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Abstract: The research focused on the new built tram system, Tram Line 1, in Zhuhai, which the tram is one kind of urban track traffic systems. Three kinds of benefits are analyzed as following. Firstly, the economic benefits have been studied including the passenger time-saving benefit and the land value-added benefit. Secondly, the social benefits, which means according to the results of the reducing traffic accidents benefit prediction model and the reducing journey fatigue model, have been analyzed. Thirdly, the environmental benefits have been analyzed, which means by using the prediction of the energy saving benefits, the reducing air pollution benefits forecasting model and the CRTN model to predict the noise effects on the surrounding environment. The paper tried to let the public fully understand the indirect and external social interests which the tram system would bring up. It also gave some suggestions for the sustainable development of the tram system.
Keywords: Economic benefits; Social benefits; Environmental benefits.

1 Introduction

The tram network system is one kind of urban track systems in China. After reviewed some literatures, this paper found that many domestic researches only focused on the financial evaluation and the national economic evaluation of a project feasible. But in the actual operation, the data of passenger flow, investment and others often appeared deviation. The model and method of economic evaluation of rail tram in the period after the whole, not a single line of cases. From the view of economic attribute, it belongs to the public product which is based on the needs of the social economy and development. For a country, the macro social benefits generated from the customers on the society or the users of the traffic are much more than the micro economic benefits generated from the constructers or the operators.

On the other hand, since 1980s', the overseas researches and academic circles paid more attention to the economic growth, the relationship between the economic development and the level of infrastructure. Alfonso (2007) proposed the infrastructure as an impact of investment on the regional economic growth and used the vector auto regression (VAR) to analyze the infrastructure system.

The project of modern tram Line 1 (ZIUPD, 2013) is the first line of tram system in Zhuhai, which the total length is about 19km. The first phase of the Line 1 is about 8.9 km including 14 stop stations and a vehicle base. The line start point is Haitian Park Station and the line end point is Shangchong Station. Line 1 is all ground line which is along the east-west route through the main areas of the city, such as Xiangzhou, New Xiangzhou and Shangchong. The carriage is 100% low-floor and steel wheels. The steel rail is 32 meters long and 2.65 meters wide. The maximum operating speed is 70 km/h. The maximum capacity of a carriage is 300 persons according to the standing standard of 6 people per one square. Along the whole line, the track structures are constructed with the whole track bed, buried rail structure and steel rail groove. The green lawn is mainly paved with some local areas using brick pavement. There are 9 island stations and 5 side stations, which are all on the ground with the open platform. The average station space is 0.7 km. The stations are designed simply and concisely with the automatic ticket vending machines and passenger information systems. The passengers can enter the station by underground walkway or intersection crosswalk line to solve the pedestrian crossing and access platform problems. The power supply adopts Ansaldo's ground power supply system which is a patent technology from Italy. Except to in the vehicle base, all the line does not have the overhead catenary line (commonly known as "braid"), which means the landscape effect is obvious. The operating control systems, including the switch control system, automatic carriage position system, signal priority system, monitoring system and wireless communication system, can control and manage the carriages to run as far as possible in accordance with the schedule to ensure the punctuality requirements. The signal for tram along the line is prior based on the green wave and active request. The total investment is 2.62 billion Yuan. For the modern tram Line 1, the average cost of the first phase of the project is about 160 million Yuan/ km.

2 Economic Benefits

The economic benefits (Jiang Yuzhen, 2002) include the passenger time-saving benefit and the land value-added benefit. The passenger time-saving benefit can be measure based on the off-job travel time-saving value. The land value-added benefit had been studied based on the real estate value-added model. In addition, the establishment of the effective and scientific return model of tram system benefits has an important theoretic and applied value.

2.1 Passenger Time-saving Benefit

Passenger time-saving benefit is a benefit of economic value that is created by passengers who save their traffic time base on the choice of tram traffic but not the traditional public buses. From theoretic aspect, the time-saving benefits of the tram passengers include the job travel time-saving value, which the tram saved the working time and improved the work efficiency, and the off-job travel time-saving value according to the welfare benefits of leisure time. The passenger time-saving benefit can be calculated according to a formula in what follows text by (1).

$$B1 = Q \times T \times G \times 50\% \tag{1}$$

B1 is the passenger time-saving benefit.

Q is the passenger traffic data per year.

T is the average saving time per person.

G is the gross domestic product per hour and per person.

50% means that the value created by people during off-job time is half of the value created during the job time.

2.2 Land Value-added Benefit

Hedonic price model (HPM) originated from the new customer theory (NCT) (Lancaster, 1966) and the market supply and demand equilibrium model (Rosen, 1974) indicates that the customers' demand for the heterogenetic goods is not based on the goods itself but based on the features or attributes of the goods. The features or attributes of heterogenetic goods are combined all together to become a feature package that can affect the benefit. The goods are sold as an aggregate of the intrinsic characteristics or features which can affect the choice of customer. In this paper, the feature variables are divided into three kinds that are the location, the neighborhood and the structure.

(1) Location Feature Variable

In the research of Adair and McMillan, they stated that the traffic reachability and the distance to CBD were the important features for the real estate price. This paper uses the distance to a tram station and the distance to the city backbone road to scale the traffic reachability. The previous literature review found that the researchers had different views on the radius of influence of a tram station, including 1 to 3 miles, 0.5 miles, 1 km, etc. Considering the habit of Chinese, the researchers chose 1 km to be the radius of influence

(2) Neighborhood Feature Variable

Clark and Herrin found that a school is the important neighborhood variable for real estate price, especially for the residential real estate price. The famous school can affect the education problem of children. The distance to a famous school is chosen to be the scale, which means that the distance is more close to a famous school the prices of real estate is more high. In addition, the public park is very important for the real estate around the park that is a place for residents to make exercises and recreations. So the famous school and the public park are the two neighborhood feature variables.

(3) Structure Feature Variable

Project scale, project type and project pre-sale year are selected as the structure feature variables. A large scale real estate project usually means a better living environment, better facilities and more standardized property management than other projects. Project types include residential, commercial and office real estate. In this paper, the focus variable of project type is residential real estate. The project pre-sale year reflects the time effect of tram system affected on a real estate project.

3 Social Benefits

The social benefits include the reducing traffic accidents benefit and the reducing journey fatigue benefit.

3.1 Reducing Traffic Accidents Benefit

The rapid growth of motor vehicles in the city resulted in the urban traffic congestion and the chaotic traffic. The number of accidents increased year by year, resulting in a huge loss. But the tram system is an isolated system because the isolated route right. So, basically, the other motorized or non-motorized vehicles and the weather can not disturb the tram system. The probability of traffic accidents on the tram is very low. The reduction of traffic accidents brings the relative social benefit.

$$B2 = M \times N \tag{2}$$

B2 is the reducing traffic accident benefit of a year.

M is the average annual cost of a bus.

N is the number of buses that need to be increased when no tram system.

3.2 Reducing Journey Fatigue Benefit

A long time journey or jam can lead to poor comfort, which the passengers may be tired and feel fatigued. But the modern tram is fast and comfortable, which reduces the journey fatigue. People can quickly enter the working state. So the production efficiency can be enhanced. According to the research result of Shi-xun Chen, the reducing journey fatigue benefit can be calculated by the following equation in the text by (3).

$$B3 = U \times H \times W \times G \times \frac{Q}{P} \tag{3}$$

B3 is the reducing journey fatigue benefit.

U is the work flow coefficient.

H is the work time of a day.

W is the increased margin of the labor productivity by tram but not by bus.

G is the gross domestic product per hour and per person.

Q is the passenger traffic data per year.

P is the round-trip work passenger coefficient.

4 Environmental Benefits

The environmental benefits (Chen, 2001) include the energy saving benefits, the reducing air pollution benefits and the reducing noise benefit.

4.1 Energy Saving Benefits

The traditional bus uses fuel but the tram' driving force is the electricity. The average energy consumption of a traditional bus is 670 kJ per person and per kilometer, which the energy consumption per unit of a traditional bus is 2.8 times than that of a tram vehicle. So the saving energy of a tram sending one person for a kilometer is about 430.7 kJ (Wang, 2011).

4.2 Reducing Air Pollution Benefits

The pollution caused by fuel combustion is the main impact of transport tools on the environment. With the increasing number of motor vehicles, the concentration of pollutants in the air is increasingly high. Compared with the motor vehicles, the modern tram vehicles can greatly reduce the release of harmful gases and respirable particulate matter. The modern tram vehicle has no direct release of gases, but its pollution comes from the energy consumption process of electricity, which is an indirect emission of the pollutions.

4.3 Reducing Noise Benefit

The noise caused by road traffic accounts for about 70% to 80% of the total urban noise. The noise does not only disturb the people's normal life, but also reduce people's work efficiency. The modern tram vehicle using steel wheel, steel rail and streamlined design can minimize the noise pollution. Based on the Calculation of Road Traffic Noise (CRTN, 1988) prediction model, the reducing noise benefit can be calculated by the following equation in text by (4).

$$B4 = 0.1 \times \sum_{i=1}^{n} H_i \times C_i \tag{4}$$

B4 is the reducing noise benefit.

H_i is the i-th residential district needed to reduce the noise along the line.

C_i is the installation cost of soundproofing for i-th residential district.

5 Conclusions

The public traffic problem is a very important factor that constricts the rapid development of the city. In the future, the backbone traffic system in the big cities will be modern tram system because it is safety based on the well-organized operation and is comfortable for the passengers. It can combine the economic benefits, the social benefits and the environmental benefits organically together to generate some enormous and external long-term benefits.

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References

Alfonso Herranz-Loncan (2007). "Infrastructure investment and Spanish economic growth, 1850-1935." *Explorations in Economic History*, 3.

Chen Zuo (2001). "Urban Track Traffic's Influence on the Environment." *China Railway Science*, 6, 126-132.

CRTN (1988). "Calculation of road traffic noise." *Department of Transport/Welsh Office*, London.

Jiang Yuzhen, and Zhang Weijin (2002). "Urban Track Traffic and Urban Economic Development." *Urban Track Traffic Research*, 4, 12-18.

Lancaster (1966). "A New Approach to Consumer Theory." *Journal of Political Economy*, 74 (2), 132.

Rosen (1974). "Hedonic prices and implicit markets: Product differentiation in pure competition." *Journal of Political Economy*, 82 (1), 34-55.

Wang Yancai (2011). "The Preliminary Research of the Applicability of Modern Trams ." *Dissertation of Nanjing Forestry University*.

Yang Wenjun (2014). "The Tram Line One Planning." *Zhuhai news network*, http://www.zhnews.net/old/jryw/index/content/136393 (Oct. 6, 2014).

Zhuhai Institute of Urban Planning & Design (ZIUPD). (2013). *Zhuhai Modern Tram Line One Planning*, Zhuhai, China.

Optimization of Transport Capacity Combinatorial Procurement in Container Sea-Rail Intermodal Transport

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Abstract: Optimization of transport capacity combinatorial procurement facing the actual carrier is an important decision that affects the operation efficiency and competitiveness of the non-vessel operating common carrier (NOVCC) type of sea-rail intermodal transport operator. Based on the hub-and-spoke network structure of container sea-rail intermodal transport, this paper conducts comprehensive consideration of sea-rail intermodal transport demand in various OD markets, capacity limitations of shipping liners and regular railway trains, connections between space and time and so on from the perspective of multimodal transport operators (MTO). In order to minimize the total cost, the slots volume of procurement based on combinatorial selection in shipping liner and regular railway train is as the decision, an optimization model of transport capacity combinatorial procurement in container sea-rail intermodal transport is established, and an algorithm is designed for solving. The experimental results show that the model and algorithm are feasible, and achieve good application effect.
Keywords: Container transport; Sea-rail intermodal transport; Transport capacity procurement; Optimization model.

1 Introduction

The container sea-rail intermodal transport is the multimodal transport mode of container cargoes which is organized by multimodal transport operator (MTO) and completed jointly with the actual carriers within the shipping and railway transport sections. The MTO shall not only provide container transport services for the shipper as the carrier, but also purchase the transport capacity resources of the above transport services from the actual shipping and railway carriers as the shipper. Therefore, it has become a difficulty for the MTO to take a systematic and scientific method to optimize the procurement in transport capacity combination under different modes of transport and transport routes, in order to effectively carry out the container sea-rail intermodal transport.

At present, the problem of transportation services procurement in container multimodal transport has attracted the attention from many scholars. Chang, et al. (2010) established the optimization model of multimodal transport for the international container in Korea highway, railway and near-sea shipping line with the objective of achieving minimum total transportation cost and the external cost caused by air pollution. Fan, et al. (2010) optimized the container sea-rail intermodal transport network of the United States imports by adopting the theory of linear programming and with the minimum total cost of rail-sea intermodal transport as the objective function. Wang and Wang (2012) studied the selection of container type and combinatorial optimization of modes of transportation in container multimodal transport system; established the mathematical model to minimize the transportation cost under condition of fuzzy demand, and optimized the algorithm solution by using the improved particle-ant colony. Riessen, et al. (2013) studied the multimodal transport network planning of the Rotterdam Port and between the inland points of northwestern Europe, and established the network programming model combining route combination with minimum network flow. Wang, et al. (2011) studied the mode of transportation and route selection model of multimodal transport based on the random characteristics of node operations in the process of modes of transportation conversion. Fan and Le (2011) established the mathematical programming model on route optimization of multimodal transport with soft time window constraint based on the random factors in intermodal transport. Jiang, et al. (2012) studied the solution selection of multimodal transport plan minimizing the transportation cost and transshipment cost, and put forward the cross entropy algorithm.

To sum up, most of the existing studies focus on the procurement in transportation services from the perspective of the shipper for the demand of once transport between single pair of OD market, and with minimum cost or time as the goal and route selection as the decision under the general multimodal transport network structure. However, existing studies have not yet considered the unique hub-and-spoke network structure of container sea-rail intermodal transport and slot volume purchased by the MTO under the scale operation. Therefore, this paper will study long-term transport capacity procurement facing the actual shipping and railway carriers from the perspective of MTO. Considering the time and space connectivity between shipping and railway transport, slot volume of procurement based on route selection is set as the decision and minimum total cost is as the objective, this paper will study the optimization model of transport capacity combinatorial procurement in container sea-rail intermodal transport and its solution methods, so as to provide scientific decision-making tool for the operation and management of MTO.

2 Problem Description

The NOVCC type of sea-rail intermodal transport operators do not own any transportation resources directly, and the allocation process of their transportation resources include purchase stage and allocation stage. In the first stage, first of all, the MTO should plan the sea-rail transport lines or network to be operated based on the investigation and prediction of long-term market demand, and then sign the purchase agreement with the actual carriers for certain amount of transport capacity within a certain period of time, so as to obtain a certain number of slots operation right on the shipping liners and regular railway trains within a lower contract price. This method not only can ensure relative stability of transportation capacity, but also reduce the operating costs, which is conducive to the realization of scale economies. In the second stage, the MTO, acting as the contractual carriers, should sign the sea-rail transport contracts with each shipper within the delivery time of each shift, and allocate the transportation capacity to each shipper rationally, in order to meet the differentiated demand of shippers. In fact, this paper studies the problem in the first stage, which is the optimization of transport capacity combinatorial procurement in container sea-rail intermodal transport facing the actual carriers.

Assume that the sea-rail intermodal transport network to be operated by the MTO is a "hub-and-spoke network" structure with two ports as the hub and radiating to their own hinterlands, of which A and B are the two hub ports; $A_1, A_2, \cdots, A_m$ are the interior hinterland railway container freight stations of port A, and $B_1, B_2, \cdots, B_n$ are the interior hinterland railway container freight stations of port B, as shown in Figure 1.

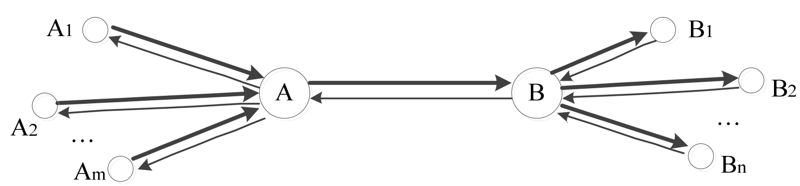

Figure 1. Hub and spoke network structure diagram of container sea-rail intermodal transport

Generally, the two-way sea-rail intermodal transport market demand at both ends of A and B is independent each other, so the MTO can adopt the strategy of one-way purchase of transport capacity respectively. This paper discusses the transport capacity combinatorial procurement decision-making in container sea-rail intermodal transport from end A to end B, as shown in Figure 1 in bold lines. Suppose that there is only one marine container liner between the hub port A and B, and a number of regular railway container trains for branch collecting and dispatching between the hub port A and B and their own inland railway freight stations. The shipping liner and each regular railway train have their own fixed transport routes, transport time, transport schedule, transport capacity (slot capacity) and transport rates. Therefore, it is necessary for the MTO to conduct comprehensive consideration of the space and time convergence of each liners and regular train, and limitations of slot capacity when conducting transport capacity combinatorial procurement decision-making. In addition, the MTO needs to determine the routes and shift of trains to be purchased in given network and the slot volume to be purchased on corresponding trains with the objective of minimizing the total cost, in order to meet the demand in each OD market formed between various inland railway freight stations of port A and various inland railway freight stations of port B.

3 Optimization Model and Algorithm

3.1 Symbolic description

(1) Relevant parameters:

i is the number of railway line from A_i to A, $i \in \{1,2,\cdots,m\}$; j is the number of railway line from B to B_j, $j \in \{1,2,\cdots,n\}$; h is the shift number of regular train on line i, $h \in \{1,2,\cdots,M_i\}$; f is the shift number of regular train on line j, $f \in \{1,2,\cdots,N_j\}$; k is the shift number of shipping liner from A to B, $k=1$; Q_{ih} is the slot capacity of regular train h on line i; Q_{jf} is slot capacity of regular train f on line j; Q_k is slot capacity of liner k; C_{ih} is slot procurement price of regular train h on line i; C_{jf} is slot procurement price of regular train f on line j; C_k is slot procurement price of liner k; T_{ih}^1 and T_{ih}^2 are departure and arrival time of regular train h on line i respectively; T_{jf}^1 and T_{jf}^2 are departure and arrival time of regular train f on line j respectively; T_k^1 and T_k^2 are departure and arrival time of liner k respectively; T_A and T_B are fixed loading and unloading time of port A and port B respectively; $\bar{D}_{AiBj}$ and $\underline{D}_{AiBj}$ are upper and lower limit of predicted container sea-rail intermodal transport demand value from A_i to B_j respectively.

(2) Decision variables:

ρ_{ih} is a 0-1 decision variable, referring to whether the MTO purchases the transport capacity of regular train h on line i; ρ_{jf} is a 0-1 decision variable, referring to whether the MTO purchases the transport capacity of regular train f on line j; x_{ih} is slot volume purchased by the MTO from regular train h on line i; x_{jf} is slot volume purchased by the MTO from regular train f on line j; x_k is slot volume purchased by the MTO from liner k.

3.2 Model building

The optimization model of transport capacity combinatorial procurement in container sea-rail intermodal transport can be described as:

Objective: $$\min z = \sum_{i=1}^{m}\sum_{h=1}^{M_i} C_{ih}\rho_{ih}x_{ih} + \sum_{k=1}^{K} C_k x_k + \sum_{j=1}^{n}\sum_{f=1}^{N_j} C_{jf}\rho_{jf}x_{jf} \quad (1)$$

Constraints: $\rho_{ih}x_{ih} \le Q_{ih}$, $\forall i, \forall h$ (2)

$$\rho_{jf}x_{jf} \le Q_{jf}, \quad \forall j, \forall f \tag{3}$$

$$x_k \le Q_k, \quad k=1 \tag{4}$$

$$\sum_{j=1}^{n} \underline{D}_{AiBj} \le \sum_{h=1}^{M_i} \rho_{ih}x_{ih} \le \sum_{j=1}^{n} \overline{D}_{AiBj}, \quad \forall i \tag{5}$$

$$\sum_{i=1}^{m} \underline{D}_{AiBj} \le \sum_{f=1}^{N_j} \rho_{jf}x_{fj} \le \sum_{i=1}^{m} \overline{D}_{AiBj}, \quad \forall j \tag{6}$$

$$\rho_{ih} = \begin{cases} 1, & T_{ih}^2 + T_A \le T_k^1 \\ 0, & T_{ih}^2 + T_A > T_k^1 \end{cases}, \quad \forall i \forall h \tag{7}$$

$$\rho_{jf} = \begin{cases} 1, & T_k^2 + T_B \le T_{jf}^1 \\ 0, & T_k^2 + T_B > T_{jf}^1 \end{cases}, \quad \forall j \forall f \tag{8}$$

Among them, formula (1) is the objective function, indicating that the total cost that the MTO purchases the transport capacity from the actual carriers is minimum.

Formula (2), (3) and (4) are the capacity constraints, indicating that the slot volume purchased by the MTO from one regular train or liner shall not exceed the maximum slot capacity of that regular train or liner;

Formula (5) and (6) are demand constraints, indicating that the sum of slot volume purchased by the MTO from various trains on a certain line shall meet the demand of all OD markets through that line;

Formula (7) and (8) are the 0-1 variable constraints, indicating that if the arrival time of the fore shift plus the handling time in a certain port earlier than the departure time of the rear shift, select to purchase the transport capacity on that shift; otherwise, do not purchase it.

3.3 Algorithm design

In the above mathematical model, the 0-1 constraints in formula (7) and (8) exist, which are used for screening whether the transport capacity of the train is purchased by using time convergence conditions, so the model is a nonlinear programming problem. Therefore, the following algorithms are designed in this paper:

Step 1: Determine ρ_{ih} and ρ_{jf} of 0-1 decision variables first, that is determine whether the MTO can choose the transport capacity of a train on a line to purchase slots according to the time convergence conditions constraints of formula (7) and (8);

Step 2: Substitute ρ_{ih} and ρ_{jf} of 0-1 decision variables determined in step 1 into the model, and transform the above model into the standard model of general linear programming problem.

Step 3: For standard linear programming model, design the program algorithm of the objective function constraints by using the solving syntax of software LINGO, and then solve the function and optimize the model.

4 Example verification

It is supposed that a MTO operates container sea-rail intermodal transport in the hub-and-spoke network with two hub ports. Take the transport capacity combinatorial procurement in this network as an example, to verify the above model and algorithms.

Suppose that there are 3 railway container freight stations in interior hinterland of port A and B respectively, namely A_1, A_2, A_3 and B_1, B_2, B_3. There is only one sea route and one liner from port A to port B, and its departure time and arrival time are known and fixed. Furthermore, there are many trains with different departure time and arrival time on each line from the inland handling stations A_1, A_2, A_3 to port A and from the inland handling stations B_1, B_2, B_3 to port B. According to step 1 of the above algorithm, with time cohesion constraint, we can determine the shift selected to be purchased by the MTO on the inland routes, as shown in Table 1.

Table 1. Situation of routes and shift selected to be purchased by the MTO

Line	Number of line	Number of shift	Price (yuan/TEU)	Slot capacity (TEU)
A_1-A	1	1	3 185	130
A_2-A	2	1	2 539	120
		2	2 235	100
A_3-A	3	1	1 560	150
B-B_1	1	1	4 562	90
		2	4 136	100
B-B_2	2	1	1 685	160
B-B_3	3	1	2 780	100
		2	2 489	80
A-B	1	1	4 576	3000

The MTO has obtained the demand of sea-rail intermodal transport in various OD markets according to the long-term investigation and forecast of sea-rail intermodal transport between the interior hinterlands of port A and B, as shown in Table 2.

Table 2. Predicted sea-rail intermodal transport demand in various OD markets

Line	Lower limit of demand (TEU)	Upper limit of demand (TEU)
A_1-B_1	30	50
A_1-B_2	40	90
A_1-B_3	50	70
A_2-B_1	70	90

A_2-B_2	60	70
A_2-B_3	80	80
A_3-B_1	50	70
A_3-B_2	50	60
A_3-B_3	40	50

Running the solving programs designed by software LINGO, we can obtain the optimization results of transport capacity combinatorial procurement in sea-rail intermodal transport conducted by the MTO, as shown in Table 3.

Table 3 Optimization results of transport capacity combinatorial procurement in sea-rail intermodal transport

Line	Number of line	Number of shift	Slot volume (TEU)	Objective value (yuan)
A_1-A	1	1	120	4 597 880
A_2-A	2	1	110	
		2	100	
A_3-A	3	1	140	
B-B_1	1	1	50	
		2	100	
B-B_2	2	1	150	
B-B_3	3	1	90	
		2	80	
A-B	1	1	470	

As seen from Table 3, the MTO conducts an effective transport capacity combinatorial procurement on the railway section and shipping section, which can not only meet the sea-rail intermodal transport demand in various OD markets, but also realize the goal to minimize the total cost under the optimization of time convergence, which lays foundation for the next allocation of transport capacity.

5 Conclusions

This paper focuses on the study of long-term transport capacity combinatorial procurement decision-making facing the actual carriers from the perspective of MTO. First of all, this paper conducts comprehensive consideration of sea-rail intermodal transport demand in various OD markets, capacity limitations of shipping liners and regular railway trains, connections between space and time. Furthermore, , this paper set the slots volume of procurement based on combinatorial selection in shipping liner and regular railway train as the decision, and established an optimization model of transport capacity combinatorial procurement in container sea-rail intermodal transport with the objective of minimum total cost. Finally, an algorithm is designed for solving.

This paper breaks through the boundary that the existing studies only focus on the transportation services for the demand of once transport under general ultimodal transport network, and studies the method of long-term transport capacity combinatorial procurement by the MTO under the scale operation based on the unique hub-and-spoke network structure of sea-rail intermodal transport. This study provides a new perspective of management and scientific technical support for the operation and organization of container sea-rail intermodal transport. The future research can focus on further improvement and in-depth study on the model and algorithm based on the hub-spoke network structure of multiple hub ports, demand uncertainty and other factors.

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References

Chang Y. T., Lee P., Kim, H. J., et al. (2010). "Optimization Model for Transportation of Container Cargoes Considering Short Sea Shipping and External Cost." *Transportation Research Record: Journal of the Transportation Research Board*, 2166, 99-108.

Fan, L., Wilson, W. W., and Tolliver, D. (2010). "Optimal Network Flows for Containerized Imports to the United States." *Transportation Research Part E-logistics and Transportation Review*, 46(5), 735-749.

Fan, Z. Q., and Le, M. L. (2011). "Research on multimodal transport routing problem with soft time windows under stochastic environment." *Industrial Engineering and Managemen*, 16(5), 1-5. (in Chines)

Jiang, Y., Zhang, X. C., and Wang, Y. L. (2012). "A Cross-Entropy Method for Solving Selection of Multimodal Transportation Scheme." *Journal of Transportation Systems Engineering and Information Technology*, 12(5), 20-25.

Riessen, B., Negenborn, R. R., Dekker, R., et al. (2013). "Service network design for an intermodal container network with flexible due dates/times and the possibility of using subcontracted transport." *Econometric Institute Research Papers*, (6), 1-16.

Wang, H., and Wang, C. X. (2012). "Selection of container types and transport modes for container multi-modal transport with fuzzy demand." *Journal of Highway and Transportation Research and Development*, 29(4), 153-158.

Wang, Q. B., Han, Z. X., Ji, M. J., et al. (2011). "Path Optimization of Container Multimodal Transportation Based on Node Operation Randomness." *Journal of Transportation Systems Engineering and Information Technology*, 11(6), 137-144. (in Chines)

Railway Passenger Dynamic E-Business Based on Web Services and RFID

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Abstract: E-business is a great challenge and opportunity to the railway passenger transportation. Through detailed analysis of the current situation of railway passenger transportation system, the logic structure and function framework of dynamic E-business system based on Web services and RFID technology in railway passenger transport are designed, which is excellent interoperability, reliability and maintainability, and will be the trend of railway passenger E-business development. Considering the current situation of railway ticket system and the operation features of the future passenger-dedicated line, the general framework of RFID-based China railway ticket system is put forward, and the key technologies of the system include: safety control system which consists of information coding, key management, access authentication, data integrity audit; the design of ticket reader compatible with multi-tickets; and the application whose characteristics reflected in the flexible check-rule control strategies, efficient gate access and fast payment self-service ticketing.

Keywords: Railway dynamic E-business; Web services; RFID; E-ticket; SSL protocol; Double signature.

1 Introduction

With the growth economy and the continuous improvement of quality of life people demand, as well as rapid popularization and wide application of information technology and network technology in China, the developing trend from the conventional business activities to E-business between enterprises as well as between enterprises and customers is inevitable.

The railway, as the main artery of China's economic construction, aims to provide a safe, efficient and convenient transportation service. Therefore, the dynamic E-business systems of railway passenger transportation which is on the basis of RFID and Web services technology will undoubtedly accelerate the information and intelligence processing, which meet the operation demand of high passenger flow and high density of high-speed passenger-dedicated line. As a result, the efficiency and automation level of fare collection are further improved and the passenger fatigue of ticketing and travel is reduced and logistics and supply chain management (SCM) are also improved, which enhances the market competition ability of passenger railway transportation in China.

2 Logic structure of railway passenger dynamic e-business system

The characteristics of dynamic E-business are to design the reusable and flexible components in respect with modeling software which is in accordance with business process.

By technical modularized and standardized means, the inter-enterprise distributed isomerous and loose-coupled application resources are modularly packaging. Moreover, the inter-module dynamic connection and messaging are realized on the basis of standard interfaces and protocols. With dynamic E-business, enterprises can instantly search for business partner, which realizes the timely search and fast dynamic integration of enterprise resources as well as provides the business processes and the dynamic extension and connection function of customers and manufacturers with enterprises (Li, 2002).

From the perspectives of technology, the railway dynamic E-business system based on Web services and RFID technology is made up of railway external network, railway dynamic E-business platform and railway internal information network Intranet. The main difference between the railway dynamic E-business system and the conventional railway E-business system is that it can provide a consistent interface for the various E-business software applications and public services (such as customer relationship management, supply chain management, etc.) support, which can integrate railway partners including suppliers, distributors, service providers and banking via Internet to form a complete end-customer-oriented E-business supply chain. Based on the consideration of the technical support from hardware and software of E-business system together with the reality of railway passenger transport, the logical structure of railway passenger transport dynamic E-business system to be built is shown in Figure 1.

The data center is the operation foundation of railway passenger dynamic E-business system. On the one hand, E-business platform provides data support and accept the information feedback from the platform in the meantime. On the other hand, the data center needs the support from the information acquisition based on TDCS, TMIS and RFID-based ticket system. The data center accepts the information from two aspects at all times and implements data updating in time. With the support of the railway passenger dynamic E-business platform, E-business system provides dynamic service for users through the specific E-business software and hardware.

The railway dynamic E-business system transforms from mainly dealing with business itself which means consumer request from the front-end to mainly dealing with back-end commercial trade and business contact which means dealing with back-end interaction of supply chain rather than the early human-computer interaction mode which B2C leads.

(l) Through open standard protocols, the dynamic E-business simplifies the integration and transaction processing of the railway enterprise and E-business related business systems.

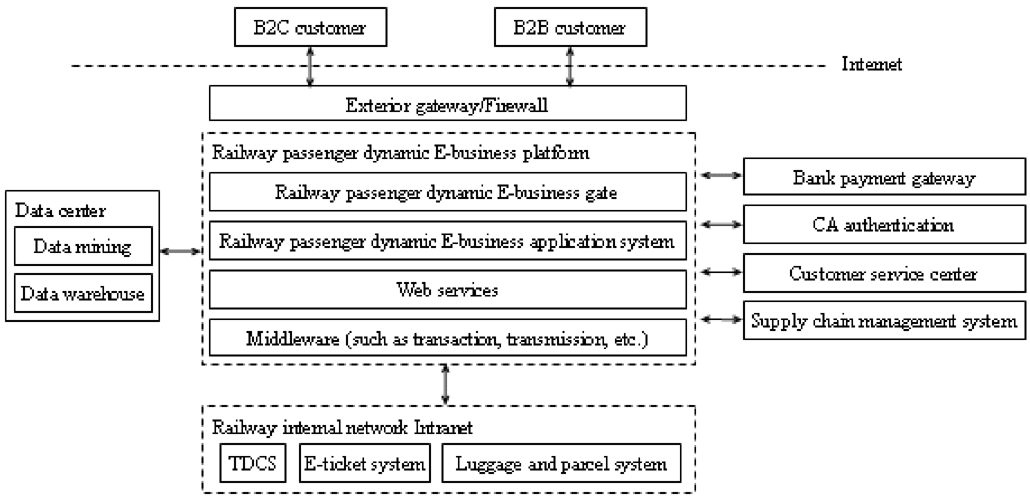

Figure 1. Logic structure of railway passenger dynamic E-business system

(2) The dynamic web pages can provide the personalized service for the customers such as passengers, business-partners and etc. In the environment of internet, the customer basic data is collected in all in the background database. Moreover, the business analysis carried out by means of data mining technology to understand the characteristics and category of customer group. According to the demand type and the consumption tendency, the related services are dynamically offered to the customer.

(3) After the packaging applications by Web services, it facilitates service integration and service customization, which realizes the information query of the ticket and the baggage and parcel as well as the omni-bearing service such as internet booking, online payment, acceptance of complaint and other value-added service.

(4) Improve the logistics and supply chain management. Through Web services, the integration of information platform between railway enterprises and the partners is realized. In addition, the information of the upstream and downstream enterprises in the supply chain is connected, which realizes the transformation of the railway from the logistics undertaker into the organizer of logistics supply chain and also improves business operation level.

3 Function structure of railway passenger dynamic e-business system

The railway passenger dynamic E-business system can simultaneously provide the decision support for the traveler and the railway transportation organization department, and the function structure is shown in figure 2.

(l) Data accessing layer. The information in the existing business system is extracted to realize resource sharing. The data source in railway system includes the file-type data and the real-time data of railway transportation production besides the traditional relational data.

(2) Data processing layer. It includes middleware, transaction processing, system data classification, mining and so on, which realizes the functions such as uniform data access, data conversion and data exchange. Data isolated island is eliminated to realize the unified management of distributed data source through data integration. However complex the bottom data source is, data access can be implemented in uniform method in all the upper application by means of changing data access into Web services.

(3) Business processing layer. It is the processing core of the railway passenger dynamic E-business system. On the one hand, data is accepted from application layer, which is sent to corresponding payment interface after filtering and integrating to realize online payment, authentication interface and other application program interface. On the other hand, business data, office data and etc. are transferred to general data stream in the bottom database. This layer takes advantage of Web services technology to package the enterprise application program into Web services, which becomes the application module. Through the established Web services interface, other systems can be connected with these Web services at any moment to complete the application integration of B2B and achieve the railway passenger dynamic E-business.

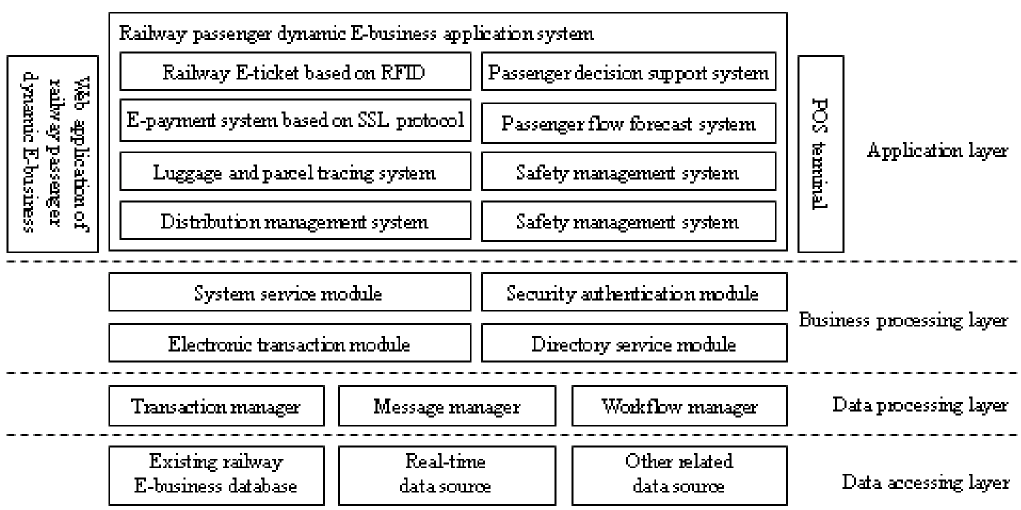

Figure2. function structure of railway passenger dynamic E-business system

(4) Application layer. It is a specific business interface which orients the railway passenger dynamic E-business system, which is the communicating bridge between the user and the system and includes the B2C application and the B2B application.

4 Railway E-ticket based on RFID

The Radio Frequency Identification (RFID) is a technology of non-contact automatic identification, which identifies target objects automatically by radio frequency signal, and obtains related data. The identification course is self-service, which has many advantages, such as long service life, good anti-collision quality, long working distance, high working speed, encrypted label data, large memory capacity, modification freely stored information and so on. Railway E-ticket based on RFID has become an important part of railway passenger dynamic E-business system.

4.1 General structure of RFID-based railway ticket system

The RFID-based railway ticket system can divide into five layers by function: the first layer is the Ministry data center; the second layer is the regional ticket data center operating on railway bureau or railway passenger-dedicated line dispatching center; the third layer is the passenger ticket system operating on owned station; the forth layer is the station AFC terminal devices, which include window ticketing machine, ticket vending machine (TVM), automatic gate machine (AGM) and so on; the fifth layer is various ticket, that is RFID single journey ticket, RFID season ticket, RFID stored-value card and so on (Zhu,2006).

The functions realized by railway ticket system based on RFID include existing operation management, transaction processing, business management, seat management, route computation, fare computation, revenue management, statistics, system management and monitoring and so on. The business functions of season ticket management, stored-value card management, passenger information management, liquidation and settlement are added. The key devices of system include ticket reader RFID-based compatible with multi-tickets and automatic fare collection (AFC) device, the application software include single journey ticketing, season ticket and stored-value card issuing, and the subsystems of stored-value card automatic ticketing, single journey ticket and season ticket checking and so on.

4.2 Key technologies of railway ticket system based on RFID

(1) Security control

According to the railway ticket rules, the read-only unique identification code (ID) of RFID chip is coded and the authentication units such as encryption bits, parity bits and so on are set. Then the non-meaning sequence code is changed into the meaning pseudorandom code to enhance the anti-counterfeiting capability which can prevent most of the active attack (GARFINKEL,2006).

Key management system is the security core of RFID-based ticket system which runs through the life cycle of the RFID-based ticket usage. By means of the key management system of multistage and dispersion, it realizes the functions such as generating, inputting, outputting, backing up, recovering, updating, destructing and etc. of the various sub-keys which the RFID-based ticket needs in the application system. The whole key system use the DES/3DES encryption algorithm and the key is stored in the key card in the form of key card which transmits in the system in security message mode, that is to say using 3DES cipher-text + MAC which means the key plaintext inside the system can not appear outside the card to guarantee the confidentiality and integrity in the transmitting processes.

The non-contact read-write equipment and IC card are mutually authenticated through the external authentication key and the internal authentication key. While the external authentication means that IC card's legitimacy identification for the equipment, the internal authentication means that the equipment's legitimacy identification for IC card. In order to guarantee the transaction legitimacy, 2 times of authenticated transactions are carried out through 2 MAC. Before the deduction, the IC card authenticates MAC1 which the equipment generates. After the deduction, the equipment authenticates MAC2 which the IC card generates.

(2)RFID-based reader and writer

With the implement of RFID-based railway ticket system, AGM can read and write the single journey ticket, the season ticket and the stored-value card which take advantage of different technology. The choice of read- write device is the key to guarantee high passenger passing efficiency. Moreover, the read- write device is directly related to the ticket system and also different ticket demands different handling of the read-write device (Wang,2008).

In order to adapt the RFID-based ticket based on the different technology standard, the read- write device supports multiple card standard including A-class, B-class and Felica-class based on ISO14443 standard, NFC standard, ISO15693 standard and etc. which is in accordance with PBOC2.0 standard to facilitate the connection with the commercial bank or the union pay system. The read- write device sets several SAM card holders to be compatible with different E-payment mode.

(3)Application system

The automatic gate system is not only compatible with multi-tickets read-write, but also its control software take advantage of the multithread structure design to realize the real-time detection and data processing for the multi-tickets. In order to improve the flexibility of the system, the checking plan and the accounting rules are stored as a unique file. The control software interprets the checking plan and the accounting rules through the internal rule engine so as to decrease the system coupling degree (Wang,2008).

Based on the combination of the application of the technology such as the process and thread pool, the workflow management and so on, the automatic gate software system with clear business state and flexible architecture is designed to increase the passenger ticketing speed. Compared with the cash payment, the stored-value card payment reduces the service links such as cash recognition, change and etc. Compared with the bank card payment, the stored-value card payment reduces the conversion and data resolution of the complex interface protocol in bank system. While the typical time of the transaction process in cash payment is 2 min, the bank card payment and the stored-value card payment is just 3s.

5 Conclusions

The development of dynamic E-business from information sharing and simple transaction to the application sharing and cooperative transaction is the new trend of railway E-business development. By using web services technology, the railway dynamic E-business system has many advantages, such as good interoperability, reliability and maintainability. It can realize the interoperation between the trade partners by integrating the existing application system, and is an effective method to process B2C and B2B E-business application integration. As an important part of railway passenger dynamic E-business system, ticket system adopts RFID technology to modify the current ticket system in both software and hardware, and it realizes the automatic fare collection, improves the passenger traveling efficiency, and makes it possible to collect passenger transport information. Secure E-payment system is the key of E-business, and the railway passenger E-payment system is based on the improved SSL protocol. By using the double signature technology in SSL protocol, the safety in trade is increased, and the transaction cost is reduced.

Acknowledgement

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References

LI J. (2002). Web services of dynamic E-business. Beijing: Tsinghua university press

ZHU J, SHAN X, ZHOU L. (2006). The Research and Implementation of China Railway Ticketing and Reservation System (TRS) Version 5.0. China Railway Science, 27 (6), 95-103

GARFINKEL S, ROSENBERG B. (2006).RFID Applications, Security, and Privacy. New Jersey: Addison-Wesley, 34-85.

WANG C. (2008). The Application of RFID in Railway Ticketing and Reservation System. Beijing: China Academy of Railway Sciences, 25-69.

Research of Complementarities between Rail Transit and Conventional Buses

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Abstract: With the acceleration of urbanization process, the problem of urban traffic is increasingly prominent. In particular, there is a dispute about whether to cancel the existing conventional rail transit buses after the rail transit goes into operation. This paper comes up with BP neural network model basing on the principle of complementarities, by analyzing the relationship between running rail and conventional public transport, and solves the problem of the adjustment of regular bus lines under the operations of both collinear.
Keywords: BP neural network; MATLAB; Complementary.

1 Introduction

Residents travel mode choice behavior research as an important part of traffic demand planning（Moshe, 1998）has always been an important content in research of transportation planning. When the rail transportation is in operation, whether to delete the original collinear bus lacks of theoretical basis. Therefore, this paper proposes the complementary relationship to determine whether the both could coexist.

Through learning the neural network we can establish BP neural network model which could automatically obtain the object of study of the relationship between input and output and strong learning training abilities. By using the model to predict the results of the transportation options and calculate the share rate of rail and bus. Finally, the levels of service are compared of coexist and non-coexist.

2 The Rail Transit and Conventional Public Relations Research

2.1 Function and location

Urban public transportation is a large system composed of a variety of public transportation. Each has its particular transportation service object and function. All kinds of transportation orderly form the system of urban public transportation through the cooperation of labor division and mutual coordination. Rail transit and conventional bus are the two most common modes of transportation in the system of public transportation. Here is the relationship among three kinds of different types of bus and rail transit shown in Figure 1.

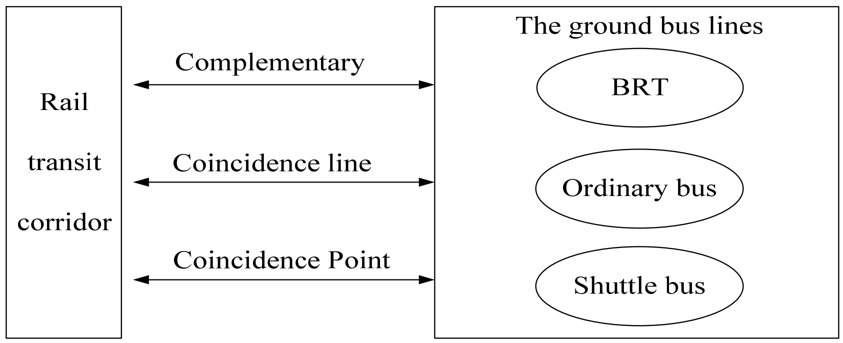

Figure 1. The relationship between rail transit and ground bus lines

2.2 The cooperation and competition of the rail transit and bus

The different modes of transportation are interdependent in the system of urban transportation, according to the different travel demand of urban residents. Therefore, any kind of transportation services are indispensable. The transportation passengers select to complete a trip will be diversified, and therefore, which requires the orderly combination of different modes of transportation, mutual coordination, and better service for residents to travel. At the same time, there are competition relations, both of the urban rail transit and conventional public traffic service object is usually urban residents, the service area is generally limited to the scope of the city and surrounding, service content, goals, and achieve results are consistent. So, faced with the same service object and range, there is inevitably a competitive relationship between providing urban rail transit and conventional public.

2.3 Complementary study theory of rail transit and conventional bus

2.3.1 Complementary theoretical implications

Complementary applies in many professional fields. In economic, the definition of complementary is reducing of costs or increasing of earnings caused by this kind of behavior of individuals, with the number of people taking some sort of behavior or the behavior itself is increasing. (Huapu,1998). As you can see both sides of the complementary is complement and promotable to each other, while directing the common to the right way. At first, the concept of complementary originated in the field of physics, the so-called "complementary", Bohr explained: "complementary is the meaning of the word: any determinable application of the concept of some classic will eliminate some other concept of classic application at the same time, the other concept is also indispensable to clarify phenomenon in another condition." It emphasizes that the both sides of the complementary cannot be separated.

2.3.2 The characteristics of relationship between rail transit and bus based on the theory of complementary

As known in economics, there is complementary relationship between commodity A and B, which refers that the two goods are complementary in utility. In traffic areas, there is also the relationship for the demand and combination of transportation. But complementary relationship in science of transportation is different from the areas of economics. The purpose of the complementary relationship applied in economics is profit to both parties maximization, while the complementary in transportation is to strengthen mutual cooperation, pursuit traveler's largest aspects of convenience, and minimize the problem of road traffic congestion.

3 The Choice Model of Residents Travel Traffic Mode

3.1 Transportation mode selection factors

There are many factors that can affect choice of urban residents travel mode, related to resources of domestic and foreign urban residents travel mode choice behavior research, it mainly including the macroscopic properties and microscopic properties of traveler (Haifeng, 2007). Personal factors also influence the choice of the ways of traffic: age, gender, family income, etc.

To test the relationship between the above property variable and the traffic mode selection, two important factors in selecting indicators of travel time and travel expenses to measure mode selection for rail transit and conventional public traffic complementary to draw reasonable basis in this paper.

3.2 The dimensionless factor

Due to various factors between different dimensions, so we need to transform the value of 0~1 according to membership functions, the normalized factors dimensionless. Membership function is divided into two kinds: ①down half a trapezoidal distribution, ②liter and a half trapezoidal distribution. Specific formula is as follows:

① lower half trapezoidal distribution

$$f(x_i) = \begin{cases} 1 & x_i \le m_i \\ \dfrac{M_i - x_i}{M_i - m_i} & m_i \le x_i \le M_i \\ 0 & x_i \ge M_i \end{cases} \tag{1}$$

② liter and a half trapezoidal distribution

$$f(x_i) = \begin{cases} 0 & x_i \le m_i \\ \dfrac{x_i - m_i}{M_i - m_i} & m_i \le x_i \le M_i \\ 1 & x_i \ge M_i \end{cases} \tag{2}$$

4 The Algorithm of BP neural Network

Regarding travel mode choice results as output, the influenced attribute variables of travel mode choice as input. By setting on the parameters of neural network such as the number of input or output layer nodes and hidden layer nodes, learning speed .etc. to carry on network training, and establish the relatively much more fitting and simulation performance of residents travel mode choice neural network model, which could map out the way to travel choices and the relationship between various influencing factors.

4.1 The BP neural network training

$net = newff(\min\max(p),[3,1],\{'\tan sig', ' purelin'\},'trainlm');$

$net.trainparam.goal = 0.001;$

………

$[net,tr] = train(net,p,t);$

When the input p (Xilin,2001), output t, after the above-mentioned non-linear function of training, the p t establish correspondence between the number of training set, the required accuracy, the learning rate parameters such as training, network training, the network of learning values and expectations to reach the precision requirements, save weights and thresholds.

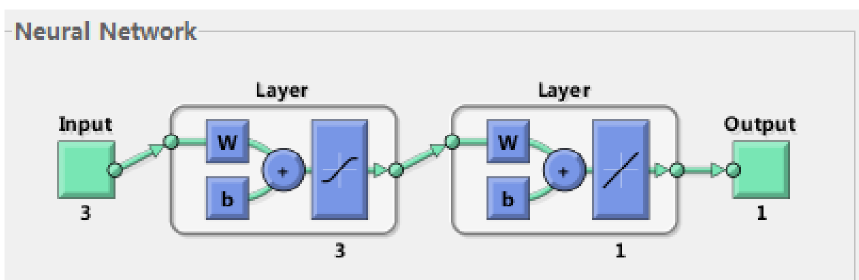

Figure 2. BP network structure

4.2 The BP neural network simulation

After the model training (Huanhuan, 2011), the network could be simulated by using the Sim function. The plot function is called to linear regression analysis the network simulation output and target output after training, to verify the training effect of the network.

$t_{12} = sim(net,[]');$

$t_2 = sim(net,p);$

$plot(4:11,t_2,'+',4:11,t)$

5 The Determination of Service Level

Road saturation is an important indicator of the level of road service, the calculation expression is: V/C, where V represents the maximum amount of traffic, C represents the maximum capacity. In this paper, in view of concept and grading of roads saturation，the concept of public transport saturation is came up , combined with levels of service to define urban road public transport passenger services. Taking the ratio of section traffic and rated capacity in peak-hours between the two sites is defined as the load factor of public transport, namely saturation.

Saturation is calculated with the formula as shown in （3）:

$$S = \frac{V}{C} \quad (3)$$

In the formula：S—Public transport saturation；V—A section of the public transport patronage；C—Public transportation rated capacity

Public transport utilized as road saturation, and is inversely proportional to the service level. The higher the saturation value is, the lower the level of public transport services.

Depending on difference of road saturation and other indicators, our country divides the level of service into the following four levels:

Table 1. The service level

Level	Saturation（V/C）	Vehicle Inside Condition	Service Level
1	0～0.6	More Spacious Interior	A
2	0.6～0.8	A Little Crowded	B
3	0.8～1.0	More Crowded	C
4	>1.0	Serious Crowded	D

6 The instance

According to a survey data of urban rail transit and conventional public traffic, the concrete numerical value shown in Table 2:

Table 2. Sample data

Traveler	Rail Time Ta	Regular Bus Time Tb	Rail Costs Wa	Regular Bus Fee Wb	Select Results
1	28.13	31.16	2.24	0.88	a
2	42.17	48.15	2.88	1.15	a
3	18.16	20.03	2.05	0.65	b
4	14.13	12.02	2.0	0.48	b
5	26.17	24.63	2.23	0.72	b
6	32.21	42.38	2.10	2.20	a
7	26.48	25.31	2.07	0.76	b

8	30.22	41.03	2.15	1.22	a
9	26.98	36.46	2.01	0.95	a
10	11.03	10.09	2.0	0.42	b
11	47.08	42.16	2.05	2.18	a
12	23.10	32.35	2.56	0.90	a
13	50.63	48.17	3.02	2.55	a
14	20.43	26.78	2.06	0.81	a
15	44.17	43.89	2.15	3.10	b
16	15.16	10.75	2.03	0.56	a
17	20.11	21.13	2.15	0.65	a
18	34.50	40.02	2.45	2.08	a
19	32.76	35.18	2.32	0.90	b
20	26.88	25.66	2.06	1.78	a
21	54.17	68.14	3.32	2.88	a
22	48.20	50.16	2.89	1.56	a
23	40.11	42.56	2.46	1.32	b
24	20.89	19.89	2.15	1.58	a
25	29.10	32.13	2.23	1.79	a

Data liter and a half trapezoidal dimensionless processing normalized results shown in Table 3:

Table 3. Normalized data

Traveler	Rail Time Ta	Regular Bus Time Tb	Rail Costs Wa	Regular Bus Fee Wb
1	0.396	0.363	0.182	0.172
2	0.722	0.656	0.667	0.272
……				
24	0.229	0.169	0.114	0.433
25	0.419	0.380	0.174	0.511

Building the model，taking the data in Table 1 as input data, of which the first 20 sets of data as a training base data, the last five sets of data as the test data, substituting the data into the MATLAB neural network to train, taking n=12,and the training function is TRAINLM, after six iterations learning and training cumulative error to achieve the target precision requirements, and predicts travelers' choice results based on this model in Table 4 and Figure 3.

Table 4. Training results

Traveler	Rail Time Ta	Regular Bus Time Tb	Rail Costs Wa	Regular Bus Fee Wb	Target Results	Actual Results
21	54.17	68.14	3.32	2.88	a	a
22	48.20	50.16	2.89	1.56	a	a
23	40.11	42.56	2.46	1.32	b	b
24	20.89	19.89	2.15	1.58	a	a
25	29.10	32.13	2.23	1.79	a	a
26	23.15	30.18	2.34	1.66		a
27	46.23	45.06	3.02	1.45		b
28	35.89	40.89	2.68	1.85		a
29	16.48	23.56	2.03	0.85		b
30	38.17	40.01	2.81	1.43		a

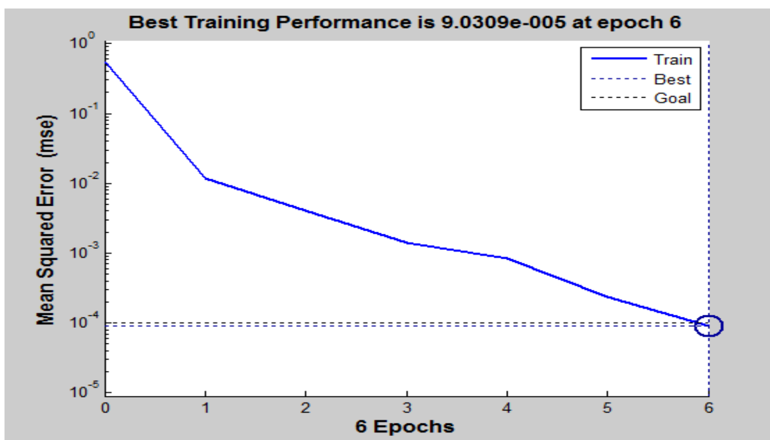

Figure 3. Training error convergence curve

According to the above calculated 30 sets of data, we can calculate the share rate of the rail transportation and conventional public traffic: about 19 travelers choose rail travel as a tool, and the rest of the travelers choose public transport, so rail transit is 63.3%, regular bus is 36.7%. It shows two kinds of traffic tools play a different role in the public traffic, which can cooperate and complement with each other, it also reflects the necessity of this research for complementary.

Based on previous forecasting section traffic data of rail transportation planning, service level of rail transportation is compared around coexist with the regular bus. The former before improvement is a single rail transportation, after improvements is rail transit and bus complementary coexistence. Comparative results are as follows:

Table 5. Comparation of improve service levels of rail decisions before and after the program

Location	Service Level					
	Initial Stage		Recent Stage		Future Stage	
	Before Improved	After Improved	Before Improved	After Improved	Before Improved	After Improved
Road1-R2	B	A	C	C	D	C
R2-R3	A	A	B	B	C	B
R3-R4	A	A	C	B	D	C
R4-R5	A	A	B	B	C	B

As can be seen from Table 5 to retain the bus, rail transportation for long-term planning is essential. For the initial construction of rail transit, traffic is not great, the supporting role of bus is not very significant. But over time, inducing and transferring passenger is becoming more and more, while service levels of rail transit will be reduced, then the role of the bus will be very important. If remove the bus lines in the early, it will cause a waste of facility resources.

6 Conclusions

Residents travel mode choice is the process of selecting the most suitable one mode of transportation to travel based on their personal property, family property and trip purpose, trip distance, traffic characteristics. The factors of residents travel mode choice are manifold. The rail transportation and bus achieve a complementary in function, although fares of rail are more than regular buses, but the running time is better than the latter, which fully reflects the two aspects. The travelers will not select single rail transportation and give up regular bus traffic, or choose to give up rail transportation. There is also fully a show about the relationship between complementary and conventional rail public transportation.

In this paper, there exists complementarities between modes of transportation which are proved by both BP neural network and the assessment about level of service, because of that relationship mode of transportation is not free to cancel. A rational suggestion has been put forward to solve these problems。

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References

Ben-Akiva M.(1985). “Discrete choice analysis：theory and application to travel demand”. *The MIT Press Cambridge*,London,31-57.

Li H,& Wang W (2007). "Transportation mode selection model based on neural network ".*Journal Of Highway And Transportation Research And Development*,Jul.24,132-136.

Lu H P(1998). "Transportation planning theory and method". *Qinghua University Press*., China.

Min X L, &Liu G H(2001)."BP network applications developed using MATLAB Neural Network Toolbox ". *Computer And Application*,Aug.21,163-164.

Subba P V.(1998)."Another insight into artificial neural networks through behavioral analysis of access mode choice". *Compute,Environment And Urban System*,May.22,485-496.

Yin H H &Guan H Z.(2011). "Residents travel mode choice model based on BP neural network". *Journal Of Transportation Information And Safety*, Mar.29,47-50.

Multimodal Transportation Government Subsidies Strategy Based Stackelberg Game and DEA

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Abstract: Multimodal transportation becomes an effective way to improve logistics efficiency and boost the regional economy eventually. The government introduced a number of multimodal transport subsidies to enterprises from different capital subsidies and tax subsidies. In addition, the government increased multimodal transportation infrastructure investment and achieve international clearance facilitation is also implicit subsidies to enterprises. This study established a "multimodal subsidies productivity" model and used DEA method to calculate the subsidies productivity value under different multimodal transportation systems. The study analyzed government and enterprises relationship under Stackelberg game theory with symmetric information. The result showed that logistics companies prefer the transportation infrastructure subsidies, producers prefer the tax incentives and freight forwarding companies prefer international cooperation policies.
Keywords: Government subsidies; Game theory; Productivity.

1 Introduction

This paper analyzed an effective way to improve logistics efficiency and boost the regional economy. The government introduced a number of multimodal transport subsidies to enterprises from different capital subsidies and tax subsidies. In addition, the government increased multimodal transportation infrastructure investment and achieve international clearance facilitation is also implicit subsidies to enterprises. First, this study established a "multimodal subsidies productivity" model and used DEA method to calculate the subsidies productivity value under different multimodal transportation systems. Second, the study analyzed government and enterprises relationship under Stackelberg game theory with symmetric information.

The nature and scale of their demand for shipping services can also affect the level of maritime emissions. Shippers also take a broader, supply chain perspective on the low-carbon process, looking beyond the sea voyage to the other finks and nodes in the supply chain which emit CO_2 and are technically part of their corporate carbon footprint. In the case of deep-sea container chains, these additional activities can account for around a third of total emissions (Woolford and McKinnon, 2011).

So we can say low-carbon logistics is not only related to a link of the whole supply chain, but also many links combined with multimodal transport. The low-carbon logistics strategy of the multimodal transport enterprise is about the future development.

Over the past decade there has been increasing company participation in government and industry led initiatives to improve the environmental performance of freight transport. The US, UK government and organization (US Environ-mental Protection Agency, 2013; UK Freight Transport Association, 2013) have attracted high levels of company participation. One of the first and most influential of the industry-sponsored initiatives has been the Clean Cargo Working Group, set up in 2004 to bring together leading cargo carriers and their customers, dedicated to environmental performance improvement in marine container transport through measurement, evaluation, and reporting (BSR, 2013).

Although the available evidence confirms that the management of multimodal transport is dominated by financial considerations, these do not necessarily conflict with environmental goals. There are several studies are quite a close correlation between the economic efficiency of a logistics operation and its environmental impact (Rao and Holt, 2005). Peter Lorange (2001) and Photis M.Panayides (2003) tried to research the relationship between the competitive strategies and organizational performance on shipping companies. The result displayed they had the positive relationship. From the perspective of quantitative analysis, decision-making through the use of fuzzy comprehensive evaluation model for in-depth analysis of the status of the shipping companies operating performance (Tsung-Yu and Gin-Shuh Liang, 2001). Compared to decentralized decision making scenario,the low-carbon level and total profit will reach its highest under the fully cooperation scenario (YANG Jian-hua et al, 2014). Some researches improve low carbon performance through estimating the value on a computer simulation system or a numerical model (WANG Lu-ping et al, 2014; Tatjana V. Sibalija et al, 2014). Our research combined the qualitative and quantitative method and gave comprehensive suggestions for the multimodal transport enterprises development.

2 Model

Suppose a product differentiation in the market, each consumer to purchase up to one unit of product, there are two different types of products in the market. Two products have different utility green, green utility is to describe the content of toxic and hazardous substances, recyclable products, product components, the use of energy consumption and the use of materials such as the level of volume, is a measure of green products from the perspective of the entire life cycle degree. Practice from simple energy efficiency rating index logo, carbon labels to indicate the effectiveness of green products. Products based on differences utility green products and green products are divided into general categories. Assuming general utility of green product v_0, product of green utility green v_1, where v_0、v_1 is a fixed constant and $v_1 > v_0 > 0$. Selling price of the product types for p_0、p_1, due to the high cost of green products, so the consumer preference for green products, θ evenly distributed between $[0,1]$. Provided consumer surplus U，$U \geq 0$ and U between the remaining consumer relations function θ. Let θ_0 represent the purchase of ordinary consumers do not buy the product and no difference in preference parameters. Consumer surplus is the relationship between green preference shown.(Figure 1.)

$$U = \theta v_i - p_i, (\mathrm{i} = 0,1) \tag{1}$$

$$\theta_0 = \frac{p_0}{v_0} \tag{2}$$

$$\theta_1 = \frac{p_1 - p_0}{v_1 - v_0} \tag{3}$$

$$q_0 = (\theta_1 - \theta_0)\,\mathrm{M} = (\frac{p_1 - p_0}{v_1 - v_0} - \frac{p_0}{v_0})\,\mathrm{M} \tag{4}$$

$$q_1 = (1 - \theta_1)\,\mathrm{M} = (1 - \frac{p_1 - p_0}{v_1 - v_0})\,\mathrm{M} \tag{5}$$

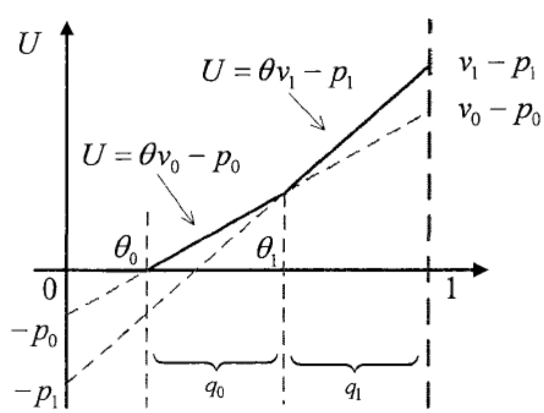

Figure 1.Consumer surplus function schematic

3 Data Analysis

The data results showed that operational factors of low carbon path highest score in 2007, the lowest in 2004. From the year 2004 to 2007, that factor is not continuously improved, indicating that the steady improvement in the level of company C operating low-carbon path. However, in the year 2008 and 2009, the factor scores dropped significantly in 2007, indicating that company C implemented a low-carbon path level operational impact of the financial crisis is showing signs of decline. In the subsequent 2010, the factor score again slightly improved description of company C implemented a low-carbon path level operations to eliminate the impact of the financial crisis began and a rebound.

Table 1. i subsidy object game show different forms of subsidies

`	Transportation Infrastructure	Tax incentives	International cooperation policies.
Producer enterprises	0.709	0.969	0.627
Freight forwarding enterprises	0.866	0.819	0.901
Logistics enterprises	0.915	0.833	0.746

4 Discussion of Results

In Germany, the first principle of government planning freight center location is to achieve seamless integration of two or more modes of transport, with transport functions. Germany has formed a standards-based vehicle system, the introduction of a series of effective support policies, such as: federal and local government to give the intermodal logistics park facilities, financial subsidies, engaged in intermodal truck to give incentives, including relaxation of the total weight limit, exempt from highway use tax, vehicle without restrictions forbidding the weekend, giving a modest operating loss for intermodal subsidies. In addition, the government also involving multimodal technology research and development, equipment improvements, public infrastructure platform for building projects and special action projects direct investment, to promote the development of multimodal transport, improve integrated transport system plays an important role.

Currently local governments in order to encourage intermodal many subsidies, these subsidies for intermodal market had an impact. This paper intends to compare with and without government subsidies environmental impact of subsidy policy on the "rail, water, iron, iron empty" and intermodal markets, analyze the key factors that influence the efficiency of intermodal operations and market development, for now There are policies to provide improved solutions to quantify the effect of improving the front and rear, to clarify the different types of cargo in intermodal pricing strategies, as well as the characteristics of different multimodal transport modes, provides a theoretical basis for government subsidies.

Promulgated the "long-term planning of the logistics industry (2014-2020)", the intermodal logistics as an effective way to improve efficiency and reduce logistics costs, was again mentioned the strategic development of the logistics industry.

Over the years, our understanding of multimodal have stayed in the choice of a single mode of transport on, but the practice has proved that all modes of transport through the rational division of labor and the establishment of an effective interface integrated intermodal transport system is to achieve foundation. We all know, China's total freight accounted for 79 percent of highway, railway 9%, water 11%, aviation 0.3%, 1% of the pipeline, transportation structure is irrational. At present, China Intermodal current prominent contradictions are various modes of transport division unreasonable, poor convergence.

Ability does not match the rules are not uniform, the information is not shared, the network is not perfect, the subject is not clear, the policy is not in place and so are the main problems existing intermodal. Li Mu original thought these questions focus on performance in nine areas: First, an early start, but slow development; the second is the mode of transport containerized rate is very low; the third is the low proportion of iron transport, and the lack of ability to dress up facilities; Fourth Intermodal rail is still the bottleneck of development; Fifth intermodal business entities is unclear; six intermodal logistics park did not become a node; Seven is multimodal resource use is low; eight is multimodal information platform construction is lagging behind; nine is no unified multimodal operating rules.

In addition, our main mode of transport containerized low, resulting in lack of multimodal core carrier; new logistics park their own way, there is no ability to form a multimodal network; rail freight structure and operating rules, customs clearance mode restricts intermodal development; emerging international logistics channel construction disorderly competition are all outstanding issues facing our country in the current intermodal.

"Ministry of Transport guidance on transport to promote the healthy development of the logistics industry," clearly the advance of the general idea of modern logistics development, key tasks and work, focusing on the economy combined with the construction of the Silk Road, the Yangtze golden waterway, Beijing, Tianjin and one major strategic implementation of construction, push forward the construction of logistics major thoroughfare. Ministry of Transport and preparation of the implementation of the "" five "road freight hub construction planning" to encourage the establishment of modern logistics park relying on the port, airport, railway hub, and create conditions for the development of intermodal transport; continue to push and pull transport pilot Container transport channel iron demonstration projects.

The study analyzed government and enterprises relationship under Stackelberg game theory with symmetric information. The result showed that logistics companies prefer the transportation infrastructure subsidies, producers prefer the tax incentives and freight forwarding companies prefer international cooperation policies.

References

Buhaug, "Prevention of Air Pollution from Ships: Second IMO GHG Study. London: International Maritime Organization", 2009, pp.42-56.

Cariou, P. "Is slow steaming a sustainable means of reducing CO2 emissions from container shipping", Transportation Research Part D, 2011, 16(3), pp.260-264.

Committee on Climate Change, "Review of UK Shipping Emissions." London: Committee on Climate Change, 2011, pp.21-24.

Peter Lorange, "Strategic rethinking in shipping companies", Maritime Policy and Management, 2001, 28(1), pp.23-26.

Photis M. Panayides, "Competitives trategies and organizational performance in ship management", Maritime Policy and Management, 2003, 30(2), pp.123-126.

Photis M. Panayides, "Competitive strategies and organizational performance in ship management", Maritime Policy and Management, 2003, 30(2), pp.123-140.

Rao P. and Holt, D., "Do green supply chains lead to competitiveness and economic performance?", International Journal of Operations & Production Management, 2005, 25(2), pp.898-976.

Tatjana V. Sibalija, Sanja Z. Petronic, Vidosav D. Majstorovic and Andjelka Milosavljevic. (2014) "Modelling and optimisation of laser shock peening using an integrated simulated annealing-based method." The International Journal of Advanced Manufacturing Technology, 73,(5-8): 1141-1158.

Tsung-Yu and Gin-Shuh Liang, "Application of a Fuzzy Multi-criteria Decision-making Model for Shipping Company Performance Evaluation", Maritime Policy and Management Magazine, 2001, (10), pp.105-120.

US Environmental Protection Agency, Smart Way Transport Overview, <http://www.epa.gov/smartway/documents/publications/overviewdocs/420f13017.pdf>, accessed 1 November, 2013.

WANG Lu-ping, XIAO Wei and WEI Qing-qi, "Study on low-carbon multimodal transport path based on irregular prism network", Application Research of Computers, 2014 ,(8), pp.76-85.

YANG Jian-hua, GUO Ji-dong and MA Shu-gang, "Low Carbonization Game of Urban Logistics Distribution System", Soft Science, 2014 , (7), pp.35-40.

Analysis of Combined Modes Choice Characteristics of Non-Motorized Modes and Motorized Modes

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Abstract: Non-motorized modes are those whose speeds are slower than motorized modes, represented as walking, bicycles and electric bicycles. With the expansion of urban size, non-motorized modes could not meet the residents' need of trips, so more people would like to choose motorized modes.

The research took trip chain as a unit based on data from a within-day travel survey in Zhongshan, Guangdong province in China. According to the cooperation of non-motorized modes and motorized modes, there are four types for the cooperation, including "non-motorized+non-motorized", "motorized+motorized", "non-motorized + motorized (mainly non-motorized modes with longer distance)", "non-motorized + motorized (mainly motorized modes with longer distance)". In order to clear the influencing factors of combined modes choice, after preliminarily analyzing the characteristic of trip chain attributes including trip purpose, departure time, consumed time, distance and stops, the research used disaggregate model Multinomial Logistic regression model to build a combined mode choice model for combined modes.

The results show age, gender, occupation, personal income, the ownership of transport tools, trip purpose, trip chain consumed time have different significant influence on mode choice. Those with low personal income prefer to choose combined mode with non-motorized, and those with high income like choose motorized mode or combined mode with motorized, so the service level of non-motorized mode should be improved to attract more people with high income to use. And especially those who have private car prefer to choose "motorized + motorized" combined mode, so the service level of "non-motorized + motorized" combined mode should be improved to attract more private car owner.

Keywords: Non-motorized modes; Motorized modes; Combined modes; Trip mode choice characteristics; Disaggregate model.

1 Introduction

Combined mode refers to contain at least 2 kinds of traffic ways. Non-motorized modes are those whose speed are slower than 15km/h, represented as walking, bicycles and electric bicycles, and motorized modes includes motor, bus and car. Foreign study on choice influence factors of combined modes mainly select individual household characteristics, travel (chain) feature, providing travel information and other aspects, which are similar to the factors of travel behavior in general(Golob, Hensher,2007). Nobis (2007) pointed out that the age of the traveler has a significant impact on young people who are more likely to choose combined modes in the study. And car use is a major cause of many traffic problems. Another part of the study show that (Bhat CR, 1997; Tringides CA, 2004; Krygsman S, Arentze T, Timmermans H, 2007) compared to combined modes mainly consists of public transport, travelers using cars and other private vehicles to travel tend to arrange a number of activities in the trip chain taking travel time and travel cost into account, namely the existence of a complex chain of its travel trend.

Affected factors by domestic scholars considered in the study of combination mode choice are similar with international mainstream research, which can be divided into family property, personal property, information and so on(Yang M, Wang W, Chen X, et al ,2007; Xianyu Jian-chuan, Juan Zhi-cai, 2010). Mei-Ping Yun and Zhen-Huan Chen (2014) compared mode choice behavior for work tours and non-work tours considering trip chain complexity. The paper suggests that if intermediate stops increase, compared to choosing car, respondents are more likely to choose non-driving modes (walk, bicycle, motorcycle, and bus) for non-work tours, whereas they are less likely to choose bicycle or bus for work tours.

Non-motorized modes and motorized modes are seen as main combined modes in this study, which are divided into four types.

2 Survey data

2.1 Survey Overview

The travel survey data came from Zhongshan city in Guangdong province, which is a typical Southern small and medium-sized city.

Survey time: Dec 1, 2009, Thursday (work day);

Survey method: SP, home interview survey;

Sample size: The objects are residents over 6 years old for each family, a total of about 30000 households, covering 53339 respondents, the overall sampling rate is 3.6%, obtaining 144496 effective travel records.

Table 1.Survey content

Basic information	Survey content
personal	age, gender, occupation, income, driving license and so on
family	population size, income, vehicles and so on
travel	times, purpose, mode, time, the departure and arrival time and so on

2.2 The use of data

Trip train links all travel starting from home until back home which has been widely used in the study of travel choice behavior, its characteristic has effects on the mode choice behavior, such as the transfer times, travel time, travel distance of chain etc.. According to the definition of trip chain, the survey data were integrated into the trip chain. The research selects trip train with one or two transfer stops and makes statistical analysis for each type (Table 2 and Table 3).

Table 2. Proportion of combined modes

proportion（%）	walk	bicycle	electric vehicle	bus	motor	car
combined with walk	-	8.8**	5.3**	10.3**	25.0**	10.7**
combined with bicycle	-	-	2.7*	1.2*	1.7*	0.3
combined with EV	-	-	-	0.4	2.2*	0.4
combined with bus	-	-	-	-	5.5**	1.0*
combined with motor	-	-	-	-	-	4.8*
combined with car	-	-	-	-	-	-
walk+（）+walk	-	0.1	0.1	0.9	0.7	0.4
bicycle+（）+bicycle	0.9	-	0.2	0.2	0.2	0.1
EV+（）+EV	1.0*	0.2	-	0.4	0.3	0.1
bus+（）+bus	2.8*	0.1	0.1	-	0.2	0.1
motor+（）+motor	4.2*	0.3	0.2	0.2	-	0.4
car+（）+car	3.1*	0.1	-	0.4	0.9	-

note：**- the most significant，*- More significant，-no data

Table 3.Proportion of combined modes

Combined modes	sample	proportion（%）
"non-motorized + motorized (mainly non-motorized modes)"	377	15.1
"non-motorized + motorized (mainly motorized modes)"	1233	49.3
"non-motorized + non-motorized"	360	14.4
"motorized +motorized"	253	10.1
other	278	11.1
total	2501	100.0

3 Study on combined mode choice model

The study analyzes the choice behavior of combined modes which consist of non-motorized modes and motorized modes, clearing the cooperation of non-motorized modes and motorized modes. The combined mode choice model uses disaggregate model, by determining the choice limbs, analyzing the influence factors, the calibration model and the model test, and ultimately obtain the combined modes choice characteristics.

3.1 Determination of model choice limb

Combined mode refers to contain at least 2 kinds of traffic ways, in order to understand the cooperation of non-motorized modes and motorized modes. According to the cooperation of non-motorized modes and motorized modes, there are four types for the cooperation, including "non-motorized +

non-motorized" , "motorized + motorized", "non-motorized + motorized (mainly non-motorized modes)", "non-motorized + motorized (mainly motorized modes)", generally the "motorized + motorized" as a reference item.

3.2 Analysis of influence factors

Combined modes choice model makes analysis according to personal property, family property and trip train property (Table 4). Because of at least 2 kinds of modes included in the combined modes, so the trip trains with the transfer over mode are taken as sample for statistical analysis to determine influence factors, providing a basis for follow-up model.

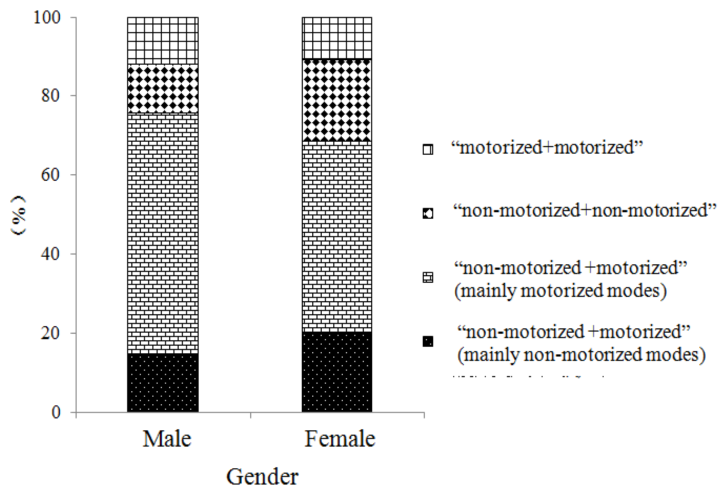
Table 4. Influence factors

Factors category	Influence factors	
Personal property	gender	
	age	
	occupation	
	personal monthly income	
	traffic cost/month	
	driving license	
Family property	population size	
	Income/year	
	vehicles ownership	bicycle
		electric vehicle
		motorcycle
		car
Trip train property	purpose	
	departure time	
	trip train time	
	trip train distance	
	number of stops	
	time of walking to bus station	

3.2.1 Personal property

1) Gender

According to the figure 1, gender has effect on the combined modes: male are more likely to choose "non-motorized + motorized" than female and the "non-motorized + motorized (mainly motorized modes)" most.

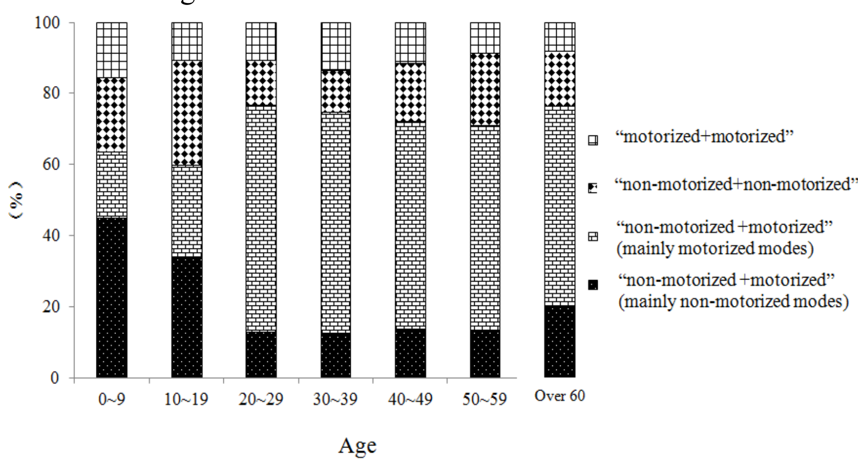


note：number of samples=2223

Figure 1. Gender effect on the combined modes

2) Age

According to figure 2, effect of age on combined modes choice is travelers under 20 years old mainly choose the "non-motorized + motorized(mainly motorized modes)" and "non-motorized + non-motorized", and there are no significant differences in the combined modes choice among travelers over 20 years old. Therefore the effect of age on combined modes is smaller.

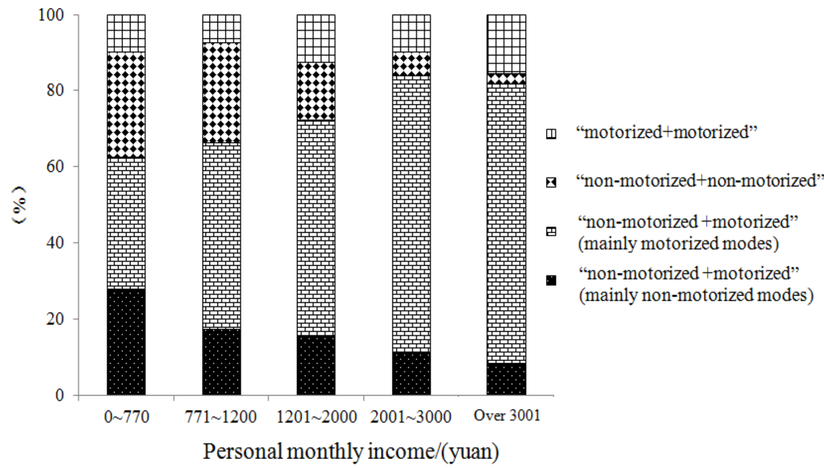


note：number of samples=2223

Figure 2. Age effect on the combined modes

3) Personal monthly income

Personal monthly income has obvious influence on combined modes choice, and presented pretty negative correlation: the higher the income, the more inclined to choose the "non-motorized + motorized (mainly motorized modes)", the other 3 kinds of combined mode ratio reduced at the same time.



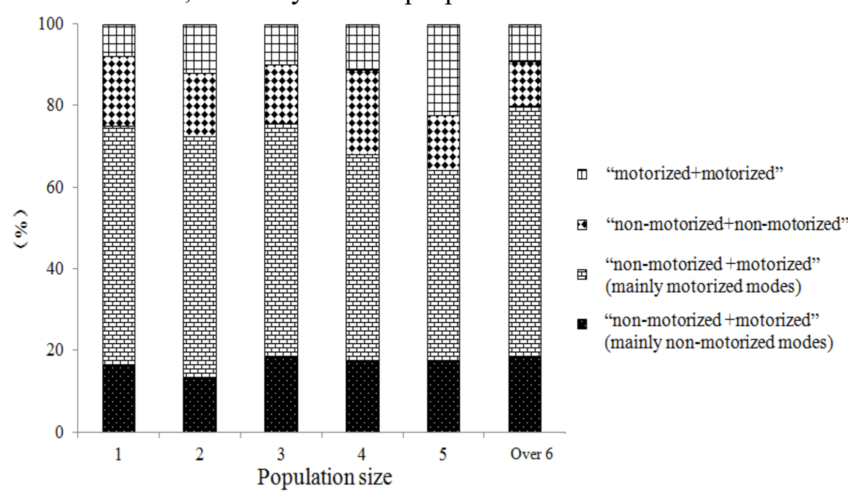
note：number of samples=2223

Figure 3. Personal monthly income effect on the combined modes

i. Family property

1) Population size

As can be seen from figure 4, population number has smaller effect on combined modes choice, basically similar proportions of all kinds of modes.

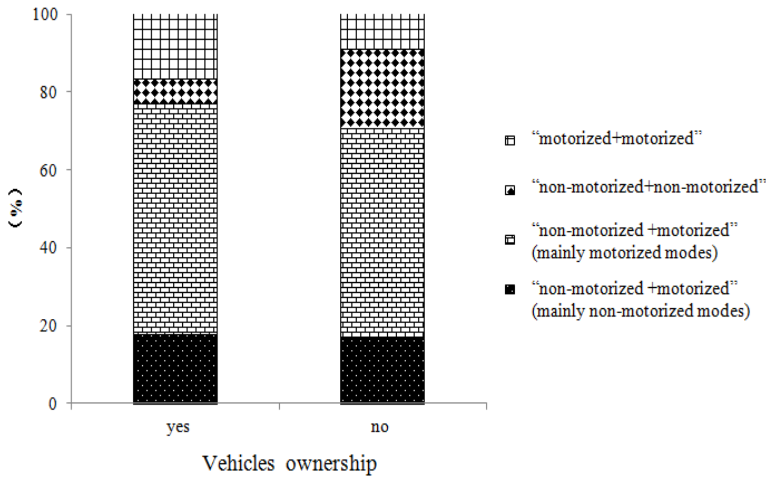


note：number of samples=2223

Figure 4. Population size effect on the combined modes

2) Vehicles ownership（car as a case）

Vehicles ownership can be seen as a necessary condition for the use of this means of transportation and is considered to have a greater influence on travel mode choice. According to figure 5 that made of cars as a case, whether owned cars will tend to choose the "non-motorized + motorized (mainly motorized modes)", and travelers owned a car prefer to choose this mode than those who do not own a car. And the “motorized + motorized” has a greater proportion which can be understood as the use of the car try to make travel after buying.



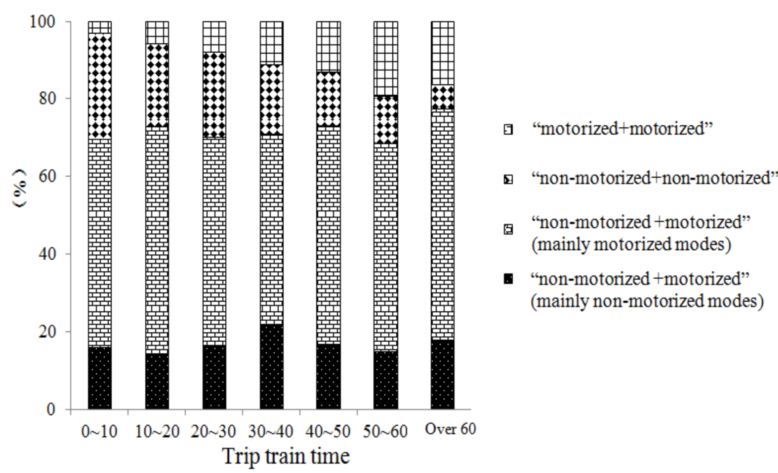
note：number of samples=2223

Figure 5. Vehicles ownership effect on the combined modes

ii.Trip train property

1) Trip train time

Trip chain time is pointed out the cost to complete whole trip chain, which has smaller effect on the “non-motorized + motorized” for travelers based on figure 6. And with the increase in time consumption, the proportion of “motorized + motorized” modes increase and “non-motorized + non-motorized” modes reduce, which explains the motorized modes are more popular among travelers with long travel time.

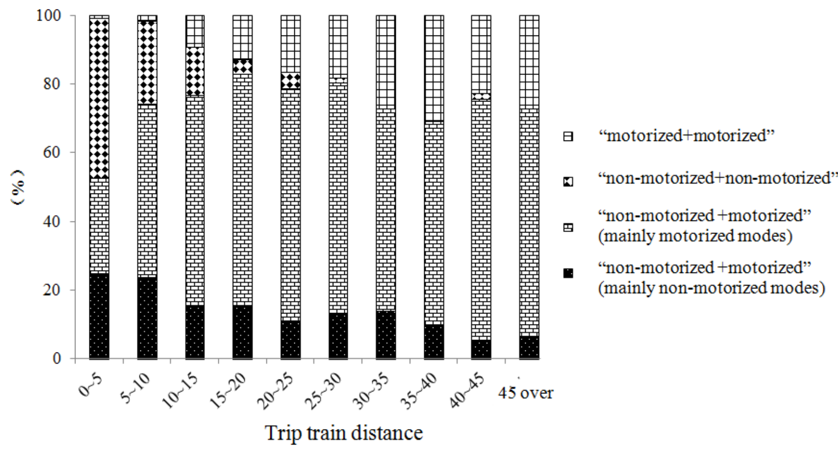


note：number of samples=2223

Figure 6. Trip chain time effect on the combined modes

2) Trip train distance

Trip train distance is all the travel distance of a completed trip train. Therefore, trip train distance not only has a significant effect on mode choice, but also has the correlation with the positioning of modes. According to figure 7, the proportion of combined modes with non-motorized reduces significantly with the increase of train distance, motorized modes increases on the contrary.



note：number of samples=2223

Figure 7. Trip chain distance effect on the combined modes

Choice characteristic variable

This study devides choice characteristic variables into two categories: general variable for all mode choice and inherent variable for particular mode choice, inherent variables (Xianwei Liu, 2013) include vehicle ownership because of the significant impact on mode choice, the significance level of 0.01 or 0.05.

Table 5.General variable chi-square correlation test

general variable	Combined modes choice model N=1000	
	Pearson correlation	**Sig.（2-tailed）**
gender	-0.082**	0.010
age	0.082**	0.009
occupation	0.088	0.065
personal monthly income	0.249**	0.000
Traffic cost/month	0.286**	0.000
driving license	0.270**	0.000
family population number	-0.054	0.088
family income/year	0.124**	0.000
travel purpose	-0.009	0.783
departure time	0.017	0.595
trip train time	0.017**	0.000

trip train distance	0.185**	0.000
number of stops	0.183**	0.000

note：**- 1% Significance level，*- 5% Significance level

From the chi-square correlation test, substantially all of the general variables are concerned with the travel mode choice. The impact of occupation, population number, trip purpose, departure time for combined modes choice are not significant, therefore they are excluded from the model of the independent variables.

Taking into account that each variable of the disaggregate model should be independent of each other, it is necessary to make the correlation analysis (Qiuli Rao, 2011) between general variable and inherent variable, getting the final model variables as shown in the following table.

Table 6. Independent variable of the model

Independent variable classification	Independent variable
Traveler characteristic variable	gender age personal monthly income
Options inherent variables	bicycle electric vehicle motorcycle car
Trip train characteristic variable	trip train time

3.4 Model calibration

In this study, by Multinomial Logistic regression model with 1000 samples of SPSS software, the optimal model is found according to the results of fitting test model and pseudo R square statistic after repeated attempts, as the following table.

Table 7. Combined modes choice model calibration results

Variable Description		"non-motorized + motorized(mainly non-motorized modes)"		"non-motorized + motorized(mainly motorized modes)"		"non-motorized + non-motorized"	
		Parameter	Significance level	Parameter	Significance level	Parameter	Significance level
Intercept	α_i	1.403*	.039	2.169**	.000	-1.167	.190
age	X_1	+.002**	.008	+.019*	.021	+.013	.080
gender（1=male）	X_2	-.491	.066	+.165	.466	-.951**	.001
personal monthly income （1=0~770）	X_3^1	--	--	-1.171**	.002	+1.648*	.014

personal monthly income （2=771~1200）	X_3^2	+1.239*	.022	--	--	+2.140**	.003
personal monthly income （3=1201~2000）	X_3^3	--	--	--	--	--	--
personal monthly income （4=2001~3000）	X_3^4	--	--	--	--	--	--
personal monthly income （5=over 3001）	X_3Reference items						
bicycle（1=yes）	X_4	--	--	--	--	+1.015**	.001
electric vehicle（1=yes）	X_5	--	--	--	--	+1.558**	.000
motorcycle（1=yes）	X_6	-1.268**	.000	+.472*	.013	-1.884**	.000
car（1=yes）	X_7	-.872**	.003	-.779**	.001	-1.313**	.000
trip train time（0=0~10）	X_8^1	+2.357*	.033	+2.369*	.022	+4.227**	.000
trip train time（1=10~20）	X_8^2	+1.306**	.007	+1.284*	.002	+2.925**	.000
trip train time（2=20~30）	X_8^3	+.853*	.034	+.607	.070	+2.214**	.000
trip train time（3=30~40）	X_8^4	--	--	--	--	+1.726**	.001
trip train time（4=40~50）	X_8^5	--	--	--	--	+1.411**	.006
trip train time（5=50~60）	X_8^6	--	--	--	--	--	--
trip train time（6=over 60）	X_8Reference items						

note：**- 1% Significance level, *- 5% Significance level, --not significant

3.5 Model test

The significance level of model fitting information here is less than 0.01, the significant level of Pearson statistics for goodness of fit and error statistics are all greater than 0.1, McFadden value reached 0.411 that far greater than 0.1, and therefore the goodness of fit of the model is better.

Table 8. Combined modes choice model fitting information

model	Model fitting standard	Likelihood Ratio Test		
	-2 log-likelihood values	Chi-square	DF	Significant level
Intercept only	2265.441			
final	1858.601	406.839	48	0

Table 9. Combined modes choice Goodness of fit

	Chi-square	DF	Significant level
Pearson	2678.344	2784	.923
Deviation	1835.950	2784	1.000

Table 10. Combined modes choice Pseudo R-squared

Cox and Snell	.334
Nagelkerke	.372
McFadden	.178

4 Discussion of Results

The model calibration results show that significant effect of age on the combined modes choice reflects that the older travelers are more likely to choose the "non-motorized + motorized(mainly motorized modes)", followed by "non-motorized+ non-motorized"; the proportion of male choosing "non-motorized + motorized(mainly motorized modes)" is greater; personal monthly income parameters show that lower income people tend to choose the "non-motorized+ non-motorized" or "non-motorized + motorized(mainly non-motorized modes)", and as incomes rise, the proportion of "non-motorized + motorized(mainly motorized modes)" grows up; traveler with a car tend to use the car as only way to travel, which can be speculated that the reason travelers reluctant to adopt "non-motorized + motorized" is the lower service level; trip train time is closely related to the mode speed, so travelers tend to choose "non-motorized + motorized(mainly motorized modes)" as time rises.

5 Conclusions

This paper uses the disaggregate model to analyze the combined modes choice of non-motorized modes and motorized modes, in order to understand the effect and impact of various variables on the combined modes under the cooperation between non-motorized modes and motorized modes. Through the establishment of the combined modes choice model, the study quantifies the influence factors for mode choice. The paper reveals influencing factors of trip chain mode choice and the relationship between non-motorized mode and motorized mode. The results of research could be applied to similar cities as reference, as well as guide and reference value to the development of urban transport system.

6 References

Bhat C R. (1997). Work travel mode choice and number of non-work commute stops. Transportation Research Part B: Methodological, 31(1): 41-54.

Golob T F, Hensher D A. (2007). The trip chaining activity of Sydney residents: A cross-section assessment by age group with a focus on seniors. Journal of Transport Geography, 15(4): 298-312.

Krygsman S, Arentze T, Timmermans H. (2007). Capturing tour mode and activity choice interdependencies: A co-evolutionary logit modeling approach. Transportation Research Part A: Policy and Practice, 41(10): 913-933.

MeiPing Yun, XiaoGuang Yang, Sheng Li. (2009). Non-motorized Traffic System Planning Brief. Urban Transport of China, 7(2).

MeiPing Yun, ZhenHuan Chen, Jiang-Yong Liu. (2014). Comparison of Mode Choice Behavior for Work Tours and Non-work Tours Considering Trip Chain Complexity. Transportation Research Board 93rd Annual Meeting.

Nobis C. (2007). Multimodality: facets and causes of sustainable mobility behavior. Transportation Research Record: Journal of the Transportation Research Board, 2010(1): 35-44.

Qiuli Rao. (2011). Research on the Commuter's Choice Behavior of Trip- chain Type and Travel Mode in CBD. Dalian University of Technology.
Tringides C A. (2004). Alternative formulations of joint model systems of departure time choice and mode choice for non-work trips. University of South Florida.
XianYu Jian-chuan, Juan Zhi-cai. (2010). Research on the Interdependencies between Trip Chaining Behavior and Travel Mode. Journal of Shanghai Jiaotong University, 44(6): 792-795.
Xianwei Liu. (2013). Comparative Study of Travel Mode and Departure Time Choice Behavior betweem Work and Non-work Trip. Tongji University.
Yang M, Wang W, Chen X, et al. (2007). Empirical analysis of commute trip chaining: Case study of Shangyu, China. Transportation Research Record: Journal of the Transportation Research Board, 2038(1): 139-147.

Quality Evaluation Indicator System for Rail Freight Service

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Abstract: On the basis of extensive research and interviews with experts, we propose a quality evaluation indicator system for rail freight service, which consider both factors of rail transport enterprise and customer satisfaction. We recommend the application of these indicators to assess the quality of rail freight services in order to improve the market competitiveness of railway enterprise.
Keywords: Rail freight; Indicator system; Evaluation.

1 Introduction

After the establishing of China Railway Corporation, a wide range of rail freight reforms was carried out, aimed to increase market share. Therefore, evaluating the quality of rail freight service, improving customer satisfaction and enhancing market competitiveness has become one of the priorities. Existing quality evaluation indicators of rail freight service emphasis on internal production management, and lack of systematic evaluation for customer satisfactory. At present, many domestic and foreign scholars studied the quality of rail freight service. Feng Fenling (2007) proposed that the current railway freight services lack of comprehensive evaluation method, she used SERVQUAL method to evaluate the rail freight service quality, proved that SERVQUAL method can be used in the field of rail freight service quality. Agrawal, R. (2008) put forward that staff's behavior is an important factor related to customer satisfaction in rail freight transportation. Yang Kai (2010) analyzed the influence factors of railway freight service quality, formed an evaluation system, and used the approximate ideal solution sorting method to evaluate.

Based on the theoretical analysis, extensive research on various types of rail customers and soliciting the views from staff of Railway Bureau, this paper propose a quality evaluation indicator system for rail freight services under the background of freight reform.

2 Principles of the Indicator System

Railway freight has a complex process, involves many units and departments (including collaboration of multisectoral, such as locomotives, electricity, finance and so on), and also includes the participation of logistics companies. Any quality defects are likely to affect the final services quality. Taking into account the quality of rail freight service has the following characteristics:

(1) Subjective judgment and dynamic differences;

(2) Fluctuation and volatility;

(3) Comprehensive and systematic;

(4) Representative;

At the same time, a general assessment of the quality for rail freight service relying on indexes is basis for National Railways to announce rewards and punishments for rail freight departments. Therefore, the establishment of the quality evaluation indicator system for rail freight service must meet the following principles:

(1) Principle of comprehensiveness: The selection of indicators should be able to reflect the quality of rail freight service comprehensively and systematically, mainly selected from the functional quality indicators and technical quality indicators, and overcome shortcomings like one-sidedness and so on.

(2) Principle of concise and science: The selection of indicators should be able to reflect the quality of rail freight service accurately and timely , have a simple method, and meet requirements of simple and scientific .

(3) Principle of stability and comparability: The results of the general assessment is a quantitative value, need to be applied to the practice, promoted to the public, meet the demands of enterprises of all types at different levels, and suit for horizontal comparison and analysis, so the evaluation index must be quantified, in order to reduce the influence of subjective factors by statistics and calculations.

(4) Principle of operability and flexibility: General assessment of the quality for rail freight service will generate new customer expectations, and promote freight companies to take corrective action, but if the rail freight enterprises cannot improve in a particular area, we should cancel the terms of evaluation index, ie the selection of indicators should be realistic and operable, and can be convenient collected.

(5) Principle of independence: Low degree of correlation between the indicators can effectively avoid intersectional, overlapping content covered by different indicators.

(6) The principle of customer satisfaction: That evaluation indicator system determined by the customer is the most basic requirement of the establishment of index system, we need to grasp the needs of customers accurately, and choose the most important evaluation indicators customers think.

3 The Establishment of the Indicator System

The quality evaluation indicator system for rail freight services is a method for National Railway Administration to supervise and evaluate the quality of rail freight services from the perspective of a third party. At present, rail freight has developed to become managers, organizers and operators of rail freight' acceptance, transport (including multimodal transport and door to door service), delivery, inquiries, complaints, and compensations. A very wide range of its business makes it difficult to proposed evaluation indicators for all parts related to their business. Therefore, the quality evaluation indicator system for rail freight services will examine seven aspects from perspectives of customers and rail transport enterprise ,including the arrival time, cargo damage、complaint handling、transportation cost、information services、Freight station service and freight operation service according to the production process.

3.1 Indicators from internal production

Existing evaluation indicators of rail transport enterprise emphasis on internal production management，through collecting statistical indicators from rail freight department and the communication with experts from rail freight department, we select effective indicators to evaluate the quality of freight services as Table 1

Table 1 The meaning of indicators from internal production

First level index	Second level index	The meaning of indicators
The arrival time	The ratio of punctuality	Batches of cargo arrived timely/ The total number of batches of cargo
Cargo damage	The ratio of cargo damage	Batches of cargo damage/ The total number of batches of cargo
	The ratio of compensation	The compensation of cargo damaged/ The total number of freight revenue
Complaint handling	The ratio of complaint	The number of customers' complaint / The number of customers
	The ratio of handling complaint satisfactorily	The number of handled complaints with customer' satisfaction/ The number of customers' complaint
Information services	The ratio of replying telephone satisfactorily	The number of telephone connected and get an evaluation "satisfaction" / The number of telephone connected

3.2 Indicators from customer satisfactory

Customer is a main part of quality evaluation for rail freight service, through the conversation with large customers of rail freight as well as questionnaires to rail customers, we conclude the factors that customer mainly concern, shown in table 2.

Table 2 The meaning of indicators from customer satisfactory

First level index	Second level index	Questions
The arrival time	The satisfaction of arrival time	Are you satisfied with the arrival time of cargo?
Cargo damage	The satisfaction of cargo damage	Are you satisfied with the safety of cargo
		Are you satisfied with the compensation service?

Transportation cost	The satisfaction of transportation cost	Are you satisfied with the transportation cost?
Complaint handling	The satisfaction of complaint handling	Are you satisfied with the way for complaint?
		Are you satisfied with the results of complaint?
Information services	The satisfaction of information services	Are you satisfied with the service of information inquiry（including the Internet and the telephone）?
Freight station service	The satisfaction of freight station service	Are you satisfied with the attitude of service in freight station?
		Are you satisfied with the environment of freight station ?
		Are you satisfied with the ease of handling process(including on Internet and in freight station)?
		Are you satisfied with the service facilities in freight station?
Freight operation service	The satisfaction of freight operation service	Are you satisfied with the service of acceptance in the originating station?
		Are you satisfied with the quality of loading and unloading of freight?
		Are you satisfied with the assigning work of railway container?

3.3 Sources of indicators

The quality evaluation indicators of rail freight services can be divided into two categories, namely quantitative indicators and qualitative indicators, both complement each other, and improve accuracy and objectivity of the evaluation ,but different indicators have different sources:

(1) For indicators from internal production，we may collect from the rail freight information system, such as railway production information system, railway e-commerce platform, railway operation management system of customer service center and so on.

(2) For indicators from customer satisfactory, We may collect from doing research on customers. The research can be carried out by a third-party professional organization, which is independent of the government and rail freight enterprise. The research on customers needs a combination of periodic surveys and occasional surveys, and must form an investigation report at last.

4 Conclusions

The quality evaluation indicator system for rail freight services proposed above is based on an extensive field research and interviews with experts, and is more close to the actual work and the demand of customers. After the indicator system, we use fuzzy comprehensive evaluation method for evaluating, taking into account the enterprise technical indicators and customer satisfaction, and propose an exercisable implementation process for the quality evaluation of rail freight services, which will cause a more accurate assessment results than ever.

References

Agrawal, R. (2008) “Public transportation and customer satisfaction.” Global Business Review. 9(2): 257-272.

Cui, J. L. Feng, F. Q.（2006）“Measurement and improvement of rail freight service quality.” China Science and Technology Information. 01:64+63.

Feng, F. L. Chen, Z. Y. (2007) “Evaluation of Rail freight service quality based on SERVQUAL. “ Journal of Inner Mongolia agricultural university (natural science edition). 01:90-94.

Gu, S. Z. (2014) “Improve the quality of rail freight service.” Management. 01:48-50.

Ji, J. L. Wei, X. T. Ai, W. Q. (1999) “The quality evaluation indicator system for rail freight services.” Railway Transport and Economy. 10:36-38.

Liu, T. Y. (2014) “Research on the evaluation for the service quality of railway freight station.” Southwest Jiaotong University.

Michael, J. C. Leo, G. Kroon. (2006) “Reliability and heterogeneity of railway services .” European Journal of Operational Research. 647-665.

Yang, K. Deng, C. M. Lin, Y. M. (2010) “Evaluation of Rail freight service quality based on hybrid TOPSIS method .“ Journal of transportation science and economy. 06:6 1-64.

Multimodal Transport Path Optimization Modeling of a Single Variety of Goods

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Abstract: The single variety of goods transportation route optimization is the basic link of organization and implementation of multimodal transport. Transport costs, transport time, multimodal transport network carriage capacity and change trains ability are the main factors affecting the multimodal transport path selection. The multimodal transport network is described as a simple undirected graph. Contrast and analyze the network characteristics. Based on the parameters definition and borders assumption, using point-arc model, structure the multimodal transport path selection model of a single variety of goods. Further analysis found that: through transforming the network and reconstructing the objective function, it can simplify a linear constraint model about shortest path.
Keywords: Multi-modal transport; Transportation path; Optimization model.

1 Introduction

In recent years, the demand for structure of transportation has been changed. The demand for mass freight has relatively substantially declined, but bulk freight and other types of goods demand have a rapid increase. Therefore, enterprises have to provide more efficient and personalized transportation services.

Cargo transport in human economic activities plays a very significant role, also provides basic material guarantee for the sustainable development and human survival economy. Because of this, cargo transport on the economic, social and human development of the country plays a vital role. Multimodal transport, an advanced form of transport organization, is a transport activity through which transport enterprises can integrate the technical and economic advantages of transport. Multimodal transport is the innovation of the method of transportation organization; also it can reduce transportation costs effectively, improve the efficiency of transportation, enrich the types of cargo, as well as expand the service scope of transportation enterprises.

The main job of transportation path selection is to select a transportation route between the start and end point, and allocate the freight volume rationally to each city node, thereby forming a viable transportation scheme. Path selection is a significant part of organization and implementation of multimodal transport.

In the past, most of the studies explored that constructing a multi target model of path selection about minimum transport times and costs, reasonable path set as the basis for the choice of path. However, the network description and model structure had some problems. But for a single variety of goods, there would be no network transport volume distribution problem, the effect of capacity constraints limit is so minimal. We can use the point-arc model, and the form will be simpler.

2 Influence Factors of Path Selection

Considering the whole process of intermodal transportation companies completing the tasks, the route selection is affected by multiple factors, including transport costs, transportation time, multimodal transport network carriage capacity, change trains ability in the city node and other factors.

(1)Transport cost

Transport cost is the major basis of how the multimodal transport enterprises select routes and transportation solutions. As for multimodal transport enterprises, faced with increasingly fierce competition on the transportation market, effectively reducing the costs is of vital importance to their survival and development. By utilizing reasonable transportation solutions, multimodal transport enterprises can effectively reduce the costs and thus acquire greater pricing space, which effectively improves their competitiveness and viability in the market.

(2) Transport time

Shorter transport time means rapid speed of goods turnover and transportation of goods with high efficiency. In the actual transport process, multimodal transport enterprises need to balance transport time and cost, and find the most favorable transportation scheme.

(3) Network transport capacity

The maximum volume of freight transport line can load, which constitutes the basis of the transportation network. The transport capacity will be greatly restricted multimodal transport enterprises to develop transport organization flexibility.

(4) Nature of goods

This is one of the important factors of transportation path choice. Generally speaking, coal, iron and steel, oil and other mass freight would certainly not use air transport and high effectiveness of goods will not be transported by water.

3 Multimodal Transport Network

3.1 Network description

Transport network can be described as a simple undirected graph $G (V, E, C, T, H, F)$, V, a set of nodes, means city; E, a set of undirected arc, means some modes of transport between two cities; C is a set of arc capacity; T is a set of arc time; H is a set of arc cost; F is a set of goods flow.

3.2 Multimodal transport network characteristics

Compared with the single mode of transport, Multimodal transport has some obvious differences.

(1)More nodes. Due to a variety of modes of transport, farther transport distance, larger transport cover areas.

(2) More alternative modes of transport.

(3) Problem is on a larger scale.

4 Model Constructions

4.1 Boundary assumption

(1) Assuming that a single variety of goods and its corresponding transport OD determined completely

(2) The structure of transportation network has been completely determined.

(3) The cargo can't exceed the time limit in the transport process.

(4) The cargo in transform modes of transport allows only one mode of transport to carry.

(5) The cargo isn't allowed to contain a loop in the transport path.

4.2 Define variables and parameters

T_{ij}^{k}——the transport time cost in code i to j by using the k mode of transport.

T_{i}^{kl}——the time cost about a mode of transport by the k converted to l.

C_{ij}^{k}——the transport capacity of the k mode of transport in code i to j.

C_{i}^{kl}——the change trains ability of transport by the k converted to l in code i.

H_{ij}^{k}——the transportation cost in code i to j by using the k mode of transport.

H_{i}^{kl}——the transfer cost in code i of transport by the k converted to l.

$$Y_{ij}^{k}=\begin{cases}1 & using\ the\ k\ mode\ of\ transport\ in\ code\ i\ to\ j\\0 & otherwise\end{cases}$$

$$X_{i}^{kl}=\begin{cases}1 & transport\ by\ the\ converted\ to\ l\ in\ code\ i\\0 & otherwise\end{cases}$$

4.3 Objective function

The objective function is determined as the minimum total transportation cost, including transportation costs inside city and transfer cost.

$$\min Z = Z_{y} + Z_{z} = Q\cdot\left(\sum_{k=1}^{M}\sum_{i=1,i\neq j}^{N}\sum_{j=1}^{N}H_{ij}^{k}\cdot Y_{ij}^{k}+\sum_{i=1}^{N}\sum_{k=1}^{M}\sum_{l=1}^{M}H_{i}^{kl}\cdot X_{i}^{kl}\right)$$

4.4 Constraint condition

(1) Path constraint

$$\begin{cases} \sum_k \sum_a Y_{ab}^k - \sum_l \sum_c Y_{bc}^l = 0 & \left(b \notin \{\mathrm{O,D}\}\right) \\ \sum_k \sum_a Y_{\mathrm{O}a}^k = \sum_l \sum_c Y_{c\mathrm{D}}^l = 1 & \end{cases} \tag{1}$$

$$\sum_{k=1}^{M} \sum_{i=1}^{N} \sum_{j=1}^{N} Y_{ij}^k \le 1 \tag{2}$$

Through (1) to ensure that the goods form a complete path in OD, through (2) to ensure that the path does not contain the "ring" structure.

(2)Transit constraint

$$\begin{cases} \sum_k \sum_j Y_{ij}^k \ge \sum_k \sum_l X_i^{kl} & (i \ne \mathrm{O}) \\ \sum_k \sum_i Y_{ij}^k \ge \sum_k \sum_l X_j^{kl} & (j \ne \mathrm{D}) \\ \sum_k \sum_l X_{\mathrm{O}}^{kl} = \sum_k \sum_l X_{\mathrm{D}}^{kl} = 0 & \end{cases} \tag{3}$$

$$\left(\sum_a Y_{ab}^k - \sum_c Y_{bc}^l \right) X_b^{kl} = 0 \tag{4}$$

$$\sum_{i=1}^{N} \sum_{k=1}^{M} \sum_{l=1}^{M} X_i^{kl} \le R \tag{5}$$

The (3) ensure that goods are only in the transport path to transfer, (4) means using the same method of transportation through the node is also considered a transfer, (5) ensures the required number of transit.

(3)Transport capacity constraints

$$\left(Q \cdot X_i^{kl} \le C_i^{kl} \right) \cap \left(Q \cdot Y_{ij}^k \le C_{ij}^k \right) \tag{6}$$

(4) Transport time constraint

$$\sum_{k=1}^{M} \sum_{i=1}^{N} \sum_{j=1}^{N} T_{ij}^k \cdot Y_{ij}^k + \sum_{a=1}^{N} \sum_{l=1}^{M} \sum_{m=1}^{M} T_a^{lm} \cdot X_a^{lm} \le T \tag{7}$$

This constraint ensures that the total transportation time does not exceed the time limit of requirements.

(5) Ordinary variables constraint

$$Y_{ij}^{k}, X_{i}^{kl} \in \{0,1\} \tag{8}$$

4.5 Model Analysis

(1) This model is a nonlinear programming, due to (4), in order to ensure the corresponding transit and transportation mode so produced quadratic term.

(2) For (6) its essence is consistent with res.8, it can use the method of simplified network to slack off those constraints.

(3) The objective function form are same with (7), it can directly be constructed as a part of objective function.

5 Conclusions

Transport network path optimization for a single variety of goods is the basis for optimization problem. Its essence is a simple network shortest path problem. For many varieties of goods transport task problem in a certain limit number of locomotive arriving at depot conditions, is same with optimal locomotive routing problem. For node splitting, network reconstruction, algorithm design, all of those are the focus of the next step research.

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References

Cheng Xiangdong (2005). "Optimal and solution of multiple transportation modes." *Journal of Tian jin normal university natural science edition.* 2005, 25 (3), 66-69.

Tian Yaming (2011). "Railway carflow distribution mode-arc and are-path models based on multi-commodity and virtual arc." *Journal of the China railway society.* 2011,33 (4), 7-12.

Xiao Tianguo (2008). "Optimizing route of multi-modal transportation based on genetic algorithm." *Sciencepaper online.* 2008,3 (10), 720-724.

Yang Xue (2013). "Research on the optimal routes and modes selection in container multimodal transportation network consider of the transshipment time." *Southeast University.*

Zhang Dezhi (2002). "A combination optimization modal for multiple transportation mode selection and solution algorithm". *Journal of Chang sha railway university.* 2002, 20(4), 71-75.

Preponderant Haul Distance of the Harbin-Dalian High-Speed Railway under Competition

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Abstract: After the operation of Harbin-Dalian high-speed railway, the market share of air transport in northeast area declined obviously because high-speed railway took over a part of aviation customers in various haul distances. On the basis of analyzing the influencing factors on travelers' choices in high-speed passenger transport, this paper provided a questionnaire based on SP survey. Through the field investigation in Dalian and Harbin, Logit model to analyze the preponderant haul distance of high-speed railway was demarcated. After solving the model and analyzing the competitive edges of Harbin-Dalian high-speed railway in different haul distances.
Keywords: Integrated transportation; Dominate transport distance; Logit; Passenger-sharing rate; Competition.

1. Introduction

Harbin-Dalian High-speed Railway is the important constituent part of Beijing-Harbin Passenger Dedicated Line in the "four vertical and four horizontal" system of China's high-speed railway, it is the "aorta" of high -speed transport in northeast China, at the same time, it is also the current high speed railway with highest designing construction standard in the most northern cold region of China, it was officially opened on December 1st, 2012. Seeing from the statistical data of relevant departments in Dalian city, the loss of business customers of Dalian civil aviation is about 40 percents, the shock of high-speed railway is obvious. Civil aviation passenger transport will adjust flights and fares to redeem the loss customers, and the competition between high-speed railway and civil aviation in northeast China region will become more intense.

This paper chooses Harbin-Dalian line as the study area, and has made indeed SP questionnaire survey to the passengers, analyzed the results, and identified the factors which influence passengers' travelling choices, demarcated Logit, and constructed high-speed railway's preponderant transport distance analytical model with the competition of civil aviation, discusses the preponderant transport distance of high-speed railway.

2. Modeling

A The construction of competition model and the utility function testing passengers' choice of high speed passenger transports is comprised of observable utility and random utility. Then the utility function of passenger choosing the k high speed passenger transport can be expressed as

$$U_{ik} = V_{ik} + \varepsilon_{ik} \tag{1}$$

Wherein V is the fixture of the utility function, ε is the probability of the utility function. Currently, there are two ways of high speed passenger transport net of high-speed rail way and air transport, therefore, the probability of high speed rail way to be chosen is.(K1 represents high speed rail way, K2 represents air transport)

$$p(k_1) = \frac{e^{V(k_1)}}{e^{V(k_1)} + e^{V(k_2)}} \tag{2}$$

There are a variety of relationships between V_{ik} in term (1) and the influence variables contained in it, in the specific form, the utility determination function can be expressed by one or more functional forms, taking convenience in results analysis and coefficients marking into accounts, currently linear function is commonly used as an expression for the utility function, namely

$$V_{ik} = \sum_{j=1}^{n} \theta_j X_{ikj} \tag{3}$$

Wherein X_{ikj} is the j influence factor of i passenger choosing the k high speed passenger transport, θ j is the parameter X_{ikj} corresponds to. Term (5) can be expressed as

$$p(k_1) = \frac{e^{\sum_{j=1}^{n} \theta_j X_{ik_1 j}}}{e^{\sum_{j=1}^{n} \theta_j X_{ik_1 j}} + e^{\sum_{j=1}^{n} \theta_j X_{ik_2 j}}} \tag{4}$$

$$p(k_2) = 1 - p(k_1) \tag{5}$$

3 .The calibration of Influence factors

Before travel, travelers usually in the subconscious, based on subjective ideological factors choice which way to travel. Through the analysis of disaggregate model of the individual requirements of the traveler's property, The main factors affecting the selections of high-speed passenger transportation way can be divided into personal attributes, transport properties and trip properties, each attribute contains factors and define variables as shown in table 1.

Table 1.BL model parameters table

	Factors	Variable	Explanation
Personal Attributes	Sex	X1	Men 1,Women 2
	Old	X2	Divided into 5 age groups: under 18, 18 to 30, 31 to 50, 51 to 60, 61 years and older, X2 values of 1 to 5
	Profession	X3	Professional for five: Students, civil, servants, enterprise staff, teachers and others,X3 values of 1 to 5
Transport Properties	Fare	X4	Ticket prices according to the discount division: the full price, 7 fold,5 fold, 4 fold, 3 fold and the following, X4 values of 1 to 5
	Punctuality Rate	X5	Punctuality rate divided according to time delays: On time,$0 < L\leq 0.5h$,$0.5h < L\leq 1h$,$1h < L\leq 1.5h$,$1.5h < L\leq 2h$,$L > 2h$, X5 values of 1 to 5
	Occupied Space	X6	Occupied space is divided into: $0 < S\leq 0.5m3$,$0.5 m3 < S\leq 1 m3$,$1 m3 < S\leq 1.5 m3$,$1.5 m3 < S\leq 2 m3$,$S > 2 m3$, X6 values of 1 to 5
	Security	X7	In accordance with the number of incidents classified as 1,2,3,4,5 and above, X7 values of 1 to 5
	Interval	X8	Interval is divided into: 1h,2h,3h,4h,5h and above, X8 values of 1 to 5
Trip Properties	Trip Purpose	X9	Travel purpose is divided into: school, travel, friends and relatives, business and others, X9 values of 1 to 5
	Trip Distance	X10	Trip distance is divided into:0 to 500km,501 to 1000km,1001 to 1500km,1501 to 2000km,2001km and above, X10 values of 1 to 5
	Before Time and After Time	X11	Before time and after time is divided into: 0.5h,1h,1.5h,2h,2h or more, X11 values of 1 to 5
	Before Cost and After Cost	X12	Before cost and after cost is divided into:30yuan,50yuan,100yuan,150yuan, 200yuan or more, X12 values of 1 to 5

4. Model calibration and result analysis

Since there are many influence factors involved in the questionnaire, so parts of the influence factors are selected, which are the five influence factors of age, costs for reaching the junction station, journey fare, time for reaching the junction station and waiting time, the survey data is integrated again, and Guibiogeme software is used to solve the model and calibrate model parameters, the calibration results of each parameter are seen in Table 2.

Table 2. The parameters of the model calibration results

Influence factor	Variable		Parameter values	T_ test	P_ test
ASC_ civil aviation		α_7	2.54	2.86	0.00
ASC_ high-speed railway		α_6	0.00		
Age	X_1	α_1	1.10195	2.23	0.01
Costs for reaching the junction station	X_2	α_2	-0.259	-0.04	0.06
Journey fare	X_3	α_3	-0.00786	-1.02	0.03
Time for reaching the junction station	X_4	α_4	-3.57	-3.36	0.05
Waiting time	X_5	α_5	-3.07	-0.98	0.04

According to the values of t_ test and p_ test in Table 3, test indexes of each factor meet with the accuracy requirement after query. It can be seen from the parameter values of each influence factor that the parameters of other influence factors are negative values except age, and it shows that the utility of this kind of trip mode increases with the decrease of costs before journey, whole time before journey and journey fare. So influence factors calibrated in Table 3 can be used to establish the utility model in Formula 6, and the data of questionnaire can be used for analysis.

$$U_i = \alpha_1 X_1 + \alpha_2 X_{2i} + \alpha_3 S_i c_i + \alpha_4 X_{4i} + \alpha_5 X_{5i} + \alpha_6 R_{HSR} + \alpha_7 R_{air} + \varepsilon_i \qquad (6)$$

$\alpha_1 - \alpha_7$ in Formula are the corresponding calibration coefficients of influence factors in Table 4, X1、X2i、X4i、X5i corresponds to the influence factors in Table

2; Si represents the transport distance of the i kind of transportation mode; c_i represents the freight rate of per unit distance of the i kind of transportation mode; $S_i c_i$ is the fare, according to the current pricing situation of high-speed railway fare and air ticket, the freight rate of per unit distance of high-speed railway is 0.43 Yuan per kilometer, and civil aviation passenger transport is 1.16 Yuan per kilometer, the freight rate of per unit distance of civil aviation passenger transport is 0.812 Yuan per kilometer when air ticket fare is 30% off, and it is 0.464 Yuan per kilometer when air ticket fare is 60% off. The related attribute value of high-speed railway and civil aviation passenger transport can be seen in Table 3 according to the investigation.

Table 3.The related attribute value of Harbin Dalian line of high speed railway and civil aviation passenger transport

	Fare（yuan）	Trip distance（km）	Time before journey（min）	Costs before journey（yuan）
High-speed railway	400	921	48	33
Civil aviation passenger transport	1 200	857	54	36

It is assumed that the transport distance of two kinds of high-speed transportation mode of high speed railway in Harbin Dalian line and civil aviation was the same, and then Formula 6 can be used to calculate the market shares of high-speed railway and civil aviation in different transport distances according to the above conditions of utility model and parameter setting, the calculation results are shown in Figure 1.

It can be seen in Figure 1 that the variation tendencies of high-speed railway share rate curve under different air ticket discounts are basically the same, the most intense competition (the both sides share the market equally, which means that the market share rate of high-speed railway and civil aviation is equal to 0.5) transport distance changes from 1000km to 850km between high-speed railway and civil aviation with the decrease of air ticket price. It shows that the preponderant transport distance of high-speed railway reduces, and the competitive advantage of civil aviation increases with the decrease of civil aviation ticket price.

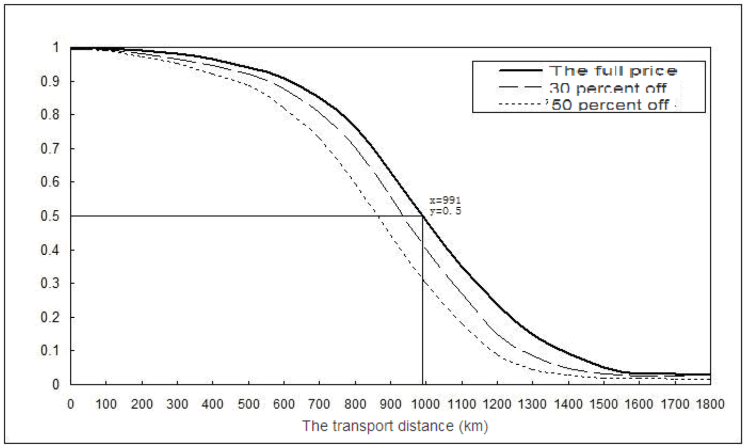

Fig1. Civil aviation under the competition of Harbin Dalian high speed railway passenger transport sharing rate and distance diagram

We analyze the share rate change of high-speed railway when civil aviation is full price at the same time, it can be seen from the figure obviously that there are two mutational sites in the curve, the first mutational site is in the distance of 700km, the passenger transport share rate of high-speed railway is 0.85 at the moment, the second mutational site is in the distance of 1400km, the passenger transport share rate of high-speed railway is 0.092 at the moment. The passenger transport share rate of high-speed railway has been at a higher level in the transport distance range of 0 to 700km; in the range of 700 to 1400km, the passenger transport share rate of high-speed railway decreases sharply with the increase of transport distance; the passenger transport share rate of high-speed railway decreases below 0.1 when the transport distance is above 1400km, and the decline range of share rate starts to decrease with the increase of transport distance.

5. Analysis on the preponderant transport distance of Harbin Dalian high speed railway

Considering that the current shortest voyage of civil aviation in our country is 150km, so Analysis on the preponderant transport distance starts with the transport distance above 150km.

(1)The transport distance of 300km to 600km

It can be seen from Figure 1 that high-speed railway still can bear more than 90% passenger flow volume with its advantages and characteristics in competition with civil aviation transportation. In this transport distance, the decline change of passenger transport share rate of high-speed railway is not obvious with the increase of transport distance in competition with civil aviation transportation, it is because that in this range of transport distance, high-speed railway has inborn advantages in aspects of travel time, travel cost, convenience and so on. The total travel time of high-speed railway is less than civil aviation transportation, and junction stations of high-speed railway are easier to connect with urban transport, the travel cost is lower than civil aviation transportation obviously. Along the line of Harbin Dalian high speed railway, the distance between Shenyang and Dalian is 400km. Hainan Airlines used to open the airline in the interval of Shenyang and Dalian, the lowest fare is 360 Yuan, a group per day, and the run time is 50 minutes, the overall travel time is more than 210 minutes if time before journey and check-in time is calculated. And the fare of second-class seats of high-speed railway that opened on December, 2012 is 180 Yuan, there are 35 high-speed trains every day, the run time is 115 minutes, the overall travel time of passengers is about 180 minutes when time before journey and waiting time is calculated. It can be seen that no matter on cost or travel time, high-speed railway both has advantages over civil aviation transportation in this transport distance.

(2)The transport distance of 600km to 800km

It can be seen from Figure 4-1 that the absolute advantage of high-speed railway starts to weaken with the increase of transport distance in competition with civil aviation transportation. It is because that the rapidity advantage of high-speed railway weakens with the increase of transport distance in the range of 600 to 800km, and it is the initiative transport distance that civil aviation transportation starts to give full play to its rapidity advantage in this range of transport distance, the rapidity of civil aviation transportation brings corresponding passenger flow volume for it. But on the whole, the transport distance is also in the range with advantage of high-speed railway, the mode share forecast of high-speed railway can still accounted for more than 70%.

(3) The transport distance of 800km to 1200km

The transport distance range is the region with intense competition between high-speed railway and civil aviation, at the same time, the market domain is paid close attention by high-speed railway and civil aviation. The competitive advantage of high-speed railway within this transport distance scope is decreasing rapidly, and the corresponding side is competitive advantage of civil aviation grows rapidly, both of the two want to take advantage in the competition, and therefore, the competition is quite fierce. The economy-class high-speed railway ticket between Changchun and Dalian is 304 Yuan, and the run time is 154 minutes.

References

Fan H. (2009). Analysis of the potential impact of high-speed railway on civil aviation. *China Civil Aviatio.*

Fu.X.Y. and Juan .Z. C. et al. (2007). "Disaggregated model-based Chang chun residents travel times data analysis." *Journal of Transportation Systems Engineering and Information Technology*.

Hu.Q.H. and Peng Z. (2009). Analysis of the impact of high-speed railway on air transport market. *Comprehensive Transportation.*

Luan W. X. and Zhang. X. et al. (2012). "Competition between Wuhan-Guangzhou High-speed Railway and Civil Aviation Based on Disaggregate Model." *Journal of Transportation Systems Engineering and Information Technology*

Peter Jorritsma (2008). Substitution Opportunities of High Speed Train for Air Transport. *transport business.*

CVaR Model and Algorithm for the Risk Assessment Problem of Hazmat Multi-Modal Transportation

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Abstract: In order to provide different result to the decision makers with different risk preference of hazardous materials transportation adaptively, we bring conditional value-at-risk (CVaR) modal into the risk assessment question of multimodal transportation of hazardous materials. First we analyzed the entire process of multimodal transportation of hazardous materials systematically, and then we built the CVaR model, and tried to change the traditional model into a new optimization model. According to the characteristics of the model, we designed an algorithm based on node-arc. A numerical example shown that CVaR model of different confidence level could be solved by the algorithm quickly and efficiently. The results show that the CVaR model could cover risk preference from risk-neutral to risk-averse, and it is a more proper and flexible risk measure for multimodal transport of hazardous materials decision making.
Keywords: Hazardous materials; Risk assessment; CVaR model; Multi-modal transportation; Link-based algorithm.

1 Introduction

Hazardous materials (hazmat) are usually transported by highway, rail and water, etc. Since China is currently in the process of industrialization phase, the transportation volume of hazmat is increasing year by year. With the increase in volume, the number of hazmat transportation accidents are increasing too. Taking into account that the low accident probability and low cost characteristics of railway and waterway, and the flexibility and convenience of highway, multimodal transportation that combine the advantages of various modes has become a major choice of long-distance transport of hazmat.

In hazmat transportation research field, risk assessment problem has been extensively studied, and the detailed review is in Shuai (2014). But in the field of multimodal theory, risk assessment problem is mainly involved with other problems. Verma (2010, 2012a, 2012b) published three papers which defined hazmat rail-road intermodal transportation total risk as the summation of in-bound and out-bound highway transportation risk and rail-haul transportation risk while studying hazmat network design problem, and among them, the first two papers chose population exposure as risk measurement index, and the last one chose expected consequence. Xie (2012) also chose expected consequence as the index while studying hazmat location routing problem, and define the total risk as the summation of transportation risk of each arc and the transshipment risk of each node along the path. Wei Hang described total risk as the summation of transshipment and transportation risk, but gave no specific risk measurement model. Kai Yanxia (2009) define total risk as the expected loss of intermodal transportation accidents of link and transshipment accident of nodes.

CVaR model is proposed based on VaR model. Kang (2014) pointed out that traditional risk assessment models (such as tradition risk, population exposure et al.) only reflect limited risk preference, therefore, she proposed VaR risk assessment model of hazmat transportation, and utilize it in the study of hazmat routing problem and network design problem. After that, Kwon pointed out that VaR model may ignore the extremely high risk which is distributed in the long tail, and the author introduced CVaR risk model into hazmat transportation, since CVaR model obviously concerns more about the distribution in the long tail in order to avoid the extreme accident, and CVaR is more appropriate to be used in hazmat transportation.

From the above analysis, we can see that there is lack of systematically study about risk assessment model of the whole process of multimodal hazmat transportation, and the existed study doesn’t provide preference-adaptive risk assessment model for different kind of decision makers according to their risk preference. We verified that CVaR model is flexible (Shuai,2014), scalable and preference-adaptive in assessment of hazmat highway transportation. Thus, in this paper we are about to introduce CVaR model into hazmat multimodal transportation risk assessment problem, build a CVaR model after systematical analysis of the whole process, and design an effective algorithm for the model. Finally, we will test the validity of the model and algorithm through a numerical example.

2.CVaR risk assessment model of hazmat multimodal transportation

2.1 Process analysis of hazmat multimodal transportation

Generally, hazmat multimodal transportation contains three processes. First one is highway drayage, includes inbound drayage and outbound drayage. Second one is long-distance transport, which is to move the goods from the starting to the ending transshipment station, and the carriers often choose railway and waterway. The last process is transshipment operation, which is to transfer goods from one vehicle to another. Therefore, while building the risk assessment model, we have to systematically consider every part of the risk, includes inbound and outbound risk, rail/water haul risk and transshipment risk.

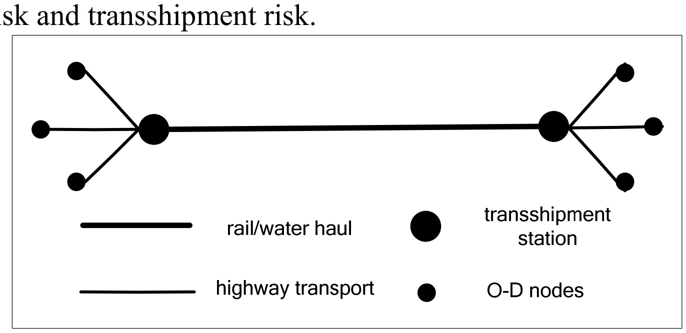

Figure1. Process of hazmat multimodal transportation

2.2 Mathematical models

We consider a graph of hazmat multimodal transportation network $G=\{V,A,A'\}$, where V means the set of nodes, both A and A' are set of arcs, respectively represent all the links and all the transportation modes of the links. Suppose a path l consists of an ordered set of arcs, transportation modes and transshipment nodes $\Re^l=\{(i,j)_\theta^{k'}\in A, i^{k''}\in V: k=1,2,...,m_l;\theta\in A'\}$, where $(i,j)_\theta^{k'}$ is transportation mode θ in the path's k' process, and $i^{k''}$ means the transshipment node i in the path's process k''. For each $(i,j)\in A,\theta\in A'$, accident probability is p_{ij}^θ, and accident consequence is c_{ij}^θ. For each transshipment node $i\in V$, transshipment accident probability is p_i, and accident consequence is c_i. To simplify the calculation, we suppose that the accident probability is of the k step is p_k, and the accident consequence is c_k.

Suppose hazmat is transported along path ,conditional probability of the accident happens in k step is:

$$p_k^l=\left[\prod_{(i,j)^h\in\Re^l, i^h\in\Re^l, h<k}(1-p_k)\right]p_k \tag{1}$$

According to hazmat transportation accident statistics(Abkowitz,1988), accident probability of hazmat transported by rail and highway is extremely small, usually in the range of $10^{-8}\sim10^{-6}$ per mile traveled, and therefore, $\prod_{(i,j)^h\in A^l, i^h\in A^l, h<k}(1-p_k)\approx1$. Thus $p_k^l\approx p_k$. So in the following words, arcs' and nodes' accident probability can be used to replace the conditional probability of that the accident happens in that arc or node in the path.

Set the value of accident consequences of $\Re^l$ in ascending order, and we can get $(C_{(1)}^l,C_{(2)}^l,...,C_{(h)}^l,...,C_{(n_l-1)}^l,C_{(n_l)}^l)$, and the corresponding order ff risk probability is $(p_{(1)}^l,p_{(2)}^l,...,p_{(h)}^l,...,p_{(n_l-1)}^l,p_{(n_l)}^l)$. Among them, $C_{(h)}^l$ means the h th accident consequence of path $l\in\wp$. Then the risk measure R_l of path l takes the following values:

$$R_l=\begin{cases}0, & w.p.\ 1-\sum_{\eta=1}^{n_l}p_{(\eta)}^l\\ C_1^l, & w.p.\ p_{(1)}^l\\ \vdots & \\ C_{(n_l)}^l, & w.p.\ p_{(n_l)}^l\end{cases} \tag{2}$$

Where n_l represents the number of arcs and transshipment nodes of $\Re^l$, and $w.p.$ represents with probability. And for a given R_l, its cumulative distribution function is as follows:

$$F_{R_l}(r)=\Pr(R_l\le r)=\begin{cases}0, & if \quad r<0\\ 1-\sum_{\eta=1}^{n_l}p_{(\eta)}^l, & if \quad 0\le r<C_{(1)}^l\\ 1-\sum_{\eta=2}^{n_l}p_{(\eta)}^l, & if \quad C_{(1)}^l\le r<C_{(2)}^l\\ \vdots & \vdots\\ 1-\sum_{\eta=h}^{n_l}p_{(\eta)}^l, & if \quad C_{(h-1)}^l\le r<C_{(h)}^l\\ \vdots & \vdots\\ 1, & if \quad C_{(n_l)}^l\le r\end{cases} \tag{3}$$

Set $\wp$ to be the paths set of the road network, when the confidence level is α, the VaR value of path $l\in\wp$ is:

$$VaR_\alpha^l=\min\{r:\Pr(R_l\le r)\ge\alpha\} \tag{4}$$

And when the confidence level is α, the CVaR value of path $l\in\wp$ is as follows.

$$CVaR_\alpha^l=\frac{1}{\alpha}\int_0^\alpha VaR_\beta^l d\beta \tag{5}$$

From (5) we can see CVaR means the conditional expectation when the losses exceed VaR.

Formula (5) is difficult to be solved, since VaR_β^l is unknown during the analysis. Based on that, Rockafellar define CVaR as the solution(Rockafellar,2000) of a optimization problem as formula (6).

$$CVaR_\alpha(X)=\min_C\left\{C+\frac{1}{1-\alpha}E[X-C]^+\right\} \tag{6}$$

Where $[t]^+=\max\{0,t\}$.

Inspired by equation (6), since the variable we study in this article is a discrete random one, we can obtain that for a given confidence level α, the CVaR value of path l of hazmat multimodal transportation is:

$$\Phi_\alpha^l(C)=C+\frac{1}{1-\alpha}E[X-C]^+\approx C+\frac{1}{1-\alpha}\left\{\sum_{(i,j)_\theta\in A^l}(p_{ij}^\theta[c_{ij}^\theta-C]^+)+\sum_{i\in V^l}(p_i[c_i-C]^+)\right\} \tag{7}$$

As can be seen from equation (7) , if we want to get the smallest value of CVaR, we have to choose path $l\in\wp$ which has the smallest Φ_α^l when the confidence level is α. That is $\min_{l\in\wp}CVaR_\alpha^l=\min_{l\in\wp,C\in R^+}\Phi_\alpha^l(C)$, where $C\in R^+$ represents C is a positive number. Therefore, we can get formula (8).

$$\min_{l\in\wp} CVaR_{\alpha}^{l} = \min_{l\in\wp, C\in R^{+}} \Phi_{\alpha}^{l}(C)$$
$$= \min_{C\in R^{+}} \min_{l\in\wp} \left\{ C + \frac{1}{1-\alpha} \left\{ \sum_{(i,j)_{\theta}\in A^{l}} (p_{ij}^{\theta}[c_{ij}^{\theta} - C]^{+}) + \sum_{i\in V^{l}} (p_i[c_i - C]^{+}) \right\} \right\} \tag{8}$$

3 Algorithm

Taking into account that the direct calculation method needs all the paths of the OD pair, and it is complicated and difficult to calculate. So we can change the path-based model into traditional link-based model, and then solve the optimization model . The specific process is as formula (9).

$$\min_{l\in\wp, C\in R^{+}} \Phi_{\alpha}^{l}(C) = \min_{C\in R^{+}} \min_{l\in\wp} \left\{ C + \frac{1}{1-\alpha} \left\{ \sum_{(i,j)_{\theta}\in A^{l}} (p_{ij}^{\theta}[c_{ij}^{\theta} - C]^{+}) + \sum_{i\in V^{l}} (p_i[c_i - C]^{+}) \right\} \right\}$$
$$= \min_{x\in\Omega, y\in\Omega', C\in R^{+}} \left\{ C + \frac{1}{1-\alpha} \left\{ \sum_{(i,j)_{\theta}\in A} p_{ij}^{\theta}[c_{ij}^{\theta} - C]^{+} x_{ij}^{\theta} + \sum_{i\in V^{l}} (p_i[c_i - C]^{+} y_i) \right\} \right\} \tag{9}$$
$$= \min_{C\in R^{+}} \left\{ C + \frac{1}{1-\alpha} \left\{ \min_{x\in\Omega} \sum_{(i,j)_{\theta}\in A} p_{ij}^{\theta}[c_{ij}^{\theta} - C]^{+} x_{ij}^{\theta} + \min_{y\in\Omega'} \sum_{i\in V^{l}} (p_i[c_i - C]^{+} y_i) \right\} \right\}$$

Where x_{ij}^{θ} means if link (i,j) use transport mode θ, and y_i means if transshipment happens in node i.

$$\Omega \equiv \left\{ x : \sum_{(i,j)\in A} \sum_{\theta\in A'} x_{ij}^{\theta} - \sum_{(j,i)\in A} \sum_{\theta\in A'} x_{ji}^{\theta} = \begin{cases} 1, & i = o \\ -1, & i = d \\ 0, & otherwise \end{cases} \quad \forall i \in V, x_{ij}^{\theta} \in \{0,1\} \quad \forall (i,j) \in A \right\} \tag{10}$$

$$\Omega' \equiv \left\{ y : \begin{matrix} \sum_{(j,i)\in A} x_{ji}^{p} + \sum_{(i,j)\in A} x_{ij}^{q} - 1 \le y_i & \forall i \in V, y_i \in \{0,1\}, p \in A', q \in A', \text{且} p \ne q \\ y_i = 0 & \forall i \in V, p \in A', q \in A', \text{且} p = q \end{matrix} \right\} \tag{11}$$

Set the value of accident consequences of all the links and nodes in the network in ascending order, and we can get $(C_{(1)}, C_{(2)}, ..., C_{(h')}, ..., C_{(n'-1)}, C_{(n')})$, and the corresponding order of risk probability is $(p_{(1)}, p_{(2)}, ..., p_{(h')}, ..., p_{(n'-1)}, p_{(n')})$. Among them, $C_{(h')}$ means the h' th accident consequence of the links and nodes $\{c_{ij}^{\theta} \,\&\, c_i : (i,j)^{\theta} \in A, i \in V, \theta \in A'\}$. Because $C \in R^{+}$, the value of C could be consisted of the following segments:

$[0, C_{(1)}], [C_{(1)}, C_{(2)}], ..., [C_{(n'-1)}, C_{(n')}], [C_{(n')}, +\infty]$, then defining $C_{(0)} = 0$, we obtain:

$$\min_{x\in\Omega}\sum_{(i,j)_\theta\in A} p_{ij}^{\theta}[c_{ij}^{\theta}-C]^{+}x_{ij}^{\theta}+\min_{y\in\Omega'}\sum_{i\in V^{l}}(p_i[c_i-C]^{+}y_i)$$
$$=\begin{cases}\sum\limits_{(i,j)\in A,\theta\in A',c_{ij}^{\theta}>C_{(h)}} p_{ij}^{\theta}(c_{ij}^{\theta}-C)x_{ij}^{\theta}+\sum\limits_{i\in V,c_i>C_{(h)}} p_i(c_i-C)y_i, if \quad C\in\left[C_{(h')},C_{(h'+1)}\right], h'=0,2,...,n'-1 \\ 0 \qquad if \quad C\in\left[C_{(n')},+\infty\right]\end{cases} \quad (12)$$

Therefore, $CVaR_{\alpha}^{*}=\min_{h'=0,1,...,n'} CVaR_{\alpha}^{h'}$, where problem:

$$CVaR_{\alpha}^{h'}=\min_{C\in R^{+}}\left\{C+\frac{1}{1-\alpha}\left[\min_{x\in\Omega}\sum_{(i,j)\in A,\theta\in A',c_{ij}^{\theta}>C_{(h')}} p_{ij}^{\theta}(c_{ij}^{\theta}-C)x_{ij}^{\theta}+\min_{y\in\Omega'}\sum_{i\in V,c_i>C_{(k)}} p_i(c_i-C)y_i\right]\right\}, C\in\left[C_{(h'-1)},C_{(h')}\right] \quad (13)$$

From formula (13) we know, for each h', we just need to minimize a linear function of C in (13), over the interval $\left[C_{(h')},C_{(h'+1)}\right]$. Since (13) is a linear function, we can get that the optimal value will be obtained either at $C=C_{(h')}$ or at $C=C_{(h'+1)}$. So we can obtain an optimal solution C^* by examining only the values in the set $(C_{(1)},C_{(2)},...,C_{(h')},...,C_{(n'-1)},C_{(n')})$. The function is as follows:

$$CVaR_{\alpha}^{*}=\min_{C=0,C_{(1)},...,C_{(n')}}\left\{C+\frac{1}{1-\alpha}\left\{\min_{x\in\Omega}\sum_{(i,j)\in A,\theta\in A'} p_{ij}^{\theta}\left[c_{ij}^{\theta}-C\right]^{+}x_{ij}^{\theta}+\min_{y\in\Omega'}\sum_{i\in V} p_i\left[c_i-C\right]^{+}y_i\right\}\right\} \quad (14)$$

We can use the following algorithm to solve (14:)

Step 1: For $h'=0,1,...,n'$, solve the following formula (15):

$$CVaR_{\alpha}^{h'}=\min_{C\in R^{+}}\left\{C_{(h')}+\frac{1}{1-\alpha}\left[\min_{x\in\Omega}\sum_{(i,j)\in A,\theta\in A',c_{ij}^{\theta}>C_{(h')}} p_{ij}^{\theta}(c_{ij}^{\theta}-C_{(k)})x_{ij}^{\theta}+\min_{y\in\Omega'}\sum_{i\in V,c_i>C_{(h')}} p_i(c_i-C_{(k)})y_i\right]\right\}, C\in\left[C_{(h'-1)},C_{(h')}\right] \quad (15)$$

Step 2: Let $h'^{*}=\arg\min_{h'=0,1,...,n'} CVaR_{\alpha}^{h'}$。

Step 3: Then we get: $CVaR_{\alpha}^{*}=CVaR_{\alpha}^{h'^{*}}$, and $x^{*}=x^{h'^{*}}$, $y^{*}=y^{h'^{*}}$。

4 Numerical Example

In order to verify the effectiveness of the CVaR risk assessment model and algorithm of hazmat multimodal transportation, we specially set up a simple multimodal transportation network shown in Figure 3. The example network consists of 7 nodes and 11 links. There are three kinds of transportation modes, highway, railway and waterway, and the OD pair of the hazmat is from node 1 to node 7. Each arc has a binary weights, respectively means accident probability and accident consequence. Probability and consequences of transshipment accidents are shown in Table1.

For the above example, we can easily get the results of the optimal CVaR values under different confidence level by using the algorithm described before, in an ordinary PC (OS Windows system , CPU is AMD Turion X2 RM-75 2.20GHz, RAM is 3GB). And the results are shown in table 2. Farther more, in order to compare the CVaR model with other models, we also find the optimal path using other models, and the results are shown in table 3.

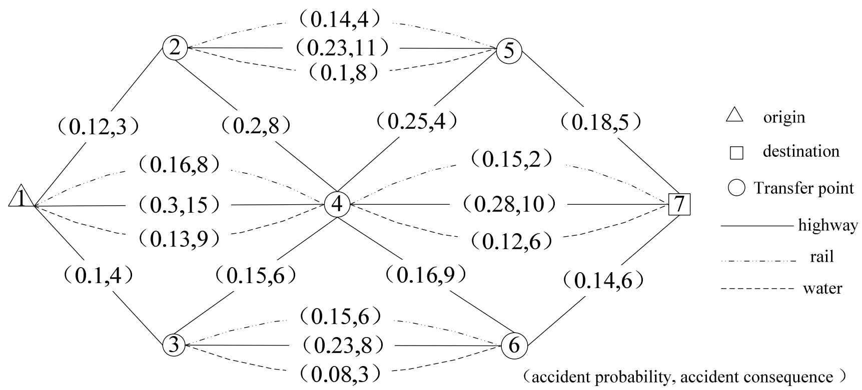

Figure 2. Network of the example

Table 1. Transshipment parameters

Transportation modes	rail		highway		water	
	Accident probability	Accident consequence	Accident probability	Accident consequence	Accident probability	Accident consequence
rail	0	0	0.1	3	0.1	3
highway	0.1	3	0	0	0.1	3
water	0.1	3	0.1	3	0	0

Table 2. CVaR results (R means rail, and W means water)

α	≤ 0	≤ 0.1	≤ 0.2	≤ 0.3	≤ 0.4
CVaR	1.58	1.76	1.98	2.26	2.63
Path*	1-R-4-R-7	1-R-4-R-7	1-R-4-R-7	1-R-4-R-7	1-R-4-R-7
α	≤ 0.5	≤ 0.6	≤ 0.7	≤ 0.8	≤ 0.9
CVaR	3.16	3.95	4.6	4.9	5
path*	1-R-4-R-7	1-R-4-R-7	1-R-4-R-7	1-2-5-R-7	1-2-5-R-7

Table 3. Alternative risk model comparison (TR & IP & PE & VaR & CVaR)

α	≤ 0		≤ 0.1		≤ 0.2		≤ 0.3		≤ 0.4	
model	*VaR*	*CVaR*	*VaR*	*CVaR*	*VaR*	*CVaR*	*VaR*	*CVaR*	*VaR*	*CVaR*
value	0	1.58	0	1.76	0	1.98	0	2.26	0	2.63
number	31	1	31	1	31	1	29	1	24	1
α	≤ 0.5		≤ 0.6		≤ 0.7		≤ 0.8		≤ 0.9	
model	*VaR*	*CVaR*	*VaR*	*CVaR*	*VaR*	*CVaR*	*VaR*	*CVaR*	*VaR*	*CVaR*
value	0	3.16	0	3.95	0	4.6	2	4.9	5	5
number	7	1	4	1	1	1	1	1	2	1
model	TR			IP				PE		
value	1.58			0.25				10		
path*	1-R-4-R-7			1-W-4-W-7				1-R-4-R-7		

From the results in Table 2, we can see that multimodal transportation of hazmat is a more competitive transportation mode. In addition, as can be seen from Table 3, compared with the conventional models, giving a different confidence level α, CVaR model could obtain different optimal solutions, while the conventional model can only obtain an optimal solution. Therefore, CVaR model could provide different path choices according to the different risk preferences of different decision makers. And with low confidence level α, the VaR value of each path might be the same, so the decision makes could choose every path they want, but compared with the VaR model, CVaR model could avoid the big accident in some links , which is more suitable for the hazmat transportation risk assessment problem.

5 Results

In this article we established a CVaR model for hazmat multimodal transportation risk assessment, and taking into the subadditivity of the CVaR model which is different with other conventional models, we customized a link-based algorithm for the model. By a computational experiment, we verified the validity of the model and algorithm. And we obtained that CVaR model has an advantage of the adaptive risk preference compared with the traditional model, and it could avoid the extreme accident to reduce the transportation risk which is different from the VaR model, and it is suitable for risk assessment of hazmat multimodal transportation.

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References

Abkowitz M, Cheng P (1988). Developing a risk/cost framework for routing truck movements of hazardous materials. *Accident Analysis & Prevention*, 20(1):39-51.

Kai Yanxia, Wang Haiyan(2009). Research on optimization of transportation mode and route for hazardous materials transportation network. Journal of Safety Science and Technology , 5(1): 37-41.

Kwon, C(2011). Conditional Value-at-Risk Model for Hazardous Materials Transportation. Proceedings of the 2011 Winter Simulation Conference:1703-1709.

Rockafellar R, Vryasev S(2000). Optimization of conditional value-at-risk. Journal of Risk, 2:21-42.

Shuai Bin, Huang Li-xia(2014). Developments in research on assessment of risk in hazardous materials transportation. China safety science journal, 24(7):50-56.

Verma M, Verter V(2010). A lead-time based approach for planning rail-truck intermodal transportation of dangerous goods. European Journal of Operational Research, 202(3): 696-706.

Verma M, Verter V, Zufferey N(2012a). A bi-objective model for planning and managing rail-truck intermodal transportation of hazardous materials. Transportation Research Part E, 48 (1): 132-149.

Verma M(2012b). A fixed-penalty cost and expected consequence approach to planning and managing intermodal transportation of hazardous materials. AIMS International Journal of Management, 6(2): 101-118.

WEI Hang(2006). Routing for hazardous materials transportation with time-varying. Southwest Jiaotong University.

Xie Y, Lu W(2012). A multimodal location and routing model for hazardous materials transportation. Journal of Hazardous Materials, (227/228): 135-141.

Yingying Kang, Rajan Batta, Changhyun Kwon(2014). Value-at-Risk model for hazardous materials transportation. Annals of operations research, 222: 361-387.

Equilibrium Model under the Condition of Multi-Mode to Travel Choice and Mixed Traffic

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Abstract: This paper analyzes travel mode choice of equilibrium problems in three kinds of travel ways that constituted the way of car, bus, subway. The research subjects are urban residents in the peak period, in the process of travel mode choice selection basis for their own travel costs. Urban road don't have bus lanes, that is to say cars and buses in the mixture on the same roads. In order to make the residents travel mode choice more accord with people's actual travel characteristics, the travel cost function are considered main factors in the residents travel mode choice process. The urban resident's travel mode choice model was established in travel peak period and under the condition of cars and buses mixed driving and based on the user equilibrium theory and the traffic bottleneck theory. Obtain the maximum delay time, the number of trips and travel costs in travel costs equilibrium station. The rationality of the model was verified by a numerical example, the next was further discussed that the high value time of travel and low time value of travel traveler's impact on travel division and time delay are analyzed in comparison. The examples show that: Firstly, subway travel was to be choice of the majority of residents, whether they are high time value of travel or low time value of travel. Secondly, there are more high time value of travel residents choose car travel, compared with the low time value of travel residents.
Keywords: Multi ways of travel; Balance of travel cost; Mode share; Delay time.

1 Introduction

In 1956, Beckmann put forward mathematical programming model to meet the user equilibrium principle based on Wardrop user equilibrium (Wang Wei, 2004) which can be defined as: travelers select the shortest path according to the traffic station, travel costs are the same in the path actually used and less than any unused path (Zhou Jing, 2001). User equilibrium principle is mainly used in route choice, research of travel mode choice barely refer to user equilibrium. We can define travel mode choice equilibrium problem as travel path choice equilibrium problems under the travel network. This will introduce user equilibrium principle to the travel mode choice.

According to the definition of route choice of user equilibrium, travel mode choice equilibrium can be defined as: in the travel peak, all residents travel from the starting points to the ending points will choose minimum cost of travel mode independently, when reaching the station of travel mode choice equilibrium, residents cannot unilaterally change their way of travel and reduce the cost of travel, all travel costs are the same. This paper will research residents travel mode choice under mixed traffic conditions according to the travel mode choice equilibrium and the relevant research results of traffic bottleneck theory (Vickrey, 1969; Arnott et al, 1988, 1990, 1993, 1998; Tabuchi, 1993; Lin Zhen, Yang Hao, 2003, 2004), establishing travel mode choice model to analyze mode share and time delay between high value travel time residents and low value travel time residents under the equilibrium station of travel mode choice.

2 Basic assumptions and associated symbol definition

2.1 Basic assumptions

The travel network consists of cars, buses and subways, residents in the morning peak travel from home to workplaces. The starting point and ending point are connected by a subway line and a road. Assuming cars and buses share a road, there is a bottleneck at the end of the road. The capacity of the bottleneck is s, when the road vehicles exceeds s, people have to queue up and wait to pass the neck.

For cars, travel have no walking time, bus and subway have walking time; comparing the convenience of bus and subway, assuming subway have longer walking time than bus. For buses, departure time interval (q) is fixed, capacities are the same, so the conveying capacity of bus line (S_2) is fixed. Similarly to the metro, conveying capacity (S_3) is fixed too.

Suppose there are N residents travel from living areas (starting points) to workspaces (ending points) every morning, in relatively stable travel process, N can be regarded as constant. Every morning peak, N_1 residents choose cars, N_2 residents choose buses, N_3 residents choose subways, the number of each travel mode is unknown.

2.2 Symbol definition

Symbols are defined as follows:

t ——Departure time of car mode and the time that arrive at the pick-up point of bus and subway;

t^* ——The time of arriving destination on time;

$C_j(t)$ ——The cost of mode j;

T_j^c ——General time of travel mode j in off-peak;

$T_j^e(t)$、$T_j^p(t)$、$T_j^l(t)$ ——When being early, on time or late, queue waiting time at the bottleneck of mode j;

T_2^o、T_3^o ——The time of walking to the bus and subway, assuming constant;

$T_2^d(t)$、$T_3^d(t)$ ——The time of residents waiting at bus station and subway station;

t_j^e、t_j^p、t_j^l ——For cars, they refer to earliest departure time, departure time when arrive on time and latest departure time; For buses and subways, they refer to earliest arriving time, arriving time when arrive on time and latest arriving time at bus station or subway station;

θ_1、θ_2、θ_3——Residents travel cost per unit time, the unit cost of penalty for early and late;

P_j——The fare of mode j;

q——Bus departure interval time;

π_j——uncomfortable cost function produced by crowded inside of mode j;

α、β——uncomfortable cost coefficient produced by crowded outside in the rush hour of bus and subway;

Among them : $j=1,2,3$; represent cars mode, buses mode and subways mode.

3 Model of travel mode choice

In the rush hour, the number of cars equals to N_1; the number of buses has to meet the demand of N_2 passengers, because the transmission capacity of buses is known, departure interval time is known too. So the number of buses in the rush hour is $K = N_2/(qS_2)$.

In order to reduce unnecessary errors in the process of modeling, convert buses into standard vehicles, conversion factor is λ. Therefore, in the rush hour standard vehicle number can be expressed as:

$$N_{12} = N_1 + \lambda K = N_1 + (\lambda N_2)/(qS_2) \qquad (1)$$

3.1 Equilibrium of cars travel cost

Cost for car mode: travel time cost (walking time, bus travel time, queue waiting time and delay time at bottleneck), penalty cost for early or late, fixed monetary cost. Residents can be divided into three categories respectively: early, on time and late. Residents bear the penalty cost for early or late.

Therefore, the cost of all residents that choose car mode can be expressed as:

$$C_1(t)=\begin{cases}\theta_1[T_1^c + T_1^e(t)] + \theta_2[t^* - t - T_1^c - T_1^e(t)] + P_1 & t\in[t_1^e, t_1^p) \\ \theta_1[T_1^c + T_1^p(t)] + P_1 & t = t_1^p \\ \theta_1[T_1^c + T_1^l(t)] + \theta_3[T_1^c + T_1^l(t) + t - t^*] + P_1 & t\in(t_1^p, t_1^l]\end{cases} \qquad (2)$$

When car mode is at equilibrium, residents' travel costs are the same. Suppose in the earliest and latest departure time, there is no delay time at bottleneck. It means residents set out at $t\in(t^e, t^l)$ have to queue up and wait. So in the station of equilibrium, the expected travel costs of residents that set out at $t = t_1^e$, $t = t_1^p$, $t = t_1^l$ are the same. Therefore, following is the equation:

$$E[C_1(t)]=\begin{cases}\theta_1 E[T_1^c] + \theta_2 E[t^* - t_1^e - T_1^c] + P_1 & t = t_1^e \\ \theta_1 E[T_1^c + T_1^p(t_1^p)] + P_1 & t = t_1^p \\ \theta_1 E[T_1^c] + \theta_3 E[T_1^c + t_1^l - t^*] + P_1 & t = t_1^l\end{cases} \qquad (3)$$

Rush hours at the bottleneck starts at t_1^e and ends at t_1^l, so queue waiting duration in the rush hour is $T = t_1^l - t_1^e$. The capacity of a path is determined by the bottleneck, it means $T = N_{12}/S$, therefore:

$$t_1^l - t_1^e = N_{12}/S = (N_1 + \frac{\lambda N_2}{qS_2})/S \quad (4)$$

When cars travel cost is at equilibrium, N_1 residents that choose car mode have same travel cost. Simultaneous equation (3) and (4), to solve t_1^e , t_1^l , t_1^p and $C_1(t)$ in the equilibrium condition of the residents that choose car travel.

$$\begin{cases} t_1^e = t^* - T_1^c - \frac{\theta_3}{\theta_2 + \theta_3} \cdot (N_1 + \frac{\lambda N_2}{qS_2}) \frac{1}{S} \\ t_1^l = t^* - T_1^c + \frac{\theta_2}{\theta_2 + \theta_3} \cdot (N_1 + \frac{\lambda N_2}{qS_2}) \frac{1}{S} \\ t_1^p = t^* - T_1^c - \frac{\theta_2 \theta_3}{\theta_1(\theta_2 + \theta_3)} \cdot (N_1 + \frac{\lambda N_2}{qS_2}) \frac{1}{S} \end{cases} \quad (5)$$

$$T_1^p = \frac{\theta_2 \theta_3}{\theta_1(\theta_2 + \theta_3)} \cdot (N_1 + \frac{\lambda N_2}{qS_2}) \frac{1}{S} \quad (6)$$

$$C_1(t) = \theta_1 T_1^c + \frac{\theta_2 \theta_3}{\theta_2 + \theta_3} \cdot (N_1 + \frac{\lambda N_2}{qS_2}) \frac{1}{S} + P_1, \qquad t \in [t_1^e, t_1^l] \quad (7)$$

3.2 Equilibrium of buses travel cost

The cost for bus mode include: travel time cost, penalty cost for early or late, uncomfortable cost produced by crowded inside and bus fare. Uncomfortable cost produced by crowded inside is associated with travel time and number of passengers, assuming the coefficient is α, so uncomfortable cost produced by crowded is $\pi_2[\alpha T_2^c(t)]$.

The cost of bus mode can be expressed as:

$$C_2(t) = \begin{cases} \theta_1[T_2^o + T_2^c + T_2^d(t) + T_2^e(t)] + \theta_2[t^* - t - T_2^c + T_2^d(t)] + \pi_2(\alpha T_2^c) + P_2 & t \in [t_2^e, t_2^p) \\ \theta_1[T_2^o + T_2^c + T_2^d(t) + T_2^p(t)] + \pi_2(\alpha T_2^c) + P_2 & t = t_2^p \\ \theta_1[T_2^o + T_2^c + T_2^d(t) + T_2^l(t)] + \theta_3[T_2^c + T_2^d(t) + t - t^*] + \pi_2(\alpha T_2^c) + P_2 & t \in (t_2^p, t_2^l] \end{cases} \quad (8)$$

Similar to cars, we can get t_2^e , t_2^l , t_2^p, T_2^w and $C_1(t)$ as follows:

$$\begin{cases} t_2^e = t^* - T_2^c - \frac{\theta_3}{\theta_2 + \theta_3} \cdot \frac{N_2}{S_2} \\ t_2^l = t^* - T_2^c + \frac{\theta_2}{\theta_2 + \theta_3} \cdot \frac{N_2}{S_2} \\ t_2^p = t^* - T_2^c - \frac{\theta_2 \theta_3}{\theta_1(\theta_2 + \theta_3)} [\frac{N_2}{S_2} - (N_1 + \frac{\lambda N_2}{qS_2}) \frac{\alpha}{\theta_1 S}] \end{cases} \quad (9)$$

$$T_2^w = T_2^d + T_2^p = \frac{\theta_2 \theta_3}{\theta_1(\theta_2 + \theta_3)} [\frac{N_2}{S_2} - (N_1 + \frac{\lambda N_2}{qS_2}) \frac{\alpha}{\theta_1 S}] \quad (10)$$

$$C_2(t) = \theta_1(T_2^o + T_2^c) + \frac{\theta_2\theta_3}{\theta_2+\theta_3}\cdot\frac{N_2}{S_2} + \pi_2(\alpha T_2^c) + P_2, \quad t\in[t_2^e, t_2^l] \tag{11}$$

3.3 Equilibrium of subways travel cost

Similar with buses, we can get t_3^e, t_3^l, t_3^p, T_3^d and $C_3(t)$ as follows:

$$\begin{cases} t_3^e = t^* - T_3^c - \dfrac{\theta_3}{\theta_2+\theta_3}\cdot\dfrac{N_3}{S_3} \\ t_3^l = t^* - T_3^c + \dfrac{\theta_2}{\theta_2+\theta_3}\cdot\dfrac{N_3}{S_3} \\ t_3^p = t^* - T_3^c - \dfrac{\theta_2\theta_3}{\theta_1(\theta_2+\theta_3)}\cdot\dfrac{N_3}{S_3} \end{cases} \tag{12}$$

$$T_3^d = \frac{\theta_2\theta_3}{\theta_1(\theta_2+\theta_3)}\cdot\frac{N_3}{S_3} \tag{13}$$

$$C_3(t) = \theta_1(T_3^o + T_3^c) + \frac{\theta_2\theta_3}{\theta_2+\theta_3}\cdot\frac{N_3}{S_3} + \pi_3(\beta T_3^c) + P_3, \quad t\in[t_3^e, t_3^l] \tag{14}$$

3.4 Equilibrium model of travel mode

When travel mode reaching equilibrium station, residents set out at rush hours have same travel cost no matter which mode they choose. A resident cannot reduce his cost by unilaterally changing his travel time or mode. That is to say, in the equilibrium condition of travel modes, meet the formula (15):

$$\begin{cases} C(t) = C_j(t) & N_i > 0 \\ C(t) \le C_j(t) & N_i = 0 \quad i = 1、2、3 \\ N = \sum N_i \end{cases} \tag{15}$$

$C(t)$ is the travel cost in the equilibrium condition of travel modes.

In practical situation, it is impossible that any travel mode isn't selected at rush hours. So, formula (15) can be converted into formula (16).

$$\begin{cases} C(t) = C_1(t) = C_2(t) = C_3(t) \\ N = N_1 + N_2 + N_3 \end{cases} \tag{16}$$

Total number of residents N is known already, $C_1(t)$、$C_2(t)$ and $C_3(t)$ have been calculated respectively；Bringing formula(7),(11) and (14) into (16):

$$\begin{cases} C = C_1(t) = \theta_1 T_1^c + \dfrac{\theta_2\theta_3}{\theta_2+\theta_3}\cdot(N_1 + \dfrac{\lambda N_2}{qS_2})\dfrac{1}{S} + P_1 \\ C = C_2(t) = \theta_1(T_2^o + T_2^c) + \dfrac{\theta_2\theta_3}{\theta_2+\theta_3}\cdot\dfrac{N_2}{S_2} + \pi_2(\alpha T_2^c) + P_2 \\ C = C_3(t) = \theta_1(T_3^o + T_3^c) + \dfrac{\theta_2\theta_3}{\theta_2+\theta_3}\cdot\dfrac{N_3}{S_3} + \pi_3(\beta T_3^c) + P_3 \\ \quad N = N_1 + N_2 \end{cases} \tag{17}$$

We can get C and [N_1, N_2, N_3] by solving formula(17):

$$\begin{cases} N_1 = \dfrac{(S-\frac{\lambda}{q})(B+S_2N)-(S_3+S_2)A}{S_2(S_3+S_2+S-\frac{\lambda}{q})} \\ N_2 = \dfrac{B+S_2N+A}{(S_3+S_2+S-\frac{\lambda}{q})} \\ N_3 = N-N_1^2-N_2^2 \end{cases} \quad (18)$$

$$C=\theta_1(T_2^o+T_2^c)+\frac{\theta_2\theta_3}{\theta_2+\theta_3}\cdot\frac{B+S_2N+A}{S_2(S_3+S_2+S-\frac{\lambda}{q})}+\pi_2(\alpha T_2^c)+P_2 \quad (19)$$

In formula(18)and(19):

$$\begin{cases} A=\dfrac{SS_2(\theta_2+\theta_3)}{\theta_2\theta_3}[\theta_1(T_1^c-T_2^o-T_2^c)+(P_1-P_2-\pi_2(\alpha T_2^c))] \\ B=\dfrac{S_2S_3(\theta_2+\theta_3)}{\theta_2\theta_3}[\theta_1(T_3^o+T_3^c-T_2^o-T_2^c)+(\pi_3(\beta T_3^c)-\pi_2(\alpha T_2^c)+P_3-P_2)] \end{cases} \quad (20)$$

4 Example analysis

According to the equilibrium model of travel mode, set up relevant numerical parameters, show the result by a numerical example, analyze the travel conditions of residents of low and high value of time. A numerical example set parameters are shown in table 1 and table 2.

Table 1. parameters 1

Parameters	N	T_1^c	T_2^c	T_3^c	T_2^o	T_3^o	P_1	P_2	P_3
Value	2000	1.0	1.5	1.2	0.1	0.15	12	2	5

Table 2. parameters 2

Parameters	α	β	S	S_2	S_3	q	λ
Value	0.8	1.2	6000	4000	10000	0.025	2

Parameters of per unit time cost of residents that have low or high value of time are shown in table 3.

Table 3. Parameters of per unit time cost

Parameters	θ_1	θ_1	θ_1
High value of time	20	15	25
Low value of time	15	10	20

According to (18),(19) and(20).and make $\pi_2(\alpha T_2^c)=\alpha T_2^c,\pi_3(\beta T_2^c)=\beta T_3^c$. We can figure the related parameters out in table 4.

Table 4. Numerical value in equilibrium station

Value	C	N_1	N_2	N_3	T_1^p	T_2^w	T_3^d
High Value of time	33.577	5843	3826	10331	0.438	0.402	0.459
Low Value of time	42.766	6825	3228	9947	0.538	0.400	0.466

Figure 1 shows the share rate of three travel modes in equilibrium station.

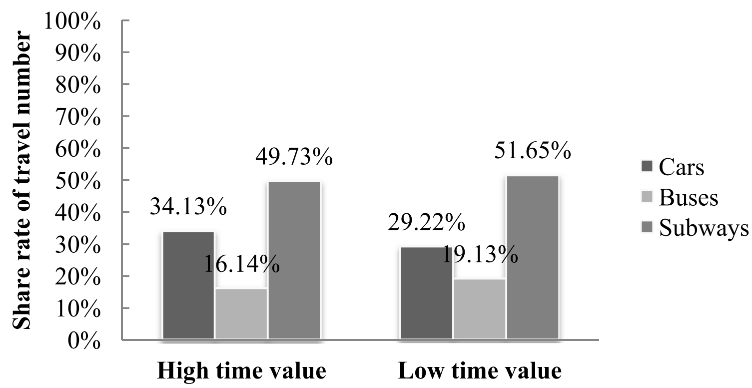

Figure 1. Share rate of three travel modes in equilibrium station

Figure 2 shows the total delay time of residents arrive on time in equilibrium station.

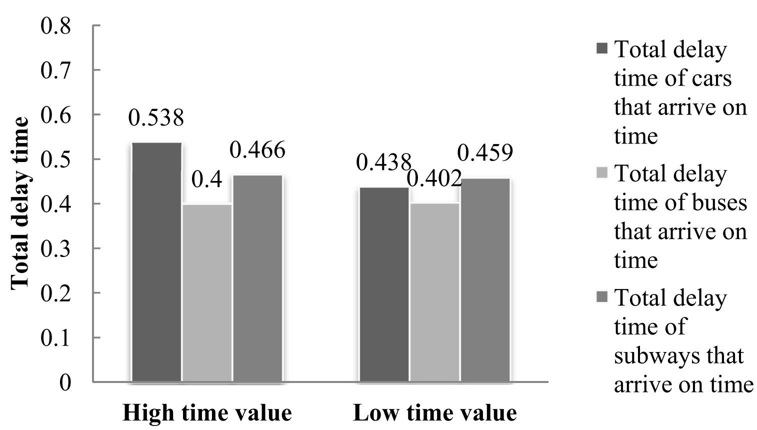

Figure 2. Comparison of total delay time of high and low time values

5 Conclusion

This paper defines travel mode equilibrium choice model based on user equilibrium theory. In the equilibrium model, analyze relevant parameters by numerical example, the result showed that: (1) Residents of high time value prefer car travel than bus travel, which is consistent with actual situation;(2) Summarize from the proportion of all travel modes, whether residents have high or low time value, subway is most residents' choice with the characteristics of time stability, large volume and cheap fares, it also explains why now in many big cities develop orbit traffic to ease urban congestion;(3) The analysis of numerical example also shows the rationality and applicability of travel mode choice equilibrium model.

References

Arnott R, Depalma A, Lindsey R.(1990).Economics of a bottleneck. *Journal of Urban Economics*, 27(1):111-130.

Arnott R, Depalma A, Lindsey R.(1993). A structural model of peak-period congestion: A traffic bottleneck with elastic demand. *The American Economic Review*, 83(1):161-179.

Arnott R, Depalma A, Lindsey R.(1998.)Recent development in the bottleneck .In: Button K J, Verhoef E T, Road Pricing, Traffic congestion and environment. *USA: Edward Elgar Publishing*, 79-110.

Arnott R, Depalma A, Lindsey R.(1988).Schedule delay and departure time decisions with heterogeneous commuters. *Transportation Research Record*, 1197:56-67.

Lin Zhen, Yang Hao.(2003).Modal split based on bottleneck model of public transport. *China Civil Engineering Journal*, .36(7)：1-6.

Lin Zhen, Yang Hao.(2004).Characteristics of trip modal equilibria under different conditions. *Journal of Industrial Engineering Management*, 18(2)：30-34.

Tabuchi T.(1993).Bottleneck congestion and modal split.*Journal of Urban Economics*, 34(3):414-431.

Vickrey W S.(1969).Congestion theory and transport investment. *The American Economic Review*, 59(2):251-260.

Wang Wei.(2004).Transportation Planning. *China Communications Press*, 85-87.

Zhou Jing.(2001).The urban traffic system analysis and optimization. Southeast University Press, 24-29.

Service Demand Forecast for an Inland Waterway Service Area: A Case Study on the Grand Canal, China

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Abstract: As a public auxiliary navigation facility for improving the service quality of inland water transport (IWT), inland waterway service area (IWSA), similar to the expressway service area, has been put forward at the Yangtze Delta in China recently. In order to satisfy the service demand, an appropriate water area for the vessel's mooring is a key point for the planning of IWSA. In this paper, with the questionnaire and field survey on main waterways in Jiangsu and Zhejiang provinces, the characteristics of service demand of IWSA were analyzed, such as the type of demand, driving-in rate, turnover rate. A model was established to forecast the service demand, the number of vessels driving-in, based on the traffic stream characteristics. Then the required water area can be calculated with the relationship between the area and tonnages of inland freight vessels. Finally, the method was applied to the Beijing-Hangzhou Grand Canal in the southern Jiangsu province, where the result is in accordance with the practical case.
Keywords: Inland waterway transport; Service area; Demand forecast; Grand canal.

1 Introduction

Inland waterway transport (IWT) is often claimed to be reliable, economic and environmentally friendly for its huge transport capacity (Lowe, 2005). IWT is an important part of the domestic transportation network in many countries and districts, such as China, the U.S., and Europe. They all insist on developing, operating and maintaining the infrastructure of their navigable inland waterway to satisfy the waterway freight demand. In the past decade, an inland waterway service area (IWSA), an excavated water zone along a navigation channel, was put forward to improve the efficiency and service quality of IWT at the Yangtze Delta in China (Wen et al, 2005; Liao et al., 2008).

As a public auxiliary navigation facility, IWSA, similar to the expressway service area (ESA), offers rest, convenience, and safety to vessels and crews. For most vessel's voyage, some fundamental service demands, such as refueling, clean water, fresh vegetables, are very necessary due to the poor living condition of vessels at present. This is also the original intention of the IWSA to provide these services. With the questionnaire and field survey on main waterways at the Yangtze Delta in China, the types of service demand of the IWSA were analyzed (Wen et al, 2005; Liao et al., 2008; Peng et al, 2011; Fan et al., 2014). Peng et al (2011) classified an IWSA into the mooring service area and the comprehensive service area according to the scale and service range, and discussed the site selection and distance for an IWSA. Fan et al (2014) proposed a feasible approach for the site selection of the IWSA whose function was divided into several categories: provision service, regulating service, cultural service, physical health, information exchange and sharing, financial and technical assistance, and repair service.

Based on the characteristics of service demand and the length of service time in the Yangtze Delta, Liao et al (2008) classified the service into three types and analyzed their corresponding service demand probability and averaged service time. The first type (Type I) is a locking service provided by a navigation lock. Due to the congestion on most main waterways in China, those locks almost provides upstream and downstream anchorages and other auxiliary facilities to wait for lockage. So, the existing facilities can be expanded and added functions to accommodate the service demand of the IWSA if necessary. The second type (Type II) is a mooring service independent of locks. The mooring service area can provides mooring at the origin and destination of a trip or having a rest at night during a voyage. The mooring services are characterized a longer time in the IWSA, usually in a few hours and even a few days. Furthermore, the other service demand also can be satisfied during the mooring including refueling, visa, daily necessities, garbage collection, and so on. The third type (Type III) is a brief service independent of locks. The brief service area usually accommodates those vessel paused temporarily for demand within one hour, such as refueling, shopping, logistics information. Obviously, as far as the water area is concerned, Type II and Type III services can be offered simultaneously or individually in a service area while they are separated from Type I.

The demand forecast is an important index for the planning of IWSAs and is also necessary to determine the scale reasonably, striking a balance between the service and investment. The earlier works mostly focused on the number of IWSAs as an index of demand forecasting for site selection (Peng et al, 2011; Fan et al., 2014). However, there is little information for the detailed design of a certain IWSA, such as the maximum vessels accommodated simultaneously, water area required, proper land area, and so on. Therefore, this paper pays more attention to the demand analysis for a certain IWSA based on the investigation by Liao et al (2008). The model is established to forecast the service demand which is denoted by the water area required for an IWSA. Then a case study, an application to the Beijing-Hangzhou Grand Canal in the southern Jiangsu province, is discussed.

2 Methodology

2.1 Method

Generally, it is a queuing process when a vessel drives into an IWSA. The service demand of the IWSA is the average length of the queue, or the mean volume of vessels in the queuing system. If the vessel arrival distribution, service time distribution and queuing discipline are known in advance, the mean length can be determined based on the queue theory. However, there are few researches on the information of the IWSA and considerable error could be made. Since the IWSA is similar to the ESA, it may be a proper method to refer the design of the ESA. For an ESA, the parking space is related with types of facilities, location, traffic volume, pause rate, turnover rate, peak rate, and so on (Japan Highway Public Corporation, 1991). Koo et al. (2014) shows the conventional process for determining the size of a new ESA in South Korea.

Therefore, based on the vessel flow characteristics, the process for determining the water area of the IWSA is shown in Figure 1. According to the observed or estimated vessel volume at a navigable section, the average vessel density can be calculated by the traffic stream characteristics (Gartner et al, 1996). Due to the stochastic vessel flow (Liao, 2013), the averaged vessel density indicates the mean level, and considerable error in density estimation could be made at the peak hour. Liao (2009) introduced a daily-flow disequilibrium coefficient with a guarantee percentage to analyze the temporal stochastic characteristics. So, the vessel density with a certain guarantee percentage can be determined on a navigable segment. Considering the demand probability or driving-in rate and average service time, the service demand, the number of vessels driving in an IWSA, can be forecasted when these factors are quantitatively analyzed by the questionnaire and flied survey. Finally, the water area required to moor those vessels can be determined with the transfer coefficient which comes from the relationship between the area and tonnage (RAT) of inland freight vessels (Liao and Zhang, 2009).

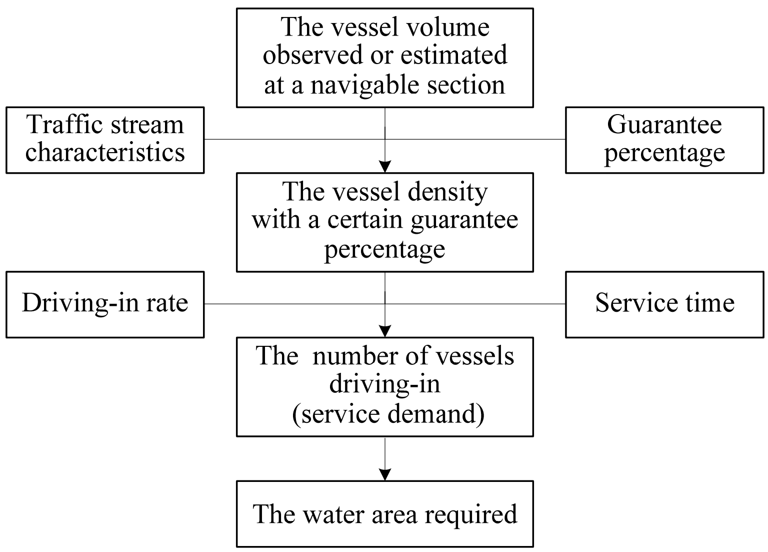

Figure 1. Process for determining the water area of the IWSA

2.2 Model

With the observed or estimated vessel flow on a navigable section at different planning years, the average vessel density can be expressed as:

$$k = \frac{Q}{Tg_a u} \tag{1}$$

where k is the average vessel density on a navigable segment interested (vessels/km); Q is the annual tonnage of vessels through a certain section (tons/a); T is the time of a year, 365 days/a or 8760 hrs/a; g_a is the averaged tonnage of a set of vessels (tons/vessel); and u is the average speed of a set of vessels (km/hr). The vessel density with a certain guarantee percentage is

$$k_p = k\alpha \tag{2}$$

where k_p is the vessel density with a p% guarantee (vessels/km), and the mean has a 50% guarantee, namely, $k = k_{50}$; α is the unit flow disequilibrium coefficient with a p% guarantee. Then, the number of vessels driving into the service area is

$$Q_{sp} = \beta k_p L_s \tag{3}$$

where Q_{sp} is the number of vessels driving into the service area with a p% guarantee (vessels); β is the demand probability or driving-in rate; L_s is the queuing length of vessels driving-in or waiting for service (km), and its value can calculated by

$$L_s = ut_s \tag{4}$$

where t_s is the averaged service time (days or hours). If the queuing length is longer than the length L covered by the IWSA, L_s is equal to L.

So, the water area required to moor those vessels for an IWSA is

$$A_{sp} = \eta Q_{sp} g_a \gamma \tag{5}$$

where A_{sp} is the value of water area with a p% guarantee (m^2); η is a safety factor related with the berthing and entrance/departure styles of vessels, more than one; γ is the transfer coefficient of the area and tonnage of inland freight vessels (m^2/ton).

Finally, combined Equations (1) ~ (5), the water area required for an IWSA is

$$A_{sp} = \eta \frac{Q}{T} t_s \alpha\beta\gamma, \quad ut_s < L \tag{6.a}$$

$$A_{sp} = \eta \frac{Q}{Tu} L \alpha\beta\gamma, \quad ut_s \geq L \tag{6.b}$$

If a service area may cover more than two navigable segments with different vessel flows, the water area can also be expressed as:

$$A_{sp} = \frac{t_s \eta\alpha\beta\gamma}{T} Q_1, \quad ut_s < L_1 \tag{7.a}$$

$$A_{sp} = \frac{\eta\alpha\beta\gamma}{Tu} \sum_{i=1}^{j} Q_i L_i + \frac{\eta\alpha\beta\gamma}{Tu} Q_{j+1} \left(ut_s - \sum_{i=1}^{j} L_i \right), \quad \sum_{i=1}^{j} L_i \leq ut_s < \sum_{i=j+1}^{r} L_i \tag{7.b}$$

$$A_{sp} = \frac{\eta\alpha\beta\gamma}{Tu} \sum_{i=1}^{r} Q_i L_i, \quad ut_s \geq \sum_{i=1}^{r} L_i \tag{7.c}$$

where r is the number of navigable segments covered by the IWSA, a positive integer; Q_i, L_i is the annual vessel flow and length covered by ith (i = 1, 2, …, j, …, r, $r \geq 2$) navigable segment, respectively. It is suggested that the serial number of the sequence begins from the segment where the service area is located or nearest.

For the equation (6) or (7), the several parameters need be discussed carefully before application. Firstly, Q can be observed at present or be estimated for the future, which is not the focus of this paper but can be referred Beuthe et al. (2001). The average speed u can also be observed or estimated easily. The values of α and γ can be analyzed with observed traffic data according to the works conducted by Liao (2009) and Liao and Zhang (2009). The value of η can be referred the design experience of other navigation facilities. Finally, the values of β and t_s can be determined based on the method developed for this work by Liao et al (2008). For example, Table 1 summaries the recommended values of the parameters for each type of service area to determine the water areas of the IWSAs on the Grand Canal in the Yangtze Delta based on the above mentioned investigation and researches.

3 Case Study

The Beijing-Hangzhou Grand Canal, the longest artificial canal in the world since 1400 years ago, becomes an indispensable part of the inland waterway network in China. Nowadays, the Grand Canal plays a huge role for the logistics and economic development at the Yangtze River Delta. Recently, the Grand Canal in the southern Jiangsu province, from the Jianbi Lock (JBL) located in Zhenjiang to Yaziba (YZB) located in Wujiang as shown in Figure 2, has being promoted the infrastructure to accommodate 1000-ton-vessels entirely.

According to the prior work conducted by Zou et al (2007), five different IWSAs, Zhenjiang, Changzhou, Wuxi, Suzhou, and Wujiang, are planned as shown in Figure 2. So, based on the Equation (7) and parameters in Table 1, the service demand and water areas can be calculated and are listed in Table 2.

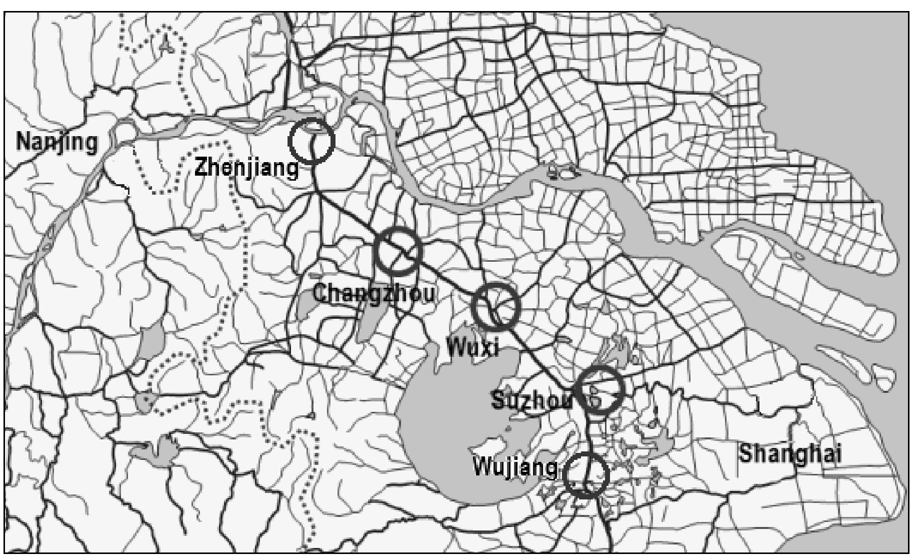

Figure 2. IWSAs on the Grand Canal in the southern Jiangsu

Table 1. List of parameters for the determination of the IWSA

Par.	u	T	t_s	α	β	γ	η
Type I	220 $km \cdot d^{-1}$	365 d	0.2 ~ 1.0 d	1.5*	0.5	$\frac{4.8g_a^{2/3}+56}{g_a}$	1.1 ~ 1.3
Type II	200 $km \cdot d^{-1}$	365 d	1.0 ~ 1.5 d	1.7*	0.2 ~ 0.4		
Type III	10 $km \cdot h^{-1}$	8760 h	1 h	2.6**	0.10 ~ 0.15		

*with a 98% guarantee for daily-flow; **with an 85% guarantee for hourly-flow.

Table 2. Service demand and water areas of the IWSAs on the Grand Canal

Service area	Service Type	Segment	Distance /km	Volume /$Tons \cdot a^{-1}$	Density* /$vessels \cdot km^{-1}$	Number /vessels		Water area /m^2
						partial	total	
Zhen-jiang	I	JBL~DJL	25.56	5007	6.96	88.9	189.1	57545
		DJL~JL	20.95	3478	4.83	50.6		
		JL~LJQ	9.39	3163	4.40	20.6		
		LJQ~CHZ	6.52	6387	8.88	28.9		
Chang-zhou	II	JL~LJQ	9.39	3163	4.98	14.0	173.9	52922
		LJQ~CHZ	6.52	6387	10.06	19.7		
		CHZ~CLX	1.69	6211	9.78	5.0		
		CLX~JHQ	15.63	5038	7.94	37.2		
		JHQ~WMK	7.33	5243	8.26	18.2		
	III	JL~LJQ	9.39	3163	6.35	11.9		
		LJQ~CHZ	6.52	6387	12.82	16.7		
		CHZ~CLX	1.69	6211	12.47	4.2		
		CLX~JHQ	15.63	5038	10.11	31.6		
		JHQ~WMK	7.33	5243	10.52	15.4		
Wuxi	II	WMK~GQ	13.45	7430	11.70	31.5	227.5	69218
		GQ~ XYX	8.13	12005	18.91	30.8		
		XYX~WQQ	17.86	6717	10.58	37.8		
	III	WMK~GQ	13.45	7430	14.92	40.1		
		GQ~ XYX	8.13	12005	24.10	39.2		
		XYX~WQQ	17.86	6717	13.49	48.2		
Suzhou	II	WQQ~SXX	25.84	7269	11.45	59.2	226.4	68880
		SXX~BDQ	7.06	9300	14.65	20.7		
		BDQ~GJK	6.91	9040	14.24	19.7		
	III	WQQ~SXX	25.84	7269	14.59	75.4		
		SXX~BDQ	7.06	9300	18.67	26.4		
		BDQ~GJK	6.91	9040	18.15	25.1		
Wu-jiang	II	GJK~PWG	24.00	9306	14.66	70.4	94.1	28623
		PWG~CHS	4.11	10432	16.43	13.6		
		CHS~YZB	14.43	2245	3.54	10.2		

* the density with a 98% or 85% guarantee for daily-flow or hourly-flow, respectively.

Table 2 shows that there are maximum 189 vessels to drive into the Zhenjiang Service Area dependent of Jianbi Lock simultaneously, which is in accordance with the practice. The area of the water area required is about 57545 square meters, about eight football fields. The mooring service (Type II) should be considered at Changzhou, Wuxi, and Suzhou to provide anchorage ground for those vessels at their origins and destinations since these segments are important component of the inland ports, which are top ten inland ports in China. Wujiang service area mainly provides the mooring and visa service due to the boundary between Jiangsu and Zhejiang provinces. It should be mentioned that the model and Table 2 only give the size of each service area without the consideration of its site selection.

4 Conclusions

In this study, the service demand and water area required analyzed for the IWSA, a public auxiliary navigation facility similar to the expressway service area. According to the characteristics analysis of service demand in the Yangtze Delta, the demands are classified into a locking service, a mooring service, and a brief service. Based on traffic stream characteristics, the model has been successfully established to forecast the number of vessels driving-in and water area required. The case study shows that the result is in accordance with the practice. This work only pays attention to the demand analysis for a single certain IWSA. More interaction between service demand and site selection of IWSAs can be considered in future studies.

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References

Beuthe, M., Jourquin, B., Geerts, J.-F., and Ndjang'Ha, C. K. (2001). “Freight transportation demand elasticities: a geographic multimodal transportation network analysis.” *Transportation Research Part E: Logistics and Transportation Review*, 37(4), 253-266.

Fan, L. Y., Chen, S. D., Lu, J., and Bi, H. Z. (2014). “Site Selection of Inland Waterway Service Area: A Feasible Approach.” *Transportation Research Board 93rd Annual Meeting*. Washington, DC., USA.

Gartner, N. H., Messer, C. J. and Rathi, M. (1996). “*Revised monograph on traffic flow theory*.” Federal Highway Administration (FHWA).

Japan Highway Public Corporation (1991). *Japan expressway design essentials*. Xi’an: Shaanxi Travel & Tourism Press.

Koo, C., Hong, T., and Kim, J. (2014). “A decision support system for determining the optimal size of a new expressway service area: Focused on the profitability.” *Decision Support Systems*, 67, 9-20.

Liao, P., Zhang, W., Jiang, Y., et al. (2008). “Analysis of characteristics of service demand on main inland waterway in Jiangsu province.” *Port & Waterway Engineering*, (6), 122-126.

Liao, P. (2009). “Temporal and spatial distributions of traffic flow in inland waterways.” *Hydro-Science and Engineering*, (2), 33-38.

Liao, P., and Zhang, W. (2009). “Research on relationship between the tonnage and area of inland vessels.” *Journal of Wuhan University of Technology (Transportation Science & Engineering)*, 33(4), 639-642.

Liao, P. (2013). “Analysis of freight vessels arrival distribution on the Grand Canal, China.” *4th International Conference on Transportation Engineering*, Chengdu, China.

Lowe, D. (2005). *Intermodal freight transport,* Oxford: Butterworth-Heinemann.

Peng, J. W., Lu, J., and Zhu, S. X. (2011). “Analysis on site selection and distance of an inland waterway service area.” *11th International Conference of Chinese Transportation Professionals*, Nanjing, China.

Wen, X. L., Li, H., and Guo, X. C. (2005). “Thinking of planning construction of serving area on the water of high grade channel.” *Modern transportation technology*, (4), 80-84.

Zou, Y., J., Xiao, S., et al. (2007). “*Layout of service areas on main waterways in Jiangsu province.*” Reported by Jiangsu Provincial Communication Planning and Design Institute Co., Ltd., Nanjing.

Prediction of Taxi Passenger Volume Based on a Gray Linear Regression Combined Model

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Abstract: For the situation that taxi passenger volume is diverse and uncertain, this paper constructs combined model of gray GM(1,1) and linear regression for a taxi passenger volume forecasting. The model which depends on the sample data itself, use linear regression equation and exponential equation to fit the curve of passenger volume. It requires less sample data and operates simply. The Lhasa city taxi passenger volume prediction indicates that the combined model obtained higher prediction accuracy than a single gray system or linear regression model. Finally, we predict the demand of taxi for the next two years in Lhasa city, and this will play a reference role in the formulation of policies for taxi industry.
Keywords: Taxi passenger volume; GM(1,1) model; Linear regression model; Gray linear regression combination model.

1 Introduction

In the abroad and domestic relevant study of taxi passenger volume, linear regression models are widely used. For example, the existing research of (Xin et al.,2005) tries to give the residents travel intensity regression forecasting method by using the city size, population and disposable income of residents and other explanatory variables. By analyzing the urban population, economic level, travel characteristic factors, taxi operating status and its law of development, the total amount of taxi travel prediction model is established. Instead of studying the internal influence factors and their mutual relations influencing taxi passenger volume, the gray model deem taxi passenger volume gray in a certain range of time-related changes and mine useful information to establish the model, reveal the law and make a prediction from its own data. This paper will combine the two methods, constitute a grey linear regression model, and predict the taxi passenger in Lhasa city as an example to illustrate. Example proves that the combined model obtained higher prediction accuracy than a single model, so it has higher practical application value.

2 Model

2.1 GM(1,1) model

Given $X^{(0)}$ is a non-negative original sequence, $X^{(0)}=(x^{(0)}(1),x^{(0)}(2),x^{(0)}(3),\ldots,x^{(0)}(n))$. After $X^{(0)}$ is accumulated, a new data column $X^{(1)}=(x^{(1)}(1),x^{(1)}(2),\ldots,(x^{(1)}(n))$ is generated, where $x^{(1)}(t)=\sum_{i=1}^{t}x^{(0)}(i),(t=1,2,\ldots,n)$ .z

For the generated sequence $X^{(1)}(t)$, there is a linear first-order albinism differential equation $dx^{(1)}/dt+ax^{(1)}=b$. When t is unit time, the difference form of the first-order differential equation is equal to the differential form, $dx^{(1)}/dt=x^{(1)}(t+1)\text{-}x^{(1)}(t)=x^{(0)}(t)$, so the differential equation of GM(1,1) model can be expressed as $x^{(0)}(t)+ax^{(1)}(t)=b$, which is called the original form of GM(1,1) model(Wang ,2011;Zhou,2005).

In order to obtain a smoother sequence of accumulated generating operation, $X^{(1)}$ is averaged with consecutive neighbors to generate the sequence $Z^{(1)}=(z^{(1)}(2),$ $z^{(1)}(3),z^{(1)}(4),\ldots z^{(1)}(n))$, where $z^{(1)}(t)=0.5(x^{(1)}(t)+x^{(1)}(t-1))$, $x^{(0)}(t)+a\mathrm{Z}^{(1)}=b$ is the basic form of GM(1,1) model, *a* is development coefficient, *b* is grey action, and $Z^{(1)}$ is the averaged sequence of $X^{(1)}$ with consecutive neighbors.

The parameters *a* and *b* of the basic form of GM(1,1) model are estimated with the least square method

$$\begin{bmatrix} a \\ b \end{bmatrix}=(\mathrm{B}^T\mathrm{B})^{-1}B^TY \tag{1}$$

Where $\mathrm{B}=\begin{bmatrix} -Z^{(1)}(2) & 1 \\ -Z^{(1)}(3) & 1 \\ \vdots & \vdots \\ -Z^{(1)}(n) & 1 \end{bmatrix}$ and $Y=(x^{(0)}(2),x^{(0)}(3),\ldots,x^{(0)}(n))^T$. The values of *a* and *b* are substituted into the albinism equation $dx^{(1)}/dt+ax^{(1)}=b$ of GM(1,1) model, and the time response function of GM(1,1) model is as follows:

$$\hat{x}^{(1)}(t+1)=(x^{(0)}(1)-\frac{b}{a})e^{-at}+\frac{b}{a}\ (t=1,2,\ldots,n-1) \tag{2}$$

Its form can be expressed as $\hat{x}^{(1)}(t+1)=c_1e^{at}+c_2$ and regressed to

$$\hat{x}^{(0)}(t+1)=\hat{x}^{(1)}(t+1)-\hat{x}^{(1)}(t)\ (t=1,2,\ldots,n) \tag{3}$$

2.2 Linear regression model

Regression analysis is a statistical analysis method to study the dependence of a random variable Y on another random variable X or a set of variables $(X_1, X_2, \ldots,.$ $X_k)$.The principle of inertia and the correlation theory were used to build the correlation model between the independent variable and the dependent variable affecting changes in taxi passenger volume. Then based on this model and the future value of the independent variable, the future value of the taxi passenger volume was predicted. The taxi passenger volume was taken as the dependent variable to build a regression model as follows:

$$X(t) = aY(t) + b \tag{4}$$

Where t is the actual year, $X(t)$ is the taxi passenger volume, and $Y(t)$ is the most significant factor affecting the taxi passenger volume.

2.3 Grey linear regression model

Use the sum of equation of linear regression and exponent equation for fitting and accumulation to generate the sequence $x^{(1)}(t)$, and generated sequence can be written as:

$$\hat{x}^{(1)}(t+1) = c_1 e^{ut} + c_2 t + c_3 \tag{5}$$

Where: u, C1, C2, and C3 are undetermined parameters.

Given $$Z(t) = \hat{x}^{(1)}(t+1) - \hat{x}^{(1)}(t) \ (t = 1, 2, \ldots, n-1) \tag{6}$$

Given

$$Y_m(t) = Z(t+m) - Z(t), (m = 1,2, \ldots, n-3; t = 1,2, \ldots, n-m-2) \tag{7}$$

Get $u = \ln[Y_{(m+1)}(t+1) / Y_{(m)}(t)]$, change $\hat{x}^{(1)}$ in (5)as $x^{(1)}$, and get approximate solution of the u $\tilde{V}_{(m)}(t) : \tilde{V}_{(m)}(t) = \ln[Y_{(m)}(t+1) / Y_{(m)}(t)]$, calculate the amount of $\tilde{V}$ as $(n-2)(n-3)/2$, that is

$$\hat{V} = \frac{\sum_{m=1}^{n-3} \sum_{t=1}^{n-m-2} \tilde{V}_m(t)}{(n-2)(n-3)/2} \tag{8}$$

Make $L(\mathrm{t}) = e^{\hat{V}t}$, and $\hat{x}^{(1)}(t) = c_1 L(t) + c_2 t + c_3$. Use least square method to get

$$C = \begin{bmatrix} c_1 \\ c_2 \\ c_3 \end{bmatrix} = (\mathrm{A}^T \mathrm{A})^{-1} \mathrm{A}^T X^{(1)} \tag{9}$$

Where $A = \begin{bmatrix} L(1) & 1 & 1 \\ L(1) & 2 & 1 \\ \vdots & \vdots & \vdots \\ L(n) & n & 1 \end{bmatrix}$; $X^{(1)} = (x^{(1)}(1), x^{(1)}(2), \ldots, x^{(1)}(n))^T$. Expectation value of generated sequence is $\hat{x}^{(1)}(t) = c_1 e^{\hat{V}t} + c_2 t + c_3$, it is arrived at: if $c_1 = 0$, linear accumulation generation sequence is linear regression model; if $c_2 = 0$, accumulation generation sequence is GM(1,1), new model improves the cases in which linear regression model does not include exponent increase trend and the GM(1,1) model does not include linear element. Down and restore are conducted as:

$$\hat{x}^{(0)}(t+1) = \hat{x}^{(1)}(t+1) - \hat{x}^{(1)}(t) \ (t = 1, 2, \ldots, n) \tag{10}$$

3 The Example Analysis

Historical statistical datas of annual taxi passenger number from 2008 to 2013 are shown in Table 1 according to the Statistical Yearbook of Lhasa. Table 1 is used for modeling and forecasting results for comparison.This paper intends to compare the predict results of the linear regression model, GM(1,1)model and gray combination of linear regression model and then predict the 2015 and 2017 passenger number in Lhasa.

Table. 1 Taxi passenger volume of Lhasa from 2008 to 2013 (ten thousands)

Years	2008	2009	2010	2011	2012	2013
Taxi passenger volume	1090.2	1249.5	1580.2	1812.9	2228.4	2606.1

3.1 Linear regression forecasting model

Using data in Table 1, respectively draw scatter plot of taxi passenger volume and various factors. A close linear relationship between taxi passenger volume and the year is found while observing the scatter plot shape and the coefficient of determination $r^2 = 0.9827$ is close to the constant 1 indicating that the fitting degree of regression straight line on the sample data points is very high. After solving linear regression equation with method of least squares, values are found to be $a = 307.11$, $b = \text{-}615690$. Get the linear regression equation $X(t) = 307.11t - 615690$ by substituting parameters into formula (3)and predictive value $X^{(0)} = (x^{(0)}(2), x^{(0)}(3), x^{(0)}(4), x^{(0)}(5), x^{(0)}(6)) = (1300.5, 1607.7, 1914.8, 2221.9, 2529)$ can be worked out.

3.2 Grey forecasting model

From previous section, it is known that: select Table 1 data for simulation and set up GM(1,1) model, original sequence is $X^{(0)} = (1090.2, 1249.5, 1580.2, 1812.9, 2228.4, 2606.1)$,conduct linear accumulation generation and close neighbor average value generation on original data, and get the values of B and Y as: $B = [-1714.95, -3129.8, -4826.35, -6847, -9264.25; 1, 1, 1, 1, 1]^T$, $Y = (1249.5, 1580.2, 1812.9, 2228.4, 2$

$606.1)^T$ .Use Matlab software, and substitute B and Y and get a and b as $a=-0.17801$ and $b=977.53$. Substitute a and b into time response function (2), and get $\hat{x}^{(1)}(t+1)=6581.6e^{0.17801t}-5491.4$. Use the equation (3) to conduct down regression and get simulation value of GM(1,1) model for original sequence as $\hat{X}^{(0)}(\mathrm{t})=(1282.3,1532.2,1830.7,2187.4,2613.6)$.

3.3 Gray linear regression combination forecasting model

Set up grey linear regression combination model based on linear regression function and exponent function,then use equations(6)~(8) and Matlab software to calculate $\hat{V}$ value as $\hat{V}=0.087$, linear regression combination model is get according to equation(5) : $\hat{x}^{(1)}(t)=c_1e^{\hat{V}t}+c_2t+c_3=c_1e^{0.087t}+c_2t+c_3$

According to equation (9), use Matlab matrix manipulation tool to get C value as $C_1=32511,\ C_2=-1972.2, C_3=-32400$, and get grey linear regression combination model as : $\hat{x}^{(1)}(t)=32511e^{0.087t}-1972.2t-32400$,then get the forecasting value of gray linear regression combination model as: $\hat{X}^{(0)}(\mathrm{t})=(1251.6,1544.6,1864.2,2213,2593.4)$

4. Error Detection

Forecast passenger traffic from 2009 to 2013 using linear regression model, GM(1,1) model and gray combination model and get the results in Table 2.

Table 2. Model error check list

Years	Actual value	Linear regression model		GM(1,1) mode		Combined model	
		Predicted value	Relative error/%	Predicted value	Relative error /%	Predicted value	Relative error /%
2009	1249.5	1300.5	4.08	1282.3	2.63	1251.6	0.17
2010	1580.2	1607.7	1.74	1532.2	3.04	1544.6	2.25
2011	1812.9	1914.8	5.62	1830.7	0.98	1864.2	2.83
2012	2228.4	2221.9	0.29	2187.4	1.84	2213.0	0.69
2013	2606.1	2529.0	2.96	2613.6	0.29	2593.4	0.49
Average relative error /%		2.94		1.76		1.29	

By comparing the results of the above example average relative error we found that although three kinds of models can be a taxi passenger volume forecasts, but the combination model has increased prediction accuracy compared with gray model and linear regression model. Use a combination model to predict the next three years taxi passenger volume of Lhasa based on the comparison and analysis of three kinds of prediction models, predicting the results in Table 3.

Table 3. Prediction value of Lhasa taxi passenger volume from 2008 to 2013 (ten thoustands)

Years	2015	2016	2017
Taxi passenger volume	3461.1	3955.0	4493.7

As can be seen from Table 3, the next three years taxi passenger volume will increase year by year and increase significantly. Lhasa as an important international tourist city, with Qingzang railway and Lari railway opened one after another, a large number of domestic and foreign tourists flocked to the city of Lhasa. As the floating population of the passengers has great impact on the taxi demand, the effects of population grow with each passing day, and frequent occurrence of various socio-economic activities resulting in travel increase dependence on motorized, which directly stimulate the taxi passenger volume growth.

5. Conclusions

Based on the gray GM(1,1) model and linear regression model, this paper constructes combination of gray linear regression model to improve deficiencies of which the original linear regression model is not include exponent increase trend and the GM(1,1) model lack of linear factor. Through analysis, this combination forecasting model is not only a true reflection of the evolving situation in Lhasa taxi passenger volume, and the prediction accuracy is higher than a single gray forecasting model or linear regression model. Finally, by forecasting the next three years taxi passenger volume in Lhasa shows that the amount of taxis need to increase.

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References

Daniel Flores-Guri(2003). "An economic analysis of regulated taxicab market." *Review of Industrial organization*.No.23:255-266.

Wang Xiufang(2011). "The Forecast of Taxi Vehicles of Zhejiang Province Based on Grey System Theory." *Journal of Taizhou University*. Vol.33,No.6.5-9.

Xin Songxin, Lin Jiawei and Xiao Zijian(2005). "Integrated planning model of urban taxi transportation." *2005 Proceedings of the National Graduate Mathematical Modeling*:5-11

Yang Shian,Zhou Shijian and Rao Guohua(2014). "Application Analysis of Based on Grey Linear Regression Combination Model Optimized by BP Neural Network." *Jiangxi Science.* Vol.32 No.1.14-16.

Zhou Ruiping(2005). "Application of the Grey Model to Forecasting Scale of Urban Population." *Journal of Inner Mongolia Normal University (Natural Science Edition).* Vol. 34 No. 1 Mar. 81-83.

Exploring the Coupling Relationship between Urbanization and Regional Transportation

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Abstract: This research explores the relationship between urbanization and regional transportation by using the coupling model. Evaluation indexes which reflect the coupling relationship have been selected out. The research evaluates the coupling relationship between urbanization and regional transportation on the basis of data stem from the city of Chengdu in Sichuan province from 2003 to 2013. The statistical results show the level and developing trend of coupling relationship in Chengdu. In the future research, the effective measures will be proposed for the mutual development of urbanization and regional transportation according to the results of this study.
Keywords: Urbanization; Regional transportation; Coupling relationship.

1 Introduction

Urbanization is not only the developing trend of society, but also the symbol of social progress. According to Ma and Zhang (2005), it refers to the gradual increase in the population of people living in urban areas. However, different attention has been paid to the term of urbanization in different research field. For instance, economists think of urbanization as the economic transition from rural to urban areas; anthropologists pay attention to the process whereby a society changes from a rural to an urban way of life; ecologists stress the environmental change in the process of urbanization. No matter how different the viewpoint on urbanization is, it has the common characteristics, including the migration of population to cities, the shift of economic structure, the change of the way of production and life, and the change of urban form.

As for the term of transportation, it is defined as the spatial displacement of people, goods and services (Chen and Shao, 1999). Modes of transportation include air, rail, road, water, cable, pipeline and space. Each way of transportation can be divided into line infrastructure, transport infrastructure, transport mobile devices, transport human resources and transport management system (Han, 2000). In detail, line infrastructure consists of roads, railways, pipelines and canals. Transport infrastructure consists of the fixed installations including terminals such as airports, railway stations, bus stations, warehouses, trucking terminals, refueling depots (including fueling docks and fuel stations) and seaports. Transport mobile devices are systems for vehicle operation. Transport human resources are people and organizations related to transport services. Transport management system is the platform for transport scheduling, cooperation and administration.

Transportation is very important because it leads to the shift of industrial structure and the change of urban spatial form, which is essential for the development of urban civilizations. Hence, most researchers focused on the interaction effect between urbanization and transportation. According to Wang and Rong (2014), urbanization asks for more demands of transportation, which causes the development of transportation; vice versa, transportation improves the urban economy and enhances effectiveness of space and time, because of its locational performance and network features. In recent years, transport oriented development (TOD) has become the mainstream of social development.

Based on the discussion, the research will evaluate the coupling relationship between urbanization and regional transportation (transportation of Chengdu which is the capital of Sichuan province) statistically. The results will help with clear understanding of the level and trends of coupling relationship between urbanization and transportation in Chengdu for a period of time.

2 Variables and Data Resources

The index system is the valid instrument for evaluating the coupling relationship between urbanization and regional transportation. Based on document reviewing (He, 2014; Wang and Rong, 2014), urbanization is measured by 6 indexes, while regional transportation is measured by 6 indexes as well. Proportion of non-agricultural population, proportion of employee in the service sector, proportion of the output value in the service sector, value of gross output per capita, the number of employee in health agency and population density are used to measure urbanization. Total distance of highway, the number of taxi, road area per capita, passenger capacity, the number of employee in transportation and volume of freight traffic are used to measure regional transportation. All the data are collected from the statistical yearbook of Sichuan province and the statistical yearbook of Chengdu city, from the year of 2003 to 2013.

3 Methodology

3.1 Data Standardization

In order to decrease the dimensional effect of variables on the results, this research takes standardization to original data by using the method of maximum difference standardization. After the data's standardization, all the data will be located in the range from 0 to 1. Because all the variables in the research are positive, the formula of maximum difference standardization will be introduced as:

$$x'_{ij} = \frac{x_{ij} - minx_{ij}}{maxx_{ij} - minx_{ij}} \quad i = 1,2,3 \dots m \ (, \ j = 1,2,3 \dots n) \tag{1}$$

m means the number of variables, while n means the number of indexes. $maxx_{ij}$ and $minx_{ij}$ are the maximum and minimum data of each index.

3.2 Weight Calculation

This research will take the way of principal component analysis (PCA) to calculate the weight of the indexes. The first step is to compute the communality of all indexes. The formula is shown as:

$$H_i^2 = \partial_{i1}^2 + \partial_{i2}^2 + \cdots + \partial_{ip}^2 \tag{2}$$

In this formula, *i* stands for the number of indexes, while *p* means the number of common factors.

The second step is to calculate the weight of each index according the results of communality of all indexes. The formula is shown as:

$$\lambda_i = \frac{H_i^2}{\sum_{i=1}^{n} H_i^2} \tag{3}$$

In this formula, *i=1,2,3…n,* $\lambda_i \in (0,1)$, and $\sum_{i=1}^{n} \lambda_i = 1$.

3.3 Evaluation of Urbanization and Regional Transportation

The evaluation results of urbanization and regional transportation can be calculated according to the formula shown as:

$$u_i = \sum_{j=1}^{n} \lambda_{ij} \times x'_{ij} \tag{4}$$

In this formula, u_i is the evaluation result of each variable. x'_{ij} are the standardized data, while λ_{ij} stands for the weight of each index.

In order to clearly understand the developing level of urbanization and regional transportation, this research divided the evaluation results into four levels which are shown in Table 1.

Table 1. Evaluation results and developing levels

Evaluation results	Developing levels
$u_i \in (0,0.25]$	Low
$u_i \in (0.25,0.5]$	Primary
$u_i \in (0.5,0.75]$	Medium
$u_i \in (0.75,1]$	Senior

3.4 Construction of the Correlation Model of Coupling Relationship

This research defines the correlation model of coupling relationship between urbanization and regional transportation as:

$$C_t = f(u_{1t}, u_{2t}) = 2\{(u_{1t} * u_{2t})/[(u_{1t} + u_{2t})(u_{1t} + u_{2t})]\}^{1/2} \quad (5)$$

The value of C_t reflects the strength of correlation between urbanization and regional transportation in the year of *t (t=1, 2, 3…T)*. In this formula, $u_i \in [0,1]$, u_{1t} and u_{2t} stand for the devotion of each index to the two variables -- urbanization and regional transportation. This research defines the relationship between the value of C_t and the levels of correlation which is shown in Table 2.

Table 2. Correlation values and levels

Correlation values	Correlation levels
$C_t \in (0,0.25]$	Low
$C_t \in (0.25,0.5]$	Primary
$C_t \in (0.5,0.75]$	Medium
$C_t \in (0.75,1]$	Senior

3.5 Construction of the Coordination Model of Coupling Relationship

This research also establishes the coordination model of coupling relationship between urbanization and regional transportation. The calculating functions are shown as followings.

$$U_t = \alpha * u_{1t} + \beta * u_{2t} \quad (6)$$

In formula (6), α and β are the weight of urbanization and regional transportation. Because of the same significance of both variables, this research deems α=β=0.5. U_t is the comprehensive evaluation index which reflects the comprehensive benefits of both urbanization and regional transportation.

$$D_t = \sqrt{C_t * U_t} \quad (7)$$

In formula (7), D_t is the coordination index of coupling relationship between urbanization and regional transportation. For C_t and U_t are located in the range from 0 to 1, D_t also belongs to the range from 0 to 1.

This research also divided the coordination values of coupling relationship into four levels. See Table 3.

Table 3. Coordination values and levels

Coordination values	Coordination levels
$D_t \in (0,0.25]$	Low
$D_t \in (0.25,0.5]$	Primary
$D_t \in (0.5,0.75]$	Medium
$D_t \in (0.75,1]$	Senior

4 Results Analysis

The standardized data were plugged into the formula (2) and (3) to calculate the communality and the weight of each index which belongs to the dimensions of urbanization and regional transportation. The results can be seen from Table 4.

Table 4. Communality and weight of urbanization and regional transportation

Indexes of urbanization	Communality	Weight	Indexes of regional transportation	Communality	Weight
Proportion of non-agricultural population	0.966345	0.164299	Total distance of highway	0.904041	0.159225
Proportion of employee in the service sector	0.980395	0.166688	The number of taxi	0.953457	0.167928
Proportion of the output value in the service sector	0.995429	0.169244	Road area per capita	0.957154	0.168579
Value of gross output per capita	0.979445	0.166527	Passenger capacity	0.932345	0.16421
The number of employee in health agency	0.984179	0.167332	The number of employee in transportation	0.986386	0.173728
Population density	0.975818	0.16591	Volume of freight traffic	0.944381	0.16633

According to the results of communality and the weight of each index, the research calculated the evaluation, correlation and coordination results of coupling relationship between urbanization and regional transportation by substituting the values of the weight and the standardized data into formula (4), (5), (6) and (7).

Based on the results shown in Table 5 and the categories of level of coupling relationship shown in Table 1, 2 and 3, we can find that the coordination level of coupling relationship between urbanization and regional transportation was quite low in the year of 2003 and 2004. The coordination level in the year of 2005 and 2006 was primary, while in the year of 2007 and 2008 the coordination level was medium. From 2009 to 2013, the coordination level of coupling relationship between urbanization and regional transportation was senior.

As for the correlation level of coupling relationship between urbanization and regional transportation, the level was medium from the year of 2003 to 2005. Since the year of 2006, the correlation level rose up to senior.

As to the developing level of urbanization and regional transportation in Chengdu, the level of urbanization and regional transportation was very low in the year of 2003 and 2004. The level of urbanization was at the stage of primary in the year of 2005, 2006, 2007 and 2013, while in the year of 2008 and 2009 it was medium. Since the year of 2010, the level of urbanization rose up to senior. In the year of 2005 and 2006, the level of regional transportation was very low, but in 2007 and 2008 it was primary. Except the year of 2013, in which the level of regional transportation was senior, it was at the level of medium from 2009 to 2012.

Table 5. Evaluation results of coupling relationship between urbanization and regional transportation

Years	Evaluation results of urbanization	Evaluation results of regional transportation	Correlation of coupling relationship	Coordination of coupling relationship
2003	0.014404	0.13244	0.59487	0.208989
2004	0.104304	0.017455	0.700879	0.206566
2005	0.342038	0.043656	0.633648	0.349567
2006	0.421205	0.139073	0.863962	0.491965
2007	0.435599	0.328878	0.990208	0.61522
2008	0.604378	0.46859	0.99196	0.7295
2009	0.686206	0.616934	0.998586	0.806628
2010	0.83705	0.596684	0.985847	0.840667
2011	0.900331	0.593234	0.978633	0.854884
2012	0.907766	0.725103	0.993723	0.900727
2013	0.493933	0.978651	0.944274	0.833823

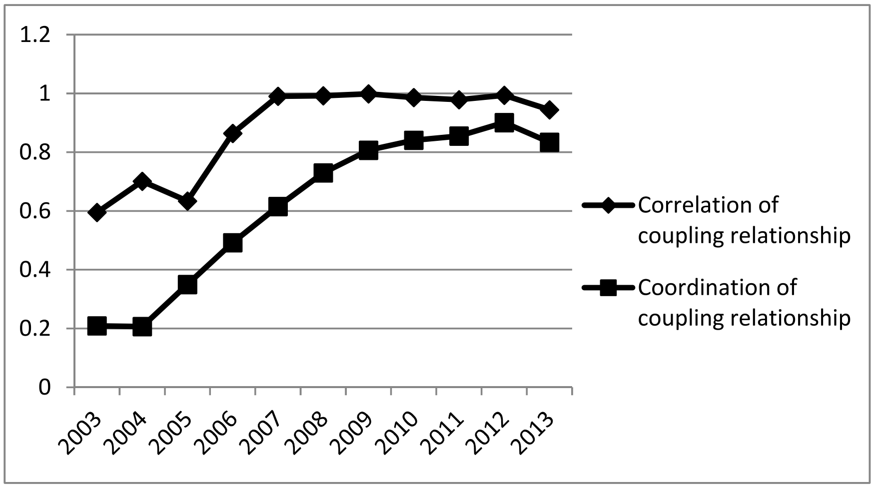

Figure 1. The trend of coupling relationship

Figure 1 shows us the trend of coupling relationship between urbanization and regional transportation in Chengdu from 2003 to 2013. From this figure, we can find that both of the correlation and coordination of coupling relationship are above the value of 0.8 since 2009. After the year of 2012, the correlation and coordination of coupling relationship show a slight drop.

5 Conclusions

Based on document reviewing, this research selected 12 indexes to describe urbanization and regional transportation. By using the model of coupling relationship, the data which stem from the city of Chengdu from the year of 2003 to 2013 were used to calculate the correlation and coordination of coupling relationship between urbanization and regional transportation. The results clearly show the strength and the developing trend of coupling relationship between the two variables during a sample period. According to the results, we can propose proper measures for the harmonious development of both urbanization and regional transportation in the future research.

References

Chen, Y. L., Shao, Z. Y. (1999). *Transport Economics*, Beijing, People's Transport Press.

Han, B. (2000). *Transport Economics*, Beijing, Economy and Management Press.

He, M. X.(2014). "The Study of Relations between Transportation and Economic Development Based on Canonical Correlation Analysis". *Ecological Economy*, 1, 100-103.

Ma, C. W., Zhang, D. H.(2005). *Development Economics*, Beijing, Higher Education

Press.
Statistic bureau of Chengdu, (2003-2013). *Chengdu Statistical Yearbook 2003-2013*, Beijing, China Statistics Press.
Statistic bureau of Sichuan, (2003-2013). *Sichuan Statistical Yearbook 2003-2013*, Beijing, China Statistics Press.
Wang, H. C. (2011). "Transportation and Regional Economics Discrepancy--Empirical Analysis of Railways in China". *Journal of Shanxi Finance and Economics University*, 2, 61-68.
Wang, X. R., Rong, C. H. (2014). "Research on the Interaction between Urbanization and Transportation". *Inquiry into Economic Issues*, 1, 52-57.

Traffic Flow Characteristics at Different Sites on an Urban Expressway from Loop Counts

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Abstract: Due to merging movements of on-ramp vehicles, the characteristics of traffic flow at upstream and downstream of merging area have significant differences. Based on the traffic data collected by loop detector in urban expressway of Shanghai, this paper firstly analyzed variation condition of traffic volume at entire merging area during the whole daytime, and then compared traffic flow characteristics at three different sites (i.e. upstream of merging area, downstream of merging area and on-ramp) based on fundamental diagram. The study found, at merging area of the Inner Ring Expressway in Shanghai, traffic volume keeps in saturating status in the daytime without obvious peak features. The upstream traffic volume can't reach maximum capacity of normal roadway segment due to early-onset breakdown of traffic flow; on the contrary, downstream traffic volume can achieve maximum capacity without early-onset breakdown phenomenon. Downstream speed-occupancy model mathematically fits well with linear model, while, upstream and on-ramp speed-occupancy models conform to exponential model.
Keywords: Urban expressway; Merging area; Traffic flow characteristics.

1 Introduction

The urban expressway, as urban road network and mass rapid transport corridor, can release the traffic pressure and improve traffic efficiency. Due to the consideration of accessibility, the distance of exit and entrance on urban expressway is short, which brings about itself unique features: overmuch weaving vehicles and a low possibility of free flow (Hao, 2007). Therefore, it is necessary to conduct a research on traffic flow characteristics of urban expressway.

In general, study on traffic flow features can start with relations among basic parameters of traffic flow: traffic volume, speed and density. The linear speed-density model was constructed at the earliest (Greenshields, 1935). Later, a more comprehensive study on the relations among the three parameters was conducted in order to explain the inherent law of traffic flow (Greenberg, 1959), (Underwood, 1961), (Persaud, 1988).

With research continuing, it was found that there is a discrepancy on traffic flow features across different lanes even at the same site (Wagner, 1997). Besides, due to the impact of ramp, the traffic flow characteristics at different sites have significant discrepancy (Hao, 2008). Therefore, using data from inductive loop detectors equipped in three different sites: upstream of merging area, downstream of merging area and on-ramp, this paper compared the discrepancy of the traffic flow characteristics and constructed basic parameters models of traffic flow at different sites. The research in this article will provide a more comprehensive understanding on traffic flow characteristic of urban expressway, which have important real-world implications to improve service capability and traffic efficiency.

2 Field Data

By the end of 2013, about 200km urban expressway network has been established in Shanghai, including Inner Ring Expressway, South-North Expressway, Mid Ring Expressway and so on. The Inner Ring Expressway is selected to be study site in this paper. The specific site is the merging area, where the ramp connects the main traffic corridor-Wuning Road(see Fig.1).

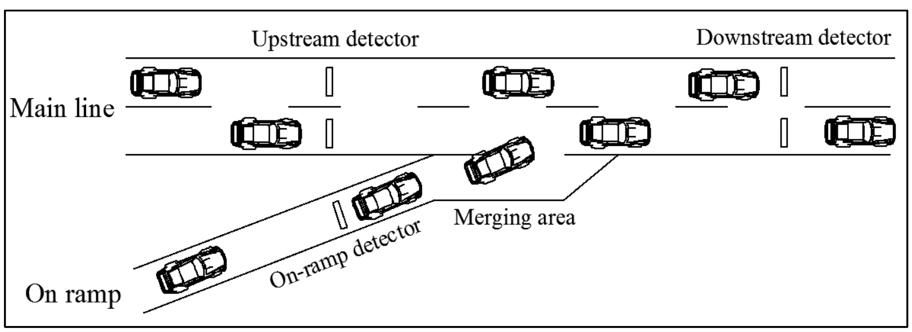


Fig.1 The sketch map of detector disposal

The data was achieved from Shanghai Municipal Roadway Administration Bureau, and it was collected from Monday to Sunday, July 2 to July 8,2012. As shown in Fig.1, the data is get through inductive loop detectors equipped in upstream of merging area, downstream of merging area and on-ramp. The detectors record vehicle count, time occupancy and time mean speed in each lane in 5minutes, a total of 21168 records. Due to equipment failure, communication failure and ramp closed control, the abnormal data often generates. The valid data set applied in this study includes 18792 records (used for training sample and validation sample).

3 Analysis of Traffic Flow Characteristics on Urban Expressway

3.1 Variation condition of traffic volume at merging area

Fig.2 shows the time series of traffic volume on workdays and weekends at downstream of merging area, from July 2,2012 to July 8,2012 (Monday to Sunday). According to the variation trend of volume, it contains two phases and three states:

The first phase is from 22:00pm to next day 07:00am (10:00am at weekends). It contains two states: traffic volume declining and traffic volume increasing. As shown in Fig.2, traffic volume declines at 22:00pm, and hits bottom at next day 04:00am. Subsequently, traffic volume becomes increasing at 04:00am, and reaches the maximum value (about 1800veh/h/lane) at 07:00am through 3 hours. However, at weekends, traffic volume reaches the maximum value at 10:00 due to the slow grow.

The second phase is from 07:00am(10:00am at weekends) to 22:00pm. This phase has the only one state: traffic volume saturation. During this phase, traffic volume of workdays keeps in 1800~2000veh/h/lane, and that of weekends is slightly less. No matter workdays or weekends, traffic volume keeps in saturation, without obvious rush hours, in the daytime.

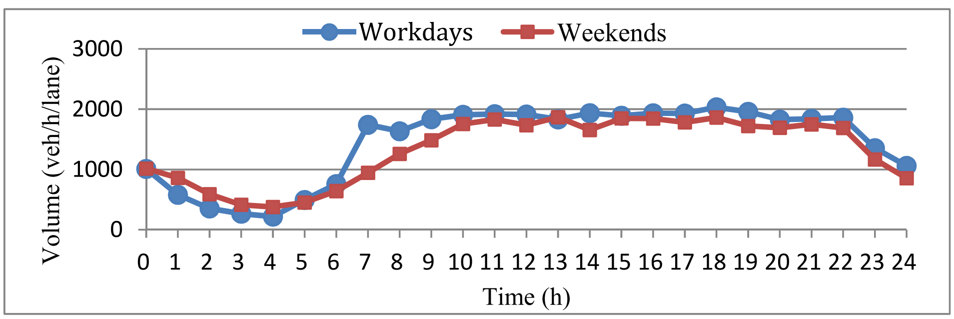


Fig.2 Variation of traffic volume on workdays and weekends

As shown in Fig.2, although traffic volume differs between workdays and weekends, variation trend of traffic volume is generally similar. So, this paper only focus on traffic flow characteristics at different sites on workdays.

3.2 Relations among traffic flow parameters at different sites

(Gartner, 1997) there is a linear relation between time occupancy and density, and time occupancy can be detected directly by detection equipment. So this paper substitutes time occupancy for density in research.

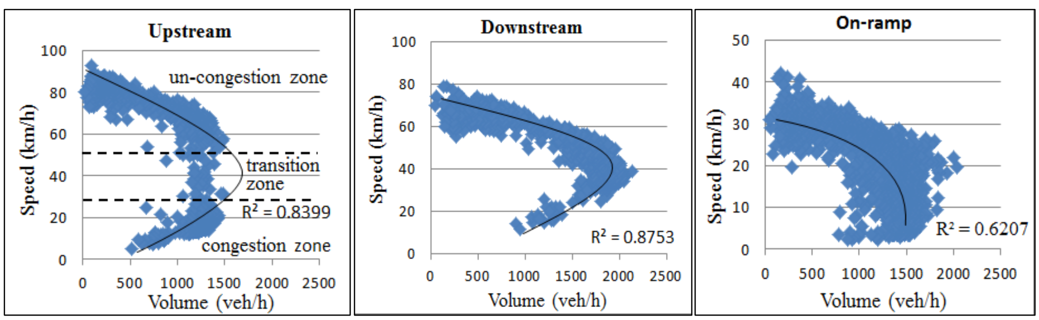
3.2.1 Traffic volume vs. Speed

Fig.3 is scatter plots of traffic volume vs. speed. It is obvious that the relations between traffic volume and speed conform to parabolic model, but the distribution law of data exists some differences at different sites.

Fig.3a is volume-speed scatter plot at upstream. It is found that data points mainly cluster into two regions: un-congestion zone(50~90km/h) , congestion zone(5~30km/h). Besides, there is a space with sparse data points, which is defined as transition zone(31~49km/h). Vehicles at un-congestion zone has faster speed and less disturbance. While at congestion zone, due to the large demand from ramp and main line, vehicles travel slowly with serious conflict. Finally, vehicles are travelling in an unstable state at transition zone, and data points are almost distributed vertically without volume falling in 1500~2010veh/h/lane. That is to say, an early-onset breakdown phenomenon (traffic flow breaks down far sooner before reaching capacity) occurs. Because of the merging movements of on-ramp vehicles, un-congestion zone contains 40.1% records; 54.8% records fall in congestion zone; the other 5.1% records belong to transition zone.

Fig.3b is volume-speed scatter plot at downstream. It is obvious that flow-speed relation at this site fits best with parabolic model ($R^2 = 0.8753$). As shown in Fig3b, the data points has no obvious zonal phenomenon. That is to say, the vehicle is traveling in a stable state, and there is no early-onset breakdown phenomenon. Furthermore, traffic capacity could be reached at downstream, and the largest volume reaches about 2100veh/h/lane.

Fig.3c is volume-speed scatter plot of on-ramp. Data distribution shows slightly parabolic form, but data points are quite scattered. Merging area has a strong impact on on-ramp traffic flow, and flow-speed relation doesn't conform to parabolic model.



(a) (b) (c)

Fig.3 Relations between traffic volume and speed

3.2.2 Traffic volume vs. Occupancy

Fig.4 is the flow-occupancy scatter plots. The volume-occupancy relations at upstream and downstream of merging area conform to parabolic model. Because there is an early-onset breakdown phenomenon at upstream, Fig.4a has obvious zonal phenomenon. When occupancy is between 0 to 20%, it is un-congestion zone; occupancy between 21% to 40% belongs to transition zone; the others from 41% to 70% fall in congestion zone. Fig.4b is the flow-occupancy scatter plot at downstream. Just like the flow-speed scatter plot, the flow-speed relation fits best with parabolic model at this site ($R^2 = 0.9843$). Beside, most data points cluster into the left side of the figure, which also verifies vehicles traveling in a stable state. Finally, Fig.4c shows the flow-occupancy relation at on-ramp. The first half of the diagram increase linearly, while the latter part is horizontal and traffic volume undulates fiercely (range: 800-2000veh/h/lane) as occupancy rising. So, flow-occupancy relation at on-ramp don't conform to parabolic model.

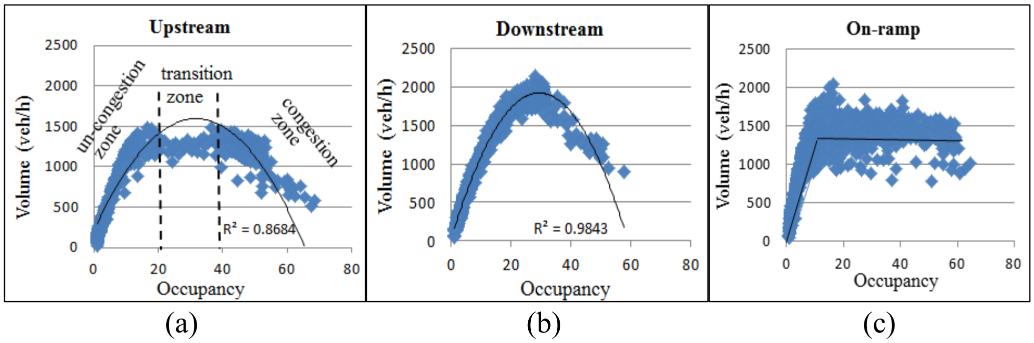


Fig.4 Relations between traffic volume and time occupancy

3.2.2 Speed vs. Occupancy

(Li,2013) Speed-density relation is the research foundation of the relations among volume, speed and density. Fig.5 is the speed-occupancy scatter plots at different sites. It is found that speed and occupancy has the obvious correlation. At downstream of merging area, variation trend of speed vs. occupancy is identical to that of Greenshields' speed-density linear model. However, at upstream and on-ramp of merging area, speed-occupancy scatter plots show obvious exponential distribution. According to the change rules of speed vs. occupancy at different sites, the optimal equations at different sites are summarized in Table.1 based on curve fitting method (y: speed, x: occupancy)

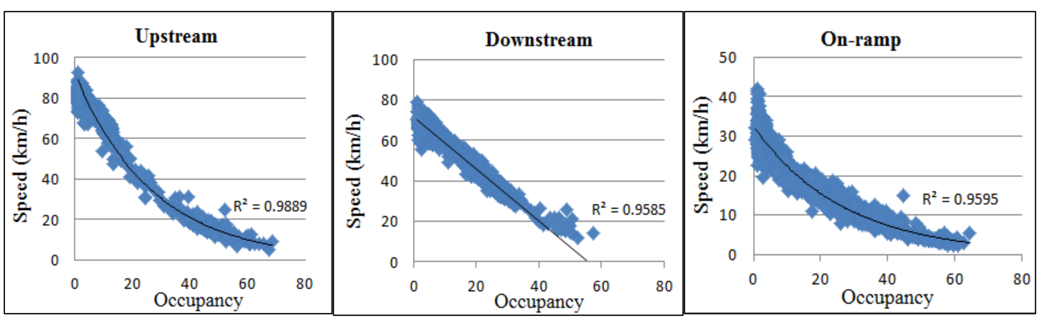


Fig.5 Relations between speed and time occupancy

Table1. Relations of Speed-Occupation at Different Sites about Merging Area

Sites	Formula	R^2(training sample)	R^2(validation sample)
Upstream	$y = 92.429e^{-0.037x}$	0.9889	0.9832
Downstream	$y = -1.2706x + 71.177$	0.9585	0.9624
On-Ramp	$y = 32.51e^{-0.037x}$	0.9595	0.9558

In summary, there is obvious discrepancy about the relations among volume, speed and occupancy at different sites. The discrepancy mainly attributes to merging area, where vehicles from main line and on-ramp scramble for the right of way, which causes disorder and conflict, especially at rush hours. Besides, the excessive traffic demand from main line and on-ramp often can't be satisfied due to the limited capacity of downstream, and at this moment, an early-onset breakdown phenomenon happens. However, traffic flow at downstream is only limited to traffic capacity itself, so no early-onset breakdown phenomenon happens. Therefore, the comprehensive research in this paper about traffic flow feature at different sites is meaningful to improve service capability and traffic efficiency of urban expressway.

4 Conclusions

In this paper, we collected inductive loop data from three locations around merging area at the Inner Ring Expressway in Shanghai. The locations are categorized into three types: upstream, downstream and on-ramp. Traffic flow characteristics at the three different sites were studied. By the comparison and statistical analysis of relations among the traffic flow parameters(volume, speed, occupancy), this paper compared discrepancy about traffic flow features at the three sites. Besides, traffic flow parameters models were constructed according to the three sites. The findings are as follows:

(1)The traffic volume, at merging area of the Inner Ring Expressway in Shanghai, keeps in saturation, without obvious rush hours and off-peak hours, in the daytime. Furthermore, no significant variation on traffic volume between workdays and weekends.

(2)Volume-speed model and the volume-occupancy model conform to parabolic model at upstream and downstream of merging area. The upstream traffic volume can't reach maximum capacity of normal roadway segment due to early-onset breakdown of traffic flow; on the contrary, downstream traffic volume can reach maximum capacity without the early-onset breakdown phenomenon

(3)Speed-occupancy model at downstream of merging area fits well with the traditional linear model; while, that at upstream and on-ramp of merging area conforms to exponential model.

Acknowledgement

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Reference

Greenshields B D, Channing W, Miller H. A study of traffic capacity. National Research Council (USA), *Highway Research Board*, 1935.

Greenberg H. An analysis of traffic flow. *Operations research*, 1959, 7(1): 79-85.

Gartner N H, Messer C J, Rathi A. Special report 165: revised monograph on traffic flow theory. *Transportation Research Board*, Washington, DC, 1997: 621-642.

HAO Yuan, XU Tian-dong. Research on Traffic Stream Characteristics of Urban Expressway. *Journal of Transportation Engineering and Information*, 2007, 4(4): 21-27.

HAO Yuan, SUN Lijun. Analysis of Traffic Congestion on Urban Expressway and Congestion Threshold Identification. *Journal of Tongji University(Natural Science)*, 2008, 36(5): 609-614.

LI Yue, LU Huapu, YU Xinxin. Research on Traffic Flow Characteristics of Urban Expressway. *Highway Engineering*, 2013,(6):87-91.

Persaud B N, Hurdle V F. Some new data that challenge some old ideas about speed-flow relationships. 1988.

Underwood R T. Speed, volume, and density relationships. *Yale Bureau of Highway Traffic*, 1961, 141-188.

Wagner P, Nagel K, Wolf D E. Realistic multi-lane traffic rules for cellular automata. *Physics A: Statistical Mechanics and its Applications*, 1997, 234(3): 687-698.

Influence Analysis of the Railway Freight Transport Reformation on the Ningbo Road General Freight Transport Industry

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Abstract: In order to further reduce the cost of road freight transport, the influence of the railway freight transport reformation on Ningbo road general freight transport industry are analyzed based on the review of background and core contents of the reformation. As a result, the railway freight reform will bring more cooperation opportunities than competition, which created new opportunities for Ningbo to build a comprehensive land transport system and the development of logistics services. From the standpoint of cooperation-competition development, multimodal transport and the transformation of modern logistics, countermeasures are proposed for the transport of less-than-truckload freight on road.
Keywords: Railway freight transport reformation; General freight; Road transport; Multimodal transport.

1 Introduction

The increase of railway mileage and double-track rate as well as the separate transport of cargoes and passengers, improve the railway freight capacity, while rail volume declining, China Railway Corporation put forword a railway freight reform measures in June 2013 (Huang, 2013): reforming the way of freight accepting formalities, transport organization and standardizing freight charges, developing the railway "door to door" services comprehensively. Subsequently, raising the railway freight price, opening e-commerce express train and launching business in national railway freight operating station which basically covers at or above the county level cities etc. These will fully participate in modern logistics competition by expanding services type and enhancing service level.

As two ways of land transport, railway has long been undertaking the “cfs to cfs” transport of bulk cargoes, while road responsible for “cy to cy” and “door to door” transport of breakbulk (Lee, 2013). Besides natural division of collecting & distributing relations, there are also direct competition in lines, types of cargo and special transport demand between them. The reform aims to newly participate in the less-than-one carload transport, globally, which will directly influence the relationship between competition and cooperation of general cargo transport.

Many scholars have studied the freight industry in China, some of them (Wei, 2013; Wei, 2013; Gao, 2014) concluded that the industry concentration, transportation organization and informationization level of road freight enterprises are relatively low, and put up strategies to cultivate intermediary organizations, adjust the structure of transport capacity and set up information platform; Others (Ma, 2012; Wang, 2013; Jiang, 2014) aim at the low modernization level of railway freight logistics, they put forward to carry out freight organization reform and develop traditional transportation value-added services, build a unified modern logistics information system platform, and cultivate modern rail logistics talents etc. But most of these studies are aimed at domestic road freight industry or domestic rail freight respectively, which lack conjoint analysis on both sides from the perspective of competition and cooperation.

As a national logistics node and regional logistics center of Yangtze river delta, road transport is the main way for Ningbo Port to have the goods picked up from the marine terminal and then delivered to other areas and cities, which occupies more than 80% of the total traffic volume; and its transport business covers major cities of almost all mainland provinces, municipalities directly under the central government and autonomous regions, which played an important role in improving the scope of material circulation as well as the quality of social life.

From the aspects of business space and types, this paper will analysis the impact that the railway freight reform may have on Ningbo road cargo transport industry, and from three perspective, namely competition, cooperation and the development of comprehensive transportation, put forward the countermeasures and suggestions for road freight Industry and competent authorities.

2 The Impact of Railway Freight Reform on General Cargo Transport Industry in Ningbo

Although the reform of railway freight aimed at restarting less-than truckload transport, due to the carrying capacity of train is much larger than truck, besides, it includes truckload and less-than truckload transport at the same time. As the timeliness demanding of less-than truckload transport is growing, which gradually separated from the conventional cargo transport business, and formed small goods transport business. Small goods transport is the fastest growing business in road transport industry, which is also one of the important content of the reform.

From the aspects of less-than truckload, truckload and small express, this paper will analysis the influence of the reform on Ningbo general cargo road transport.

2.1 The impact of railway freight reform on general cargo transport space

Through the survey on Ningbo road freight enterprises, it is obvious that the general freight business in Ningbo covering almost all inland provinces and cities, some even covered above the county level in developed areas; Vehicle transport is given priority to Zhejiang province, a few lines in northern Jiangxi province, Shanghai, southern Jiangsu and other surrounding areas. Because of cross-provincial lines must base on an extension of the lines in Zhejiang, as a result, the following part will discuss the impacts of railway freight reform on Ningbo road freight space.

Currently, the road cargo transport lines start from Ningbo involving all at or above the county level cities in Zhejiang. According to the transport distance and nonstop feature to, these lines are divided into three categories, as shown in table 1.

Table 1. The categories of general cargo transport lines in Ningbo

Categories	Transport Destination
Similar distance and nonstop lines of railway and road	Hangzhou、Shaoxing、Shangyu、Huzhou、Changxing、Taizhou、Wenling、Sanmen、Linhai、Wenzhou、Rui'An、Yongjia
transport distance: railway>road, and direct railway	Jinhua、Dongyang、Lanxi、Wuhan、Yiwu、Yongkang、Jiande、Quzhou、Jiangshan、Longyou、Lishui、Jinyun、Qingtian、Jiaxing、Haining、Jiashan、Zhuji
Indirect railway	Pan'an、Pujiang、Changshan、Kaihua、Jingning、Longquan、Qingyuan、Songyang、Suichang、Yunhe、Haiyan、Pinghu、Tongxiang、Chun'An、Fuyang、Lin'An、Tonglu、Shangxing、Shengzhou、Xinchang、Huangyan、Jiaojiang、Luqiao、Tiantai、Xianju、Yuhuan、Cangnan、Leqing、Pingyang、Taishun、Wencheng、Anji

On the condition that railway can provide "door to door" service, considering the same distance for both road and railway, the owner of cargo has two transport choice, therefore, the competition between the two is relatively fierce; For long route lines, the owner's choice mainly depends on the efficiency and timeliness of railways; for those indirect railway area, road transport has absolute advantages.

2.2 The impact of railway freight reform on road cargo transport business

According to the statistics of Ningbo Road Transport Administration, by the end of 2013, there are 48755 general freight enterprises, accounting for 98.76% of the total; 64717 ordinary truck, which occupies 79.20% of the total. Similar to the nationwide situation, few are large and medium-sized enterprises. According to the statistics, in the general freight enterprises, those who own more than 50 vehicles accounted for about 0.35%, and vehicles owned range from 20 to 49 accounted for about 0.68%, while the rest 99% only own less than 20 trucks.

From the aspects of less-than truckload, truckload and small express, the following will analysis the influence of the reform on Ningbo general cargo road transport.

(1) the impact of railway freight reform on less-than truckload transport in Ningbo

As to less-than truckload transport started from Ningbo, transport via networks of expressways and urban trunk roads to send goods to the receipt places, generally passing two pivotal hubs and two neighboring regional distribution centers, so as to sort and handle. Due to road transport vehicles tonnage is relatively small, the time of sorting, loading and unloading is short, while to long distance transport, laboring, energy consumption, transport time and economic costs may be the disadvantage. As to breakbulk cargo from Ningbo to destinations by railway network, which have to regroup in more than two railway administration districts, and to be sorted in two or more railway stations. To guarantee its economic benefit, the train must have its load ratio achieved before operation. High speed, short transport time, low cost, energy conservation and environmental protection are all the benefits of railway transport, but it consumed more time than road transport in both ends of loading and unloading, sorting and marshalling, therefore, its overall timeliness is not necessarily better than road transport.

To confirm the above analysis, this paper set 300 kilograms of clothing groceries as an example, from north Ningbo station to Shanghai Anting station, both ends of the door distance are 20 km and 50 km respectively. There are two truckload freight price, one is 10.2 yuan, the other is 14.28 yuan, and not responsible for door-to-door service. So the pickup time is unpredictable. If CRE undertakes the transport, the total freight is 570 yuan, including the pickup charge in Ningbo (50 yuan), and delivery in Shanghai is free of charge, which needs 3 to 4 days in total. If Yangtze River Delta Express Railway undertakes the transport, the freight is 20 yuan, both ends shuttle fees amounted to 208 yuan, the railway running 2 days and 9 hours, but sorting and delivery time on both ends is not included. A certain less-than truckload transport company in Ningbo charges 60 yuan, both ends shuttle fees amounted to 250 yuan, which delivering on the third day.

The survey results show that among all the schemes for middle and short distance transport, total freight by regional express train is the cheapest, but its timeliness is bad, for railway cannot cover all middle and short lines in Ningbo. Therefore, the current shunt effect on Ningbo is not obvious. CRE has good spatial coverage, but its freight and timeliness is not in advantage, which will not greatly influence road cargo transport in Ningbo. For long transport distance, the price and spatial coverage of railway transport is obvious, but the gap between convenience and timeliness, would no impact Ningbo road network.

In the long run, the strength of railway freight reform will further increase, then the frequency of freight train will increase, and the possibility of raising transport price also increase. The former is beneficial for decreasing waiting time at the station yard; the latter will weaken the price advantage of rail freight. Due to the longer the transport distance, the more obvious the advantages price and currency of railway, therefore, for those transport of longer than 800 km, railway transport has more attractions. General less-than truckload transport business can provide "door to door" service, and its customers are usually "small, scattered and frequently". Considering the costs and resources, railway freight enterprises are hard to achieve "door to door" service. After long-term accumulation, road transport enterprises have established good scattered goods distribution network, which created initiative for them to collaborate with the railway in long-distance transport.

(2) The impact of railway freight reform on general cargo vehicle transport in Ningbo

From the survey, we found that general cargo vehicle transport mainly focused on Zhejiang province, a small amount are distributed in the south of Shanghai, Jiangsu and surrounding areas in the north of Jiangxi. Zhejiang region is small, about 378 km from jinxing to Wenzhou, the farthest distance in the province; as for the transport from Ningbo to Shanghai, southern Jiangsu and northern Jiangxi, transport mileage is less than 800 kilometers, which takes six to eight hours to reach the destination.

For rail and road are at the same distance, or at a longer but direct route, vehicle road transport can serves "door to door" and start at any time. As for vehicle transport with the same direction railway freight lines, entrusting the vehicle cargo to railways will increase the sorting, loading and unloading and marshalling time, besides, departure interval limitations also further increased the waiting time. As for the non-express cargo, railway hasn't provided "door-to-door" service, thus time and costs have to be borne by the road transport enterprises. If the "door to station" and "station to door" transferring process causes large goods loss, then further reducing the feasibility of entrusting road vehicle goods to rail.

(3) The impact of railway freight reform on small goods

According to the National Bureau of Statistics, from 1995 to 2005, the national express parcel average growth rate is 115.5%, especially from 2006 to 2013, when e-commerce developed rapidly, the national express parcel average growth rate reached 192.2%. In 2013, there were 9.2 billion express parcels in China, which is expected to exceed 12 billion pieces in 2014 (Xie, 2014). From B2C, B2B to O2O, then to cross-border e-commerce, parcel express will be improved significantly.

CRE provided small ordinary express and time-limited express. Ordinary express provide from more than 700 cities, deliver "door to door" to nearly 2000 cities and counties nationwide, and arrive destinations within 4 days once delivery; for transport mileage above 3500 km or unable to direct delivery between cities, it provide within 4 to 6 days' "door to door" service. Time -limited express including "Next Day Delivery" and "Third Day Delivery", there are 101 major cities in China can deal the service, and 163 cities can be delivered. Compared with small road express business, railway ordinary express has the absolute advantage in price, but the gap in its service area, the scope of free "door-to-door" service, the receipt charges in non-free areas and timeliness are large; Time-limit express significantly improved the timeliness of ordinary express, and lowered its freight; but its service coverage, the free service area and its charges etc. has not changed.

Although small railway express's price advantage is obvious, its limitation on the density of distribution network, business spot, timeliness and economy of its service are still the bottleneck.

(4) The overall impact of railway freight reform on general cargo transport

From the above, it can be found that the railway freight reform bring both opportunities and challenges for road transport enterprises in Ningbo, overall, opportunities are more than challenges.

Firstly, less-than truckload transport by road in Ningbo has comprehensive advantages in terms of timeliness, convenience and economy, thus it will not significantly affected by the reform in the short term, while in the long run, road and railway has a potential for cooperation. Secondly, road vehicle transport has more advantages in timeliness and convenience than railway transport in Ningbo, it will not significantly affected by the reform in the short term. Thirdly, the price of small road express is a little in Ningbo, but its service coverage, convenience and delivery timeliness has significant advantages, thus it will not significantly affected by the railway freight reform in the short term, but small express and railway has a potential for cooperation in the long run.

To sum up, as for general cargo road freight industry in Ningbo, the railway freight reform will bring more cooperation opportunities than competition, which created new opportunities for Ningbo to build a comprehensive land transport system and the development of logistics services.

3 Development Countermeasures for Road Cargo Industry Under The Condition of Railway Freight Reform

"Two Belts and One Road" strategy and its continuous promotion, the emerge of national new urbanization and long-term planning of logistics industry development, as well as the continuing growth of the e-commerce, all of these have created a prosperous perspective for the development of land transport industry; the current railway freight market reform, bring more cooperation opportunities than competitive challenges for road freight industry in Ningbo. Combined road transport with railway, which will cause the excess of freight capacity in part of road freight enterprises, the transforming from traditional goods transport to specialized transport and logistics service is forced by the situation, is also a leapfrog development opportunity. Under the background of railway freight reform, development strategies for the road less-than truckload transport freight industry in Ningbo are put forward as follow.

(1) Hierarchical cooperation with railway

Considering the features that railway freight enterprises are absolutely monopoly and the regional-management oriented, therefore, Ningbo's road transport enterprises should cooperate with railway hierarchically. Firstly, strategic cooperation. merging and consolidating, restructuring and shareholding to form large groups, or based on the experience of the shipping industry, to form a more powerful new enterprises as a truck free carrier, and strategic cooperating with Ningbo's railway freight department, establishing a long-term cooperation mechanism and participating in planning and construction of intermodal transit depot, coordinating transport price formation mechanism and the mechanisms of freight trains resource allocation. Secondly, the higher level cooperation. Large and medium-sized freight enterprises, relying on multimodal transport operations and large, medium-sized enterprise alliance and cross-regional enterprise alliance, multimodal transport transshipment terminal yard warehouse in contracting, train, freight train, railway freight departments with higher level of cooperation. Thirdly, indirect collaboration. setting up small transport enterprises oriented information service system, small road freight enterprises can join in 'door station', 'stand to door' services by competing large and medium-sized enterprises, or join in large and medium-sized enterprises' service outlets, so as to participate in intermodal service with railway freight enterprises indirectly.

Only under the macro management, such as laws, regulations, policy support, can market mechanism in the development play a proper role. Firstly, establishing regular communication mechanism on road and rail freight enterprises. As the multi-body and small scale of road freight enterprises, cooperate with railway is relatively weak, the dialogue platform is helpful to enhance mutual trust, expand and deepen cooperation models; also conducive to timely solve the cooperation problem, and then develop more targeted supportive policy. Secondly, supporting Hierarchical cooperation, so as to improve the distribution efficiency of road and rail multimodal transport. Thirdly, providing more priorities to the intermodal terminal planning and land using, learning from the patterns of ports construction, road freight enterprises are encouraged to participate in multimodal transport facilities construction, and improve the stability of the multimodal transport resources and bargaining power. Fourth, to multimodal transport as the breakthrough point, promoting the less-than truckload transport containerization, miniaturization and encouraging containers and vehicles miniaturization; intensifying the development of drop and pull transport, improving the transfer efficiency and reducing the energy consumption and pollutant emissions of distribution centers.

(2) Expanding new field of goods transport coverage

In cooperating with railway under the condition of combined goods transport, making the excess capacity of long road cargo transport enterprises more serious, therefore, road freight enterprises still have to improve services and open up new markets.

With the implementation of urbanization, the huge demand potential of small and medium-sized cities and small towns will be satisfied by road transport, so rural transport network should be layout as soon as possible. Due to the vast area and low cargo demand, building and maintenance of the rural freight network is much more difficult than in cities, therefore, it is necessary to build large and medium-sized enterprise alliance, unified planning and hierarchical divided countryside transport network, so as to develop rural transport of goods. Duo to railway network is not as dense as road network, and its capacity may not completely satisfied with all needs of the goods on the trunk line transport. According to the market demand, road freight enterprises should choose the favorable freight competition area, provide high-quality services for cargo transport. Make full use of its timeliness advantages, develop professional high value goods transport service, and compete with rail freight.

Formulate small towns oriented logistics parks, distribution centers and end distribution network planning layout, improve the storage, transshipment, unloading and other infrastructure, further promote the experience of Ninghai mailed urban and rural distribution project, and build public service platform, promote the transport network system. Providing appropriate policies to the enterprises engaged in rural transport in a certain period, and promotes the integration of urban and rural construction.

(3) Developing new logistics business

Except carrier, Expanding road freight business chain, new business development of logistics has stronger comparative advantages, which is the inevitable choice to realize transformation and upgrading. By cartels, cross-combination alliance and merger and reorganization, large and medium-sized enterprises should extend to warehousing, distribution processing, distribution etc., developing and participating in the logistics business. There are three main directions for road goods transport logistics to develop new business; one is to form a coalition with manufacturing enterprises, so as to develop manufacturing logistics. The second one is to form a coalition with business enterprise, so as to develop business logistics and city distribution logistics. The third one is to form a coalition with circulation enterprise, so as to develop agricultural products logistics.

Participants in the survey said they were planning to develop logistics business, but the transformation need more logistics parks and public warehouses, which is difficult to achieve individually. Therefore, it is necessary to further improve logistics hub layout planning, and increase the strength of freight hub port, produce service, business service and port service etc. Supporting utilizing old factories, warehouses and inventory land resources to construct logistics facilities or provide logistics services, creating conditions for road freight enterprises to develop integrate and specialized logistics services, manufacturing logistics, city distribution logistics and the logistics of agricultural products.

(4) Improving the degree of informationization

To carry out joint with the railway transport and cooperate with other similar enterprises, road freight enterprises should further improve the management of goods transport and informatization degree, and reduce the possibility of inefficient operation due to lack of information sharing. Small and medium-sized enterprises also have to strengthen their own information construction, actively mining business resources with the help of the public information platform and raise their credit rating; expand the opportunity to building enterprise alliance.

Speeding up the construction of data center, and comprehensively optimize the operation management system, increase the public service function of the government affairs information system. Strengthening data sharing with commerce, taxation, public security, roads, ports and other departments, improving the credit rating mechanisms and credit system of road transport enterprises, so that providing information support for strengthening their integrity service. Based on the transport logistics public information platform, actively guiding and encouraging large and medium-sized road transport enterprises to further perfect the function of information system, with information as the link, strengthening cooperation with small freight enterprises.

4 Conclusions

As two ways of land transport, there are obvious cooperation and competition between road and rail. The reform of railway freight set less-than truckload transport as the breakthrough point, in the long run, it will have an impact on the road freight industry which have direct relationship on competition and cooperation.

From the aspects of space scope and business types, this paper analyzed the possible impact of railway freight reform on general cargo transport in Ningbo. The result shows that the current railway freight market reform, bring greater opportunities than challenges to the road freight enterprises in Ningbo. Among them, less-than truckload transport, vehicle transportation and small express will not significantly affected by the railway freight reform in the short term, while in the long run, there is potential for less-than truckload and long-distance small express to make joint transport with railway.

References

Gao Yingchun. (2014). "Road freight Current situation and development analysis." *Journal of management*, 24:394.

Huang Yadong. (2013). "Personal views on railway freight reform." *Journal of small and medium-sized enterprise management and science (the ten-day)*, 06:158-159.

Jiang Yongchang. (2014). "Modern railway logistics resources sharing based on the SOA research." *Journal of goods and quality of construction and development*, (6) : 555.

Lee. Minghui, (2013). "The study on transformation development for the traditional road freight transportation enterprises in Guangxi Zhuang autonomous region." *Journal of transportation enterprise management*, 12: 28-29.

Ma Da. (2012). "Logistics ability improve railway overall strength strategy research." *Journal of Shijiazhuang Institute of Railway Technology*, (2): 91-94.

Wang Jin. (2013). "Based on the concept of modern logistics of railway freight organization reform research." *Journal of logistics engineering and management*, 35(8): 7-8.

Wei Juan, Xing Zhanwen. (2013). "American road freight organization mode and enlightenment." *Journal of management modernization*, 01:123-125.

Wei Juan, Xing Zhanwen. (2013). "Our country road freight organization evolution process and development trend." *Journal of commercial age*, 21:46-48.

Xie Tao. (2014). "China express packages for 2014 is expected to exceed 12 billion." [ED/OL]. *O wisdom tak news agency.* http://www.gw.com.cn/news/news/2014/0718/200000362645.shtml.

Fuzzy Chance-Constrained Programming for Optimal Containership Slot Exchange and Allocation in Liner Alliances

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Abstract: Containership slot exchange is a new cooperation strategy allowing participating carriers to seek to benefit from sharing capacities. On the basis of analyzing the characteristics of containership slot exchange and allocation problem in short sea cycle routes operated by liner alliances, this paper considers the uncertainties in revenue and demand then proposes a fuzzy chance-constrained slot exchange and allocation optimization programming model. The model takes marginal revenues and demands of different markets in fuzzy environments as fuzzy variables and aims at maximizing the total revenue of the liner alliance which operates multi-routes. A numerical example is applied to attest the method's practicability and feasibility. The conclusion suggests that in fuzzy environments, a proper containership slot exchange and allocation strategy can increase the total revenue of liner alliances significantly.

Keywords: Fuzzy environments; Liner alliances; Slot exchange; Fuzzy chance-constrained programming.

1 Introduction

In the contemporary international sea transportation industry, containership liner service has become the dominant mode. With the rapid development of economic globalization, more and more carriers began operating in alliances. Recently, slot exchange has become a common cooperation strategy adopted by many alliances. Slot exchange allows carriers to benefit from exchanging some of their capacities among certain routes. By adopting slot exchange, carriers can reduce cost, simplify management and decrease the risk brought by fluctuations in transportation demand markets. Due to these unparalleled advantages, slot exchange is gaining more and more popularity among liner alliances.

In the last decades, many scholars studied the slot allocation problem of liner services. Ha (Ha, 1994) and Maragos (Maragos, 1994) first studied slot allocation, slot control strategy, dynamic slot allocation in multi-legs and joint slot allocation of loaded and empty containers. Recently, scholars began to study slot allocation in a Joint fleet or alliance. Lu et al. (Lu, 2010) analyzed slot purchase strategy in containership liner service fleets and proposed a mathematical programming model to solve fleet deployment problem and slot allocation problem. Studies on slot exchange are quite scarce. The probably first relevant study is Lu (Lu, 2010), where the characteristics of slot exchange was studied and two integer programming models considering slot exchange alone and the integration of slot exchange and slot purchase respectively were proposed to maximize the concerned revenues.

International sea transportation has been proved to be a market suffering drastic volatility. There are great uncertainties in both transportation demands and revenues of liner services due to changes in global economy and oil prices. To deal with the uncertainties, this paper adopts the *fuzzy theory* which was first introduced by Zadeh (Zadeh, 1965). In this paper, *fuzzy chance-constrained programming* is adopted to formulate our model. *Fuzzy chance-constrained programming* was introduced by Liu (Liu, 1998).To the best of our knowledge, there is little research on chance-constrained slot allocation problem in fuzzy environment.

To conclude, the majority of relevant studies focus on slot allocation problem. Although some scholars have begun studying the problem of slot exchange (Lu, 2010), their research is confined under the assumption of deterministic environments and in the view of a single carrier. This paper considers the problem in an alliance's view and extends the problem into a fuzzy environment.

2 Preliminaries

In this paper, we adopt the concepts of *fuzzy chance-constrained programming theory* to help formulate the model with fuzzy variables. This section presents some basic knowledge about *fuzzy theory* and *credibility-based fuzzy chance-constrained programming*.

Let ξ be a fuzzy variable with *membership function* μ, and u and r be real numbers.

Definition 2.1 The *possibility* of a fuzzy event, characterized by $\xi \le r$, is defined by:

$$\text{Pos}\{\xi \le r\} = \sup_{u \le r} \mu(u)$$

Definition 2.2 While the *necessity* of $\xi \le r$ is defined by:

$$\text{Nec}\{\xi \le r\} = 1 - \text{Pos}\{\xi > r\} = 1 - \sup_{u > r} \mu(u)$$

Definition 2.3 The *credibility* of $\xi \le r$ is defined by:

$$\text{Cr}\{\xi \le r\} = \frac{1}{2}(\text{Pos}\{\xi \le r\} + \text{Nec}\{\xi \le r\})$$

Definition 2.4 The *credibility-based fuzzy chance-constrained programming model* maximizing the objective is given as follows:

$$\begin{cases} \max \ \overline{f} \\ s.t. \\ \quad \text{Cr}\{\text{f}(x,\xi) \ge \overline{f}\} \ge \beta \\ \quad \text{Cr}\{\text{g}_j(x,\xi) \le 0, j = 1,2,...,p\} \ge \alpha, \end{cases}$$

where α and β are *confidence level* given by the decision makers.

Lemma 2.1 Let $\xi_k = (r_{k1}, r_{k2}, r_{k3}, r_{k4})$, $k = 1,2,...,t.$ be a *trapezoidal fuzzy variable* and let function $\text{g}(x,\xi)$ be shown as follows:

$$g(x,\xi) = h_1(x)\xi_1 + h_2(x)\xi_2 + ... + h_t(x)\xi_t + h_0(x) \quad .$$

Let $h_k^+(x) = h_k(x) \vee 0$ and $h_k^-(x) = -h_k(x) \wedge 0$, $k = 1, 2, ..., t$.

The *Crisp Equivalent* of credibility-based fuzzy chance-constrained equation $\text{Cr}\{g(x,\xi) \le 0\} \ge \alpha$ is given by:

If $\alpha < 0.5$, $\text{Cr}\{g(x,\xi) \le 0\} \ge \alpha \Leftrightarrow (1-2\alpha)\sum_{k=1}^{t}[r_{k1}h_k^+(x) - r_{k4}h_k^-(x)] + 2\alpha\sum_{k=1}^{t}[r_{k2}h_k^+(x) - r_{k3}h_k^-(x)] + h_0(x) \le 0$

and if $\alpha \ge 0.5$, $Cr\{g(\text{x},\xi) \le 0\} \ge \alpha \Leftrightarrow (2-2\alpha)\sum_{k=1}^{t}[r_{k3}h_k^+(x) - r_{k2}h_k^-(x)] + (2\alpha\text{-}1)\sum_{k=1}^{t}[r_{k4}h_k^+(x) - r_{k1}h_k^-(x)] + h_0(x) \le 0$.

3 Problem description and formulation

We consider the problem in *Short sea cycle routes* which are a common route structure of short sea liner services. In cycle routes, cargoes are shipped by vessels at fixed freight rate, in fixed routes, among fixed ports and in a fixed cycle sequence, all of which should be listed in a *Shipping Schedule* published by carriers. Slot exchange deals with the mutual exchange of slot capacity among alliance participants. When adopting slot exchange strategy, slots can be exchange in and out by a carrier in different routes. In this paper, we measure the value of a slot in a certain route by the duration of a complete voyage of the route. For a liner alliance, its slot exchange and allocation decision can be stated as a two-stage process: first, each participant of the alliance should decide whether to exchange slots (both in and out) with its partners and the specific amount in each of its operating routes; second, the alliance should decide how to assign its slots so as to satisfy transportation demands and obtain the overall maximum revenue in all of its operating routes. As in containership liner services, the fixed cost is relatively high and constant, therefore, the objective to maximize the overall revenue of an alliance equals to maximizing the overall marginal revenue.

Assume a liner service alliance adopts slot exchange strategy in a shipping sector which includes several call ports. Without loss of generality, symbols for variables and parameters used in the formulated models are introduced and interpreted as follows.

S: set for carriers in the alliance; *R*: set for routes operated by the alliance; *P*: set for call ports; *T*: set for trade port pairs, $T=\{(i\to j)|i,j\in P,i\ne j\}$; L_r : set for legs in route *r*; ξ_{ij}^{kr} : a fuzzy variable, marginal revenue of shipment between port pairs $(i \to j)$ for carrier *k* in route *r*, $k \in S$; q^{kr} : voyage duration for carrier *k* in route *r*; M^{kr} : number of slots in TEUs hold by carrier *k* in route *r*; c_{ij} : contract transportation demands that must be satisfied between port pair $(i \to j)$; η_{ij} : a fuzzy variable, total transportation demands(including contract demands) between port pairs $(i\to j)$. Clearly, we have $Cr\{\text{c}_{ij} \le \eta_{ij}\}=1, \forall(i \to j) \in T$; *N* is a big number. μ_{ij}^r : μ_{ij}^r =1, if route *r* incudes trade pair $(i \to j)$ μ_{ij}^r = 0, otherwise; γ_{ijl}^r : γ_{ijl}^r =1, if the delivery passage of consignments of port pair $(i \to j)$ passing the sailing leg *l* of route *r*, γ_{ijl}^r =0, otherwise.

The decision variables are listed as follows. x_{ij}^{kr} : number of slots carrier *k* deploys in route *r* to ship cargoes between port pair $(i \to j)$; d^{kr} : number of slots company *k* exchange in from partners in route *r*; e^{kr} : number of slots carrier *k* exchange out to partners in route r. $h^{kr}: h^{kr}=1$, if company k exchange in slots in route r, $h^{kr}=0$, otherwise.

Based on the *fuzzy chance-constrained programming theory* the model maximizing the overall revenue can be formulated as follows:

$$\max \overline{f} \tag{1}$$

$$s.t. \quad Cr\{\sum_k \sum_r \sum_{(i\to j)} \xi_{ij}^{kr} x_{ij}^{kr} \geq \overline{f}\} \geq \beta \tag{2}$$

$$Cr\{\sum_k \sum_r x_{ij}^{kr} \leq \eta_{ij}\} \geq \alpha \qquad \forall (i \to j) \tag{3}$$

$$\sum_k \sum_r x_{ij}^{kr} \geq c_{ij} \qquad \forall (i \to j) \tag{4}$$

$$x_{ij}^{kr} \leq \mu_{ij}^{r} N \qquad \forall (i \to j), k, r \tag{5}$$

$$\sum_{(i\to j)} \gamma_{ijl}^{r} x_{ij}^{kr} - e^{kr} + d^{kr} \leq M^{kr} \qquad \forall k, r, l \tag{6}$$

$$\sum_k e^{kr} = \sum_k d^{kr} \qquad \forall r \tag{7}$$

$$e^{kr} \leq h^{kr} N \qquad \forall k, r \tag{8}$$

$$d^{kr} \leq (1-\beta^{kr})\, N \qquad \forall k, r \tag{9}$$

$$\sum_r q^{kr} e^{kr} = \sum_r q^{kr} d^{kr} \qquad \forall k \tag{10}$$

$$x_{ij}^{kr},\ e^{kr},\ d^{kr} \in N \cup \{0\} \qquad \forall (i \to j), r \tag{11}$$

$$\beta^{kr} \in \{0,1\} \qquad \forall k, r \tag{12}$$

In the model, the objective function in (1) maximizes the total transportation revenue of the alliance. Equation (2) means the alliance can obtain the maximal revenue at confidence level β. Equation (3) enforces that the distributed slots to ship cargos between port pair $(i \to j)$ should not exceed the corresponding transportation demand at confidence level α. Equation (4) means the contract demands must be satisfied. Equation (5) enforces that cargoes must be consigned through a certain route. Equation (6) constrains the sum of distributed slots on each sailing leg cannot exceed the available capacities which including the originally controllable slots plus the exchanged results. Equation (7) enforces the numbers of exchanged slots in TEU-days for both sides are consistent in each route. Equations (8) and (9) enforce that a carrier cannot exchange in and exchange out slots at the same time in the same route. Equation (10) enforces the slot exchange equity for each carrier. Equations (11) and (12) are nonnegative and integral constrains for decision variables.

Assume ξ_{ij}^{kr} and η_{ij} are both *trapezoidal fuzzy variables,* such that $\xi_{ij}^{kr} = (r1_{ij}^{kr}, r2_{ij}^{kr}, r3_{ij}^{kr}, r4_{ij}^{kr})$ and $\eta_{ij} = (t1_{ij}, t2_{ij}, t3_{ij}, t4_{ij})$, where r and t are both real numbers.

According to Lemma 2.1**,** equations (2) and (3) can be replaced by their crisp forms, where $\alpha > 0.5$, $\beta > 0.5$ and $x_{ij}^{kr} \geq 0$:

$$-(2-2\beta)\sum_k \sum_r \sum_{(i\to j)} r2_{ij}^{kr} x_{ij}^{kr} - (2\beta-1)\sum_k \sum_r \sum_{(i\to j)} r1_{ij}^{kr} x_{ij}^{kr} + \overline{f} \leq 0 \tag{13}$$

$$-(2-2\alpha)\, t2_{ij} - (2\alpha-1)\, t1_{ij} + \sum_{k\in S} \sum_{r\in R} x_{ij}^{kr} \leq 0 \qquad \forall (i \to j) \in T \tag{14}$$

Therefore the above model can be transformed into a *crisp mixed integer programming model* and can be solved by *Cplex* to obtain the optimal solution.

4 Numerical Experiment

We consider an alliance that consists of three carriers (K1, K2 and K3). The alliance operates three routes, namely R1, R2 and R3 between sectors A and B. Further, we assume consignments within the same sector are forbidden due to policies like *Cabotage Reservation*. The route structure and operation details are shown in figure 1 and table 1:

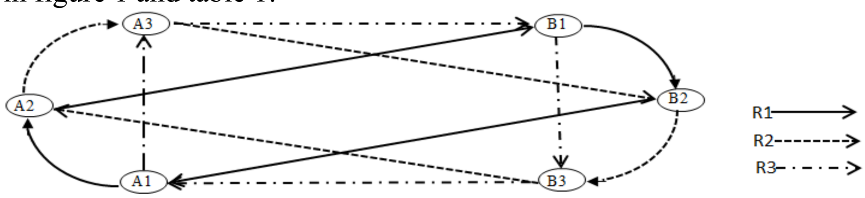

Figure 1. Route structure

Table 1. Operation details

Route（Carriers）	R1（S1, S2）	R2（S2,S3）	R3（S1,S3）
Structure	A1→A2→B1→B2→A1	A2→A3→B2→B3→A2	A1→A3→B1→B3→A1
Capacity（TEU）	K1:2000, K2:2100	K2:2550, K3:2500	K1:2500, K3:2600
Duration（Day）	K1:14 K2:14	K2:14 K3:14	K1:14 K3:14

Table 2 and table 3 show details of the demand and revenue in different routes operated by the alliance in fuzzy environments.

Table 2. Fuzzy demands of different port pairs

Port pair	Total(TEU)	Contract(TEU)	Port pair	Total(TEU)	Contract(TEU)
A1-B1	(1300,1400,1500,1700)	500	B1-A1	(1020,1040,1050,1100)	340
A1-B2	(1330,1390,1530,1630	510	B1-A2	(1380,1440,1500,1540)	500
A1-B3	(1190,1250,1330,1450)	450	B1-A3	(1600,1700,1800,1860)	600
A2-B1	(1360,1420,1500,1600)	500	B2-A1	(1350,1370,1400,1430)	470
A2-B2	(612,632,642,672)	212	B2-A2	(1800,1820,1840,1860)	600
A2-B3	(1200,1220,1240,1250)	400	B2-A3	(760,800,840,900)	300
A3-B1	(965,1045,1085,1125)	365	B3-A1	(1280,1340,1400,1480)	480
A3-B2	(710,750,790,830)	270	B3-A2	(990,1070,1150,1270)	390
A3-B3	(945,985,1025,1065)	345	B3-A3	(2000,2040,2100,2160)	700

Table 3. Fuzzy revenues ($/TEU) of different port pairs in different routes

	Carrier	A1-B1	A1-B2	A2-B1	A2-B2
R1	K1	(220,240,250,265)	(200,220,230,250)	(150,155,165,170)	(260,270,276,284)
	K2	(250,255,260,270)	(210,215,220,224)	(175,180,185,192)	(290,295,300,305)
	K3	(225,230,235,240)	(205,210,213,217)	(160,167,174,180)	(275,280,284,288)
	Carrier	B1-A1	B1-A2	B2-A1	B2-A2
	K1	(270,278,288,292)	(190,198,207,214)	(180,190,196,206)	(200,207,214,220)
	K2	(280,285,290,294)	(220,224,229,235)	(205,210,216,220)	(200,206,212,220)
	K3	(275,280,285,291)	(210,216,220,226)	(190,194,200,208)	(202,205,210,215)
R2	Carrier	A2-B2	A2-B3	A3-B2	A3-B3
	K1	(250,255,259,265)	(215,220,224,228)	(185,190,194,200)	(280,286,292,299)
	K2	(220,225,230,235)	(205,210,215,220)	(185,190,194,198)	(260,266,272,280)
	K3	(260,265,270,276)	(225,230,234,242)	(195,200,204,211)	(290,295,300,306)
	Carrier	B2-A2	B2-A3	B3-A2	B3-A3
	K1	(285,290,294,300)	(225,230,236,242)	(205,210,218,227)	(200,210,218,222)
	K2	(265,273,280,285)	(200,206,211,217)	(195,200,206,212)	(190,196,203,209)
	K3	(295,300,306,311)	(235,240,248,255)	(215,220,227,232)	(210,214,220,227)
R3	Carrier	A1-B1	A1-B3	A3-B1	A3-B3
	K1	(250,255,260,267)	(225,230,234,238)	(205,208,213,220)	(260,266,270,274)
	K2	(230,236,244,250)	(210,214,218,223)	(200,206,212,220)	(240,244,249,256)
	K3	(220,227,234,240)	(200,204,208,213)	(200,207,212,220)	(230,235,240,247)
	Carrier	B1-A1	B1-A3	B3-A1	B3-A3
	K1	(270,276,280,285)	(220,224,230,236)	(220,226,232,240)	(210,216,221,230)
	K2	(255,260,267,274)	(206,210,215,220)	(210,218,222,230)	(190,195,202,210)
	K3	(245,250,256,268)	(200,214,219,224)	(200,206,212,220)	(180,186,193,200)

Let the confidence level $\alpha = 0.95$ and $\beta = 0.9$. The model and data were input into *Cplex*. The exchange and allocation results solved by *Cplex* are shown in table 4 and table 5.

Table 4. Slot exchange result

Route	R1		R2		R3	
carrier	Strategy	Amount(TEU)	Strategy	Amount(TEU)	Strategy	Amount(TEU)
K1	Exchange-out	2000	None	0	Exchange-in	2000
K2	Exchange-in	2000	Exchange-out	2550	Exchange-in	550
K3	None	0	Exchange-in	2550	Exchange-out	2550
Total revenue($)			3456644			

Table 5. Slot allocation result

	Carrier	A1-B1	A1-B2	A2-B1	A2-B2	B1-A1	B1-A2	B2-A1	B2-A2
R1	K1	0	0	0	0	0	0	0	0
	K2	483	510	500	615	1022	500	470	0
	K3	0	0	0	0	0	0	0	0
	Carrier	A2-B2	A2-B3	A3-B2	A3-B3	B2-A2	B2-A3	B3-A2	B3-A3
R2	K1	0	0	0	0	0	0	0	0
	K2	0	0	0	0	0	0	0	0
	K3	0	875	270	949	1802	764	390	0
	Carrier	A1-B1	A1-B3	A3-B1	A3-B3	B1-A1	B1-A3	B3-A1	B3-A3
R3	K1	827	1196	0	0	0	726	1051	700
	K2	0	0	315	0	0	0	235	0
	K3	0	0	50	0	0	0	0	0

After adopting slot exchange strategy, the total revenue of the alliance is 3.46 million dollars. The revenue without slot exchange is 3.33 million dollars which is obtained by setting variables d^{kr} =0 and e^{kr} =0. Therefore, by adoption slot exchange, the alliance can increase its revenue by 3.7% without increasing capacities.

5 Conclusions

This paper studied slot exchange and allocation problem in containership liner services in fuzzy environments in an alliance's view, proposed a fuzzy chance-constrained programming model and transformed it into a crisp programming model. The result of the numerical experiment shows slot exchange can significantly increase the overall revenue of liner alliances. Here we may draw the following conclusions. (1) Slot exchange ensures the equity and convenience among alliance participants and at the same time, enables participating carriers to optimize slot allocation in an alliance level so as to enhance the profitability of capacities. (2) *Fuzzy theory* or *fuzzy chance-constrained programming* can be successfully adopted in analyzing, formulating and solving slot exchange and allocation problem in liner alliances in fuzzy environments.

Reference

Ha D. (1994) "Capacity management in the container shipping industry: The application of yield management techniques." University of Tennessee.

Lu H., Chu C., and Che P. (2010) "Seasonal slot allocation planning for a container liner shipping services." Journal of Marine Science and Technology, 18(1): 84-92.

Lu H, Chen S., and Lai P. (2010) "Slot exchange and purchase planning of short sea service for liner carriers." Journal of Marine Science and Technology, 18(5): 709-718.

Liu B. and Iwamura K. (1998) "Chance-constrained programming with fuzzy parameters," Fuzzy Sets Systems, 94(2): 227–237.
Maragos S A. (1994) "Yield management for the maritime industry (shipping, itineraries)". Massachusetts Institute of Technology.
Zadeh L A. (1965) "Fuzzy sets." Information and Control, 8:338-353.

Cohesion of Urban Rail Transit and Other Transportation

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Abstract: A period of construction developed rapidly has already came up in urban public transport system, and in which urban rail transit is the backbone. Urban rail transit consists of light rail with large capacity and subway. The trend of urban transportation's development is the division of labor and cooperation of all modes of transportation. Then a development model of traffic integration could be formed. The joins between various transportation modes and rail transit are important links. Joins and coordinators of urban rail traffic system and other means of transportation include two points, that is the links between paths and transfers between stations. This paper mainly conducted studies in aspects of rail link modes, transfer time and transfer distance. And the influence factors and planning objectives of urban rail transit are also analyzed. Taking the subway under construction in Nanchang for example and concrete analysis and evaluation about links of urban rail transit was obtained.

Keywords: Urban rail transport; Connection modes; Transfer time; Transfer distance; Planning goals.

1 Introduction

The development of economy and the change of industrial structure, bringing the expansion of city scale and sharply increase of urban populations. According to relevant statistic, the number of urban population in China reached 731 millions in 2013, the urbanization rate reached 53.7%, it leads to enormous pressure to urban traffic. Furthermore, the number of motor vehicle in China also in growth, in 2014 the number of domestic cars is about 140 millions. The number of cars in China has grown from 24 millions to 137 millions, which is 5.7 times of that in 2003.Traffic demand expand rapidly, while the road traffic infrastructures are outdated. That leads to the sharply contradiction of city traffic between supply and demand, meanwhile, traffic congestion situation happens.

People, vehicle and rode are three important elements in traffic, deal with the contradiction between three elements are very important in solve city traffic problems. Construction of the urban traffic is a decision-making engineering system. Lacking of scientific and comprehensive transportation strategy should be responsible for current traffic problems. The governments' disorder works make investment very large, but without returns. The wrong understanding of city functions will cause traffic intersect and overlap as well as over-expansion of passengers and logistics, then will certain cause traffic jams. The goal of city traffic development is establish a comprehensive transportation system. The traffic in big city should combined with construction planning to set up a network system, the urban traffic also need convenient public transportation, trams, taxi and necessary urban rail transit (Lv, 2005).

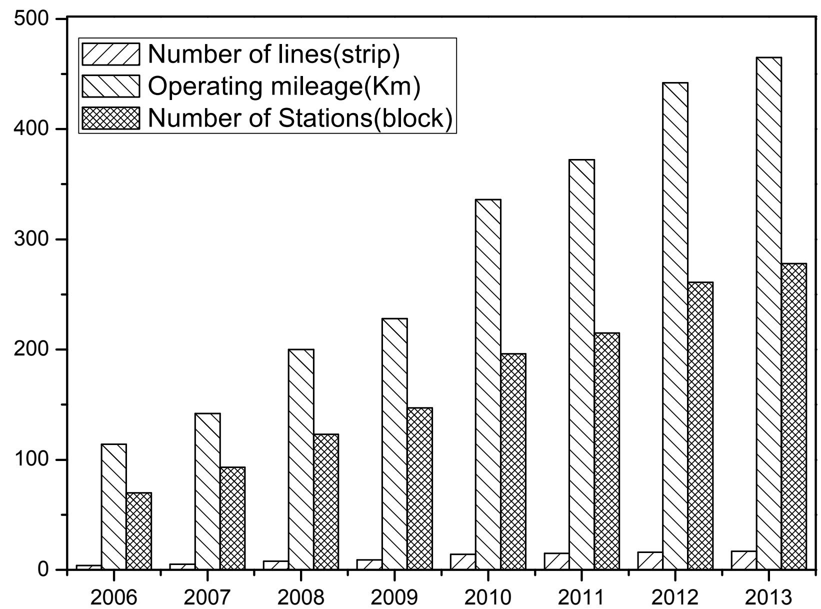

Figure 1. Beijing rail transit network situation

In city, urban rail transit system is a kind of public passenger transport, it has many advantages such as large capacity, fast, safe, energy-saving, comfortable and low pollution. Among the compositions of urban transport system, rapid rail transit system hold the dominant and backbone position. However in order to try best use of the traffic potentiality, transportations must combine with good feeder system and cohesion system (Wang, 2009). Thus the reasonable planning, designing and construction of transportation hub play a key role in the increase of economic benefits of urban integrated passenger traffic system, reducing residents' travel time and determine the public transportation.

2 Analysis of rail traffic connection mode

2.1 The city rail convergence

Urban rail transit mainly comprise of light rail with large capacity, subway and other transportations. There are many means of the convergence between urban rail transit and other transport modes. It can be divided into city traffic and city outskirts traffic. Convergence of city outside traffic includes rail, aviation and ports. Convergence of city inside traffic includes rail, buses, cars, bicycles and walking.

Railway is an important part of comprehensive transportation system, it contains railway transportation and city traffic. Passengers who take trains always use buses and other public transportations to go to railway station. Adding urban rail transit into railway station could evacuate passengers quickly and efficiently. There are many connected modes between railway station and rail transit. The common ways are: (1) Construct rail transit station in front of railway station square and channel intersection set in station square, then through station square to form cohesion with the railway station. (2) Rail station export channel directly lead to the hub of station hall, after outbound, passengers will be able to enter station's waiting room or ticket office. (3) The hall layer of rail station leads to the platform of the passenger station directly, and connected with it through stairs or escalators. (4) Rail transit united with railway to set stations.

Air transport is a main method of high-speed transportation, with many advantages such as fast speed, long transport distance, comfortable, safety, mobility, less investment, short construction period and so on. Air transport is suitable for the goods freight which have the following features, long distance, small volume, time requirement or high freight etc. Due to high requirement of the clearance of space, the airport always apart from city center areas. Due to high requirement for time, the rail transportation with the characteristics of rapid, convenient and large capacity is more suitable than the conventional bus for air transport connection system.

Large passenger port is the hub of urban passenger traffic. Conventional bus, taxi, rail transportation and other public transportation could all be used in harbor transportation system. While rail transit needs the turning radius and high vertical requirement of construction, its application in urban rail transit has yet to be further perfected.

2.2 The outskirts rail convergence

Bus rapid transit combined with modern bus technology, intelligent traffic and operations management to set up bus special lane and build the new form of bus station. The cohesion of bus rapid transit and rail transit can transfer through the station or use one-stop tickets as well as near distance transfer (Figure 1). One-stop tickets make the seamless connection of Bus Rapid Transit and rail transit come ture. Reasonable cohesion can expand the service scope of urban public transportation system effectively and improve the operation efficiency of city traffic rapidly (Lv, 2005).

(a) With the transfer station (b) Iso-station transfer

Figure 2. Transfer modes

Conventional bus is a common transport of city public traffic, and its characters are wide coverage and accessibility. The connection of conventional bus and rail transit use more midway stops and rail transit stations for near distance transfer. Introducing station line in public transport hub station could guide the transfer between conventional bus and rail transport. In particular, the walking facilities between public transport hub station and fore and aft of bus station do good to the transfer.

Set up a special station in the planning of the linkage between taxi and rail transit. In order to cooperate with footwork system the transfer area can be in the same position or be scattered layout. The location of taxi station should be farther than public station and trams station. The areas of taxi turnover, passenger stream areas, the waiting areas and the queue areas should separate from bus and trams routes, thus could reduce the interference of bus and trams travel (Li, 2005).

The growth of private motor vehicles is a major pressure of city road. Building car parking around the urban rapid rail transit station, and then forming a transfer station between car and urban rapid rail transit(Jiang, 2001). This kind of convergence means driving from residence to high-capacity rail transit station then taking rail transit to their destination. This transfer mode need attract vehicle and reduce the load of roads. Meanwhile, the reduced traffic on the relevant roads could drop crowds and improve travel speed and comfort of vehicle (Gan, 2006).

Bicycles play a significant role in city traffic. Therefore, in the connected planning of Urban Rail Transit, government could propose to set certain size parking in residential areas and the city’s main intersection. This setting of bicycle parking should take the land and buildings around the station into consideration. In the downtown area where land valued can use underground space to set parking lot. It would facilitates passengers realize their transfer at the short distances and save transfer time.

Walking is an indispensable part of public transportation. Improve walking conditions will be help to lift transit service levels. In public transportation system, walking plays a role in short distance transfer, and it is a convenient transfer transportation for subway riders. Pedestrian crossing facilities include pedestrian platform bridge and underground passageway. Reasonably pedestrian facilities, transfer security and transfer patency are the key points to improve the walking transfer.

3 The influence factor of urban rail transit cohesion

There are many factors that affect urban rail transit cohesion, generally can be divided into residents travel habits, urban character and guidance policy.

(a) the factors of residents' travel habits include: travel behaviors, easy of transfer, travel time and comfort of travel and so on(Shi, 2012). Affecting by city traffic situation and city scale, acceptable transferring times is one of the reference factors of the convergence of rail transit and other transportation. Such as, residents can through one transportation modes reach majority of the urban areas if the traffic situation is good. Residents have high requirement of connection, rarely choose bus, cars, bicycle as their transfer transport modes, therefore complete the connection work between pedestrian traffic and rail traffic is very important. Travel time is also an important factor in transit linking system. The same time for different transportation modes have different travel distance. Subject to travel time, residents will choose the efficient one.

(b)the factors of urban areas characters include: topography, climate and other aspects of urban features. The influence of topography on urban transport is mainly reflected in travel mode, the roads' slope is large in those cities where have lots of mountainous and hilly. So citizens would prefer to choose public transportation rather than bicycle or pedestrian travel and government should pay more attention public transportation; Cities in plain areas should focus on bicycle and pedestrian traffic.

The impact of climate mainly was the proportion of residents who travel use bicycle, motorcycle or on foot decreased on cold day. In the city where climate pleasant, residence are more likely choose bicycle or walking as their travel tools. Therefore these cities should focus on the convergence of pedestrian and bicycle traffic.

Urban construction area is wide, cities that have fewer building always have higher motorization lever, so they should concentrated on the connection of motor vehicle and rail transit. Cities with more buildings means with high travel proportions, meanwhile they are more suitable for residents who travel by bike, bus or other transportation which occupy less land resource. Therefore, cities should pay more attention on the convergence of rail transit and these transportations.

(c)factors of urban guidance policy include: development policies of cars and buses etc. Cars development policies are the main way to guide the city traffic development. Such as Shanghai, Beijing and other cities adopt rules such as restrict new vehicle licensing, inhibit motor vehicle quantities and raising parking fees in central area to guide private cars application. Simultaneously, those cities should improve the convergence of rail transit and private car and encourage transfer private cars to transportation(Shi, 2012).

4 The analysis of the connected of Nanchang rail transit under construction

4.1 Forecast planning of Nanchang city's rail transit

Nanchang track traffic is the first underground subway transport system in Jiangxi province metropolitan areas. The line is divided into two stages. The first stage was composition of the first phase of line 1, line 2, line 3 subway; the second stage includes line 4, line 5 subway and the second phase of line 1, line 2, line 3 subway. The two stages constitute of a complete rail transit network and achieve the overall goal of network planning.

4.2 Advice on connection mode

According to the survey, the urban motorized numbers were 2.44 millions passengers/day in 2010, vehicle turnover numbers were 22.84 millions passengers*km/day, numbers was respectively 2.58 times, 6 times than those in 2002. In addition, according to the geographical environment, Nanchang Located in the subtropical regions have humid and monsoon climate. In there the humid climate is mild, sunshine abundant, summer and winter long while spring and fall short. Nanchang is a typical city where summer hot and winter cold. If you choose a bike for your trip, you will get a sweat body in summer and stiff arms in the winter, hence residents are more likely to choose motor vehicles, such as buses or private cars as their travel tools.

(a)Based on function features in different areas, we should have different attitude for them and choose different convergence as the key point. Such as: the central area gathered many works, so the morning rush hour attract a lot lf traffic and the evening rush hour arise many traffic. City center was strain on the land resources and have a large number of buildings, so central areas should focus on the convergence of tramp or bus with rail transit. T he convergence facilities should mainly serve commercial and finance areas, administrative office and other areas where jobs gathered. In city neighboring areas, the morning rush hour arise much traffic, the evening rush hour attract much traffic. Peripheral areas are living areas, so they should focus on the convergence of buses, cars, or cars with rail transit. Their convergence facilities should mainly serve residential areas. Mixed areas of commercial and residence split by residential and employment, and located in middle areas of center region and peripheral region in city. Both the morning rush hour and the evening rush hour will attract a lot of traffic. Due to the multiple functions, they should focus on the convergence of walking, buses, taxis with rail transit. Similarly, the convergence facilities should serve both employees and residents. The peak time in tourist areas are different from urban areas. Its peak time always arise during holidays. Different tourism projects also meet different peak time. Tourist areas should pay more attention on the convergence of walking or buses with rail transit. The convergence facilities should reached the entrance of tourist areas.

(b)Diversification of convergence modes means the various forms of convergence. As for Nanchang rail transit, the core area should focus on the convergence of buses, private cars and rail transit, and supplement with the convergence of walking, taxis with rail transit.

Walking is suitable for short-distance travel. In core areas of Nanchang, if you travel on foot, the average time is about 10min and the average distance about 0.8km. So the coverage of convergence facilities, where rail transit transfer by walking, should within 1km. Bus is suitable for long distance travel, and the travel distance about 1 km to 4km. So the coverage of the convergence facilities, where rail transit transfer by the bus, should be between 1km and 4km. Car and taxi is suitable for longer distance travel, with which the acceptable travel speed is higher than 15km/h and the travel distance about 3km to 10km. Therefore, the coverage of the convergence facilities, where rail transit transfer by cars or taxis, should be between 3km and 10km.

5 Conclusion

Modern city need modern transportation system, which adapt to modern life. In order to ease and improve the heavy traffic, city should form a comprehensive traffic pattern that highly coordinate with the urban develop. In order to improve its attractiveness and realize its functions of rail transit, rail transit should closely connected with other transportations, their transfer should be easy and their work should be interoperable. Through the integration of space and time implement “seamless and zero transfer”.

Acknowledgement

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References:

Gan, Y. H. (2006). “Guangzhou Integration Planning of Urban Transport and Other Transport Modes.” *Journal of Huazhong University of Science and Technology(Urban Science Edition),* 23(S2), 112-116.

Jiang, F. (2001). “Analisis and Study of Joining and Cooperation Between Urban Rail Traffic and Other Modes.” *Journal of Beijing Jiaotong University,* 25(4), 108-110.

Li X. X. (2005). "Research on track traffic linking up with other traffic means." *Shanxi Architecture,* 31(24), 21-22.

Lv D. (2005). "The cohesion of urban rail transit and various transportations." *Urban Mass Transit,* (5), 87-88.

Shi Y. F. (2012). "Evaluation Method for Connecting of Region Rail Transit." *Journal of Chongqing University,* 31(5), 939-943.

Wang S. C. (2009). "The cohesion of urban rail transit and various transportations." *China New Technologies and Products,* 16, 37.

Optimization of the Structure of Comprehensive Transportation Systems Based on Energy Consumption

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Abstract: In recent years, with rapid development of the comprehensive transportation system, the contradiction between transportation and energy has become more and more serious; energy has become a constraint to the sustainable development of China's comprehensive transportation system. How to optimize the comprehensive transport system structure effectively and promote the comprehensive transportation system sustained development has become an important problem that urgent to be solved. This paper considers the "energy consumption" as constraints, establish decomposition model to analysis the variation of energy consumption. Research shows that, when considering the constraints, it increases the proportion of rail transport and waterway transport in a comprehensive transport system. Therefore, under the constraints of energy consumption, the system should make planning to realize the coordination of transport modes. Especially, should greatly develop railway and waterway which have low energy consumption and little effect on environment.

Keywords: Comprehensive transportation; Energy consumption; Decomposition model; Environmental protection.

1 Introduction

This paper establishes the complete decomposition model to analysis the variation of energy consumption of comprehensive transportation. On the basis of the analysis of energy consumption of different period corresponds to the comprehensive transportation system structure, we parsing the relationship between them. A calculation example is gave based on the statistical data of 1995-2011.The resulting in optimizing the structure of the comprehensive transport system.

2 Modeling

By establishing a complete decomposition of the following model will divided the influencing factors of energy consumption into three parts, traffic volume, energy consumption intensity and system structure of comprehensive transportation.

Decomposition model is show as follow:

$$E(t)=VA(t)\times\frac{\sum_{i=1}^{n}E_i(t)}{VA(t)}=VA(t)\times\frac{\sum_{i=1}^{n}VA(t)\times SV_i(t)\times EI_i(t)}{VA(t)}=VA(t)\times\left[\sum_{i=1}^{n}SV_i(t)\times EI_i(t)\right] \quad (1)$$

$$\Delta E(t)=VA(t)\times\left[\sum_{i=1}^{n}SV_i(t)\times EI_i(t)\right]-VA(0)\times\left[\sum_{i=1}^{n}SV_i(0)\times EI_i(0)\right]$$

$$=\left[VA(0)+\Delta VA(t)\right]\times\left\{\sum_{i=1}^{n}\left[SV_i(0)+\Delta SV_i(t)\right]\times\left[EI_i(0)+\Delta EI_i(t)\right]\right\}-VA(0)\times\left[\sum_{i=1}^{n}SV_i(0)\times EI_i(0)\right]$$

$$=\left[VA(0)+\Delta VA(t)\right]\times\left\{\sum_{i=1}^{n}\left[SV_i(0)\times EI_i(0)+\Delta SV_i(t)\times EI_i(0)+SV_i(0)\times\Delta EI_i(t)+\Delta SV_i(t)\times\Delta EI_i(t)\right]\right\} \quad (2)$$

$$-VA(0)\times\left[\sum_{i=1}^{n}SV_i(0)\times EI_i(0)\right]$$

$$=VA(0)\times\sum_{i=1}^{n}\left[\Delta SV_i(t)\times EI_i(0)+SV_i(0)\times\Delta EI_i(t)+\Delta SV_i(t)\times\Delta EI_i(t)\right]$$

$$+\Delta VA(t)\times\left\{\sum_{i=1}^{n}\left[SV_i(0)\times EI_i(0)+\Delta SV_i(t)\times EI_i(0)+SV_i(0)\times\Delta EI_i(t)+\Delta SV_i(t)\times\Delta EI_i(t)\right]\right\}$$

Where t is time period t; i is kinds of modes of transport;

$E(t)$ —The total energy consumption of the transport sector (tones of oil equivalent)

$\Delta E(t)$ —Relative to the reference periods, increased amount of total energy consumption in the transport sector;

$E_i(t)$ —transportation energy consumption of mode i;

$EI_i(t)$ —transportation energy consumption intensity of mode i;

$EI_i(0)$ —transportation energy consumption intensity of mode i in reference period;

$\Delta EI_i(t)$ —relative to the reference periods, the increases of energy consumption intensity of mode i;

$VA(t)$ —turnover of all modes of transport;

$VA(0)$ —turnover of all modes of transport in reference period;

$\Delta VA(t)$ —Relative to the reference periods, the increase of turnover in period t.

$SV_i(t)$ —in period t，percentage of turnover by transport i of total.

$SV_i(0)$ —percentage of turnover by transport i of total in reference period;

$\Delta SV_i(t)$ —Relative to the reference periods，the increase of percentage that turnover by transport i of total in period t.

According to theory of "jointly created and equally distributed", we can obtained the contribution value of $VA(t)$、$SV(t)$ and $EI(t)$. The influence analyses are as followed:

(1)Effect of $VA(t)$ on $\Delta E_{VA}(t)$.

$$\Delta E_{VA}(t)=\Delta VA(t)\times\left\{\sum_{i=1}^{n}\left[SV_i(0)\times EI_i(0)+\frac{1}{2}\times\Delta SV_i(t)\times EI_i(0)+\frac{1}{2}\times SV_i(0)\times\Delta EI_i(t)+\frac{1}{3}\times\Delta SV_i(t)\times\Delta EI_i(t)\right]\right\} \quad (3)$$

(2)Effect of $SV(t)$ on $\Delta E_{SV}(t)$.

$$\begin{aligned}\Delta E_{SV}(t) &= VA(0)\times\sum_{i=1}^{n}\left[\Delta SV_i(t)\times EI_i(0)+\frac{1}{2}\times\Delta SV_i(t)\times\Delta EI_i(t)\right] \\ &+\Delta VA(t)\times\left\{\sum_{i=1}^{n}\left[\frac{1}{2}\times\Delta SV_i(t)\times EI_i(0)+\frac{1}{3}\times\Delta SV_i(t)\times\Delta EI_i(t)\right]\right\}\end{aligned} \quad (4)$$

(3)Effect of (EI) on $\Delta E_{EI}(t)$.

$$\begin{aligned}\Delta E_{EI}(t) &= VA(0)\times\sum_{i=1}^{n}\left[SV_i(0)\times\Delta EI_i(t)+\frac{1}{2}\times\Delta SV_i(t)\times\Delta EI_i(t)\right] \\ &+\Delta VA(t)\times\left\{\sum_{i=1}^{n}\left[\frac{1}{2}\times SV_i(0)\times\Delta EI_i(t)+\frac{1}{3}\times\Delta SV_i(t)\times\Delta EI_i(t)\right]\right\}\end{aligned} \quad (5)$$

(4)The relationship between（3）and（5）

$$\Delta E(t)=\Delta E_{VA}(t)+\Delta E_{SV}(t)+\Delta E_{EI}(t) \quad (6)$$

By analyzing the decomposition results, combine the data of transportation volume and energy consumption of comprehensive transport systems, we can find the variation of energy consumption.

3 Case studies

3.1 Data and method

Supported by the available literatures, the conversion coefficient is determined as follows: Railway is 1, Highway is 0.1, Water transport is 0.33, and Aviation is

0.072.Data of turnover is from China Statistical Yearbook and data of energy consumption is from energy balance of IEA.

3.2 Results and discussion

The Converted turnover of comprehensive transportation, structure, energy consumption intensity is shown in Table 1; the decomposition result is shown in Table 2.

Table 1. Converted traffic turnover, structure and energy intensity of comprehensive transportation system in China from 1995-2011

Years	1995	2000	2005	2010	2011
Converted turnover (*VA*)	40020.66	49621.89	87418.87	152416.34	170963.17
Structure(*SV*)	(%)				
Railway	41.5	36.9	31.6	24.9	23.9
Highway	13.9	14.7	11.3	29.5	31.7
Water transport	44.4	47.9	56.8	44.9	44.1
Aviation	0.2	0.2	0.3	0.3	0.3
Energy intensity (*EI*)	(Kilogram oil equivalent/KMS)				
Railway	0.0077	0.0079	0.0075	0.0072	0.0069
Highway	0.0721	0.0703	0.0672	0.0631	0.0616
Water transport	0.0076	0.0068	0.0067	0.0065	0.004
Aviation	1.0326	1.0103	0.9061	0.7513	0.6512

Table 2. Contribution of different factors on energy consumption of comprehensive transportation (10^5tons of oil)

Years	1995-2000	2000-2005	2005-2010	2010-2011
$\Delta VA(t)$	9601.23	37796.98	64997.47	18546.83
$\sum SV_i \cdot EI_i$	0.0179	0.0178	0.0162	0.0255
$\sum SV_i * \Delta EI_i$	-0.0005458	-0.0003561	-0.001121	-0.001937
$\sum \Delta SV_i * EI_i$	0.0006223	-0.0007803	0.0113134	0.0010989
$\sum \Delta SV_i * \Delta EI_i$	-0.0000593	-0.0000042	-0.0007611	-0.0000195
Turnover contribution（Iva）	172.1	651.2	1367.7	465.1

Structure contribution（*Isv*）	26.6	-59.3	1307.9	176.3
Energy intensity contribution（*Iei*）	-25.8	-21.5	-184.3	-315
Total	172.9	570.4	2491.3	326.4

The results show that the contribution to the energy consumption of structure has become more and more important. As the Fig 1 shown, the contribution of structure from 1995-2000 was just 15.4%, but it increase to 52.5% from 2005-2010, what more it reach 54% in 2010-2011.

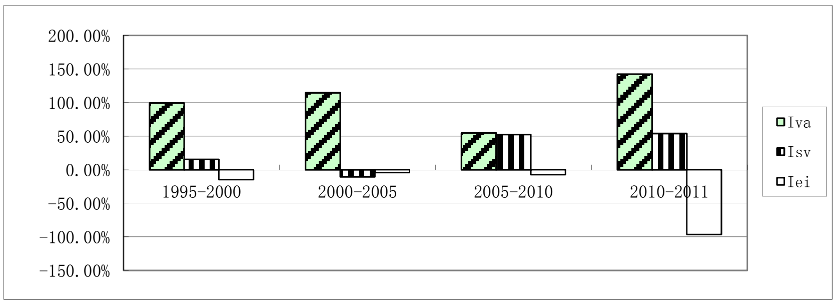

Fig 1. Contribution rate of three factors of comprehensive transportation system in China from 1995-2011

The contribution rates from 2000-2005 was -10.4%, it looks like unreasonable, but when combine the data of turnover (Fig.2) with it, we found that it due to the percentage of turnover of water transport increased in 2003-2005.Beacuse of the low energy consumption of water transport, when its share increases, led to the structure had negative effect on energy consumption growth, it also reflects the importance of an comprehensive transport system structure influence on energy consumption.

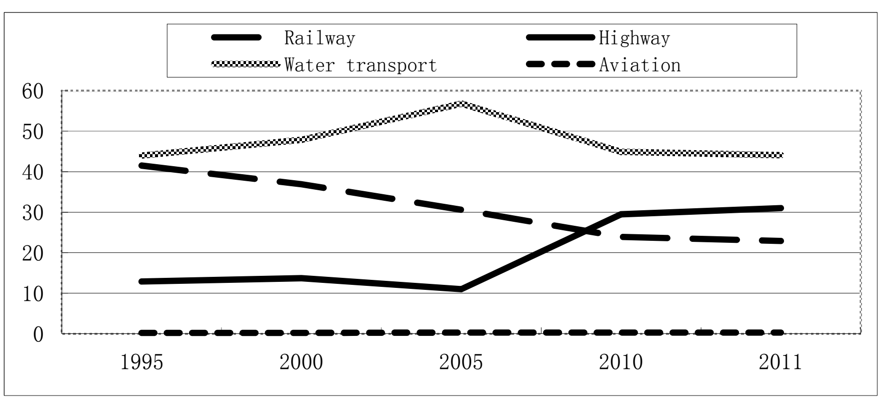

Fig 2. Structure of comprehensive transportation system from 1995-2011

4 Conclusions

Research shows that, when considering the energy constraints, the proportion of waterway and railway increased obviously because of the excellent performance in energy consumption. In the long run, when the traffic volumes grow inevitably, we can optimize the structure of integrated transportation system to save resources by improving the structure of comprehensive transport system. Therefore, the system should make planning to realize the coordination of transport modes. Especially, should greatly develop railway and waterway which have low energy consumption and little effect on environment.

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References

IEA. (1995-2011). "*Energy statistics and Balances",* http://www.iea-ebc.org/.

LIU C. A. (2007). "stud on decomposition of industry energy consumption". *Wseas Transactions on Mathematics*, 6(6): 741-744.

SUN J-w. (1998). "Changes in energy consumption and energy intensity: A complete decomposition model." *Energy Economics*, 20(1): 85 - 100.

SUN, QP, WANG, QY, MAO, BH. (2009). "Framework Design of Different Transportation Modes' Energy Consumption Factors and Comparabilities Study." *Journal of Transportation Systems Engineering and Information Technology*, 9, 10-14.

Key Problems of the Development of Piggyback Transport in China

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Abstract: Based on the study of development and technical features of piggyback transport abroad, this paper analyzes the necessity and feasibility of developing piggyback transport in china under the new situation of promoting comprehensive transportation system, and focuses on the key problems concerning policies and regulations, vehicles and transportation organization, yard facilities, technical personnel and so on.
Keywords: Piggyback; Comprehensive transportation; Demand; Problem.

1 Introduction

Characterized by safe, convenience, large capacity, all-weather, energy-saving and environmental protection, piggyback transport is an integrated transportation for goods, which can play the advantages of long distance trunk railway transportation and also achieve superiority of road logistics for 'door to door' service. It's truly seamless between railway and road logistics.

At present, to develop piggyback transport, we need to solve barriers on laws and regulations and a series of technical problems such as equipment, yard facilities, operation and management and information platform construction. Meanwhile related standard system needs building and revising.

2 Overview of Foreign Piggyback Transport

Dating back to 1940s, the piggyback transport in North America has been more than 70 years of history. Its application in Europe can also track back to 1980s. Therefore, after years of development, the piggyback transport in foreign countries has formed a mature operating pattern and management system.

2.1 Piggyback Transport in North America

The piggyback transport is one of the ways of railway express transport in North America. Over 160 cities was involved in its transport network, which is almost covering the whole region. To meet the needs of the market and be accepted by the customers, North America strengthens the combination of railway, road, airway and water transport to offer inter-modal services, so as to achieve 'door to door' logistics by one-stop service in the whole journey. In this region, the economic transport distance on railway for piggyback transport is about 900km and beyond. At present, highway semi-trailers are used as its main transport objects. Due to a relatively-high railway clearance, the type of common rail container flat car can actually achieve piggyback transport. For semi-trailers, the way of lifting is necessary when loading and uploading. Hence, the forklift or front loaders will be well-equipped in the rail station.

2.2 Piggyback Transport in Europe

In Europe, the flexible road logistics had big advantages before due to the short transport distance brought by the narrow lands of European countries. However, with dense population and high motorization rate, the traffic congestion has become more and more severe. Adding the continuous improving standards on environmental protection, the suitability of road logistics is reducing. In view that the piggyback transport could efficiently solve the above-mentioned issues, like over-congestion, it has made great progress in Europe, especially under the push of France and Germany. The traditional piggyback transport objects in Europe are highway truck, trailer, highway semi-trailer, container trailer, cars, etc. Flat cars are commonly used as carrying tools, most of which are specialized flat cars with low center of gravity (Lin Jieliang,2014). Besides, restricted by the height of clearance, the concave bottom structure is applied into piggyback vehicle to suit the height.

2.3 Key Features of Foreign Piggyback Transport

(1)Techniques on specialized railway vehicles in foreign countries have been very mature and reliable. The lifting way in piggyback transport will be constantly replaced by self load-and-upload to improve efficiency, which will be the direction of piggyback vehicles.

(2)The infrastructures are dedicated to supporting the use of the specialized railway vehicles, which forming a complete standard system on 'collecting and distributing'. The integral train with fixed-point and routing operation has high efficiency and good benefits.

(3)With the rapid development of highway semi-trailers, the piggyback transport has made further progress in economic benefit and efficiency. Hence, the highway semi-trailer is also the future direction.

3 Demands of Piggyback Transport for Comprehensive Transportation

The comprehensive transportation system, as a new trend and direction to develop modern transport, requires to coordinate each way of transport to operate reasonably and orderly, to optimize transport structure, so as to play their respective advantages to realize coexistence and complementary (Hong yan,2013). On one hand, the development of piggyback transport can make railway and road logistics inseparable; on the other hand, to ensure the safety of the whole process, the following demands for comprehensive transportation need satisfaction.

3.1 Policy and Regulation

(1)License Management

At present, the trailers and semi-trailers can make free combination, which breaking the limits in manufacturing and administrative sector. However, due to the implementing differences, the original system is still playing a role to some extent to restrict the development of drop and pull transport. In our country, the license management should be a priority issue to be solved to develop piggyback transport with semi-trailers.

(2)Insurance

In piggyback transport, the highway truck is the carrier of freight transport, and also a part of railway carrying goods in the perspective of goods weight and package. Therefore, once traffic accident happening, it is easy to generate problem on responsibility and cause economic dispute. Based on this situation, the issues concerning insurance should be taken into consideration when implementing related transport systems.

(3)Annual Inspection

The highway truck or semi-trailer will obviously reduce damage when applying to piggyback transport. Therefore, to improve efficiency, the annual inspection time should be extended appropriately.

(4)Rate Policy and Charge Standard

In China, the piggyback transport is still in the initial stage without any organization pattern being used successfully. Hence, to make it healthy, a new freight rate policy and charge standard should be studied and formulated in accordance with the features of piggyback transport.

3.2 Highway Trucks

(1)Dimension Specification

The dimension of the highway truck (lengthen, breadth and height) should get through the limits of detecting equipment installed in the railway station to accept related tests in accordance with *Regulations for Railway Freight Traffic* and *Railway Cargo Loading Reinforcement Rules*. The ones whose dimension cannot reach the standard should be strictly prohibited in piggyback transport. It is suggested that the van truck would be a good choice in the preliminary stage of piggyback transport.

(2)Loading Weight Specification

The weight of the highway truck should pass the test of the electronic weighing machine equipped in the station. For the ones with overloading or unbalance loading, a relevant reorganizing is necessity. After compliance, the piggyback transport is allowed to continue. Once the total weight exceeds 55t, the piggyback transport should be forbidden.

(3)Loading Reinforcement Specification

It is necessary for non-vans to make reinforcement after loading goods. Moreover, the reinforcement should conform the related rules. If not, the piggyback transport should be prohibited.

(4)Technology State Specification

Due to the huge differences of highway trucks on technology state, some of them with poor state are actually incapable of meeting the requirements of piggyback transport. Therefore, the related technical standard should be set to help improve the highway trucks applied in. To be more adaptive, new structures and new technologies should be strengthened on highway trucks.

3.3 Station Infrastructures

The piggyback transport has high demands on railway station and railway clearance. Based on the structural features and operating modes of the piggyback transport, the railway station involved in must have the following conditions so as to make sure the highway trucks could up-and-off the piggyback vehicles by themselves.

(1)Specification on Operation Area and Hardened Ground

A special operation area for the piggyback transport should be laid off within the large marshaling yards or freight yards to meet the needs of complete train-load (straight line better). Besides, the ground here should be hardened and in line with the height of track. A certain breadth should be given as well, taking vehicle steering, safe operation and temporary parking into consideration.

(2)Specification on Freight Detecting Equipment

Before loading onto the piggyback vehicle, it is necessary to carry out security check to the goods loaded in the trucks so as to conform the regulations for railway freight transport.

(3)Specification on Limits and Weighing Machine

The limit testing device and weighing machine must be installed in the station to avoid the situation of over-limit and overloading.

(4)Ground Power Supply

The ground power should be provided in the railway station to support the lifting and rotating of the piggyback vehicles. Meanwhile, issues concerning water feeding and trash cleaning should be solved as well.

3.4 Personnel

In China, it is still blank in transporting freight trucks by railway. Because of large dimension and weight of freight trucks, this kind of transport can be classified into transportation of special goods. Hence, it is necessary to train on-site operation workers in the perspective of combined transport and transportation of special goods (Zhang Guoping,2009).

(1)Driver

In the piggyback transport, the highway truck needs up-and-off the specialized railway vehicle by itself. In accordance with the structural features of the specialized railway vehicle, some highway trucks need back into the vehicle. Therefore, the drivers must possess high skills in backup. To avoid unnecessary collisions between highway truck and piggyback vehicle, the drivers should accept the professional training to meet the loading requirements.

(2)On-site Operation Workers

In accordance with the structural features of the specialized railway vehicle, the on-site operation workers need help finish a series of actions like lifting and rotating, so that the highway truck could on-and-off it by itself. Hence, it is necessary to carry out special training for on-site workers to make the loading successful and to meet the needs.

4 Key Problems of Development of Piggyback Transport in China

(1)Establishing Coordination and Communication Mechanism

The piggyback transport is one of the modes of combined transport between railway and road logistics. It depends on several factors whether this combined transport could enjoy a rapid development or not, especially depending on the coordination and cooperation of the two sides. Therefore, the related regulations should be implemented and mechanism established to ensure its rapid development based on the features of the piggyback transport.

For example, we should establish freight timeliness safeguard mechanism. Time freight has high added value, but high demand on time. Many freight owners request not only fastness and punctuality, but also arriving then leaving. To ensure the interests of the consumers, it is suggested to set up corresponding transport contracts. For those based on contracts, once meeting commitments failure, the consumers have the right to claim for compensation. The contract guarantees not only the severe quality management and supervision on time freight, but also the commitments of timeliness and other services.

(2)Standard Operating

The drop and pull transport is the most advanced transport modes, but it is still in the initial stage in China. At present, many difficulties need overcoming and solving to develop this kind of transport in our country, including laws and regulations and technical issues concerning transport equipment, station infrastructures, operating organization and management and information platform construction. Meanwhile, related standard system needs building and revising.

As a relatively novel combined transport, the piggyback transport needs a complete set of feasible operating standards. Therefore, to ensure the safety, it is necessary to refine standards and establish severe system in each side, such as vehicle type, flat car type, loading machine, loading mode and so on.

(3)Integrating and Transforming Freight Station

Transport is the part and parcel of logistics. The realization of express freight transport not only depends on the speeding up of transport itself, but also requires the time compression through the whole process from consignor to consignee. Therefore, in accordance with railway development plan, the optimal configuration of freight stations should be carried on to integrate existing ones, namely closing small ones and developing large ones, so as to move towards scale expansion and intensification, with station layout adjustment as its core.

At the same time, the related equipment should be updated and transformed. In view of high demands on railway station and clearance, the current technologies may not meet the needs of piggyback transport. So, the relevant checking and redesigning are inescapable (Zhang Guoping,2009).

(4)Optimizing the Allocation of Resources

The freight operating entities present the characteristics of "small, loose and weak" in China. The individual transportation even accounts for 90% or so. Their demands are diversified, hence bringing some difficulties in allocation of railway resources. Under such background, information integration and unifying allocation of resources need intensifying. To carry out piggyback transport, it is necessary to collect demands from freight transport agents to make use of it to allocate resources.

To enhance efficiency, the railway should identify transport routes and numbers of trains in accordance with highway freight resources. Meanwhile, the road logistics should optimize its allocation of resources so as to maximally reduce the empty-loading ratio in piggyback transport to save cost. In sum, it is necessary to make reasonable planning on routes and numbers of trains based on the allocation of resources.

(5)Vehicle Supporting

Capability expansion and equipment improvement are strategic cores of great-leap-forward development of Chinese railways. In regard to the status of Chinese railways, it is our strategic needs to develop specialized piggyback vehicles to enhance comprehensive operating capabilities, which is also in line with the recent development plan of Chinese railways (Wang Aiming,2007). Therefore, China should learn from the foreign mature technologies on piggyback transport to develop the advanced and practical specialized piggyback vehicles adapted to the Chinese national condition.

Meanwhile, the piggyback transport in China is still in the initial stage. The infrastructures supporting piggyback vehicles haven't been developed yet. Therefore, the design of piggyback vehicles should be adapt to the existing stations as far as possible. In this way, the existing stations only need slight adjustments, then could meet the needs of developing piggyback transport.

In sum, the piggyback transport of complete highway truck should be the priorities in our country so as to meet the current logistics demand. When it is qualified to develop the drop and pull transport, this kind of way should take dominance in piggyback transport, supplemented by complete highway trucks.

5 Conclusions

(1)Comparing with traditional road logistics, the piggyback transport has the characteristics of safe, convenience, large capacity, all-weather, energy-saving and environmental protection. It should occupy a corresponding proportion in the comprehensive transportation system in our country.

(2)With the rapid development of high-speed railway construction and the continuous expansion of network in our country, the in-depth advancing of the railway freight organization reform and the brisk market demand of express freight and 'door to door' transportation, piggyback transport in China has been provided a broad space for development.

(3)China should learn from the foreign mature technologies on piggyback transport to implement related policies and standards as well as to develop specialized piggyback vehicles adapted to the Chinese national condition.

(4)In accordance with the status of Chinese road logistics, it is suggested that complete highway trucks should be used in the near future to develop piggyback transport; and highway semi-trailers should be chosen in the long term. Moreover, it is suggested that vans could be a good choice in the initial stage.

References

Hong yan,Guo Chunjiang.(2013). Problems and suggestions on development of railway express freight. *Railway Economics Research* (2/3) : 9-14.

Lin Jieliang,Wang Aiming, Deng Chengyao,Li dong.(2014). Development of railway container multimodal transport. *Railway Freight Transport*, (1)

Wang Aiming, Lin Jieliang. (2007). Design of special railway carry back vehicles - based on container transport. *Railway Vehicle*,45(10) : 24-27.

Zhang Guoping,Wei ran,Miao Jianrui.(2009). Feasibility of piggyback transportation applied in highway-railway combined transport. *Comprehensive Transportation*, (5) : 69-71.

Attraction Area Model for Urban Rail Transit Stations Compared with Different Traffic Tools

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Abstract: Based on prospect theory to analyze walking time, travel time and time sensitivity. Preference survey investigation was used to quantify the affects factors of path choice to build the generalized cost calculation function. According to the cumulative prospect theory to explore the attraction area of urban rail transit compared with other traffic tools. On the surveyed data of a rail transit station. Through a comparison between the traditional walking areas and surveyed data, it is clear that the model is effective and reasonable, and could provide references for the planning, selection and evaluation of urban rail transit.
Keywords: Cumulative prospect theory; Walking attraction area; Travel mode choice.

1 Introduction

Attraction area of urban rail transit is an important factor to ensure the traffic sources. Current research usually takes the experience when it comes to this kind of problem and the quantitative calculation is not too much. (Zhang, 2012) use Logit model to calculations the attraction area of urban rail transit stations in connection with the pedestrian access way. (Wang, 2010) use the aggregate effect theory model build the roads bus passenger range model, (Wu, 2014) calculated the attraction area according to the uniform accessibility principle and the algorithm is also presented. Such methods is accurate for those have been investigated urban rail transit station because it have a strong dependence on the sample, besides, they did not take travel behaviors factors into account.

To solve the above problem, this article from the angle of travelers' psychological point, considering it presences different ways to travel in a trip, and the prospect value is difference, by calculating the prospect value of each travel modes. When the value is equivalent study the attraction area compared with other traffic tools.

2 Cumulative Prospect Theory

In the actual road network system, the road network is a complex dynamic system subject to many external factors influence, the passage time is a random variable, under this condition, the passage of time and the probability distribution of the path has become the traveler's choice basis. In order to facilitate the calculation, we assume that travelers choose the travel path bases on the utility obtained.

We use the $x_{\max}$ represent the maximum benefit that travelers can get at the destination, and is integrated travel fee. So the utility is

$$x_i = x_{\max} - c_i \tag{1}$$

Travelers will choose all feasible paths to arrive their destination, when in the choice of the travel route, each one of the feasible path has actual travel utility variables x and probability functions p .

2.1 Value function

Value function is subjective utility based on the practical utility of various paths, which characterization the effects of the actual level of utility for travelers psychology, is a concave function when travelers gains and is a convex function when losses. As shown in Figure 1 and is defined as follows:

$$v(x_k) = \begin{cases} x_k^{\alpha}, x_k \geq 0 \\ -\lambda(-x_k)^{\beta}, x_k < 0 \end{cases} \tag{2}$$

In the formula, x_k represent the behavioral outcomes with respect to the reference point of the pros and cons, α, β is risk attitude coefficient and $0 < \alpha, \beta < 1$, λ is Loss aversion parameter and $\lambda \geq 1$. Generally $\alpha = \beta = 0.88, \lambda = 2.25$

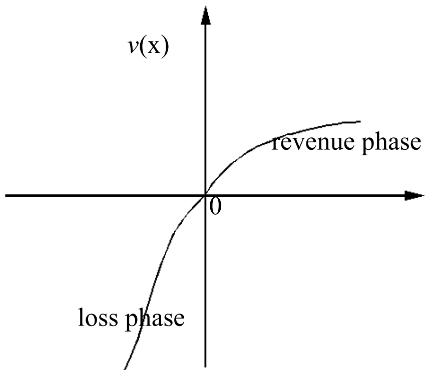

Figure 1. Value function curve

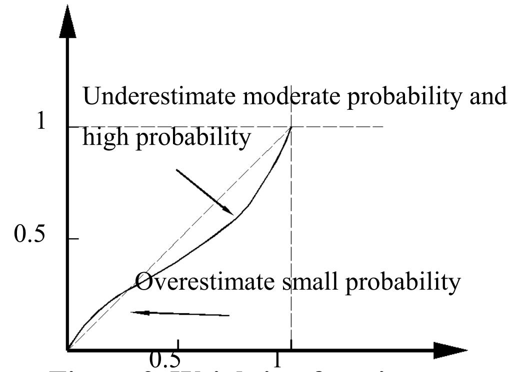

Figure 2. Weighting function curve

2.2 Weighting function

Weighting function is a monotonically increasing function, as shown in Figure 2. In this paper, we use the weight function manifestations based on Kahneman (1979). The actual probability of events is p, the perceived probability is $w(p)$. When it will gains, $w^{+}(p)=\frac{p^{\gamma}}{[p^{\gamma}+(1-p)^{\gamma}]^{1/\gamma}}$ and when it will loss $w^{-}(p)=\frac{p^{\delta}}{[p^{\delta}+(1-p)^{\delta}]^{1/\delta}}$. And $\gamma=0.61$, $\delta=0.69$.

2.3 Cumulative prospect theory and its values

Assuming uncertain prospect f is reflect by a series of combinations (x_i, p_i), w^{+} and w^{-} is entitled to and loss of weight function. The decision weights π_i^{+} and π_i^{-} is:

$$\pi_i^{+}=w^{+}(p_i+\cdots+p_n)-w^{+}(p_{i+1}+\cdots+p_n) \quad (3)$$

$$\pi_i^{-}=w^{-}(p_{-m}+\cdots+p_i)-w^{-}(p_{-m}+\cdots+p_{i-1}) \quad (4)$$

Prospect value (f) can be calculated by the following:

$$f=\sum_{i=1}^{n}\pi_i^{+}v(x_i)+\sum_{i=-m}^{n}\pi_i^{-}v(x_i) \quad (5)$$

3 Perceived Value of Arrival Time

3.1 Travel time costs

Travel time costs (TTC) mainly refers to the time that travelers use transportation costs and walking time in a trip, the value of walking time (t_{walk}) is 1.5 times of the value of travel time (t_{way}) (Chen, 2011). We use $\varphi(t_A)$ represent travel time costs, and x is revenue of per unit (0.14Yuan/min). So the travel time costs is defined as the follows:

$$\varphi(t_A) = (1.5t_{walk} + 0.5t_{way}) \cdot x \tag{6}$$

The sensitivity of different travelers on travel time cost is different, sensitivity coefficients is when taking the travel time and travel costs of economic (c_a) into account, the costs of travel time sensitivity. The value is 0.751 (Yin, 2012).

3.2 Subjective perception of costs

Travelers using different modes of transportation to reach the destination, if travelers arrive time t_A earlier than the actual work time t_w, will have time cost for early arrival. Conversely, travelers will have time cost for late. We assume the $\theta_i (i = 1,2,3)$ represent the cost of travel time, early arrival costs and the late arrival costs of per unit time, $\theta_2 = 0.5\theta_1$, $\theta_3 = 1.5\theta_1$ (Zhao, 2006), when $\theta_1 = 1$ $\eta = 0,1$, the subjective perception of costs is:

$$C_t = 0.751\varphi(t_A) + 0.249c_a + \eta\theta_2(t_w - t_A) + (1-\eta)\theta_3(t_A - t_w) \tag{7}$$

4 Examples

In order to study the situation of different travel models change with time walking, we choose the data of Riverside Road - Longgang Road intersection to Wenjin Road - Road intersection Sungang in Shenzhen as the research object for numerical example. There are four kinds of travel modes can be selected: car, taxi, bus, and rail transit. According to the data obtained by the traffic survey, the travel time probability distribution of each travel modes shown in the following table:

Table 1. Travel time probability distribution

Travel Modes	Probability Distribution（Time/min, Probability /%）

Car (C)	（25,55）；（28,30）；（32,15）
Taxi (T)	（28,60）；（35,30）；（40,10）
Bus (B)	（40,50）；（45,30）；（50,15）；（55， 5）
Rail Transit (R)	（30,85）；（35,10）；（40,5）

Assuming travelers working time is 08:45 am, for those who travel by public transport, the psychological expected travel time earlier than cars and taxi. The time is 08:00 am when traveler departure by bus or rail transit, and the time is 08:10 and 08:15 by taxi and car. As can be seen from Table 1, the traveler may encounter a trip in 13 cases, we select the expectations cost of all travel cases as the reference point. The prospects value (PV) changes over the walking time can be seen in the table 2.

Table 2. Prospects value changes over walking time

PV	0	2	4	6	8	10	12	14
Car	-0.0163	0.1459	0.3016	0.4564	0.7176	0.8790	1.0404	1.2018
taxi	-0.3821	-0.2533	-0.1111	0.0091	0.1630	0.2870	0.4110	0.5350
rail	0.7752	0.6220	0.4687	0.3155	0.1543	-0.0042	-0.1618	-0.3194
bus	0.9215	0.7411	0.5607	0.3802	0.2197	0.0402	-0.1402	-0.3206

As can be seen from the table 2, the prospects value for cars and taxis increase with the walking time increases, originally it was loss phase and then turn into revenue phase. Conversely, the prospects value for bus and rail transit increase with the walking time increases, revenue phase turn into loss phase. That means the walking time will have a greater impact on travelers when choose transportation mode.

From the figure 3, we can see that when the walking time is less than 5.1min, the prospects value for the use of public transport travel mode is much greater than the value of cars and taxis, and at this point the state is revenue. If the walking speed is 6km/h, means when the walking distance less than 500m, travelers prefer to choose rail transit. When the time of travel time reach to 8.5min, the prospects value of taxi, bus and rail transit are flat. That is when walking distance is about 850m, the probability travelers choose public transport as a way to travel will decrease. When the travel time reach to 13min, the rail transit travel mode will be at the loss phase, that is, when walking distance approaching to 1300m, the attractiveness of rail transit decreased rapidly, therefore, the largest urban rail transit attraction area should not exceed 1300m.

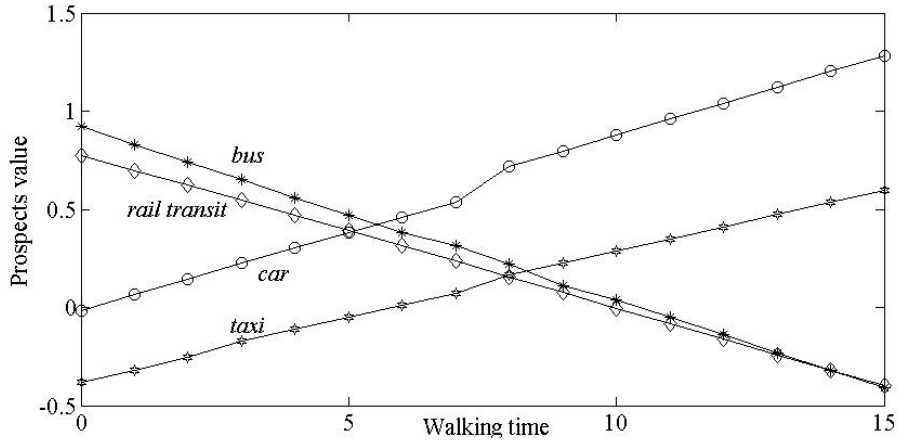

Figure 3. Prospects value changes over walking time

5 Conclusions

We obtain subjective perception cost function by analyzing the way to travel based on traveler psychological, according to the cumulative prospect theory, select the appropriate reference points to calculate each transportation modes based on the walking time. It shows that in the choice of travelers transport, the sensitivity of the economic costs and time sensitivity will be taken into account by traveler. Therefore, in order to improve the utilization of urban rail transit and determine a reasonable attraction area of urban rail transport services, not only will the travel distance into account, but also the economic level around the site should be investigated.

References

Charles. H. (1970). The Demand for Urban Mass Transportation. The Review of Economies and Statisties, 53(3).

Chen, X. M., Liu, Q. X., and Du, G. (2011). "Estimation of Travel Time Values for Urban Public Transport Passengers Based on SP Survey." *Journal of Transportation Systems Engineering and Information Technology*. 11(4), 77-84.

Gan, Y. H. (2006). "Guangzhou Integration Planning of Urban Rail Transport and Other Transport Modes." *Journal of Huazhong University of Science and Technology*. 23(2s), 113-116.

Kahneman, D., and Tversky, A. (1979). "Prospect theory: An Analysis of Decision under Risk." *Econometrica*, 42(2), 263-291.

Sui, R. L., and Tan J. C. (2014). "Resident Travel Mode Choice Based on Cumulative Prospect Theory under Congestion Pricing." *Journal of Chongqing Normal University (Natural Science)*, 31(3), 130-134.

Wang, J., and Hu, G. L. (2010). "Attraction Scope of Urban Rail Transit Station to the Conventional Public Transit Passenger Flow." *Systems Engineering,* 28(1), 14-18.

Wu, Q. N., Ye, X. F., and Lin, X. W. (2014). "Attraction Area Model for Urban Rail Transit Stations." *Journal of Tong Ji University (Natural Science)*, 42(7), 1058-1095.

Yin, H. Q. (2012). Research on Public Transport Mode Choice Based on the Prospect Theory. Chang'an University, Xi'an, China.

Zhang, N., Dai, J., and Zhang, X.J. (2012). "Walking Affect Area of Rail Transit Station Based on Multinomial Logit Model." *Urban Mass Transit*, 05, 46-49.

Zhao, L., and Zhang, X. C. (2006). A Prospect Theory-Based Route Choice Model of Traveler with Prior Information. *Journal of Transportation Systems Engineering and Information Technology*, 6(2), 42-46.

Research on a Freight Modal Split Model Based on Transportation Distance

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Abstract: How to reasonably determine the freight modal split model has always been a hot topic of research at home and abroad. In recent years, while a lot of researches have been made both at home and abroad on the passenger transport modal split mode, researches on the freight modal split model are scarce. Due to the sharp increase of freight demands as well as the theoretical need of the planning for the comprehensive transportation system, the freight modal split model have attracted the attention of experts and scholars. In this study, the expression of the functional relation between various freight volumes and transportation distance is constructed through analyzing a large number of aggregate data regarding different freight volumes and transportation distances among Chinese cities, and the change law of freight modal split with different transportation distance in the comprehensive transportation system is analyzed, so as to provide a reference and basis for the rational allocation of transportation resources and the optimization of transportation structure.
Keywords: Transportation distance; Freight; Transportation modes; Modal split model; Aggregate data.

1 Introduction

China will witness a continuous rise in freight demand in the future. According to the prediction, at the end of the "Twelfth Five Years", the highway freight volume in China will reach 30 billion tons, the cargo throughput of coastal ports will reach 7.8 billion tons, the inland waterway freight volume will reach 3.85 billion tons, and the airway freight volume will reach 9 million tons (2012). Whether the freight system, as an important part of the comprehensive transportation system, can adapt to the development of the regional freight demand and run conveniently, safely, economically and efficiently will significantly influence the construction and development of China's comprehensive transportation system. A grasp of the freight modal split model, namely, the proportions of transports by highway, railway, waterway, airway and pipeline in the whole freight system, can provide not only as the basis for analyzing the characteristics of various transportation modes, their mutual connections and restrictions, but also as the foundation of the optimization of the freight-mode structure and the rational allocation of transportation resources.

With regard to the freight modal split model, domestic researches are still at a preliminary stage, and foreign researches mainly focus on the improvement of traditional algorithms according to the characteristics of the problems existing in the comprehensive transportation system. The domestic and foreign researches on the freight modal split model are carried out mainly from the following three perspectives:

(1) A research on the freight modal split model is carried out from the perspective of evaluation. Such researches consider from the perspective of evaluation and present different evaluation index systems. For instance, (Duan Aiyuan, 2007) established an evaluation index system of quantitative research chosen by the tools of freight transportation and solved the decision-making of the comprehensive and optimal transportation modes in the decision-making of freight transportation. (Bo Hongxiang, 2007) comprehensively evaluated the decision-making of selecting transportation modes, built the decision-making model of selecting transportation modes. (Liberatore, 1995) built a bistratal analytic hierarchy model of the total cost of transportation network and corresponding customer service level based on every transportation mode, considered service cost and quality, compared and determined modes of cargo transportation and selected the optimal scheme.

(2) A research on the freight modal split model is carried out from the perspective of cost. Such researches conduct an analysis from the perspective of cost and build correlation models by taking the minimum total cost and the lowest generalized cost as the goal. For example, (Hu Junhong, 2013) adopted a quantitative method to combine the generalized cost outside of transportation modes with the local actual situation of traffic and transportation, took Jiangsu Province as an example and raised three transportation modes including highway transportation first and railway transportation second, the combination of highway and railway transportation and giving consideration to the development of railway transportation. (Sheer Yosef, 2000) determined the influence factors of the total cost of freight transportation and storage and inventory, started from the charges of freight transportation, refined the factors like the actual situation of the starting point and terminal point of transportation, analyzed them, obtained the best solution and carried out case researches. (M.Beuthe, 2001) analyzed the multimode models of freight transportation in Belgium, obtained three modes of freight transportation, namely, railway transportation, highway transportation and inland waterway transportation in the

Balkan region and the demand elasticity of 10 types of cargos, adopted the method of the minimum cost to establish the allocation model of transportation demands and determined different transportation modes and the freight volumes of transportation routes.

(3) A research on the freight modal split model is carried out from the perspective of decision-making. For instance, (Jung Dazhi, 2009) built a multi-target grey situation decision-making model, determined the selection of transportation modes in comprehensive transportation and carried out empirical studies. (Reza Banai-Kashani, 1989) selected and used analytic hierarchy process, analyzed different levels of transportation modes in target cities through models and made an optimal decision. (G.P.Kiesmulle, 2005) suggested choosing the modes of freight transportation after packaging freight, calculated a lot of data and proved the feasibility of delaying decision-making in the aspect of economy, especially for low-value cargos.

Domestic scholars still haven't conducted systematic studies on the freight modal split model with insufficient quantitative researches and usually establish inadequate model calibrations due to the limited data they collect. For instance, they complete calibrations only by manners of the data of a specific transportation corridor, which leads to the poor universality of models. The study will research the freight modal split model based on transportation distance and analyze the change law of the freight modal split model with the change of transportation distance.

2 Data and Method

2.1 Data

The research on the freight modal split model in the study includes highway transportation, railway transportation, waterway transportation and airway transportation and leaves out pipeline transportation for the moment.

Through collecting and calculating the data of "The Inter-regional Freight Volumes of Various Transportation Modes in China in 2008". The freight volumes and corresponding distances of various modes in the different administrative regions of China can be obtained. Through classifies, summarizes and computes them and the corresponding freight volumes of various transportation modes at different distances can be gained. The distance here refers to intercity straight-line distance. As not all modes of freight transportation exist in every region or reach the same development level, every 50 kilometers are taken as a node in order to make various transportation modes of comparable at different distances. Here is an example about the concrete method, which selects 0, 50, 100, …, and 3,500 as the horizontal axis, regards the intercity freight volumes with distance from 0 to 50 as one class, accumulates the freight volumes of this class of cities and takes the median 25 as the corresponding transportation distance of the class of freight volumes. Freight modal split equal to the freight volumes of various transportation modes at a given distance dividing by the total freight volumes of four transportation modes at this distance. On this basis, the function and curve of the freight modal split model at different distances are fitted.

Therein, the study arranged and summarized 811 pieces of data about highway freight volume among different cities, 907 pieces of data about railway freight volume among different cities, 240 pieces of data about waterway freight volume among different cities, and 240 pieces of data about airway freight volume among different cities. In 2008, among the total freight volume of 25.87413 billion in our country, the highway freight volume was 19.16759 billion tons, occupying 74.080% of the total freight volume with average freight distance of 171 km; the railway freight volume was 3.30354 billion tons, occupying 12.770% of the total freight volume with average freight distance of 760 km; the waterway freight volume was 2.9451 billion tons, occupying 11.380% of the total freight volume with average freight distance of 1,707 km; the airway freight volume was 4.08 million tons, occupying 0.016% of the total freight volume with average freight distance of 2,934 km; the pipeline freight volume was 453.82 million tons, occupying 1.754% of the total freight volume with average freight distance of 428 km.

2.2 Method

Models were built by the method of ordinary least squares (OLS). Computation was conducted by SPSS statistical analysis software. Specific steps are as follows:

(1) Make a scatter plot of data

(2) Conduct model estimation

During establishment of the model, different alternative models such as polynomial model, exponential function model, logarithmic function model and linear regression model could be set up according to data fitting. During model establishment, the method of ordinary least squares was adopted, namely that proper parameters were selected to minimize the residual sum of squares of all the sample values.

Hence, the paper needed to solve $y = f(x, a_1, a_2, ..., a_n)$, where, $a_1, a_2, ..., a_n$ are undetermined constants and (x_i, y_i) is corresponding to each piece of data. In this way, $\sum_{i=1}^{k}[f(x_i, a_1, a_2, \cdots, a_n) - y_i]^2$ was minimized for the parameter estimation.

(3) Verification and Determination of Model

Reference standards are necessary for model evaluation and model comparison. The study mainly adopted the following two standards. The first standard is the goodness of fit. The basic idea of regression analysis is that explanatory variables contained in the model are used to explain changes of dependent variables as much as possible. In practice, the degree of fitting can be measured by a corrected coefficient of determination which sign as R^2. Higher R^2 indicates a better model. The second standard is that the model shall pass the significance test. Respectively, the study conducted F test, which refers to significance test of equation. And T test can be conducted, which refers to significance test of model variables. If the model can pass both the F test and the T test, the model is deemed to be acceptable. According to these two standards, the optimal model was determined among the multiple models established above.

3. Results

According to results of comparison and optimization of the models, the original fitting function of each freight modal split model is shown in Fig.1 and listed as follows:

Highway: $y_1 = -0.141\ln x + 1.383$ (1)

Railway: $y_2 = -0.004x^{0.648}$ (2)

Waterway: $y_3 = 8.850 \times 10^{-18}x^5 + 6.790 \times 10^{-14}x^4 - 1.270 \times 10^{-10}x^3 - 1.110 \times 10^{-7}x^2 + 3.260 \times 10^{-4}x + 0.116$ (3)

Airway: $y_4 = 2.093 \times 10^{-10}x^2 + 1.017 \times 10^{-6}x - 0.289 \times 10^{-4}$ (4)

Where:

y_i refers to sharing rate; $i = 1, 2, 3, 4$ respectively stand for highway, railway, waterway and airway; $0 \le Y_i \le 1$, unit: %;

x indicates transportation distance, unit: km.

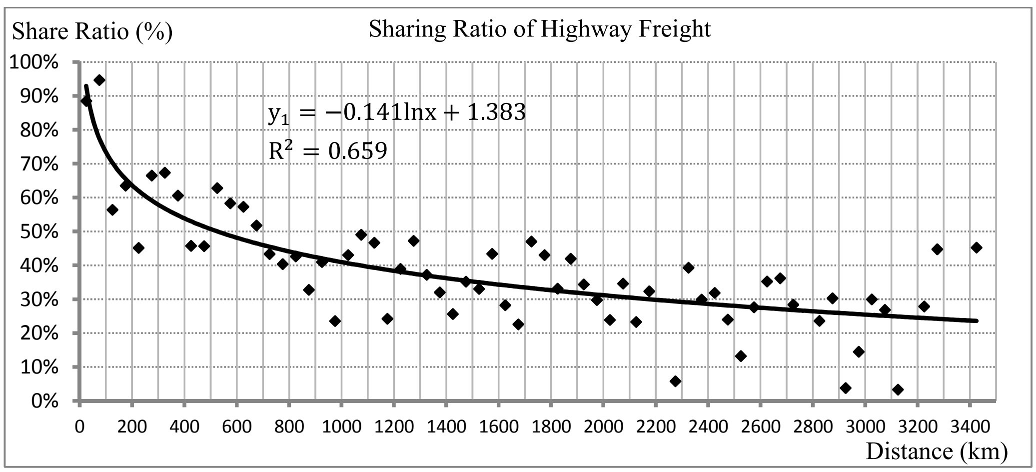

Figure 1. (a) Fitting Share Ratio Curve of Highway Freight Mode

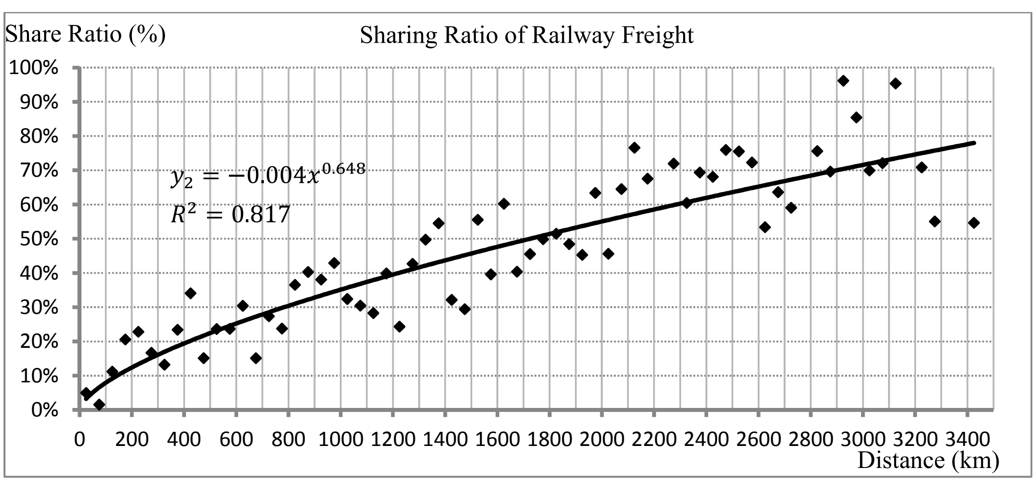

Figure 1. (b) Fitting Share Ratio Curve of Railway Freight Mode

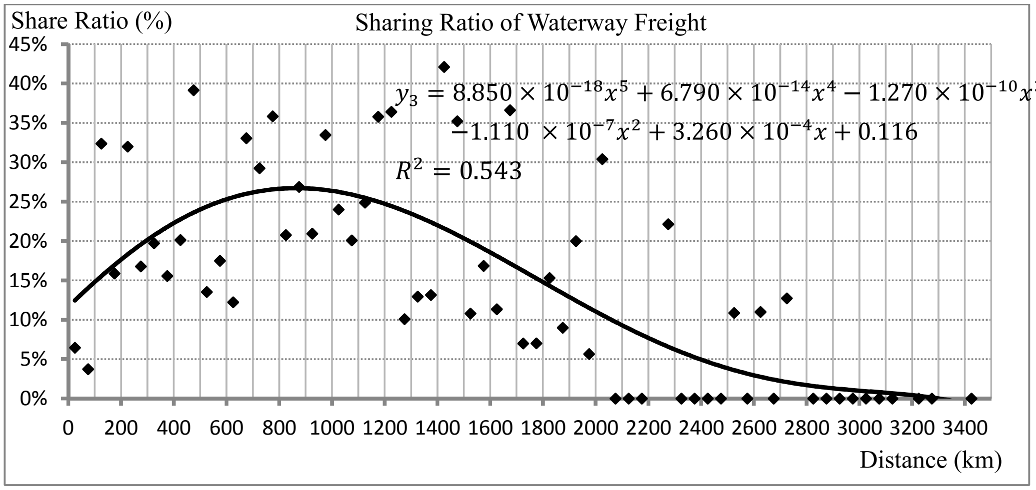

Figure 1. (c) Fitting Share Ratio Curve of Waterway Freight Mode

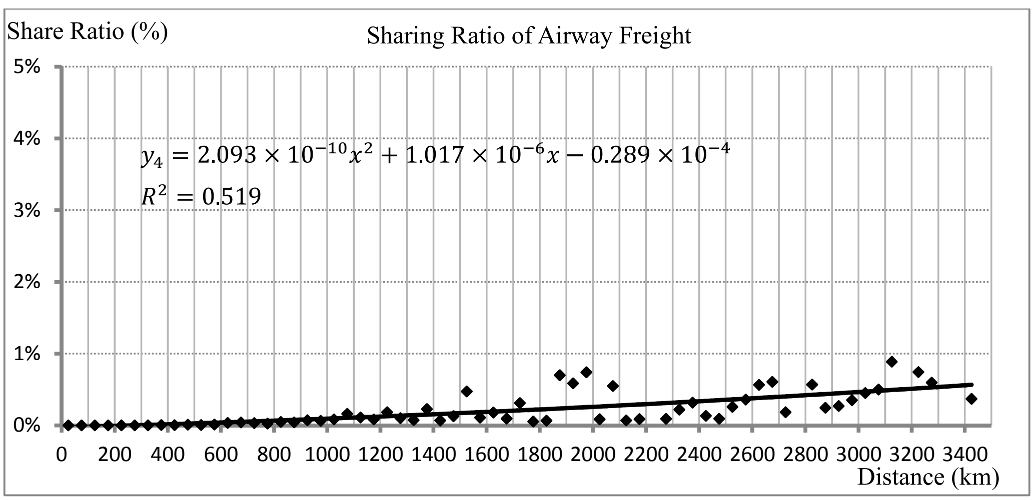

Figure 1. (d) Fitting Sharing Ratio Curve of Airway Freight Mode

According to analysis results of SPSS, the goodness of fit R^2 of highway, railway, waterway and airway is respectively: 0.66, 0.81, 0.52 and 0.52; and all the established models (Formulas 1-4) passed the F test and the T test. Hence, the model is acceptable. The freight modal split models are shown in Fig.2.

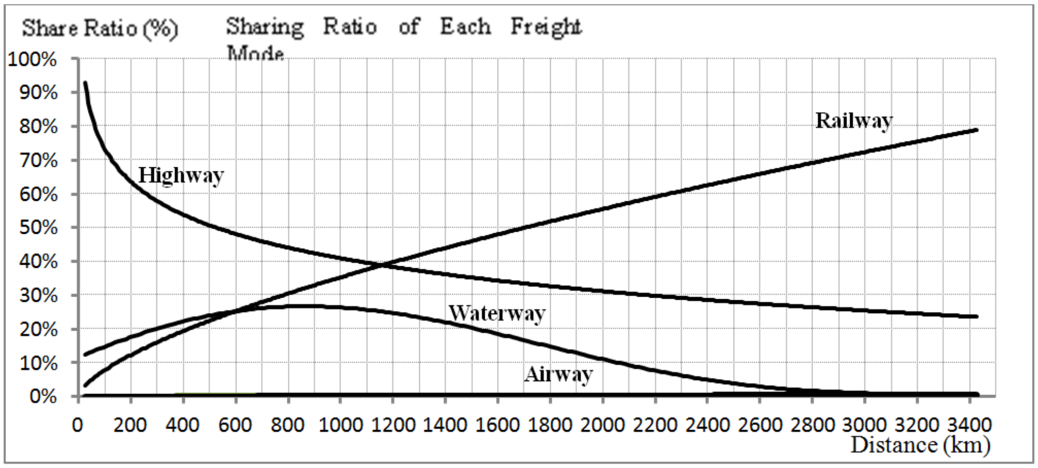

Figure 2. Curves of Fitting Sharing rate of Four Freight Modes

4. Conclusion

The goodness of fit of the model established in this study is not very high, but still satisfying. The reason for this result lies in that data used for fitting was the freight data of various administrative regions in our country all through the year; various freight modes in different administrative regions of our country have not developed in a balanced mode; various freight modes in some regions are highly developed; in other regions, one or two freight modes develop to a low level or are even absent. Hence, as for direct fitting of such kind of macroscopic data, the current goodness of fit of the model is acceptable and valuable in applications to a certain extent.

By establishing the above models, freight modal split in our country, which change with the transportation distances, can be obtained; and the advantageous distance of each freight mode can also be deduced. By virtue of the research results, laws about changing of various freight modes along with the distances can be further understood; the rational utilization scope of each transportation mode under different distances can also be analyzed. These results have certain theoretical values and practical significance to planning and construction of a freight transportation system which is suitable for regional freight demands. Meanwhile, only by knowing the current sharing rate of freight modes in our country, the future freight mode structure can be optimized, the freight structure can be matched with freight traffic demands, resources in the whole comprehensive transportation network can be integrated more easily, transportation efficiency of cargo can be increased, and social comprehensive benefits of freight transportation can be realized.

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References

Bo Hongxiang, Liu Bin. (2007). *Synthesized Evaluate on Choosing Transport Ways of Freight by Analysis of Hierarchy Process*. Journal of Qinghai Junior Teachers' College, 5: 63-67.

G. P Kiesmuller, A. G. de Kok, J. C. Fransoo. (2005). Transportation mode selection with positive manufacturing lead time. Transportation Research Part E: Logistics and Transportation Review, 41(6): 511-530.

Hu Junhong, Li Jing. (2013). Discussion on Patterns of Transport Modes' Coordinated Development. Journal of Chongqing Jiaotong University(Natural Science), 28(2):294-297.

Jiang Dazhi, Deng Wei, Zhang Xiaoli. (2009). Study on the Application of Multi-objective Grey Situation Decision-Making Theory for Transportation Mode Choice. International conference on Measuring Technology and Mechatronics Automation.

Liberatore, Matthew J, Miller, Tan. (1995) A Decision Support Approach Transport Carrier and Mode Selection. Journal of Business Logistics.

Luo Jun. (2012) Research on Model of Freight Transportation Mode Choice based on Behaviour Analysis. PhD Dissertation of Wuhan University of Technology.

M. Beuthe，B. Jourquin. (2001). Freight transportation demand elasticities: a geographic multimodal transportation network analysis. Transportation Research Part E.， 37(4):253-266.

Reza Banai-Kashani. (1989).Discrete ModeMChoice Analysis of Urban travel Demand by the Analytic Hierarch Process. Transportation.

Shan Linan. (2007).Choose of Transportation in Project Logistics. Master Dissertation of Dalian Maritime University.

Sheffi Yosef, Eskandari Babak, KoutsOpoulos Haris N. (2000). Transportation Mode Choiee Based on Total Logistics Costs. Journal of Business Logistics, 3(7).

Personnel Psychological Metaphor System about Time-Space Conversion in Intelligent Transportation Processes

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Abstract: With the development of transportation technology, increasing the degree of intelligent transportation, intelligent transportation affected staff travel is also growing. Fast time-space conversion to personnel changes have an important psychological impact, Especially in intelligent transportation area, the difference of languages and understanding ways between different countries makes a great deal of obstacles. Foreign language teaching is a second language teaching, its goal is to train students for the language skills of the target language and language communication ability. This paper established the architecture and application mode of saptio-temporal metaphor system in transportation engineering teaching internationalization process.
Keywords: Intelligent transportation; Time-space conversion; Psychological metaphor; Architecture; Application mode.

1 Introduction

Generally speaking, there are different methods of classifying metaphor. Based on different source domains from cognitive perspective, Lakoff &Johnson (1980) classified metaphor into three types – structural metaphor, ontological metaphor, and orientational (spatial) metaphor. Structural metaphor is to form a concept by using the structure of another concept or to refer to a concept by using a system of words belonging to another concept. Ontological metaphors allow us to view events, activities, emotions etc. as entities and substances. Orientational metaphor, or spatial metaphor, refers to the metaphor with mapping from spatial orientation as source domain to non-space domain (usually abstract domain) as target domain.

The spatial domain is important not only in its own, but because it is commonly mapped onto other more abstract domains, giving rise to spatial conceptualization of those more abstract domains in a metaphorical fashion, as Levinson (1996) has commented. In a word, a special metaphor called "spatio-temporal metaphor", belongs to the range of orientational (or spatial) metaphor and is a kind of spatial metaphor used to represent time. It is a mapping from the concrete spatial domain onto the abstract temporal domain.

In English, two dominant spatial metaphors – ego-moving metaphor and time-moving metaphor- are used to sequence events in time. They are indeed two space→time metaphoric systems which are also called two spatio-temporal metaphors..

2 Instruments Preparation

There were 3 instruments used in the study, including Pretest, Cross Modal Experiment and Students' Scores in CET4. Pretest was intended to find out 3 pairs of time-moving metaphors and 3 pairs of ego-moving metaphors with very similar accuracy and response time, which formed the test sentences in the following Cross Modal Experiment. Cross Modal Experiment was to test the effects of English metaphor consistency. Meanwhile, subjects' reaction time and accuracy for the two spatial-temporal metaphors in Pretest and Cross Modal Experiment were recorded. Students' scores in CET4 were the indicators of their proficiency in English to a large extent because CET4 has been implemented in China for more than ten years and its validity has already been proved. Both the Pretest and Cross Modal Experiment were conducted in the Autonomous Learning Center in Southwest Jiaotong University.

3 Pretest

The first test was indeed a pretest, so its name was Pretest. The Pretest consisted of 50 spatio-temporal metaphorical sentences of which 25 sentences were time-moving metaphors and 25 sentences were ego-moving metaphors. All the 50 sentences were chosen from Evidence for System-mappings in Understanding Space-time Metaphors, Spatial Metaphors in Temporal Reasoning, As Time Goes by: Evidence for Two Systems in Processing Space → Time Metaphors, Back (or forward?) to the Future: the Role of Perspective in Ttemporal Language Comprehension, Does language shape thought?: English and Mandarin speakers' conceptions of time, Metaphoric Structuring: Understanding Time through Spatial Metaphors. The sentences in Pretest were all conventional metaphors and used simple English words so that Chinese learners had no difficulty comprehending them.

To ensure that subjects fully processed the sentences, we made the task more interactive by asking subjects to place an event on a time line. Subjects were instructed to respond by pressing one of two keys to indicate whether the first event (E1) in the sentence took place in the past (A) or future (B) relative to the second event (E2).

4 Cross Modal Experiment

The second instrument was named Cross Modal Experiment. The Cross Modal

Experiment was a 2 (Metaphor Type)×2 (Consistency) between-subject design in which there were 4 between-subject conditions, consisting of 4 possible combinations of setting sentences and test sentences. Condition 1: time-moving setting – time-moving test; Condition 2: ego-moving setting – ego-moving test; Condition 3: ego-moving setting – time-moving test.; and Condition 4: time-moving setting – ego-moving test. Condition 1 and Condition 2 were consistent conditions and Condition 3 and Condition 4 were inconsistent conditions. In the consistent condition, the setting (prime) sentences and the test (target) sentence belonged to the same spatio-temporal metaphoric system. In the inconsistent condition, the setting sentences and the test sentence belonged to different spatio-temporal metaphoric system. The critical measure was the effect of consistency on the response time to the very similar test sentence by the same subject. A sample set of materials appears in Table 1.

Table 1. Sample stimuli for cross modal experiment

Consistent Condition
Setting sentences, time-moving
I will take the Math exam before the English exam.
My birthday is ahead of John's birthday.
I will take two months vacation after graduation.
Test sentence, time-moving
Dinner will be served preceding the session.
Inconsistent Condition
Setting sentences, ego-moving
I am looking forward to the concert.
In the weeks ahead of him, he wanted to finish this project.
We are coming into troubled times.
Test sentence, time-moving
Dinner will be served preceding the session.

Totally, every condition has 12 （4 sentences×3 groups）sentences and every subject would finish 48 sentences. Three setting sentences were followed by a test sentence. All the sentences were chosen from the spatio-temporal metaphors in Pretest. Just like Pretest, a sentence on the time-line with A/B choice-making would appear one at a time in the middle of the computer screen, as depicted in Figure3.1. Subjects were instructed to respond by pressing one of two keys to indicate whether the first event (E1) in the sentence took place in the past (A) or future (B) relative to the second event (E2). The only one different point from Pretest was the order of the sentences. But the subjects wouldn't be aware of the difference between setting sentence and test sentence.

From table 3.1, it can be shown that in the consistent condition, both the setting sentences and the test sentence belonged to the same spatio-temporal metaphoric type – time-moving metaphors. But in the inconsistent condition, the setting sentences belonged to the ego-moving metaphors while the test sentence was a time-moving metaphor. What the experiment wanted to seek was whether the accuracy and reaction time for the test sentence would be affected by the previous setting sentence in the same or different spatio-temporal metaphoric type.

The order of the sentences was arranged in terms of the following principles. The 6 pairs of metaphors with very similar accuracy and response time either in time-moving or in ego-moving chosen from Pretest would be adopted as the test sentences in Cross Modal experiment. 3 time-moving metaphors and their corresponding time-moving metaphors were used in Condition 1 and 3 respectively; 3 ego-moving metaphors and their corresponding ego-moving metaphors were used in Condition 2 and 4 separately. Verbs indicating "before" and verbs indicating "after" were chosen in the 48 sentences, such as ahead of, follow, precede, behind. The setting sentences were arranged not so strictly only with one consideration that the same verb appearing in the same group at the same time would be avoided as far as possible. A summary table on the English materials was given in the Appendix III.

5 Conclusions and Recommendations

This thesis has made an exploration of English spatio-temporal metaphors for English learners. The results obtained from the two experiments provide evidence for the two distinct psychological systems used in processing event-sequencing statements (ego-moving metaphors and time-moving metaphors). The major findings from the experiment are listed below:

In terms of time-moving metaphor and ego-moving metaphor, the results indicate that subjects take longer to respond to time-moving metaphors than to ego-moving metaphors. It supports the view which is opposite to Tzyyin V. Lai's (2002) primacy of time-moving metaphor in Mandarin for Chinese people and consistent with Zhou Rong's (2001) point of view, i.e., ego-moving seems to be easier to process and ego-moving is primary in Mandarin. So for Chinese English learners, the ego-moving metaphor is easier to comprehend and is therefore the primary conceptualization of time.

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References

Boroditsky, L. (2000). Metaphoric structuring: Understanding time through spatial metaphors. *Cognition* , 75(1), 1-28.

Boroditsky, L. (2001). Does language shape thought?: English and Mandarin speakers' conceptions of time. *Cognitive Psychology* , 43, 1-22.

Casasanto, D &. L. Boroditsky. (2008). Time in the mind: Using space to think about time. *Cognition*, 106 (2): 579-593.

Casasanto, D. & L. Boroditsky. (2008). Time in the mind: Using space to think about time. *Cognition* . 106, 579-593.

Gentner, D, M. Imai & L. Boroditsky. (2002). As time goes by: Evidence for two systems in processing space → time metaphors . *Language and Cognitive Processes.*

Grady, J. E. (2007). Metaphor , In D. Geeraerts & H. Cuyckens (eds.). The Oxford handbook of cognitive linguistics . *Oxford: Oxford University Press*, 188-213.

GUO Chun, WANG Mingnian, Tang Zhaozhi. (2011). "A Study on Surge and Stall under the Interaction of Parallel Axial Flow Fan in Tunnel" *J. Noise and Vibration Worldwide*, 42(11): 9-14

GUO Chun, WANG Mingnian, Yu Li. (2012). "Control and Behavior Prediction of Personnel Evacuation in Underground Ventilation Equipment Room on Fire" *J. Applied Mechanics and Materials*, (121-126): 2582-2586

GUO Chun, WANG Mingnian, ZHAO Haidong. (2007). "Research into Fire Disaster Prevention and Rescue of Super-long Railway Tunnel" *J. China Safety Science Journal*, 17(9): 153-158

Jaszczolt, K. M. (2009). Representing Time: An Essay on Temporality as Modality . *Oxford: Oxford University Press.*

Design and Achievement of the Vehicle Information Terminal Based on the Internet of Vehicles

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Abstract: In recent years the Internet of vehicle has been paid much attention as a new development direction of intelligent transportation technology. According to the function requirements of Internet of Vehicle (IOV), a complete set of vehicle's information terminal solution for Internet of Vehicle has been put forward based on GPRS wireless communication, GPS, on-board diagnostic (OBD), digital voice synthesis and other relative technologies. The hardware embedded circuit and software of control has been designed. Finally, to accomplish the test of hardware circuit and software debugging by experiment in laboratory and on vehicle, and to realize functions which include the vehicle position, wireless communication between vehicle and schedule center, path navigation, voice scheduling, fault detection and so on.
Keywords: ITS; Internet of vehicle; GPRS; GPS; On-board diagnosis.

1 Introduction

With the increasing number of vehicle every year in China, it has caused a series of issues, such as traffic congestion, traffic accidents, atmosphere pollution and energy consumption. Thereinto, traffic accidents and traffic congestion have seriously affected people's life and travel. Thereby urban traffic congestion has become a focus problem concerned widely in the course of urbanization. To solve these potential problems, it is imperative to develop urban intelligent transportation. Under the strong impetus of mobile Internet technology, IOV technology emerges as the times required. Currently, it is a better solution to ease urban traffic congestion. The IOV technology can realize information interaction between vehicles and traffic management centers or vehicles. It's convenient for traffic management departments and drivers to obtain running state of vehicle and routes information in the real time. It can optimize the routes and avoid traffic jam and accident effectively, so it is help for improving the efficiency of urban traffic. At the same time it helps to energy saving and emission reduction.

2 Functions of the Vehicle Information Terminal for Internet of Vehicle

Internet of Vehicle (CHENG Gang, 2011) is a new technology in progress, which based on advanced technologies of Internet, computer, communications, path allocation, navigation and sensor. It can realize the functions of routes optimization, real time scheduling, vehicle fault alarm and collision avoidance according to the information of the state of vehicles and traffic.

Through the study of the IOV system, a kind of vehicle information terminal will be designed in this paper, it can realize the following functions:

(1) Vehicle positioning. Get real-time position information of vehicle and send to schedule center.

(2) Path navigation. If the vehicles request for navigation, the schedule center can calculate the optimal route based on real-time traffic conditions in the area, and provides voice navigation for vehicles.

(3) Voice and words prompting. Issue information by modes of voice or words.

(4) Fault code picking-up. Obtain vehicle's fault code information from ECU of vehicles through the CAN bus communication interface, as reference for engineer to locate faults in the future.

(5) Traffic information acquisition. Get road condition and public services information in real-time from the schedule center.

(6) Automatic stop announcement. According to position information obtained by information terminal, it can realize to announce stop information automatically when the bus closes to the bus stop.

3 Hardware Architecture of Vehicle Information Terminal

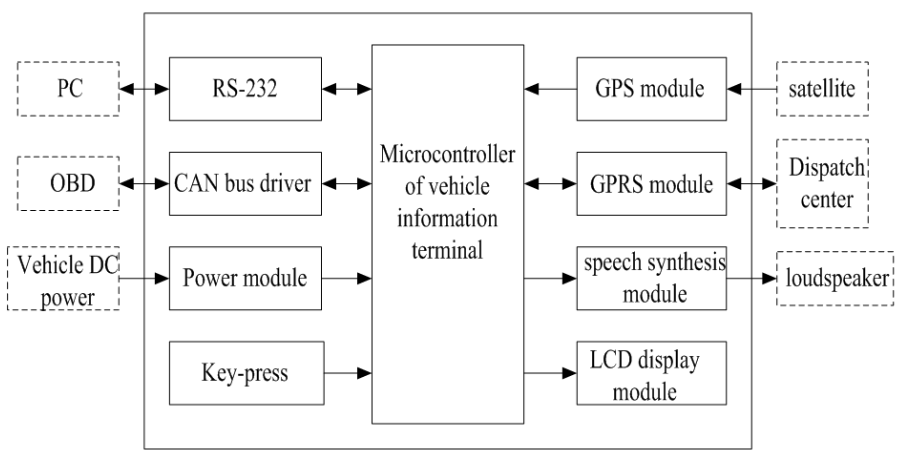

Figure 1.The hardware architecture of vehicle information terminal

The hardware architecture of vehicle information terminal is shown in figure 1. It includes modules of MCU, GPS positioning, GPRS communication, speech synthesis, LCD display, key-press, asynchronous serial ports, CAN driver and system power. Each module of the terminal can realize its functions only under unified control of MCU. With the help of schedule center, the final design goal of IOV system is realized.

3.1 Selection of microcontroller

S9S08DZ60 chip is selected as microcontroller, which is made by Freescale, it has strong anti-interference ability. The microcontroller chip is embedded with CAN bus controller and two independent asynchronous serial communication interfaces. It can communicate with both modules of GPS and GPRS by different serial ports at the same time, thereby to avoid trouble caused by port multiplexing, and to simplify the circuit and program design of asynchronous serial communication. In addition, the microcontroller is also embedded with synchronous serial interfaces, which can provide the communication ports for speech synthesis module. Developed Physical object of vehicle information terminal is shown in figure 2

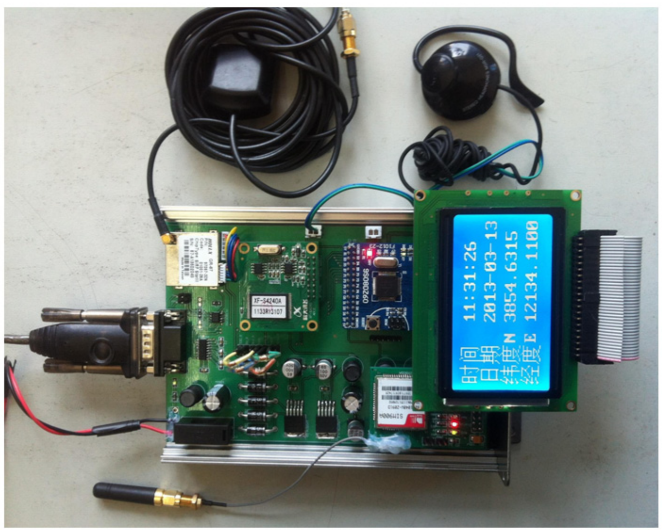

Figure 2.The physical object of vehicle information terminal

3.2 The interface circuit design of GPRS module

To select SIM900A as GPRS module, it's a double frequency GSM/GPRS module. The working frequency of EGSM and DSC is respectively 900MHz and 1800MHz, the operation voltage range is from 3.4V to 4.5V. The GPRS module has electricity-saving technology. Its lowest current is only about 1mA in sleep mode. The figure 3 shows the basic circuit of GPRS module, which includes switch circuit, indicator circuit of network status, indicator circuit of working status, antenna circuit and bypass capacitor circuit. Among these, the bypass capacitor circuit should be put next to pin VBAT as close as possible. Pin DTR, pin RI and pin DCD of the GPRS module connect with pin PTA6, pin PTB0 and pin PTB2 of MCU respectively. Its Pin CTS and RTS are short circuit connection. The pin NRESET and pin STUTAS of GPRS module connect with pin PTA4 and pin PTA0 of MCU respectively. To realize communication between SIM900A and microcontroller, pin TX and pin RX of SIM900A connect with pin TXD1 and pin RXD1 of microcontroller in cross way.

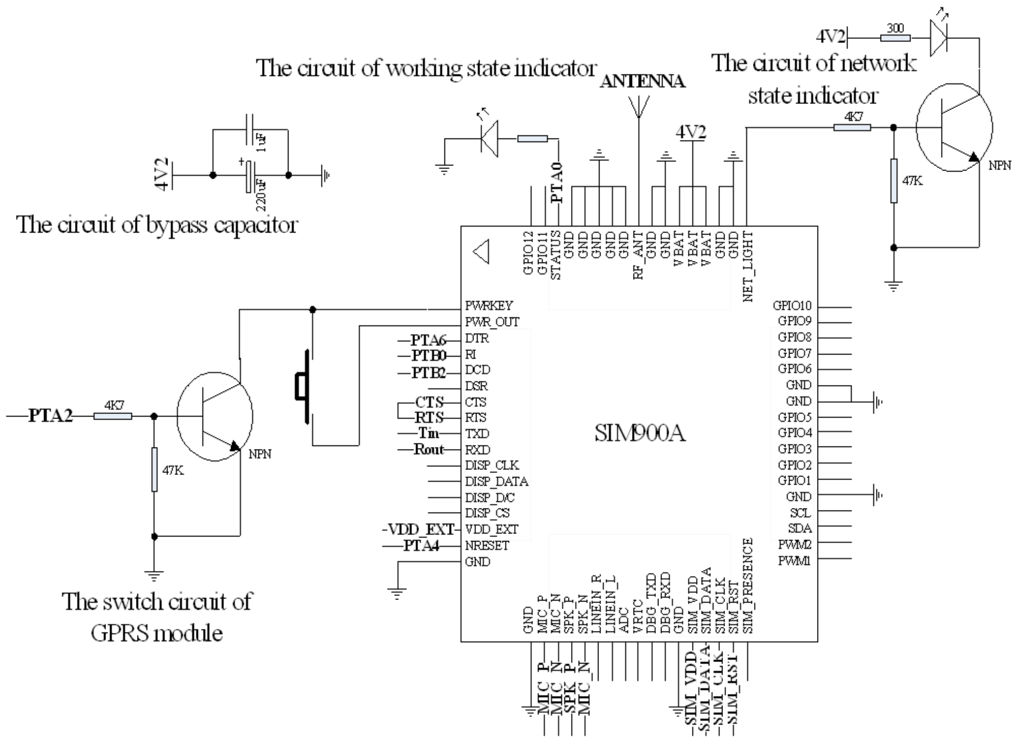

Figure 3.The basic circuit of GPRS module

3.3 The interface circuit design of GPS module

In order to facilitate maintenance and reduce circuit complexity, select model GR-87 as the GPS signal receiver. The basic circuit of GPS module is shown in figure 4. The GPS module use 5V DC power supply. To realize asynchronous serial communication between GR-87 and MCU, pin TX and pin RX of GR-87 connect with pin TXD2 and pin RXD2 of MCU in cross way.

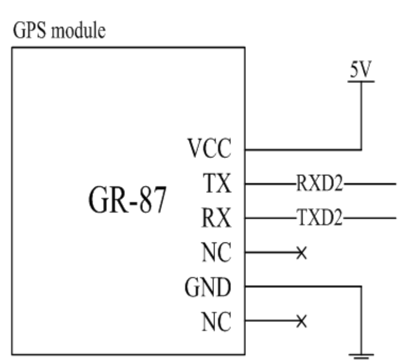

Figure 4.The basic interface circuit of GPS module

3.4 The interface circuit design of speech synthesis module

The model of speech synthesis module uses XF-S4240. It supports a variety of communication ports, such as I^2C, SPI and UART. XF-S4240 has flexible ability of speech synthesis in Chinese text or English alphabets. Considering that two serial ports of MCU have been used by GPS and GPRS module, SPI synchronous serial port of MCU is used to drive the XF-S4240 module, its operation voltage is 3.3V. The basic interface circuit of XF-S4240 is shown in figure 5.

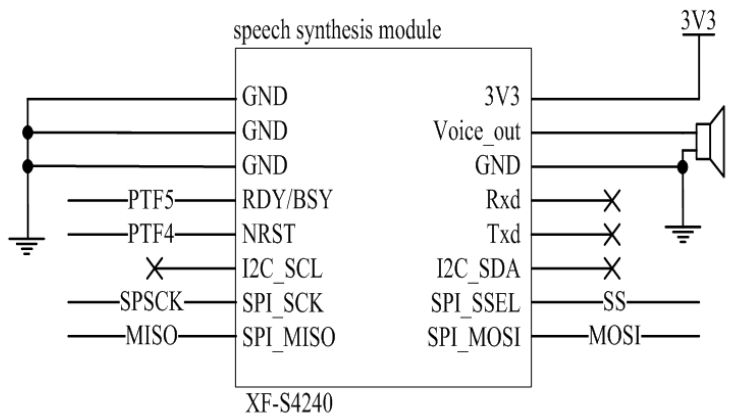

Figure 5.The basic interface circuit of speech synthesis module

4 Software Architecture of Vehicle Information Terminal

As shown in figure 6, software system of the IOV is composed of vehicle information terminal subsystem and schedule center subsystem, through GPRS wireless network, information interaction between the two subsystems can be completed. The software subsystem of vehicle information terminal for IOV (Kevin C. Lee, 2010), as following:

(1) Initializing of each functional modules. Initialize the clock and pins of MCU, and configuring communication interfaces of every modules and MCU.

(2) GPRS wireless communication program. Realize the functions of sending and receiving by AT commands.

(3) GPS satellite positioning data processing program. Receive GPS data by bits, and make extraction, consolidation and analysis to received satellite data through data processing subfunction.

(4) Digital speech synthesis program. Through the SPI communication interface, it can send commands of speech synthesis data frame, wake-up and energy saving, etc.

(5) Fault self-diagnosis and CAN communication program. Extracting the data frame of vehicle fault codes, and send them to schedule center for procession, classification and analysis.

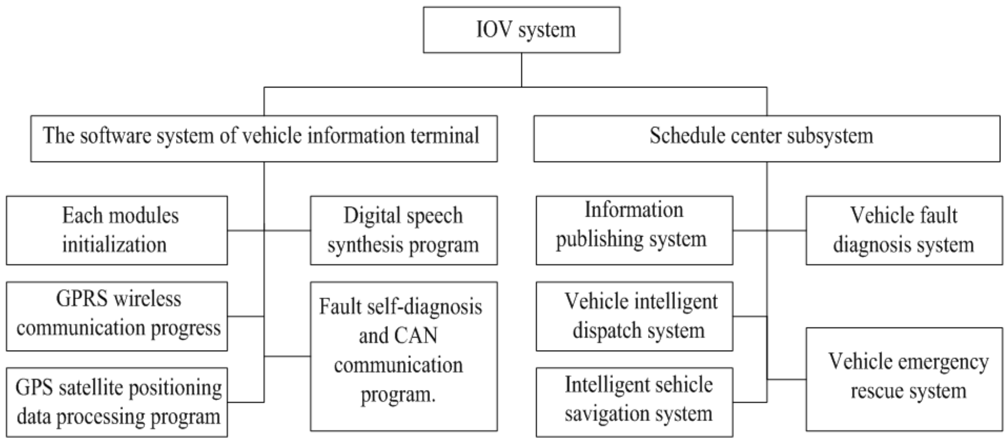

Figure 6.The software framework of vehicle internet information terminal

Software subsystem of schedule center including:

(1) Publishing information system. The system sends public information to vehicles by GPRS wireless network, such as traffic conditions, weather broadcast and public service announcement and so on.

(2) Vehicle intelligent schedule system. The system can realize intelligent schedule and optimize the most efficient and safest route for the vehicles based on vehicle status information and traffic conditions.

(3) Vehicle intelligent navigation system. If the vehicle request for navigation, the schedule center can calculate the optimal route based on real-time traffic conditions in the area, and implement voice navigation for vehicle.

(4) Vehicle fault diagnosis system. The system can get real-time fault codes during vehicle operation, and send them to schedule center for analysis and processing. The system will inform drivers about faults location in advance.

(5) Vehicle emergency rescue system. When the vehicles occur traffic accidents or faults, the system will send emergency signal to schedule center automatically by wireless network, and help to protect life and property safety effectively.

5 The Working Flow of Vehicle Information Terminal

The working flow of vehicle information terminal (LUO Jinxiu, 2013) can be divided into two following parts:

(1) System initialization, it includes MCU initialization, GPRS working state detection, GPRS module boot, and establish GPRS wireless communication connection. The programs run only once after the hardware circuit is powered on, mainly to realize the following functions: configuration clock, communication ports and I/O ports of MCU, and initialization of modules, opening interruption, establish TCP transparent transmission between GPRS module and schedule center server.

(2) Main programs. The system will go into the looping state of the main program after initialization; the system can realize the each function through calling each subprogram, which includes GPS data processing, OBD fault code reception, GPRS wireless communication, speech synthesis and so on. The working flow of vehicle information terminal is shown in figure 7.

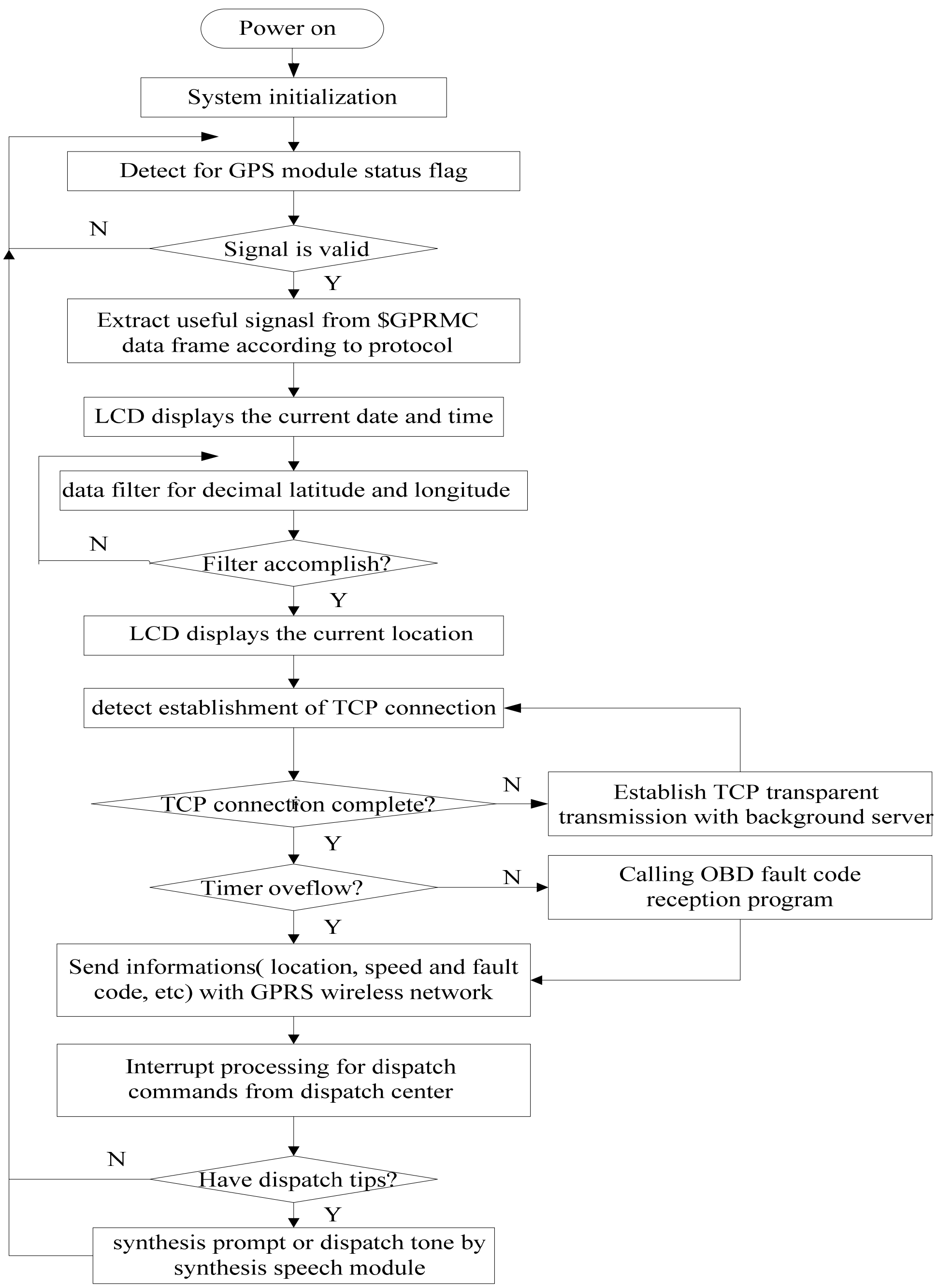

Figure 7.The workflow of vehicle information terminal

6 Experiments on Vehicle

In order to test general functions of vehicle information terminal, to make a road experiments in campus, which includes vehicle positioning, wireless communication, automatic stop announcement, fault code acquisition and schedule information broadcasting and so on. The vehicle for road test is four-wheel drive mini electric vehicle which independently developed by ourselves. The vehicle information terminal uses 24V DC power supply. As shown in figure 8.

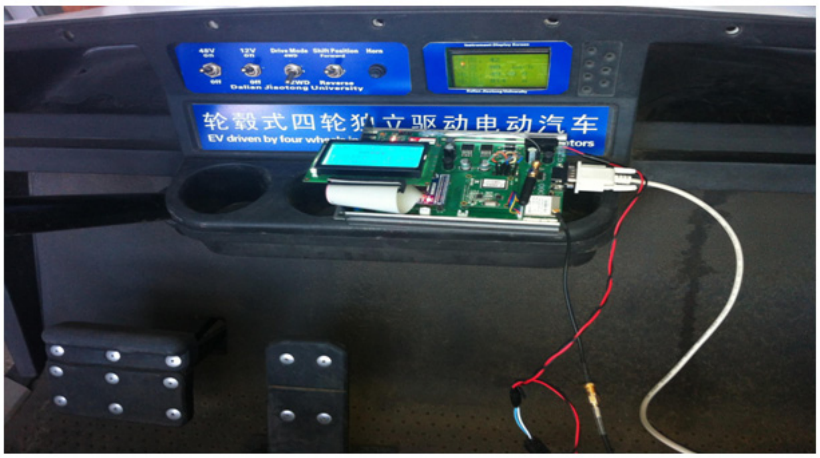

Figure 8.The experiment of vehicle information terminal on an electric car

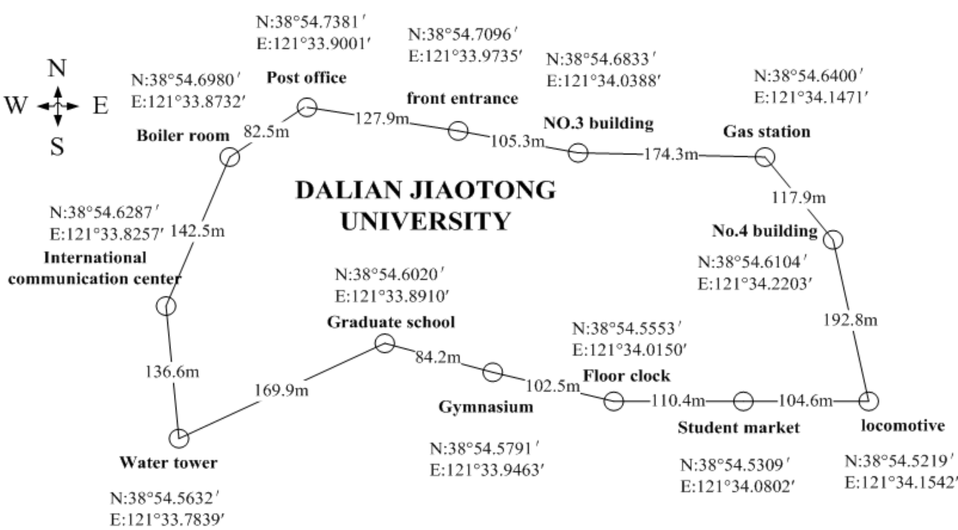

Figure 9.The route map of vehicle terminal experiment

Firstly, to select appropriate route for the test in the campus, then calibrate stops based on geographic information of landmark building, and download geographic information into MCU. Drive the electric vehicle in the setting route to complete actual function tests. The schedule center in the laboratory will analyze the feed-back data from vehicle information terminal to generate actual route trail and simulate fault diagnosis reports, then send schedule information and fault alert to vehicle terminal, by comparison with actual map, the data of latitude or longitude coordinates which is got from vehicle information terminal is basically correct. However, due to the short distance of sites in the campus as well as GPS data errors, the function of automatic bus-stop announcing should be enhance in accuracy. In addition, the experiment about vehicle fault code acquisition based on CAN communication is completed. The route map is shown in figure 9.

7 Conclusions

Through analyzing the basic functions of internet of vehicle system , to build the vehicle information terminal hardware architecture with the aid of the advanced technologies of mobile internet, IOV, computer, communication, position and navigation, automobile electronics. Then based on the mastery of embedded development tools and electronic devices, interface circuits of GPS module, GPRS module, fault diagnosis module, digital voice module and display module with microcontroller are designed and implemented. At same time, to design software architecture and working flow based on its required functions. By experiments on vehicle, the basic functions of vehicle information terminal have been realized. The experimental results show that design of the circuits are reasonable, collaborative work between each function module is normal, the vehicle information terminal can achieve the desired design goal. With the development of mobile internet and internet of things technologies, internet of vehicle is closing to people's life. As an important part of IOV, vehicle information terminal will have bright future.

Acknowledgement

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References

Cheng Gang and Guo Da(2011). "The Research on Developing Situation of IOV." *Mobile Communications,* Guangzhou.

Kevin C. Lee, Uichin Lee, Mario Gerla, et al (2010). "Geo-Opportunistic Routing for Vehicular Networks." *IEEE Communications Magazine,* New York.

Luo Jinxiu(2013). "Design and Implementation of Vehicle Internet Information Terminal." *Dalian Jiaotong University*, Dalian.

Distributed Hierarchical Control for an Urban Rail Transit Intelligent Transportation System Based on Multi-Agent

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Abstract: Through detailed analysis of control problem of urban rail transit intelligent transportation system, a distributed hierarchical control method was proposed by blending the factitious division of hierarchical system and the natural division of distributed control system. This method is based on the hierarchical control theory of large scale system, and includes three levels: the organization level, the coordination level, and the execution level. The objectives are decreasing the total delay time and increasing the absorption to passengers of the successive trains, a method for train operation adjustment based on Multi-Agent is developed, and the control strategy based on rules is proposed. The distributed hierarchical control method deals with the train planning, the coordination of trains, and the action control of trains in different layers. The simulation results show the effectiveness of the model and the revised algorithm based on Multi-Agent comparing with the traditional control theory.

Keywords: Urban rail transit; Intelligent transportation system; Distributed hierarchical control; Multi-agent; Dispatch.

1 Introduction

A typical intelligent control system uses hierarchical structure to assign control and management task. It emphasizes the function of pursuing objectives of the system, and is prone to analyzing description. However, a distributed control system uses the system structure, which has such characteristics: geographic distribution, disperse control function and centralized management operation (Wang, 2001). The train operation process of intelligent urban rail transit is a complex human-computer cooperation process, which includes the analysis of qualitative and quantitative, time and space, local linear and integral non-linear. The system has several input and output variables, while most parametric variables are non-linear, time-variable, uncertain and spatial distributed (Dong, 2004). To such discrete event dynamic system, the difficulty of the train operation adjustment is huge. It will be hard to recover train behind schedule fleetly, if it uses the traditional control theory, such as optimization method, scheduling rules, simulation method and so on. The distributed hierarchical intelligent control system based on Multi-Agent blends the factitious division of hierarchical system and the natural division of distributed control system can preferably solve the above problems.

2 Model Establishment

The train operation adjustment is a process to reschedule the train timetable and assure most trains running on time by some adjustment measures when the actual train operation status deviate the project train schedule. The train operation adjustment of urban rail transit intelligent transportation system must adopt real-time control mode, which uses the decreasing the total delay time and increasing the absorption to passengers of the successive trains as its performance guidelines according to the characteristics of train operation of urban rail transit.

Suppose there are n stations in line *A-B*, the station set is $S=\{1,2,3,\ldots, n\}$, the corresponding section set is $Q=\{1,2,3,\ldots, n-1\}$, the train set running in the line is $L=\{1,2,3,\ldots, m\}$. The planned arrival time of train l ($l \in L$) at station k ($k \in S$) is $A_{k,l}$, the actual arrival time is $A'_{k,l}$, the planned departure time of train l from station k is $D_{k,l}$, the actual departure time is $D'_{k,l}$. The minimal running time of train l between station k and k+1 is $t^{l}_{k,k+1}$, the additional starting time at station k is τ^{k}_{q}, the additional stopping time at station k is τ^{k}_{t}, the planned stop time for train l at station k is $T_{k,l}$, the actual stop time is $T'_{k,l}$. The minimal train tracking interval time is I, the minimal arrival headway interval time for trains at station k is I^{k}_{d}, the minimal departure interval time for trains at station k is I^{k}_{f}. Define $level(l)$ the level of train l, the smaller the value l, the higher the train level. Define $\omega(j)$ the operation adjustment weight value of level j, and $j=level(l)$, the higher the train level, the bigger the value of $\omega(j)$. The optimization model of train's total delay time is as formula (1) (Wang, 2006); the optimization model of passenger waiting time is as formula (2).

$$\min F = \sum_{k=1}^{n}\sum_{l=1}^{m}\omega(level(l))\left[\left|A'_{k,l} - A_{k,l}\right| + D'_{k,l} - D_{k,l}\right] \tag{1}$$

$$\min P = \sum_{k=1}^{n-1}\sum_{l=1}^{m-1} level(l)\left[\left(A_{k,l+1} - A_{k,l} - T_{k,l}\right) - \left(A'_{k,l+1} - A'_{k,l} - T'_{k,l}\right)\right] \tag{2}$$

$$A'_{k+1,l}\Theta D'_{k,l} \geq t^{i}_{k,k+1} \tag{3}$$

$$D'_{k,i}\Theta A'_{k,l} \geq \delta_{k,l}\left(T_{k,l} + \tau^{k}_{q} + \tau^{k}_{t}\right) \tag{4}$$

$$\left|A'_{k,j} - A'_{k,l}\right| \geq I^{k}_{d} \qquad \left|D'_{k,j} - D'_{k,l}\right| \geq I^{k}_{f} \tag{5}$$

$$A'_{k,j}\Theta A'_{k,l} \geq I^{k}_{d} \qquad D'_{k,j}\Theta D'_{k,l} \geq I^{k}_{f} \tag{6}$$

$$D'_{k,j}\Theta D_{k,l} \geq 0 \tag{7}$$

Formula (3) is the constraint of the section of the train operation. Formula (4) is the constraint of the station working time. Formula (5) is the constraint of the station tracking interval. Formula (6) is the constraint of the train overtaking. Formula (7) is the constraint of the departure time. Formula (8) is the constraint of station's arrival and departure tracks capacity, where $u(x,t)$ is binary step function, $u(x,t)$=1($x \le t$), $u(x,t)$=0($x > t$). Formula (9) is the constraint of the skylight time.

3 Multi-Agent Characteristic and Structure of Train Operation Adjustment

The characteristics of urban rail transit train agent include: autonomy, communication, reaction, oriented-objective, facing-environment and so on. Autonomy indicates that agent possesses control right to its behavior or action, without external interference, autonomously completes its special task; Communication indicates that each agent accepts task assignment or feedbacks the task execution information by intercommunication in organized train group; Reaction indicates that agent should possess the ability of perception environment and reaction. For example, agent confirms the train acceleration according to the sampled environment parameters (such as track parameters: curvature and gradient, the velocity or state of forward train, and so on). Because the parameters of every agent is the environment parameter of the following train agent, every action of agent actually changes the correlative environment parameter of the whole system; Oriented-objective indicates that agent can evaluate its own behavior, and gradually orientate targets; Facing-environment indicates that agent can only works in special environment, which is to realize the safety and reliability of train operation with the communication between one after another agents or agent and dispatcher agent.

According to the above request, Multi-Agent System (MAS) uses compound structure with cognitive process and reactive process, as figure 1. In which the external environment mainly includes dispatching section status information, train operation adjustment decision and so on. Perception receives environment information by sensors, and carries through preprocessing and character identification. Reactor makes judges of the information from perception, directly starts up performer to control train operation towards emergency state or simple state. Towards un-emergency state, it usually starts up the performer after the decider making a decision. The decision of decider depends not only on environment information, but also environment model to forecast the action. Meanwhile, other agents might request to its future action by communication machine, control strategy and might make a strategy of its action beforehand. In this circumstance, the designer might clear up according to conflict resolution knowledge, and determine the corresponding behavior.

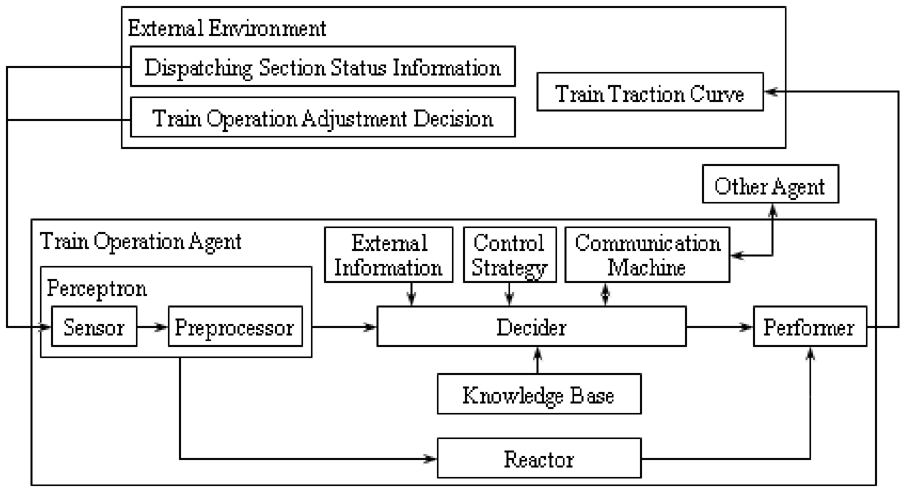

Figure 1. Multi-Agent compound structure of train operation adjustment.

4 Distributed Hierarchical Control Structure of Train Operation Adjustment

The urban rail transit distributed hierarchical intelligent control system, which is based on the Multi-Agent, decomposes the train operation adjustment problem into several sub-problems, and each problem corresponds to a sub-MAS. The agent of each layer follows the rule: the higher the level, the more intelligent the agent, the lower the precision, the longer the information processing time, contrarily, lower level requires high precision, fast information processing. At the same time, the whole system possesses a coordinated organization (Saridis, 1983).

The urban rail transit operation has the requests of high speed, high density, high-punctuality rate and high safety, so consider transport task decomposition and train coordination in different lever by distributed hierarchical control structure, which includes three levels: the organization level, the coordination level and the execution level (see Figure 2). The organization level locates in the high layer of MAS, it receives and translates input instructions and correlated system feedbacks, determines the task, and decompose it into sub-tasks with appropriate execute order, which is realized by administer computer. The coordination level locates in the middle layer of MAS, it receives instructions from organization level and feedback information in each sub-task executing course, and coordinates the executing course with the execution level, which is realized by operating station and monitoring computer. The execution level locates in the bottom layer of MAS, its task usually includes executing certain movement, which requires the knowledge of course mathematical model, course end state and performance criterion or cost function defined by coordinator, which is realized by spot controller.

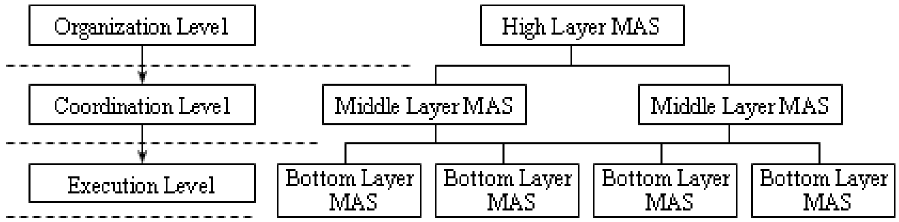

Figure 2. Distributed hierarchical control structure.

5 Model Simulation

In order to verification the validity the algorithm, simulation is made in the Matlab environment. Taking the transport and organization of passenger dedicated the first line of Chengdu subway as an example, the simulation condition is supposed as follows:

The total length is18.5 km, station number n=17, plan to run L=24 trains, which include 12 up-ways and 12 down-ways. the additional stopping time is 1 min, and additional starting time is 1 min, train tracking headways time is 5 min, the weight of trains with different level is (4 3 2 1), population size is 30, crossover probability is 0.8, mutation probability is 0.001, maximum algebra is 200. By combining genetic algorithms, the model is showed in figure 3. The test results show that the distributed hierarchical control method based on Multi-Agent can complete train operation adjustment in disturbing situation efficiently.

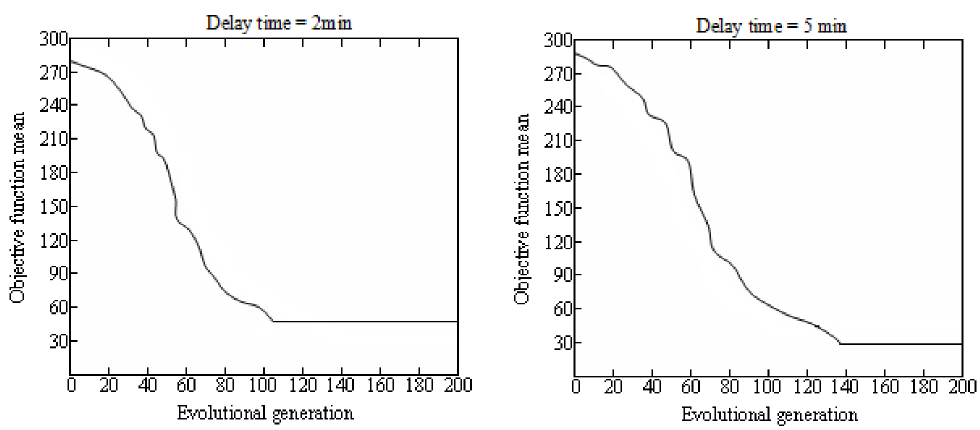

Figure 3. Objective function evolution process.

6 Conclusion

Train is the objection with distributed character in logic and physics, train operation dispatch system is one of the important measures to improve urban rail transport efficiency and keep the safety and punctuality of train transportation. The transport task of urban rail transit intelligent transport system has the characteristics of uncertainty, complexity and spatial distribution, the thought and method of large scale system control is an effective way to solve the system control problem. Multi-Agent technology which possesses autonomy, reaction and oriented-objective characteristic, is used to design train operation adjustment algorithm of urban rail transit based on distributed hierarchical control method. By the method of decomposition and coordination, local adjustment and global adjustment, the cooperation ability and initiative of every part of the control system can be improved, the total delay time of train group can be decreased, the absorption to passengers of the successive trains can be increased, and ultimately improve urban rail train dispatching automation level.

Acknowledgments

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References

Wang J., and Chen H. (2001). "Study of Agent-based Distributed Hierarchical Intelligent Control." *Control and Decision*, 16(2), 177-180.

Dong H., and Jia S. (2004) "Distributed Intelligent Control of Train Based on Multi-agent." *Journal of the China Railway Society*, 26(5), 61-65.

Wang H. (2006). "Study on Passenger-special Line Train Regulation Model and Algorithm." *Master's Thesis*, Southwest Jiaotong University, 16-21.

Saridis G N. (1983). "Intelligent robotic control." *IEEE Trans on Automatic Control*, 28(5), 547—557.

Zhao S., and Dang J. (2009). "Study on Chaos-improved Genetic Algorithm for passenger-dedicated lines train operation adjustment." *Computer Engineering and Applications*, 45(9), 220-222.

Intelligent Train Dispatching for Urban Rail Transit Based on a Fuzzy Neural Network

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Abstract: Through detailed analysis of train operation control procedure of urban rail transit, in view of the present condition of Fuzzy Neural Network (FNN) in train operation control, a new model of train operation adjustment on the FNN is developed, Five levels fuzzy neural network were built and its input and output were designed, the weighing and parameters were revised in order to get different membership function, then corresponding fuzzy rule and could execute fusion decision could be got in the new method. Furthermore, The simulation perception processing of train operation adjustment was completed using Matlab, the mean square error between actual output and experiments output was got The simulation results show that the validity of train operation control procedure of urban rail transit based on FNN.

Keywords: Fuzzy neural network; Urban rail transit; Dispatch; Intelligent transportation; Train operation adjustment.

1 Introduction

An intelligent dispatching system of urban rail transit requires to acquire, transport, process and output correlative information so as to realize the high-efficient incorporate operation of train operation program, dispatching supervision and control, accident settlement, emergent rescue, passenger service and so on (Liu, 2006). In the normal operation condition, the dispatching of train group can be rule processed in the direct of planned train diagram. However, in the abnormal situation, the measures of the adjustment in the train operation are different as a result of the vary factors that influence the trains. The dispatching command confronts a lot of matters, and different kind of matters require different dispatching countermeasures, especially when train is behind schedule or a big disaster or accident is happened, which is a biggish test for the dispatchers. In these situations, they are supposed to react nicety, take effective measures, deal with all kinds of abnormal instances duly and decidedly and recover the normal train operation rapidly. Therefore, the key-point of the intelligence of the dispatching system is that the system should possess intelligent dispatching function in abnormal situations, the main issue of which is to automatically adjust the train operation in the train behind schedule situation.

3 Model Establishment

3.1 Mathematical Model of Train Operation Adjustment

The train operation adjustment of the urban rail transit has many obvious characters, such as excessive restrict conditions and optimize indexes, strong dynamics, high request of real time, combinatorial optimization and so on. Suppose there are $n+1$ stations and n sections in a urban rail line down direction, and the arrival and departure tracks of each station is as $G_i\,(i=1,2,\cdots,n+1)$ that able to receive trains in this direction. There are J trains needed to be adjusted in an adjustment period (commonly 3 to 4 hours), marked as $L=\{l_1,l_2,\cdots,l_j\}$. the weight is ϖ_j ($\varpi_j \in \{0.1,0.2,\cdots,1\}$), which means the characteristics of the train, such as relative priority and so on. When the trains pass each section and station in the dispatching section in order, it will produce y section events with a certain sequence. Each adjusted train has a earliest receiving time h^l, a earliest departing time f^l and a last leaving section time or arriving endpoint time g^l,and should finish the course of this adjustment section in the appointed period (h^l, g^l). Each train has an occupancy time c_i^l and an optional beginning time b_i^l when passing each section. If the finishing time is defined as e_i^l, there exists $e_i^l=b_i^l+c_i^l$, in which b_i^l is constrained by f^l and c_i^l. Samely, trains produce z station events when pass each station of the section. Each train has an occupancy time o_i^l and an optional beginning time b_i^l when passing each station. If the finishing time of occupying the station is defined as v_i^l, then there exists $v_i^l=u_i^l+o_i^l$, in which u_i^l is constrained by h^l and o_i^l. Based on the assumption, the mathematical model of the train operation adjustment in the urban rail line down direction can be defined as formula (1), the adjustment goal is to occupying the least time after being weighted (Jia, 2005).

$$\min z=\sum_{i=1}^{n}\sum_{l=1}^{j}\varpi^l c_i^l+\sum_{i=1}^{n+1}\sum_{l=1}^{j}\varpi^l o_i^l \tag{1}$$

$$e_i^l \leqslant b_j^l \quad i,\ j\in\{1,2,\cdots,n\},\ (\ i< j) \tag{2}$$

$$\left(b_i^a-b_i^b\right)^2 \geqslant I^2,\quad \forall\, a,\ b\in L \tag{3}$$

$$u_i^l \leqslant v_i^l,\ i\in\{1,2,\cdots,n\} \tag{4}$$

$$\sum_{l} L_i^l(t)\, G_i\,, \quad \forall\, t \in T \tag{5}$$

$$b_i^l \geqslant f^l \tag{6}$$

$$u_i^l \geqslant h^l \tag{7}$$

$$\left(u_i^b - v_i^a\right) \geqslant \tau_{发到}, \quad \forall\, a,\ b \in L \tag{8}$$

$$\left(u_i^a - v_i^b\right) \geqslant \tau_{到发}, \quad \forall\, a,\ b \in L \tag{9}$$

Formula (2, 3) is the constraint of the section order of the train operation, which means that trains need to pass each section in turn, and *I* is the interval time of tracking train headways. Formula (4) is the constraint of station occupation condition, which means that train cannot leave before arriving time. Formula (5) is the constraint of station's arrival and departure tracks capacity, which means that in any time *t*, the occupied tracks cannot exceed the capacity of the station. Formula (6) is the constraint of the train's earliest leaving time, which means that trains cannot leave earlier than the daily-shift plan time. Formula (7) is the constraint of the train's earliest occupying station time. Formula (8, 9) means that a station can't transact trains with the same direction at one time, which should have different departure-arrival interval time τ_{da} and arrival- departure interval time τ_{ad}.

3.2 Fuzzy Partition of Input and Output Space

For the train operation adjustment system, the most important part in the control objective function is the train occupancy time ($c_i^l + o_i^l$), which can be indicated from (1). The Root Mean Square (RMS) is used to be the linguistic variable in the control rules, as in (10).

$$d = \text{RMS}\ \left(c_i^l + o_i^l\right) \tag{10}$$

When the control inputs are confirmed, the constraint conditions are equally important. The format expressed by formula (2) - (9) is different from objective function. It must distort each constraint condition to adapt the linguistic variables of fuzzy neural networks. The constraint conditions have only two statuses: satisfied or unsatisfied. Suppose 0 denotes that the constraint condition is satisfied, while 1 denotes unsatisfied, then the most ideal situation can be described as a 9-dimension array with all the members being 0, expressed by C_0. $C(h)$ denotes the satisfied practical operation constraint conditions, the RMS of $C_0 - C(h)$ is used as the linguistic variable of constraint conditions, that is

$$z = \text{RMS}(C_0 - C(h)) \tag{11}$$

The fuzzy set, which is composed by the train occupancy time *d*, constraint conditions *z* and output adjustment *y*, is divided into saturations {*NB*(Negative Big), *NM*(Negative Middle), *NS*(Negative Small), *ZE*(Zero), *PS*(Positive Small), *PM*(Positive Middle), *PB*(Positive Big)}. The control value ϖ denoted by the train weight is divided into saturations, described by *V*={*B*(Big), *M(*Middle), *S*(Small)}.

The Gaussian-type membership function is tally with people's thinking habits and the statistical law, and the maximum value of any membership in the fuzzy subset won't be too small, and it can avoid the dead zone, increase the control performance of the whole train operation adjustment system. Therefore, each fuzzy subset's membership function is Gaussian function $e^{-\left(\frac{x-c}{\delta}\right)^2}$, in which *c* denotes the central point, δ denotes the width and δ=0.03. Take the train occupancy time's linguistic variable *d* as an example, suppose universe is (-3, 3), the unit is *h*, and then the membership function is described as figure 1.

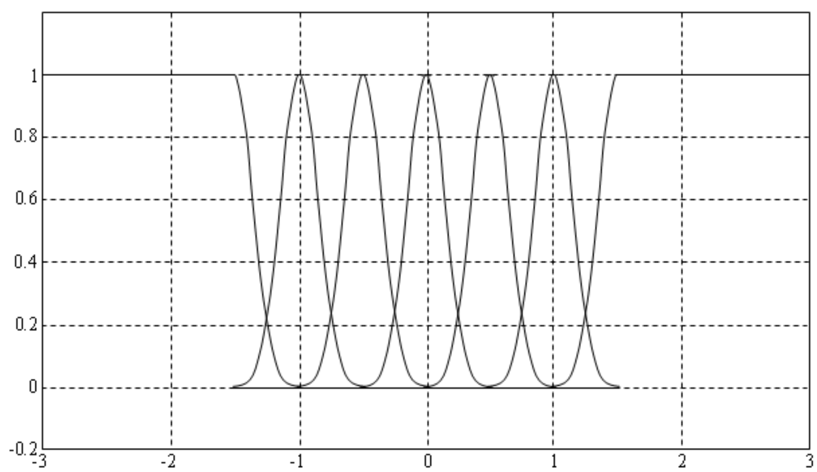

Figure.1 Membership function

3.3 Establishment of Fuzzy Control Rules

The choice of fuzzy control rule affects the effect and precision of the system control directly. The fuzzy rules library is composed of implicit knowledge and explicit knowledge. For example, the operation experience of dispatcher is explicit knowledge, while the rule produced by the input and output of an ideal train operation dispatch course is implicit knowledge. By linguistic rules, it can be denoted as follows: if DE is Ai, DEC is Bi, and U is Ci, then Y will be Di.

There into, DE, DEC and U delegate the linguistic variables of the train's occupying time, constraint condition and control quantities, and Y is the linguistic variable of operation adjustment result. The fuzzy subsets of their linguistic value in correspond universe are Ai, Bi, Ci and Di.

In order to get quantization results of fuzzy control, the fuzzy variables can be coded. For example, {*NB*，*NM*，*NS*，*ZE*，*PS*，*PM*，*PB*} can be denoted by {0,1,2,3,4,5,6}. After accidence establishment, the system rules can be optimized by persistent learning and training of the network. The control course of trains' operation adjustment is showed by Figure 2.

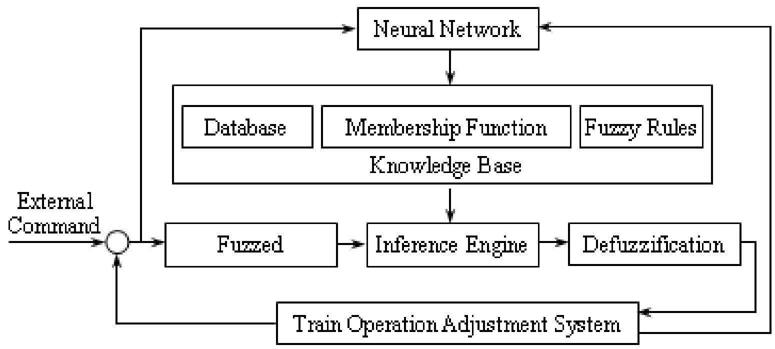

Figure.2 Process of train operation adjustment based on the FNN

3.4 Fuzzy Neural Network Structure

According to the above analysis, fuzzy neural network with 5 layer nodal point can be established, which are input layer, fuzzy layer, regulation layer, normalization layer and output layer.

The first layer: it includes 3 original input variables d，z， ω. Fist establish Gaussian-type membership function to d，z， ω. In the design, 2 neural weighted methods are chosen to simulate hyperbolic Tangent Function, which is also the input activation function.

The second layer: each input component corresponds to a group of nodal points, the number of which corresponds to the number of fuzzy grades of input values, there into, each nodal point delegates a fuzzy linguistic variable. Each nodal point delegates a linguistic variable value, the function of which is to calculate the subjection function belonging to linguistic variables fuzzy set of each input component. To 3 linguistic variables d，z and ω, 7,7 and 3 fuzzy subsets are carved up, and 7×7×3=147 control rules are received.

The third layer: each nodal point delegates a fuzzy rule to accomplish the match of rules, and the outputs corresponding applicability of rules. For a given input, the linguistic variables around input points can have bigger subjection values, while the far-away variables has small subjection values or the value is zero. Therefore, most nodal points' output is zero, which is similar as local approximation network. The algebras algorithm of input value subjection function is used when computing.

The forth layer: the number of nodal points is the same as the third layer. Each rule's application is normalized. In this layer, only a few nodal points have big output value, while most nodal points' output is zero.

The fifth layer: it realizes the clear calculation of system.

4 Model Simulation

In order to verification the validity of the algorithm, simulation experiments is done in the Matlab environment by using anfis function to accomplish the training work of self-adaptive neural network fuzzy inference system. The network structure parameters are: 3 input variables, 2 output variables and 147 regular nodal points. In the condition of the actual train operation status deviate the project train schedule, choose 400 sample data, in which 300 data is used as learning samples, and the 100 remained data is used as testing samples to test the network. During the training, the change of the Mean Square Error is tracked. After the network training restrains, all samples will be identified fuzzily. The testing results show that, with the increase of the training period, MSE decreased gradually, the network converged gradually, the network output basically inosculate the experiments output, and neural network reflect the control rules well, when the error in the network training course is controlled in the range of expected error.

5 Conclusion

Fuzzy Neural Network theory is a relatively new kind of software calculating method, and it can effectively analyze and process imperfect information. The international science field thinks highly of this theory, and it has been widely and successfully used in many science and technology fields such as the mode identifying, machine learning, decision supporting, process controlling, model predicting and establishing and so on. Aiming at the characteristics of the urban rail transit and its construction, this paper uses this theory on solving the problem of decision making in the train operation adjustment, and provides a new method and thought in realizing the high-efficiency, modernization, intelligence in the operation dispatching.

Acknowledgments

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References

Liu, Z., and Wang, G. (2006). "The Development of Intelligent Railway Transport System," *Control and Automation*, 22(7), 16-19.

Jia C., and Hu, S. (2005). "Double-Line railway dispatch management system based on Multi-Agent," *Journal of Beijing Jiaotong University*, 29(6), 13-17.

Lane Changing Model Based on a Discrete Dynamic Game in an ICT Environment

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Abstract: In ICT environment, more and more information can be obtained. On the basis of analysis of lane changing action, this paper establishes the vehicle lane changing model based on discrete dynamic game. In this paper, the game stages are divided by the lane width, then the stage process between two vehicles and action strategy of each vehicle are described more reasonable by discretizing acceleration of the vehicles, and PICUD is used as the expected return of the income matrix .This paper use the model to analyze the high-speed road vehicles' lane-changing processes and to determine its revenue, to indicate the effectiveness of this model.
Keywords: Discrete dynamic game; Lane changing model; Intelligent transportation system; ICT environment.

1 Introduction

Lane changing behavior of vehicles is a complicated process, affected by many factors. Many scholars have conducted a detailed study, and proposed the corresponding lane changing models, including vehicles repeated game theory based on dynamic lane changing model and so on.

Considering reasons of changing lane, behaviors can be divided into two types: (1) Forced lane changing. It mainly due to the presence of an accident on the road, construction, control measures or path selection (left turn in front of the intersection) and so on; (2) Independent lane changing. Vehicles due to the current speed or road space can not meet the needs. This paper does not consider specific reason, assumes that the vehicles have the motivation, and has already begun to change lane.

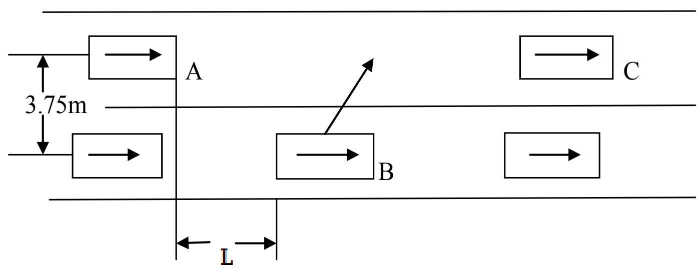

Figure 1. Process of lane changing

Process of lane changing is shown in figure 1. The target of vehicle B is to improve its satisfaction with the current traveling speed and space by changing lane. But vehicle A is likely to take measures to stop B, because the lane changing of B will decreases the distance between A and vehicles in front, and will bring adversely influences on traveling speed or space of vehicle A.

Through the above analysis we can find the fact that there is just competition between the vehicle A and B. As the target vehicle, vehicle B is going to change lane, so its vertical speed is V_B, its vertical acceleration is α_B and its rampant acceleration is α_{Bh}. Vehicle A has vertical speed set as $V_A$and vertical acceleration set as α_A. The lateral distance between the two vehicles is 3.75m which is the width a lane and the longitudinal distance L. Now the lateral distance between vehicles is divided into five equal portions, and every 0.75m is set as a stage of dynamic game theory in this paper.

2 Dynamic Game in The Process of Lane Changing

Game can be divided into static game and dynamic game, and repeated game is a very special kind of discrete dynamic game. Generally, in a repeated game, each participant is to take action at the same time, which is more similar to the static game, but is different from static game. All participants are to take actions at the same time in repeated games, but in the static game, participants are only to take actions at beginning.

In a repeated game, the game that is repeatedly performed is called stage game. In every game stage, the game strategy spaces and payoff functions are the same. If a game which contains a finite number of stages and each participant can observe other participants' actions in the past stages at the beginning of the game, this game is called a limited time repeated game. Game theory contains three important elements:

(1)In the actions of a countermeasure, participants who have the right to determine their own countermeasure actions are known as the players. Although the players in this model are the vehicle A and B, vehicle B has longitudinal acceleration and lateral acceleration in the process of lane changing. These two acceleration have no effect on each other, so the vehicle B's decisions can be divided into longitudinal decision B and transverse decision B_h.The players of this model can represented as $I = \{A, B, B_h\}$.

(2) In a game, practical actions for players to choose are called strategies. Every player $i(i \in I)$ has its own set of strategies S_i . In this model, decision of players is accelerating or decelerating. In order to make expected revenue more accurate, the acceleration is discrete and each decision is set as follows: S_A ={-5,-3,-1,0,1,3,5}, S_B ={-5,-3,-1,0,1,3,5},S_{Bh} ={-0.5,-0.3,-0.1,0,0.1,0.3,0.5}. A negative value indicates deceleration, 0 means neither accelerating nor decelerating, and positive value indicates accelerating, and the unit is $\mathrm{m/s^2}$.

Vehicle A can have 7 decisions each stage, and vehicle B can have 7*7=49 decisions each stage. Each policy group the players selected form a strategy called a situation, the set S of all situations in this model can be expressed as

$S = \{S_A, S_B, S_{Bh}\}$

(3) The expected revenue set of each participant under the strategy combination of specific participants is $R = \{R_A, R_B\}$.

3 Lane Changing Model

Every stage B will observe behavior of A at the same time. By the definition of repeated games, at the beginning of each stage of the repeated game, each participant can observe other participant's actions of past stage. So in the corresponding actual process of drivers' changing lane we can get the following data: the vertical distance between A and B is L_m. Relative distance variation in the last stage is ΔL_{m-1}. The speed of A was $V_{A(m-1)}$ and longitudinal acceleration was $\alpha_{A(m-1)}$. A can also get the corresponding data of the vehicle B to make appropriate judgments and actions at each stage.

A will assume that in the later stages B will have the longitudinal speed V_{Bm} acceleration α_{Bm},and transverse velocity V_{Bmh} and acceleration α_{Bmh}. It assumes that A will has the speed $V_{Am}$and acceleration α_{Am},so we can calculate the distance L_{mf}between the two vehicles after the completion of the vehicle lane changing, at the same time vehicle B has the speed of V_{Bmf} and vehicle A has the speed of V_{Amf}. m represents the number of stage, $m = 1,2,3,4,5$.

The horizontal distance between two vehicles is 3.75 m. vehicle B will have lateral movement of 0.75 m every stage. So the actual time t_m in stage m can be concluded by the equation (1).

$$V_{Bhm} + 0.5\alpha_{Bhm}t_m^2 = 0.75 \tag{1}$$

Then the distance of vehicle A and B, speed of A, lateral speed and longitudinal speed of B at the beginning of stage m+1 can be calculated by the equation (2).

$$\begin{cases} l_{m+1} = l_m + V_{Bm} t_m + 0.5\alpha_{Bm} t_m^2 - V_{Am} t_m - 0.5\alpha_{Am} t_m^2 \\ V_{B(\mathrm{m+1})} = V_{Bm} + \alpha_{Bm} t_m \\ V_{Bh(\mathrm{m+1})} = V_{Bhm} + \alpha_{Bhm} t_m \\ V_{A(\mathrm{m+1})} = V_{Am} + \alpha_{Am} t_m \end{cases} \tag{2}$$

At the end of the stage m, it is assumed that the vehicle A and B will complete the lane changing at the current motion state,. So the total time of lane changing process and ultimately speed and acceleration of vehicle A and B are available through the equation (3).

$$\begin{cases} 0.5\alpha_{Bhm} t_{mf}^2 = 0.75(6 - \mathrm{m}) \\ V_{Bmf} = V_{Bm} + \alpha_{Bm} t_{mf} \\ V_{Amf} = V_{Am} + \alpha_{Am} t_{mf} \\ l_{if} = l_m + V_{Bm} t_{mf} + 0.5\alpha_{Bmf} t_{mf}^2 - V_{Am} t_{mf} - 0.5\alpha_{Amf} t_{mf}^2 \end{cases} \tag{3}$$

4 The Expected Revenue

PICUD is introduced as evaluation of expected revenue and it means the difference between the distance of two vehicles and the stopping distance of avoiding collision. It is calculated as shown in equation (4).

$$PICUD = l_{mf} - \frac{v_{Bmf}^2}{2\alpha_{B\max}} + \frac{v_{Amf}^2}{2\alpha_{A\max}} - v_{Amf} t_r \tag{4}$$

α_{Amax} and α_{Bmax} are the maximum decelerations of vehicles A and B. l_{mf} is the distance between the vehicle A car and B, after lane changing is complete in the situation. t_r is the driver reaction time and vehicle braking system response time and its desirable value is 1s.

A. When PICID≥0, it indicates that there is a certain safety margin. Two vehicles can slow down within a given distance, even vehicle A has higher speed. The value of R_A is -10 and the value of R_B is 10.

B. When PICID<0, there is the same conflict between the two vehicles and there is no certain distance between two vehicles to keep safe. It is very dangerous for vehicle A and B, because collision situation that is not allowed will happen. So the value of R_A is -10 and the value of R_B is -10.

5 Conclusions

At present, our country's intelligent transportation is increasingly developed. We can get the exact vehicle location, speed, acceleration and other data by GPS, mobile positioning technology. Therefore, using of advanced positioning technology can help better control of the vehicle lane. In ICT, this paper establishes the vehicle lane changing model based on discrete dynamic game to help vehicles determine lane changing behavior and protect the safety of the vehicles.

This paper uses the method of dynamic game theory to analyze the behavior of lane changing. Based on one lane width 3.75m, the whole process is divided into five stages, and each stage can be calculated qualitative analysis to ensure the accuracy of the model. The decisions in each stage are discretize and quantized with a high accuracy. But on the analysis of the lane changing model, although there is a competitive relationship between vehicle A and B, in fact, there is more impact on them with other vehicles. So analysis in this model is simplified. In future studies, it needs to consider the influences and the game relations between the vehicles and establish a more scientific and complex model.

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References

Li Deren,Li,Yang (2008).“Techniques of GIS,GPS and RS for the Development of Intelligent Transportation.” Journal of Wuhan University,4,331-336.

Liu Xiaoming,Zheng,Jiang(2008). “Lane Changing Model Based on Discrete Dynamic Game.” Journal of Highway and Transportation Research and Development,25,120-125.

Song Lubin(2006). “Global Positioning System (GPS) in Highway Measurement.” Highways & Transportation in Inner Mongolia,1,83-84.

Wu Chaozhong,Yan Xinping(2001). “Automated highway system lateral control research.” Computer and Communications,19,23-25.

Zou Zhijun,Yang Dongyuan(2002). “Lane Changing Model in Microscopic Traffic Simulation.” *China Journal of Highway and Transport* ,15.

Real-Time Travel Information System Based on Wearable Technology

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Abstract: The real-time traveling information collecting and distributing systems are important parts of intelligent traffic system. However, the existing information collecting and distributing technology have been unable to meet people's personalized needs. The wearable technology that rises gradually has been widely used in the fields of medical, military and fashion. This paper applies the wearable technology to the real-time traveling information collecting and distributing systems. The real-time traveling information can be collected by the intelligent steering wheel cover, and is transmitted by wireless communication technology. At last, the information is distributed to users by intelligent watches. So, users can easily obtain the real-time traveling information.
Keywords: Real-time traveling information; Wearable technology; Information collection; Information distribution.

1. Introduction

Intelligent Transportation System (ITS) includes multiple subsystems. Traffic information collection system is an important part of ITS. With higher demands levels for transportation, it requests the collected traffic information to be real-time. The collected real-time traffic information is the foundation of advanced dynamic traffic guidance, traffic management system and traffic information system. Therefore, information collection system requires advanced traffic information detection technology to collect. The management effects and control effects of road traffic system are directly related to reliability, accuracy and real-time performance of traffic information detection (LIU X, 2011).

With the development of technology, tablet PCs and intelligent phones rapidly spread. Travelers easily get real-time traffic information by personal information terminals (such as in-vehicle information terminal, variable message boards, computer terminals and handheld devices, etc.) However, it's difficult to satisfy travelers' demands for comprehensive traffic information service and personalized real-time dynamic service because of the existing information service system and its manner of publication.

Wearable technology refers to a technology that users use wearable clothing (such as watches, glasses, etc.) which is embedded multimedia, sensors and wireless communications technologies to get access to health-related signs. It can support a variety of interactive modes such as gestures and eye movements operation. It can easily integrate and connect with users' daily needs tools and equipment. Wearable technology now is used in medical, military, fashion, computers, etc. With its convenient and smart features, this technology is applied to real-time traffic information collection and distribution system, developing into intelligent transportation.

2. The development of Wearable technology

Wearable technology in the medical field can be widely used in home health care, clinical control, emergency ambulance, sleep analysis, special populations care, aerospace, heart evaluation, physical training and other aspects. The so-called wearable applications in the medical field is a detection system which can be "put" on the body, that is, using daily clothing and accessories to collect the physical information of people's bodies. The specific approach is making integration of medical researchers' sensor rings, watches, clothing and other apparels, which makes people feel comfortable, get their own signs monitoring parameters and their health status (ZHENG J W, 2008). Now, the concept, forms and functions of wearable devices are all in constant evolution and the product has become increasingly diverse belonging to the product of "human unity" concept (ZHU Y H, XU B Y, WANG X F, 2013).

With the development of technology, the formal technology products of wearable technology mainly include intelligent glasses, intelligent watch, intelligent bracelet, GPS tracker, BrainLink idiodynamic headband and other products.

Tab 1.The technology and function of wearable technology products

Products	Technology	Function
intelligent glasses	Micro-display screen on the upper right side of Google glasses, 720p camera on the right side of the glasses, the touchpad, speakers, a microphone, a gyro sensor and in-built battery able to support 6 hours installed	It combines sound control, navigation, photography and video chatting functions with all the features of mainstream smart phone, communications and data services.
intelligent watch	iOS system installed, supporting Facetime, WiFi, Bluetooth, Airplay, Retina touchscreen capabilities, 16GB of storage space,	It displays part of the message can be presented on the smartphone, such as phone calls, text messages, maps and weibo by display screen.
intelligent bracelet	GPS, gyroscope, accelerometer needles and other sensors that can measure the wearer's physical	It records human movements, sleep, diet and other health-related data by matching software to help

	activity, calorie consumption and so on	consumers adjust rest rules, enhance health and achieve a healthy life.
GPS tracker	GPS chip	It trackers lost equipment according to the GPS chip and achieves GPS positioning with the software and real-time transmission of information to the user.
BrainLink idiodynamic headband	Smartphone, tablet PCs, laptops, smart TVs and other devices linked by Bluetooth with the appropriate application software	It helps phone or tablet know the status of user's brain timely, for example, whether user is focused, tense, relax or fatigue. User can also adjust the focus degree and relaxation degree to give instructions to Mobile Phone Tablet.

3. Wearable technologies in Transit

Urban traffic information system provides varieties of traffic information system for travelers, able to reflect latest real-time traffic information because travelers always develop travel plans based on real-time traffic information before the travel or at the process of changing travel plans. Each traveler's demands for traffic information are different also limited, but all the information demands of all travelers get together to be a lot. So, urban traffic information system should provide travelers with a lot of comprehensive traffic information.

Traffic Information is various. According to the different characteristics of travelers' demands, information can be divided into dynamic traffic information, static traffic information and related traffic information. Dynamic traffic information changes over time and space, including the basic information of traffic jam, car incidents, travel time, location and driving routes, traffic guidance information, traffic control signals. Static traffic information may remain unchanged or changed very little over a period of time information status, including the distribution of transportation, parking, transfer points, ticket selling stations, the charged prices, traffic restrictions, construction and maintenance information, road conditions, etc. Related traffic information refers to other information related to traffic travel, such as travel, hotels, entertainment, shopping, weather, sports, etc. ([YANG L Q,ZHANG N,TAO Z X, 2007). In addition, the vehicles' own information includes fuel consumption, vehicle mileage and inspection notification.

Urban traffic information system includes three subsystems of information collection, information processing and information distribution. Wearable technology can be applied to the information collection and information receiving terminal. The system consists of three parts: the intelligent steering wheel covers, urban traffic information center and the users' intelligent watches system as is shown in Figure 1.

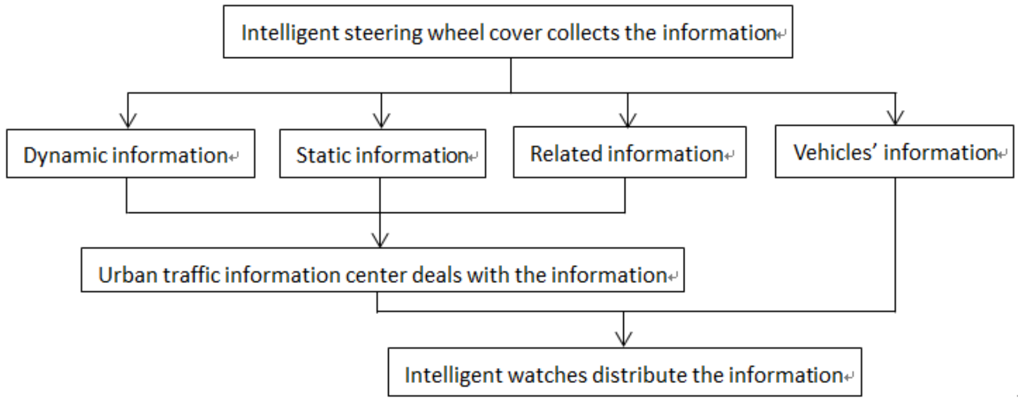

Fig.1 The structure of wearable real-time traveling information system

3.1Wireless Communication Technology

Nowadays, information transmission sends information mainly through cable transmission or wireless transmission. People's traveling mainly relies on travel motor and non-motor vehicles. Movability is a major character of travel, so the information terminal system can only receive information through wireless communication. With the development of technology, GPRS and CDMA networks have almost universal coverage. By the two networks, we can achieve real-time remote transmission of data. Therefore, wireless communication technology among the systems uses CDMA networks (YU C Q, 2002). In addition, when the distance between the intelligent steering wheel cover and the intelligent watch is near, Bluetooth wireless communication can be used. But Bluetooth communication distance is limited. When the user is away from the vehicle, unable searching the Bluetooth signal, it automatically changes into CDMA transmission network. Wireless communication function can be added into the design of intelligent steering wheel cover.

3.2Power supply Mode

Wearable system is a kind of mobile terminals. Power is the key of wearable function. High-performance but low-power batteries and related supply methods are mainly used. Intelligent steering wheel cover is powered by the vehicle terminal and intelligent watch is powered by small lithium batteries.

4. Functional Design

4.1 Intelligent steering wheel cover designs

Intelligent steering wheel cover is an intelligent vehicle signal acquisition sets with sensors and electronics devices. Seemly to be an ordinary steering wheel cover, it can collect dynamic, static, related traffic information and transmit i to the urban traffic information center through the CDMA network. Also, it collects vehicles' information and transmits it via the Bluetooth network or CDMA network to the users' intelligent watches.

Intelligent steering wheel cover can achieve the functions of information collection, driving recording, drunk driving test and so on. Its main functions are shown in Table 2.

Tab 2.The functions intelligent steering wheel cover can realize

Functions	Details
information collection	It can get the information of the current vehicle speed, location, direction, travel distance and so on.
driving recording	It is the part of the driving tracker. It records, stores, displays and prints the information of vehicle speed, time, mileage, operation conditions and other information which is transmitted to the smart watches to record.
drunk driving test	It can detect whether the driver is drunk. If driver is drunk, the vehicle will shut of the engine automatically.

The details of function achieving are as follows:

(1) Location information collection mainly obtains location information via the VPS. Now it mainly relies on GPS satellite positioning technology to track the location of a vehicle. When the GPS acquisition module is embedded in intelligent steering wheel cover, users can directly read the current location information from the GPS acquisition module.

(2) It directly reads the information of vehicle speed, trip information, fuel consumption and other information from the vehicle's own vehicle speedometer, odometer and oil gauge. Information then will be transmitted to intelligent steering wheel cover via the CAN bus (fieldbus).

(3) Traveling direction may be determined by the Grating encoder and other angle sensors. Grating encoder output signals can be directly input into timer part of processor, confirming the angle turned by a counter technique.

(4) Testing drunk driving can be achieved by sensors embedded in the intelligent steering wheel cover. If the driver's alcohol level reaches a certain amount, steering wheel sensor detects the alcohol from the sweat of palm. Vehicle will shut off the engine automatically, unable to start up.

4.2 Intelligent watches design

Since more and more people use mobile phones, people who used to wear a watch become less and less for phones can completely replace the watches' timekeeping function. Watches become an ornament or a symbol of noble status. With the development of technology, watches also gradually step into the intelligent era. With the emergence of intelligent watches, it can not only achieve the function of timing, but also help users experience the more new features of watches.

The main function of the intelligent watches is receiving the data sent by the intelligent steering wheel cover and urban traffic information center.

Achievable functions are as follows:

(1) Alarming. Intelligent watches receive the speed information from steering wheel cover when vehicle moves on the roads with speed limits. If the vehicle is overspeed, it will tell owners by vibrations. Also, intelligent watches can show the remaining oil and remind the owners of refueling with vibrations. Owners can also check remaining oil in advance avoiding the embarrassment of not finding a gas station when away from home. If there is a road traffic accident or a traffic jam ahead, the watch will vibrate to warning the user. Then the driver can select the travel route again with the real-time information. In addition, people usually forget where vehicle is parked after shopping. At this time, simply clicking on the intelligent watch, users can accurately get their vehicles' location via GPS. When it comes to the vehicle inspection time, intelligent watches will remind owners in advance.

(2) Inspection. After parking for a long time, owners begin to suspect that they have not locked the central locking, but it's far away from the vehicle. Owners just tap on the wrist watches border to light up the screen and see whether the door is locked instead of getting back to the vehicle.

(3) Customization. There are three user-defined function keys in the left side of the watch. The owner can set the function buttons according to their needs, such as navigation, multimedia remote control, sending text messages or looking around nearby. In addition, based on GIS maps, the system uses the vehicle location technology getting users' locations and showing the surrounding location information .Besides, the system can constantly update information when users move. They can check the information including photos near the monitoring point, highway entrances and exits, toll stations and other information.

5. Conclusions

This paper introduces real-time traffic information collection system and distribution system based on wearable technology, which uses intelligent steering wheel cover to get the basic real-time traffic information, transmits information to the urban traffic information center through wireless communication technology and finally distributes information through the users' intelligent watches. Users can know their vehicle conditions, road conditions, traffic conditions and any surrounding traffic information by intelligent watches.

The application of wearable technology in traffic is in two forms, intelligent steering wheel cover and intelligent watches. The technology of intelligent watches has become matured, with only some improvements on functions to do. Intelligent steering wheel cover needs building in-sensors and electronics technology which are able to achieve with today's science and technology development. With the use of wearable technology in traffic, it can be more convenient, smart and fast for travelers getting access to real-time traffic information so that the ways of real-time traffic information collecting and distributing will updated. With the development of technology and the popularity of the wearable products, wearable technology in traffic will go further in application and development.

References

LIU X,(2011). *Collection and Processing Method for Intelligent Traffic System based on IPv6*.JI LIN: Ji Lin University.2011.

YANG L Q,ZHANG N,TAO Z X,(2007). *Application of 3rd Generation Mobile Communication Technology in Urban Transportation Information System*. Journal of Highway and Transportation Research and Development. 2007：12-0132-04.

YU C Q,(2002) *Dynamic Information System of Real-time Traffic Data on Beijing Road Network*. Journal of Transportation System Engineering and Information Technology. 2002:03-0022-07.

ZHENG J W,(2008). *Real-time diagnosing, alarming, mobile monitoring health system based on wearable technology*. China PLA Military Medical Science Academy of the PLA.2008.

ZHU Y H, XU B Y, WANG X F,(2013). *Discussion and Application on Intelligent wearable technology*. Science & Technology Information. 2013：11(a)-0026-02

Analyzing Travel Time Variability on Transit Routes Using GPS Data

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Abstract: Travel time variability has been considered as an important quantitative measure of bus service reliability. It deteriorates reliability by increasing in-vehicle travel time and passenger waiting time. Less attention has been paid to it due to the lack of reliable data. The problem is being addressed by the use of advanced public transport systems. The paper mainly used the GPS data to explore the form and the extent of travel time variability at different times of the day. The process of data cleaning was built for the characteristics of bus GPS data in Chengdu. The appropriate measures of travel time variability based on the travel time distributions were adopted by the study to make the best use of the abounding data. At last, the paper briefly discussed the factors which might affect the travel time and proposed aims for the further research.
Keywords: Travel time variability; Data analysis; GPS data; Travel time distribution.

1 Introduction

Bus service reliability can be defined as the ability of the service to provide a consistent service over a period time. (Avishai, 1977) For passengers, it means the accessibility of transit system, the stability of travel time, and the predictability of the arrival time. For operators, the high quality of service reliability will make the operation of bus system efficient and the service satisfaction high.

Reliability is a compound concept and can be described by several factors. (Seung-Young, 2005) Among which, travel time variability is one of the quantitative measures of reliability.

The high variability of travel time makes passengers anxiety about the waiting time and in-vehicle time. It also brings difficulty to operators to maintain the regular headway and normal schedule. Therefore, the use of run time variation as a reliability indicator is the most appropriate for routes that cover longer distances with many signalized intersection and in cases in which traffic delays and passenger loads are irregular from day to day. (Strathman et al)

Despite its importance, less in-depth attention has been paid to travel time variability, mainly due to the difficulty in collecting complete and reliable run time data. This problem is being solved by the use of advanced public transport systems which collect and record operational data automatically.

The paper used GPS data from automatic vehicle location system combination with smart card data to get complete trips of route 8 in Chengdu. Day-to-day travel time variability is selected as the quantitative measure of service reliability. And the study explored the form and extent of travel time variability at different times of the day.

2 Literature review

Due to the different aspects of reliability, it is defined in a variety of ways. Turnquist and Blume suggest it is “the ability of the transit system to adhere to schedule or maintain regular headways and a consistent travel time.” (Turnquist& Blume，1980) Abkowitz offers a broader definition: the invariability of transit service attributes that affects the decisions of both the user and operations. (Abkowitz, 1978) The complex meaning of reliability leads to a variety of quantitative indicators.

Many papers studied the measure of service reliability. Some indicators are based on the operational level. Avishai considered travel time variability as an indicator of reliability and fitted a beta distribution for travel time. (Avishai, 1977) Strathman et al analyzed the service reliability on selected routes which used a new bus dispatching in Portland, focusing on running times, headways, and on-time performance. (Strathman et al) Seung-Young et al considered different definitions of punctuality in different situations and calculated punctuality indexes for different types of bus routes. (Seung-Young, 2005)

Although many researches discussed the indicators of bus service reliability on operational level, some of them suggested that the reliability perceived by operators and passengers is different. Therefore, the passenger-centered reliability awareness is appeared to grow. Some researchers studied the customer-oriented service standards and scheduling. (Peat et al, 1980; Furth&Muller, 2007) And others developed the customer-driven metrics which could be useful and meaningful for both customers and operators. (Schil, 2011)

From the previous studies, the indicators of service reliability on operational level mainly were about two aspects: travel time variability and punctuality. The metrics of passenger-centered reliability focused on the time consumed by a travel. However, any indicators described reliability should be chosen to be consistent with the operation environment. In some countries, the service frequency of bus is low, so the passengers’ behavior is affected by the schedule and the punctuality is meaningful for the operation. The situation is different for many large cities in China. Due to the high passenger volume, the scheduled frequencies are high even during off-peak and there is no such a timetable which sets the scheduled time at each stops. For this operation environment, the calculation of passenger-driven metrics is complex and the meaning of punctuality lessens. Therefore, more attention should be paid to the travel time variability.

Carrion and Levinson state that travel time variability is caused in general by predictable (e.g. peak hour congestion) and unpredictable (e.g. incidents) variations. The paper is aimed to explore the extent and form of variability at different times of day.

Travel time variability can be mainly viewed from 3 perspectives including vehicle-to-vehicle variability, period-to-period variability, and day-to-day variability. The paper focuses on day-to-day variability which can be defined as the variation of travel time of the same journeys made at the same time on different days.

3. Data

The GPS data and smart card data collected by advanced public transport system are gradually used by a variety of researches. Although data acquired in this way should be richer and more reliable compared to the manual survey, much work would be conducted to improve the quality of data and get the useful information. (Hounsell, 2011) The high quality of data is premise for next analysis. This section briefly introduces the basic information about the data as well as quality issues of the data used by the study and data cleaning methods.

This paper used the GPS data of route 8 in Chengdu. The route runs from HUA Longmen Station in west of Chengdu to the SHL Lidian Station in east of Chengdu. The length of the route is consistent with the length of the town and it connects to two subway station at its midway point. It is one of the busiest bus routes in Chengdu with an average ridership of 60,000 on weekdays, proving a typical route for conducting travel time variability. The route operates with 2.5 to 12 minutes scheduled headways in both directions. The data available for this application includes GPS data and smart card data of route 8 for the 16 weekdays of November, 2014. Table 1 is a list of the major characteristics for route 8.

Table 1.Characteristics of route 8

Characteristics	Direction	
	Eastbound	Westbound
Length(km)	20.9	21.9
Traffic signals	39	40
Number of stops	35	36
Average stop spacing(m)	615	626

The original GPS data includes two types of data. The first type of GPS data records the operation information of vehicle which transmission interval is less than 15s. The second type of GPS data only records the information when vehicle arrive at each stop or depart from each stop.

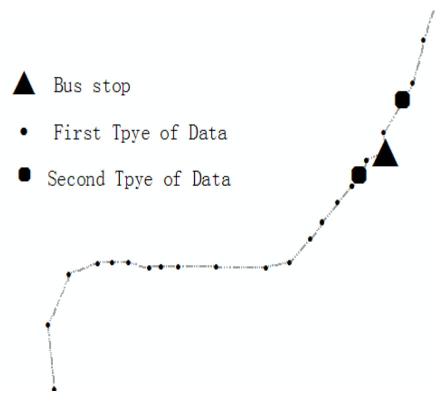


Figure 1. Two types of data

The figure 1 shows the relationship of two types of data. Taking into account the purpose of the study and characteristics of data, the paper tended to use the second type of data to analyze the travel time variability. Useful fields extracted from original data including recording time, speed of vehicle, vehicle ID, stop ID, longitude, and latitude.

In general, the special geographical environment such as tunnels, boulevards, etc may cause the loss or delay of GPS positioning signal even recording errors. Specifically, there are three kinds of problem for GPS data in Chengdu including duplicate data, irregular data and missing data. The paper establishes data cleaning process which mainly consists of two steps to get the reliable trips from the original data. In the first step, the original data were divided into distinguishable trips. Figure 2 is a flow chart for the first step. The second step is to identify the problems may exist in the initial trips and to deal with them. In final, the paper marked 97,859 duplicate records, 4,307 missing record, and 465 irregular records.

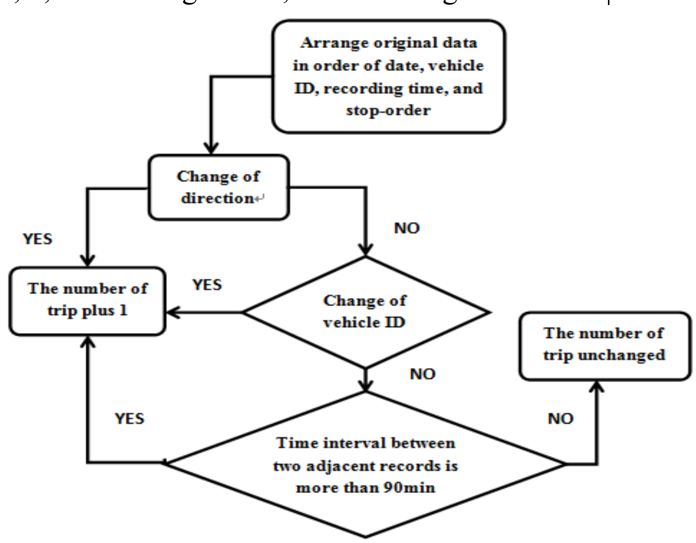


Figure 2. Flow chart for data cleaning

4. The analysis of travel time variability

After data cleaning, 7537 trips were used for travel time variability analysis. The run time for the whole route was calculated from the departure at the first stop until the arrival time at the last stop. Furthermore, the run time within the First Ring Road of Chengdu, the run time from the First Ring Road to the Second Ring Road, and the run time outside the Second Ring Road were calculated by the same way for deeper analysis.

Travel time distributions are an important area for this study because they describe the nature and pattern of variability and exploring the causes of travel time unreliability. This section aims to investigate the form and extent of travel time variability by exploring the shape of travel time distribution in different 15min interval.

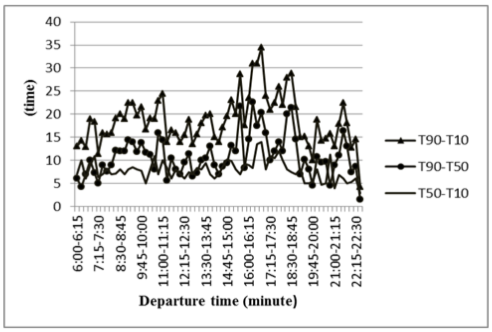
Table 2 shows a series of key descriptive statics for run time. The skewness is a measure of asymmetry of a distribution, while the kurtosis measures the weight of tails in relation to the rest of a distribution. The distribution of run time for the whole route as well as run time within the First Ring Road is close to the normal distribution because of the low value of the skewness and the kurtosis. However, the run time from the First Ring Road to the Second Ring Road and the run time outside the Second Ring Road are skewed distributions which have longer tails than those in a normal distribution for the high value of kurtosis and the observations cluster more.

Table 2. Descriptive statistics of run time

Statistical items	Mean value(min)	SD	Skewness	Kurtosis
Run time for the whole route	98.5	4.5	0.49	0.80
Run time within the First Ring	46.2	9.2	0.42	0.47
Run time from the First Ring to the Second Ring	19.5	3.6	2.57	38.2
Run time outside the Second Ring	32.9	5.4	1.86	8.17

The analysis of travel time variability is based on the percentiles for the travel time. The value of T90 shows that 90% of travel time values are less than this value, while the value of T10 indicates that 10% of travel time values are less than it.

There are four measures of travel time variability for further analysis. T90-T10 illustrates the width of the distribution. The higher value of it means more variable travel time. (T90-T10)/T50 is the width of the distribution relative to the median. T50-T10 is a measure of how early trips relate to the median. And T90- T50 is a measure of how late trips relate to the median. Figure 3, Figure 4, and Figure 5 presents these four measures in different 15 min intervals over the day for both directions. The T90-T10 measure peaks in the evening peak for both directions, while it shows significant increase in morning peak only for the eastbound. And the trend of the T90-T50 is almost parallel with the T90-T10, while the T50-T10 has a gentler trend and shows slight increase in peak hours.



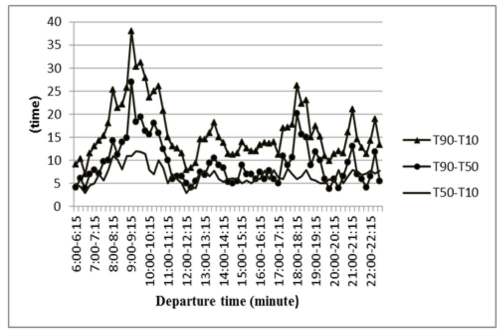


Figure 3. TT percentiles of eastbound **Figure 4. TT percentiles of westbound**

It can be concluded that the travel time of eastbound experiences a more significant variation in the morning compared to the evening peak and has a slighter variation in the afternoon and evening. The situation of westbound is quite different for the slight increase in the morning peak and the irregular increase in the afternoon. In addition, the lateness is responsible for higher values of T90-T10 for both directions.

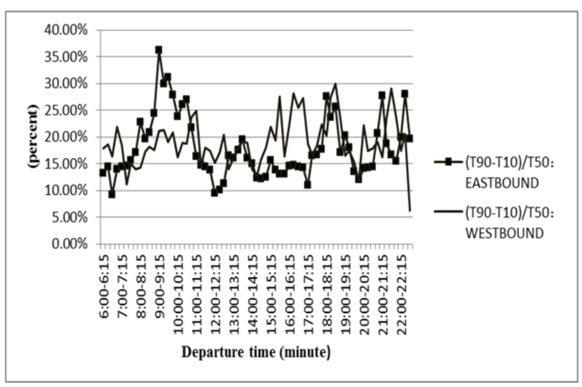


Figure 5. TT percentiles for both directions

It is proved that day-to-day variability is caused by fluctuations in travel demand, variation in driving behavior changes in the amount of roadside activity, accident and other reasons. (Ehsan et al, 2010) Travel time variability is mainly affected by the demand of commuter passengers and traffic condition in the peak hours, so it can be considered that the eastbound is the main direction of commuter traffic cause the high value of the T90-T10 in peak hours. However, the situation of westbound is more complex.

For the further analysis, the paper studied the form of travel time variability for the different sections of the route. The paper presents the (T90-T10)/T50 which is a relative measure of travel time variability for both directions in Figure 6 and Figure 7. It can be seen that the form of travel time variability within the First Ring Road is more significance in peak hour for the eastbound. For the westbound, the travel time variability is gentle and has a slight increase in peak hour which is different from the whole route. The more intense variability for the First Ring Road may be caused by more congested traffic and higher passenger volume. It is proved that the eastbound is still the main direction of commuter traffic for the First Ring Road. However, the variability of the westbound for the Second Ring Road has a large fluctuation, and the maximum value of the measure is higher than the value of eastbound in the peak hour. In a sense, it can be concluded that the irregular variability for the whole route in the afternoon is largely due to the high variability outside the Second Ring Road.

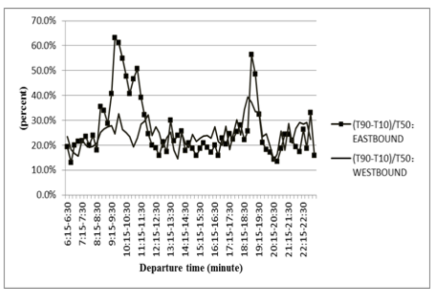


Figure 6. **TT percentiles within the Frist Ring Road**

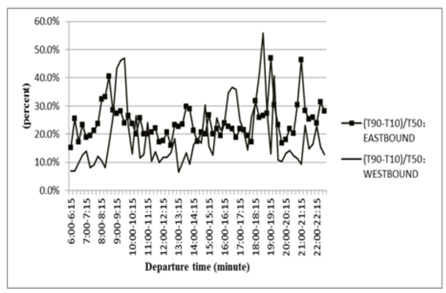


Figure 7. **TT percentiles outside the Second Ring Road**

In addition, the paper tried to explore the factors which may have an effect on the travel time. The whole route was divided into six sections in order to develop the model using a linear regression analysis. Several factors including section length, number of traffic signals, number of stops, number of boarding, and time period is considered in the model by using 8475 records. The result shows that the factor of section length has the highest positive coefficient value (0.65). The number of stops and the number of traffic signals are both significant. The conclusion is almost consistent with the previous studies. However, further analysis should be conducted based on more records.

5. Conclusion

Despite of the importance of travel time variability for public transport, limited research has been conducted on it partly because of the difficulties in collecting the travel time data of operation. This paper explores the approach to analyze the travel time variability using GPS data of certain route in Chengdu.

First, the paper explains why the travel time variability could be considered as the most appropriate measure for the service reliability of bus system based on previous studies and domestic operation environment. Second, the paper illustrates the characteristics of the data used by the study and builds up the process of data cleaning to acquire the reliable data from the original GPS data. Travel time percentiles are selected as the measure of travel time variability to analyze the form and the extent of the variability. The results show that different directions as well as different sections of the certain route have different features in travel time variability. The variability in peak hours may be caused by the higher passenger demand and more congested traffic. However, the irregular large variability in off-peak hours may be due to the complex reasons related to the characteristics of a certain route which should be further investigated.

Although the approach of studying bus GPS data in this paper provided a valuable method for analyzing GPS data, there is much scope to broaden the range of application of the data from advanced public transportation system. And the deep meaning of travel time variability should be mined in the environment of big data.

The next step for the study would combine the analysis of travel time variability with headway to see how travel time variability deteriorates the headway. The features of travel time variability for routes with different characteristics could be further explored. And deeper research should propose some measures to improve the service reliability of bus system.

Acknowledgements

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References

Abkowitz M.（1978）. “Transit service reliability.” USDOT Transportation Systems Center and Multisystems.

Abkowitz, Isreal Engelstein. （1981）. “Factors affecting running time on transit routes.” Department of Civil Engineering.

Avishai Polus. “Modeling and measure of bus service reliability.”*Tanspn-Res Vol 12,253-256.*

Ehsan Mazloumi, S.M.ASCE1, Graham Currie, Geoffrey Rose.（2010）. “Using GPS data to gain insight into public transport travel.” *J.Transp.Eng. 136:532-631.*

Furth, Muller. (2007). “Service reliability and optimal running time schedules.” *Transportation Research Record 2034:55-61.*

Hounsell, B.P.Shrestha, A.Wong. (2012) . “Data management and applications in a word-leading bus fleet." *Transportation Research Part C 22(2012):76-87.*

Mickael Schil. (2011). "Measuring journey time reliability in London using automated data collection systems." Massachusetts Institute of Technology.

Peat, Marwick, Mitchell, Co. (1980). "Service Frequency, schedule reliability and passenger wait times at transit stops." Cornell University, Ithaca.

Strathmen, et al. "Automated bus dispatching, operations, control, and service reliability baseline analysis." *Transportation Research Record 1666.*

Seung-Young Kho, et al. (2005). "A development of punctuality index for bus operation." *Journal of the Eastern Asia Society for Transportation Studies, Vol. 6:492-504*

Turnquist M, Blume S. (1980). "Evaluating potential effectiveness of headway control strategies for transit systems." *Transportation Research Record*

Xumei chen, Lei Yu, Yushi Zhang, Jifu Guo. (2009). "Analyzing urban bus service reliability at the stop, route, and network levels." *Transportation Research*

RITS-Based Intelligent Railway Dispatching System's Vision

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Abstract: At present, the level of our nation's information of traffic dispatching system is low. Some dispatching departments did not form a complete and unified dispatching system .This will result in security risks, reduce the quality of services and transport efficiency. Been unable to meet the railway sector under market conditions demand for dispatching, the new dispatching system development is imminent.

In this paper, we contrary to the current status of China's dispatching system, for a brief analysis of its shortcomings and possible impact. Meanwhile, according to market needs, proposed the concept of intelligent dispatching system, combined with China's specific conditions and customer needs, the existing dispatching system is divided into eight sub again. By introducing RITS overall research program means, Through the demand for internal railway system users dispatching system analysis, and then，complete the intelligent traffic service dispatching system logic architecture and function architecture. Make the system tends to be more complete, and provide some idea of the intelligent railway traffic control system innovation.

Keywords: Intelligent railway; Intelligent dispatching system; The overall scheme.

1 Intelligent Dispatching System Vision

One obvious drawbacks of our existing freight traffic dispatching system is less degree of information, among dispatching department information can not be comprehensive, and timely interaction. It did not form a complete, unified dispatching system, result in safety hazards, reduce the quality of services and transport efficiency. Based on the rapid development of China's current status of railway intelligent technology, and after the rail transport market, the competition with other transportation industry intensified unprecedented. I put the new era of intelligent vision dispatching system.

The new era of intelligent railway traffic control system need first to solve the scheduling department information exchange each other difficult, and the question there is no unified dispatch system. By relying on intelligent transportation technologies, combined with the current demand for railway dispatching system, overall layout. This paper based on the dispatching system and new demands. Divided the system into planning scheduling, locomotive scheduling, vehicle scheduling, freight scheduling, train dispatching, construction scheduling, power scheduling and comprehensive maintenance scheduling eight parts. By building a interconnected unified whole, to guarantee dispatching various aspects of information interoperability, timeliness and accuracy. Scheduling process to achieve the various departments, real-time sharing of information among all sectors. Meet the transport train conductor production and meticulous management requirements, so dispatching efficacy can be fully realized.

2 RITS overall technical scheme of step

RITS overall technical scheme of the steps shown in Figure 1.

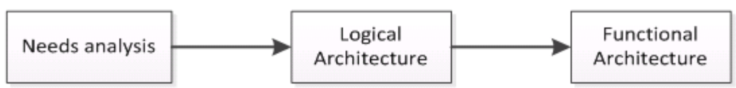

Figure 1: RITS overall technical scheme of step

Step 1:System Requirements Analysis

The system will be faced with specific management issues and transportation services for system development requires research.To fully elucidated the question of this system "what to do" ,to build the railway to make intelligent transport systems tend to be more intelligent and Information Technology. To ensure the security of cargo, to achieve timely delivery, better lay the foundation for customer service.

Step 2:Determine the content of the service architecture

On the basis of the analysis of business requirements, classify, merger, and consolidation,form RITS service architecture content based on the formation of intelligent scheduling needs of cargo transport. We can clear that what kind of service can be provided each RITS.

Step 3:Clear all business platform features

Business platform capabilities need to start from the service architecture, determine the system should have the main function. Corresponding with service, function of the system can be completed by some combination of a particular service. And analyze the interaction, the interactive content between internal logical structure business.

3 Intelligent Dispatching System Requirements Analysis

The purpose of the intelligent traffic dispatching system needs analysis, Aimed at breaking the "information silos" and "fragmentation" of the state of the existing railway. Adoption "system construction integration" of research ideas, starting from the entire intelligence freight services process. Analyze business requirements and its subsidiaries manage demand, in order to build a comprehensive information structure unit as a whole.

Specific analysis of the implementation process to follow, "drill down, from outside to inside, combined with near and far" method in accordance with the RITS system requirements. To build intelligent railway system based on time fundamental needs as the starting point. For intelligent railway transport tasks to be completed by the business process needs analysis. While the overall system as the foundation, gradually raise the goal of building subsystems, obtained division of structural units. Through information exchange technology aggregated into an organic whole, ensure linkage and purpose of each segment structural units of business processes are the same. Finally, we use goal-driven method develop services, making the system practical guidance and can boot the system the forward way.

3.1 Planning and scheduling needs

We need to establish a system of traffic projections，it can project the distribution of real-time traffic that day and the next day and the traffic trends. On the basis of the traffic projections and the basic diagram, achieve planning and scheduling can collaborative preparation boundary handover of heavy vehicles and emptying plan; marshalling scheduling and planning and scheduling collaborative preparation the marshalling starting train plan, make integrated scheduling system and subsystem can share information.

You can get the train automatically attribute information, real-time automatic updates actual train running time, train marshalling content, achieve access, produce summary statistics of the traffic service and traffic forecasting, early warning. Station technical working train diagram can display the number of lines to send and automatic correction; You can also automate statistical analysis plan to honor rate, the actual transfer of the station boundary columns, number of trains, motorcycles reentry frequency, and the time; Through the system to the train dispatching and locomotive scheduling issued freight trains daily plan and adjust the plan and adjust the plan; According the station train, in-transit vehicles, and daily demand plan. Projections with air required by the stage, classes plans should be submitted at the same time generate with empty plans. Traffic condition according to the set focus, related traffic tracking tips; Automatic generation locomotives, and technical capabilities warning.

3.2 Locomotive scheduling needs

Locomotive locomotive scheduling service primarily for the establishment of a dynamic tracking database,by TDCS, the station reports, and reports to track locomotive depot in transit, at the station and the information in paragraph,track locomotive, locomotive repair tips, labor crew super alarm.According the trains daily plan, automatically generate locomotive diagram, and the crew plans to send classes,conduct analysis locomotive.The locomotive diagram reached maintenance department.Monitor the actual implementation of locomotive working diagram,surveillance crew over labor conditions and help deal with locomotive accident.

3.3 Vehicle scheduling needs

Vehicle scheduling needs according to each depot maintenance vehicles numbers and standard,the median standard depot repair station,median standard of repair station,day disabled train repair,plant repair,planned completion date of the number ,the actual number of completed,depot repair, temporary repair to be scrapped, identification car, car accident, car assembly segment repair case,provides vehicle maintenance generated statistical reports,dynamic update trucks use state.We need to within the jurisdiction of passenger and cargo vehicles loopback overhaul plan and key requirements,in the station, in-transit vehicle breakdown, repair dynamic distribution, provide transportation and loopback generate hang plan to achieve dynamic control.

3.4 Freight scheduling needs

Freight dispatcher responsible for loading and unloading trucks each station plan,responsible for approving the work,shippers schedule loading date.Office of the cargo transfer system requests based on traffic projections and the priority automatic approval empty.Auto arrange trucks plan based on the situation and recognize the train unloading.The loading and unloading trucks plan broken down into the various stations and issued stop execution,the station automatically returns the actual loading and unloading trucks.In the long-term system.Intelligent cargo tone will change from passive to active,analysis of transport demand shippers,initiative for the owner to arrange trucks plan,determine transporting cargo plan.Estimated sub-periods pipe weight distribution and the expected arrival time of the service.

3.5 Traffic scheduling needs

Traffic scheduling needs based on actual daily plan and driving,planning phase,and analysis and adjustment the late trains;Safety information monitoring and safety information release,safety precautions promptly reached under various stations ;Daily plan text commands automatically form,accepted plan dispatcher stage plan,automatic on the diagram;Warning to form the focus of the train operating conditions during system running,Train collision check;Achieve a set of commands between each command and the feedback on the implementation form mechanism of mutual control information.On receipt of the case can automatically check and prompt,order to achieve a preview before release,command can be queried by construction plans,you can query by construction plans and other services.

3.6 Construction scheduling needs

Construction scheduling needs preparation of annual and monthly construction plans,receive applications for the construction of various departments, organize the construction approval;Increase in construction plans on the day shift plan diagram;Issued construction scheduling order,Supervise the construction process;Analysis of planned and actual construction.

3.7 Power scheduling needs

Power plan execution,complete stop transmission operation;Monitoring and management operation of the power supply system;According to the need for timely adjustment of power plan;When the power supply equipment failure,Processing power equipment failure;Management of power supply system overhaul plan and maintenance operations.

3.8 Comprehensive maintenance scheduling needs

Comprehensive maintenance scheduling needs organize and direct the implementation of a comprehensive maintenance plan,manage the maintenance operations;Grasp the system of monitoring and analysis;According to the maintenance,proposed speed train proposa;Responsible for organizing the infrastructure,repair equipment;Master affect the safe operation of the train disaster situations.Centralized monitoring of communications,signal and working condition of information system equipment;Tissue repair communication signals.

4 Intelligent Railway Traffic Control System services and functions architecture design

Intelligent Railroad transportation of goods traffic scheduling system is a complex information system involves multi-disciplinary, multi-disciplinary fields.Its architecture is a service to provide services functional architecture,it answers the system can provide what services, and how to provide services.Using a reasonable model to describe the system requirements, structure, data, and linkages,make complex information easy to understand.Facilitate the entire intelligent traffic scheduling system forming a comprehensive understanding.

Through a comprehensive analysis of the needs of freight intelligent dispatching system,should have the corresponding functions.The purpose of this system is that services framework to integrate a variety of business needs,formation of various subsystems in order to meet the demand of users.Collate the results of needs analysis,merging those requirements and the nature of similar.Obtain services framework of the system.

And then,build a whole dispatching by planning and scheduling subsystem,locomotive scheduling subsystem,vehicle scheduling subsystem,freight scheduling subsystem,dispatching subsystem,Construction scheduling subsystem,power scheduling subsystem and comprehensive maintenance scheduling subsystem.These subsystems were driving task dispatching the corresponding item,including the collection of appropriate information, the preparation of the plan, issued the order and the information release.The following figure shows the service architecture and functional architecture.

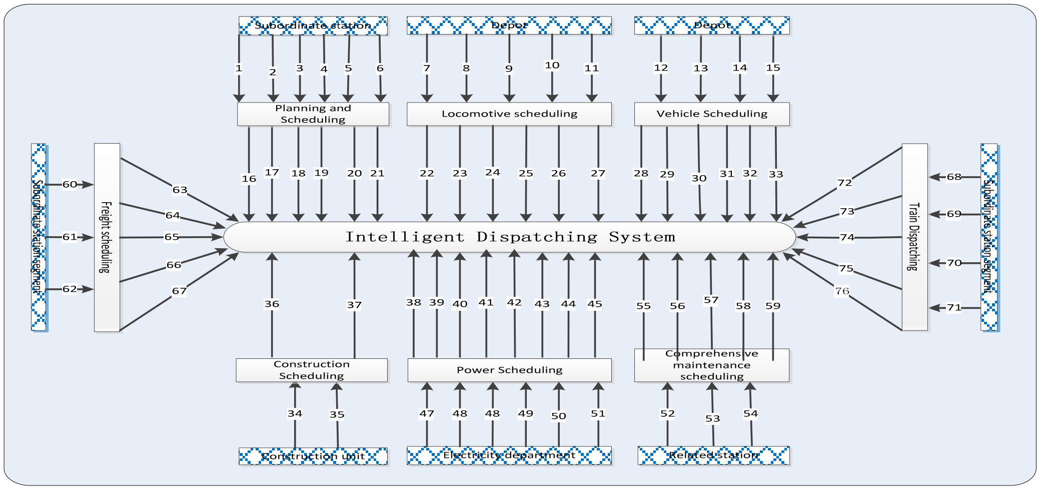

Figure 2：Intelligent Dispatching System services and functional framework

Note： 1.CDB Program Reported 2.Related Equipment Information 3.Operational data 4.Accident Situation 5.Daily program-related information 6.Traffic information 7.Motorcycle basic information reporting 8.Driver Crew Information 9.Locomotive status monitoring 10.Locomotive running state 11.Locomotive fault information 12.Vehicle Information 13.Rescue Train Information 14.Vehicle use of information 15.Vehicle fault information 16.Train Information query results 17.Device information query, analysis 18.Results of operational data analysis 19.Accident Analysis results 20.Day planning results and the evaluation report 21.Traffic projections 22.The result of Locomotive information inquiry 23.Drivers crew information query results 24.Motorcycle Safety Information query results 25.Troubleshooting locomotives and cause analysis 26.Preparation locomotive plan 27.Maintenance Index statistics 28.Vehicle use management results 29. preparation vehicle distribution adjustment plan 30.Vehicles using the data analysis results 31.The results of rescue train information 32.Preparation of the vehicle maintenance plan 33.Preparation of vehicle scheduling command 34.The construction plans 35.The construction of command 36.Construction plan approval results 37.Preparation of construction order 38.Failure Analysis 39.Power Equipment Information query results 40.Power equipment monitoring information query results 41.Production of daily supply plan 42.Preparation of power dispatch command 43.Power plans to adjust the program 44.Troubleshooting program 45.Service Information query results 46.Failure to report 47.Power Equipment Information 48.Power Supply Information 49.Power Plan Related Information 50.Fault information reporting 51.Repair Information 52.Security technology solutions 53.Maintenance Resource Information 54.Maintenance Job Information 55.Preparing comprehensive maintenance plan together 56.Approval of safety technology solutions 57.Allocation of resources to develop maintenance plans 58.Completion of repair work query results 59.Maintenance operations Analysis 60.Truck Information 61.Shipping Information 62.Scheduling information 63.Change of cargo flow forecast 64.Preparation of loading and unloading trucks plan 65.Scheduling order preparation 66Specific pathways management 67.Preparation of special circumstances scheduling command 68.Train running status 69.Information about train delays 70.Within the jurisdiction of the Security Information 71.Failure and Disaster Information 72.Class locomotive engine warning information 73.Train line monitoring results 74.Driving Organization's planning 75.Safety Information Monitoring Results 76.Rescue treatment options

5. In conclusion

Firstly, through needs analysis，discusses the intelligent railway dispatching system overall technical program.Clearly intelligent railway dispatching system overall technical program role and gives specific research ideas and overall program implementation steps.Second, determine the contents of the system's service architecture based on demand analysis.And then design the railway traffic control system intelligent overall technical program.Analysis and summarized the various business platforms internal logic structure and function,making it an effective overall.Compared with existing scheduling system,mainly to solve several problems in the following areas:

1.Integration of current relative dispersion of traffic dispatching system,form a more unified dispatching system.

2.Increases the likelihood that figure by running lane,reduce operating by dispatch personnel.Thereby reducing the impact of individual factors on traffic scheduling scheme,improves security,ensure the timely implementation of transportation.

3.Strengthening the information level of dispatching system,We can change the situation of scheduling department manually transfer information.

Acknowledgement

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References

Peng hui(2012)"Reliability of high-speed railway dispatching and emergency-related issues"，Southwest Jiaotong University

Cao xiaoyun(2011)"Research and Design of Intelligent Scheduling System",Fudan University

Luo qiang(2013)"Integrated high-speed railway scheduling system integration architecture",Southwest Jiaotong University

Operation Effects of a Factory Rail Line on a Traffic Artery

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Abstract: With the enlargement and the development of urban areas, the road intersecting with rail line of the factories has become the artery in the city. As the result, the operation of factory rail line has a great impact on the road traffic. In this paper, based on the field data of the railway crossing through Yellow River Road, Fiveone Road and Southwest Road in Dalian, the factories railway line's influence on road traffic under different operation conditions was analyzed; the relation model between operating parameters and traffic efficiency was established and discussed.

Keywords: Traffic influence; Factories railway line queue length; Blocking time.

1 Introduction

The safety and economic loss due to vehicle delays were considered on the evaluation of at-grade rail-road intersection (Victoria Gitelman, 2006). The parameters, such as capacity, volume, velocity and delay, have been used to research the effects of bus stop and on-street parking on the traffic flow (Ge Hongwei, 2006; Guo Hongwei, 2011). The traffic jam at the intersection on traffic artery caused by the factory rail line is becoming more serious with the increasing volume and should be noticed now. Based on the field data on Yellow River Road, Fiveone Road and Southwest Road in Dalian, the paper analyzes the characteristic of traffic flow and operation of crossing section between artery and railway. The blocking time and queue length are the parameters to measure the operation of such crossing sections. According to the relation among the operational parameters and influence factors, the influence of the rail line on the traffic artery is discussed.

2 Influence factors of railway on the traffic flow

2.1Operational Parameters of traffic flow

The crossing section between the railway and road is like a signalized intersection. When the train is passing, the traffic flow stops just as red light on. The difference is that train's passing time is longer than the red light time in general, so the time of car passing, which includes the more queue waiting time and the more dissipation time, becomes longer. So the paper chooses the queue length and the blocking time including queue time and dissipation time as the operational parameters.

2.2Influence factors of railway on the traffic flow

When the train is passing, the traffic flow stops and queues. The longer the train runs, the more vehicles queues and the longer queue length becomes. The more traffic volumes queue, the longer time the traffic flow dissipates. So the passing time of train is the main factor that influences traffic flow. The passing time depends on the train length and width of road.

The dissipation time not only depends on the road volume, but also depends on the vehicle's speed through the rail. The fewer volume pass the crossing section, the less dissipation time is needed; the higher speed the vehicle has, the more capacity could result, and then less dissipation time is needed. So both the road volume and vehicle's speed are the influence factors.

3 Data Analysis

3.1Field data

The Yellow River Road, Fiveone Road and Southwest Road in Dalian become the traffic artery, the traffic jam is serious. The long queue can be caused when the train is passing. Sometimes the queue even extends to the next intersection. Field data was collected on these three roads by using video and manual method. The volume, speed, passing time of train, road width, queue length and blocking time are all observed.

3.2 Volume on these three Roads

The railway crossing the Yellow River Road and Southwest Road is used to convey the coal to the power plant, so the length of train consisting of 10 or 20 rolling stocks is long. The railway crossing the Fiveone road, also crossing the signalized intersection between Fiveone Road and Nansha Street is used to convey the oil to an oil deport, the train consists of 10 rolling stocks.

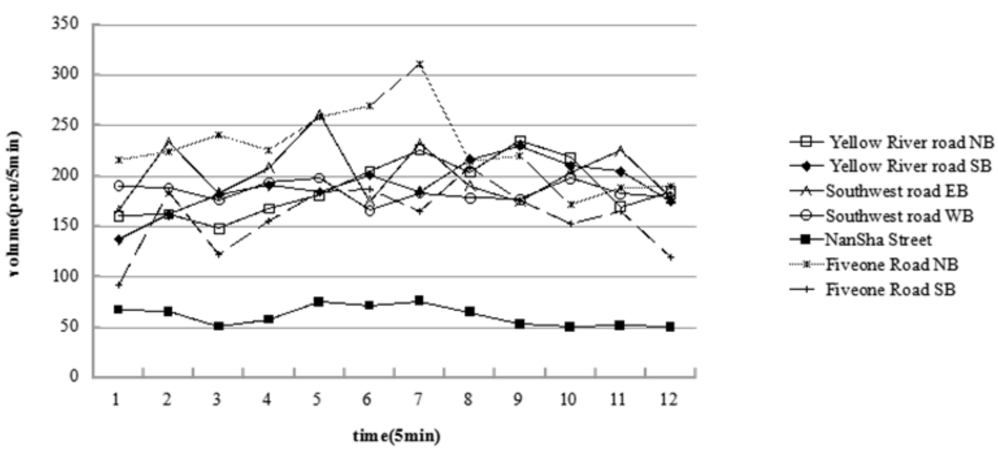
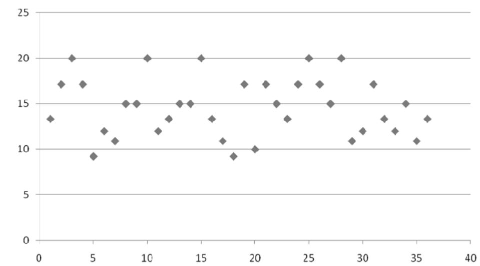


Figure 1.Volume on crossing section

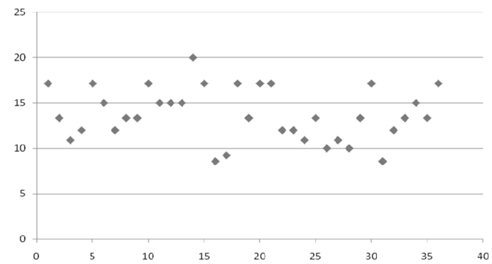
The volume accumulates while the train is passing, and decreases when the train passed (Figure1) in general. The volume variety at signalized intersection is different from the road.

3.3 Speed at the crossing section

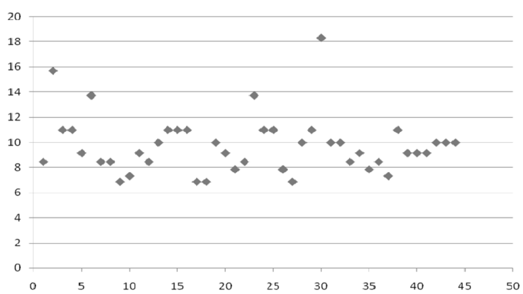
The speed through the crossing section is observed (Figure 2). The speed at the road is higher than that at the intersection. The speeds of Southwest Road are different because of the road slope. The speeds of Fiveone Road are different because of the road alignment.



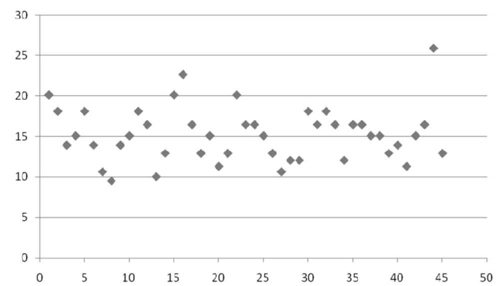
a:Yellow River Road NB



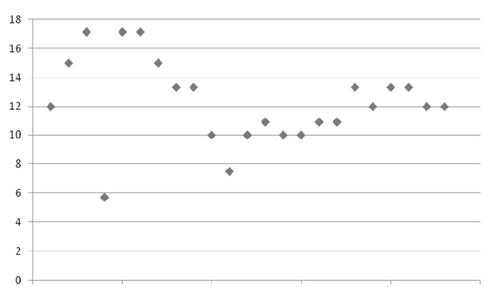
b:**Yellow River Road SB**



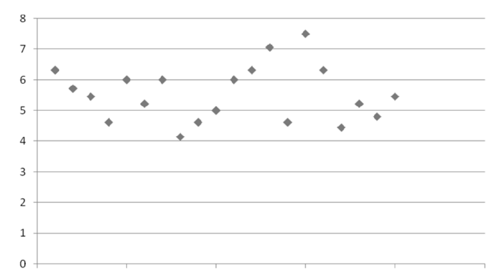
c:Southwest Road WB



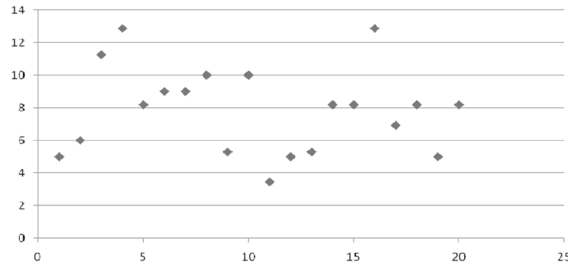
d:**Southwest Road EB**



e:Fiveone Road SB



f:**Fiveone Road NB**



g:Nansha Street

Figure 2. the Scatter of speed through the rail line

3.4 Time on the crossing section

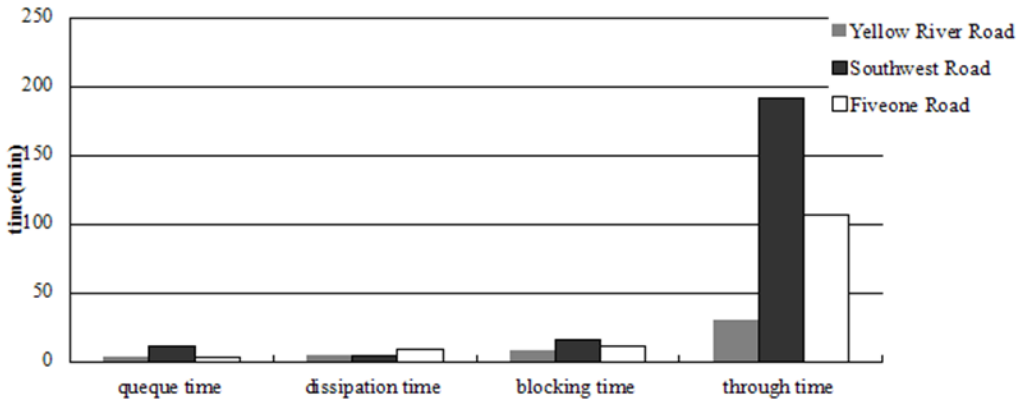


Figure 3. Time of the queue , dissipation ,blocking and passing time of train

The blocking time of traffic flow varies disproportionately with the passing time of train. The more passing time, the more blocking time. The dissipation time at the signalized intersection is more than that on the road. (Figure 3).

3.5 Queue length on the crossing section

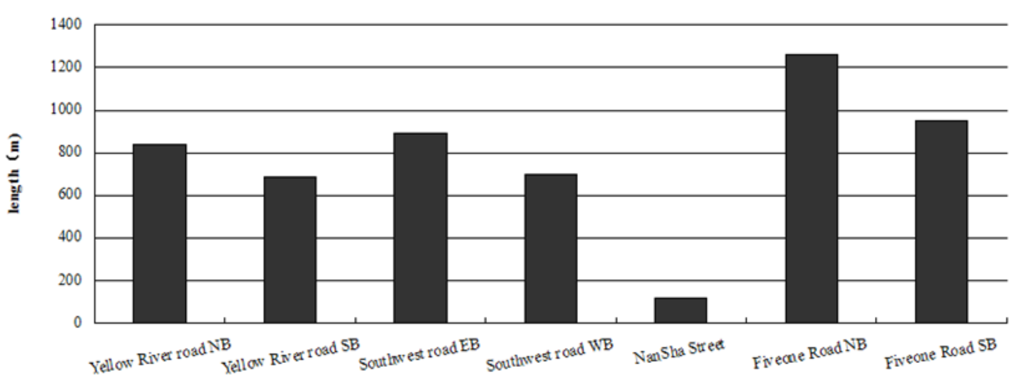


Figure 4. Queue length on the road when train is passing

The queue length is more than 500m with an exception on Nansha Street, which is a branch. The max queue length is 1260m, extending to the next intersection on the traffic artery (Figure 4).

4 Discussions of Results

4.1 Relationship between the queue length and influence factors

The queue length depends mainly on the volume, the passing time. The passing time depends partly on the road width and train length. Table 1 shows the queue length and influence factors on the different section. We found the relationship:

$$Y=0.4101X_1+111.3731X_2+5.6473X_3-117.6710X_4-277.6459 \quad (1)$$

While Y ----queue length (m)

X_1----volume on the road (pcu/h)

X_2----road width (m)

X_3----passing time of train(s)

X_4----train length (veh)

Table 1. The queue length and influence factors (one hour data)

Section	Queue length(m)	Volume (pcu/h)	Road width(m)	passing time of train(s)	Train length(veh)
Southwest EB	894	2432	12.5	192	20
Southwest WB	701	2211	12.5	192	20
Yellow River NB	680	2278	10	30	10
Yellow River SB	840	2263	10	30	10
Nansha Street	120	736	6	107	10
Fiveone NB	1260	2731	9	107	10
Fiveone SB	950	1915	9	107	10

4.2 Relationship between the blocking time and influence factors

The blocking time is the sum of queue time and dissipation time. The queue time depends on the passing time, while the dissipation time depends on the speed passing the section and queue volume. Table 2 shows the blocking time and influence factors on the different section. We found the relationship:

$$Z=0.0079Y+0.2403X_5+0.0469X_3-4.1227 \quad (2)$$

While Z ----blocking time (m)

X_5----speed (m/s)

Table 2. The blocking time and influence factors (one hour data)

Section	Blocking time(min)	Queue length(m)	Speed (m/s)	passing time of train(s)
Southwest EB	14	894	14.55	192
Southwest WB	16	701	9.32	192
Yellow River NB	7.33	680	13.1	30
Yellow River SB	7.83	840	13.9	30
Nansha Street	2	120	7	107
Fiveone NB	12	1260	5.4	107
Fiveone SB	9	950	11.5	107

5 Conclusions

From the table1 and formula 1, no more factors are more significant than others. From the table2 and formula 2, the vehicle's speed passing the railway line is more significant than other factors, and is main influence factor.

Here we may draw the following conclusions:

(1) While the train is passing the crossing section on traffic artery, the operation would be affected, and the phenomenon such as the queue and blocking emerges.

(2) It is also observed that a more passing time could cause the blocking time to increase, but the high vehicle's speed would reduce the impact.

(3) The queue length is the complex combination of all factors. The more passing time could cause the longer queue on the big volume road.

6 Recommendations for Future Research

Obviously, factory railway influences the traffic flow of artery. The influence factors and degree should be known. The more important thing is to know how to reduce the influence. The reasonable threshold of various parameters and factors should be researched. It can provide a reference to operation plan of factories' railway line and organization of traffic flow in order to reduce the influence.

References

Ge HongWei (2006), Traffic effect analysis and optimization techniques of bus stop, Southeast University, Nanjin.

Guo Hongwei (2011), Modeling and Properties of the Influence of Urban On-street Parking, Beijing Jiaotong University, Beijing.

Victoria Gitelman (2006), Screening Tools for Considering Grade Separation at Rail-Highway Crossings. Journal of Transportation Engineering ASCE.

Intelligent Decision-Making Optimization Model of a Traffic Emergency Based on Learning Bayesian Network

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Abstract: According to the incomplete and uncertain factors contained in the real-time information of traffic incidents, the automatic optimization model of incident response plan was developed based on loop learning Bayesian Network (BN) to support for the intelligent decision-making of network traffic emergency management. The first layer (structure learning) adopted the combination of expert knowledge and the K2 algorithm data training method, the second layer (parameter learning) adopted maximum likelihood estimate of the network parameter optimization methods. Firstly, item data were extracted to transform 19 discrete variables with different factors levels. Secondly, consulting some experts in the field of freeway incident management was applied to representing all the key factors that affect the successful operation of incident. Thirdly, this initial model was built with the method of GTT-K2 (Greedy Thick Thinning). Finally, BNs was optimized and modified according to expert knowledge. The core of the proposed model is a loop learning Bayesian network that quantifies the causal dependencies between incident information and response decisions. The model was validated using incidents data to indicate that the proposed algorithm is reliable and accurate.
Keywords: Traffic incidents; Emergency response; Decision-making optimization; Bayesian network.

1 Introduction

Bayesian network is a graphical model which represents the joint probability distribution of a collection of variables by using graph theory, proposed in 1986 by Pearl according to the probability relationship between the variables. It provides a way to represent causal information naturally so that the potential relationships between the data can be identified. In this network, nodes represent variables while directed edges representing dependencies of variables. The characteristics of Bayesian network are as follows: (1) Bayesian theory gives the trust function calculation method in mathematics which contributes to its solid mathematical foundation. Meanwhile, Bayesian theory characterizes the consistency between trust and evidence and the incremental learning characteristic that trust varies with the evidence; (2) In the process of data mining, Bayesian network can deal with incomplete and noisy data set, and describe the correlation of data through probability measure weights, so that the problem of data's inconsistency and even independent have been solved. (3) Graphical method is used to describe the relationship between data, which is semantic clear and easy to understand, so it's helpful for using the causal relationship between data to conduct predictive analysis.

1.1 The basic point of Bayesian methods

The characteristic of Bayesian analysis method is using probability to represent all forms of uncertainties. Learning and other forms of reasoning are all realized by probability rules. The results of Bayesian learning is expressed as a probability distribution of random variable, it can be interpreted as the confidence in the different possibilities. Bayesian School started in two works: Bayes' theorem and Bayesian hypothesis.

Suppose that the joint distribution density of the random variable x,θ is $p(x,\theta)$, and the marginal densities of x,θ are $p(x), p(\theta)$ .Let x be the observation vector, and θ is the unknown parameter vector, so the unknown parameter vector can be estimated through observation vector. The Bayes' theorem is:

$$p(\theta \mid x) = \frac{\pi(\theta) \times p(x \mid \theta)}{p(x)} = \frac{\pi(\theta) \times p(x \mid \theta)}{\int \pi(\theta) \times p(x \mid \theta) d\theta}$$

$\pi(\theta)$ is the prior distribution of θ.

1.2 The Bayesian network of emergency response optimization

Suppose that a joint probability distribution is $P(X_1, X_2, \cdots, X_n)$ and a sort of variables is d . X_1 starts as the root node. And the priori probability distribution of X_1 is $P(X_1)$. X_2 represents a node. If X_2 is related to X_1, then we establish a link from X_1 to X_2 and make $P(X_2 \mid X_1)$ representing the coupling strength. If X_2 has nothing to do with X_1, then the priori probability distribution of X_2 is $P(X_2)$. Then we draw a direction line linking to X_i from it's parent node set $\prod_{X_i}$ in the first stage, ($\prod_{X_i} \subseteq \{X_1, X_2, \cdots, X_{i-1}\}$) and being conditional probability represented by $P(X_i \mid \prod_{X_i})$ quantitatively. As a result, we can obtain a directed acyclic graph which can be used to represent many independent relations embodied in $P(X_1, X_2, \cdots, X_n)$, and this graph is called Bayesian networks. In turn, $P(X_i \mid \prod_{X_i})$ contains all the information necessary to reconstruct the original distribution function. There is a following relationship in sort d .

$$P(X_1, X_2, \cdots, X_n) = P(X_n \mid X_{n-1}, X_{n-2}, \cdots, X_1) \cdot P(X_{n-1} \mid X_{n-2}, \cdots, X_1) \cdots P(X_3 \mid X_1, X_2) \cdot P(X_2 \mid X_1) P(X_1) = \prod_i P(X_i \mid \prod_{X_i})$$

2 Construction of loop learning Bayesian network

There are generally three ways of modeling Bayesian network: 1) modeling based on expert knowledge; 2) learning from the data; 3) creating from knowledge base. The network structure will inevitably involve subjective color if it simply relies on expert knowledge to build. The knowledge of an expert is difficult to fully reflect the objective facts even the expert has enough experience. Historical data contains a wealth of information and experience in hiding. Although you can dig deep level of information simply by learning from data, the redundant information and no logical related information cannot be avoided. Therefore, this article integrated these methods in the actual process of modeling, taking experts knowledge as the guidance while database and knowledge base as the auxiliary, developing advantages and avoiding disadvantages, so as to ensure the efficiency and accuracy of the modeling.

2.1 Bayesian network structure learning based on dependent test K2

The K2 algorithm is to choose the problem by using the greedy search processing model. Firstly, we define a scoring function which can evaluate a network structure, and then start with a network, according to the predetermined number of maximum father node and the order of nodes, select node with the highest score as a parent node of the node. This algorithm use a posteriori probability as the scoring function:

$$p(D \mid B_s) = \prod_{i=1}^{n} score(i, pa_i)$$

Among them, $score(i, pa_i) = \prod_{j=1}^{q_i} [\frac{\Gamma(\partial_{ij})}{\Gamma(\partial_{ij} + N_{ij})} \prod_{k=1}^{r_i} \frac{\Gamma(\partial_{ijk} + N_{ijk})}{\Gamma(\partial_{ijk})}]$

2.2 Parameter learning based on maximum likelihood estimation

In the maximum likelihood estimation method, when giving the value of father node set, we calculate the frequencies of occurrence of different nodes' values and put the frequencies as the conditional probability parameters of that node. The basic principle of maximum likelihood estimation is trying to find the parameter which makes the likelihood function maximum.

When we judge whether it is suitable to put θ^* as the estimation of θ, we should consider its' fitting degree with data. The fitting degree between some possible value of parameter θ and data D can be measured by the conditional probability $P(D \mid \theta = \theta_0)$. And the bigger the probability is, the higher the fitting degree between θ_0 and data D is. The conditional probability $P(D \mid \theta)$ of data D is called the likelihood of θ, denoted as: $L(\theta \mid D) = P(D \mid \theta)$.

If we fix D and let θ change in its definition domain, then $L(\theta \mid D)$ is a function of θ, calling the likelihood function of θ. The maximum likelihood estimation of the parameters θ is to make $L(\theta \mid D)$ achieve the largest value θ^*, which means if $l(\theta \mid D) = \log L(\theta \mid D)$ uses the logarithm of likelihood function $L(\theta \mid D)$ then the likelihood function $l(\theta \mid D) = \log L(\theta \mid D)$ can be obtained. Obviously, the maximum value of $l(\theta \mid D)$ is the maximum point of $L(\theta \mid D)$.

For any fixed *i* and *j*, because $\sum_{k=1}^{r_i} \theta_{ijk} = 1$, when θ_{ijk} takes the value as follows, then

$$\theta^*_{ijk} = \begin{cases} \dfrac{m_{ijk}}{\sum_{k=1}^{r_i} m_{ijk}}, \sum_{k=1}^{r_i} m_{ijk} > 0) \\ \dfrac{1}{r_i} \end{cases}$$

If the value of expression $\sum_{k=1}^{r_i} m_{ijk} \log\theta_{ijk}$ reaches the maximum, $l(\theta \mid D)$ reaches the maximum. Therefore, θ^*_{ijk} which the above formula gives is the maximum likelihood estimation of θ_{ijk}.

3 Case Studies

3.1 Bayesian network structure learning

We determine the Bayesian network structure model of traffic events response decision-making by using the actual data sample learning and comprehensive structure learning method combined with the expert experience. Firstly we express the historical event recording information digitally and extract 19 main variables and dispose them levelly (Table 1). Then, according to the correlation analysis between different variables, several experts find out the variable combination of which the influencing factors are more obvious and the correlation are stronger, and then screen the main variables and construct the basic structure relation. The related variable selection results of structure background based on expert knowledge. Thirdly, the initial Bayesian network structure was constructed based on the GTT-K2 method. Finally, we optimize and correct Bayesian network structure according to the expert knowledge. We can find 8 new correlation edges if we compare the background structure and the training structure. Among them, the correlation edges of ambulances and trailer and the number of people who are stuck in the car and tire repair vehicle don't have clear logical relationship according to the expert knowledge, so we do not consider them (Table 2) . Therefore, according to these four steps, the definitive training result of Bayesian structure based on expert knowledge is as shown in Figure 1.

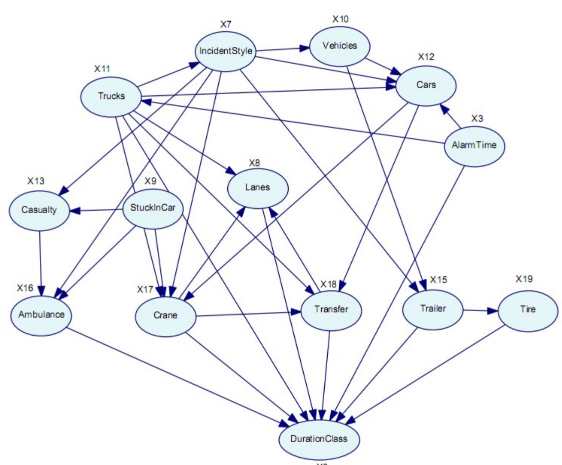

Figure 1.Training results of Bayesian structure based on expert knowledge

Table 1.Explain and statistical properties of each variable after the digital pretreatment of historical events information

No.	Variable name	Explanation	Level	Factor level interpretation	Mean	Variance	StdDev	Min	Max
X1	Weekday	weekday	7	Monday to Sunday	4.10	3.79	1.95	1	7
X2	Weather	weather	4	1 sunny, 2 cloudy, 3 rainy, 4 snowy	1.524	0.68	0.83	1	4
X3	AlarmTime	alarm time	3	1 daytime non-peak, 2 daytime peak, 3 night	1.93	0.62	0.79	1	3
X4	AlarmStyle	alarm style	4	1 driver, 2 traffic police, 3 expressway, 4 traffic department	1.57	0.64	0.80	1	3
X5	SpotTimeClass	spot time class	3	1（0~15 mins）, 2（16~30 mins）, 3（31~60 mins）	1.21	0.21	0.46	1	3
X6	DurationClass	duration class	9	1(0,30], 2(30,60], 3(60,90], 4(90,120], 5(120,150],6(150,180], 7(180,210], 8(210,240], 9(240,+∞)	2.64	2.84	1.69	1	9
X7	IncidentStyle	incident style	8	1 pileup, 2 dumper, 3 hit the intermediate guard rails 4 break down, 5 scratch,6 tire explosion, 7 hit the side guardrail, 8 fall-out, 9 catch fire	2.57	4.51	2.12	1	8
X8	Lanes	number of lanes	5	1 one lane, 5 one-way road closed (regard shoulder as a lane)	1.47	0.40	0.64	1	5
X9	StuckInCar	number of people stuck in car	5	0~3 represent 0~3people, 4 represent more than 3 people	0.08	0.13	0.36	0	4
X10	Vehicles	vehicles involved	6	0~4 represent 0~4 vehicles，5 represent more than 4 vehicles	1.65	0.87	0.93	0	5
X11	Trucks	number of trucks	5	0~3 represent 0~3 vehicles，4 represent more than 3 vehicles	0.45	0.44	0.66	0	4
X12	Cars	number of cars	6	0~4 represent 0~4 vehicles，5 represent more than 4 vehicles	1.20	1.28	1.13	0	5
X13	Casualty	number of casualties	6	0~4 represent 0~4 people，5 represent more than 4 people	0.53	0.94	0.97	0	5
X14	FirstOnSpot	rescue vehicle first on spot	7	1 police car, 2 trailer, 3 tire repair vehicle, 4 Medical vehicle, 5 road administration, 6 management office, 7 patrol	4.00	6.232	2.50	1	7
X15	Trailer	trailer	2	0 don't need a trailer, 1 need a trailer	0.46	0.25	0.50	0	1
X16	Ambulance	ambulance	2	0 don't need an ambulance, 1 need an ambulance	0.30	0.21	0.46	0	1
X17	Crane	crane	2	0 don't need a crane, 1 need a crane	0.20	0.16	0.40	0	1
X18	Transfer	transfer	2	0 don't need a transfer, 1 need a transfer	0.14	0.12	0.35	0	1
X19	Tire	tire repair vehicle	2	0 don’t need a tire repair vehicle, 1 need a tire repair vehicle	0.31	0.22	0.46	0	1

Table 2.Illustration of new variables' related factors based on K2 structure training

No	Related factors	Trade-off	Illustration of related factors
1	StuckInCar→Crane	√	The traffic accident with people stuck in the car usually caused more serious damage, so a crane is needed to clear up obstacles.
2	IncidentStyle→Crane	√	More serious accident need a crane to clean up the scene
3	Trucks→IncidentStyle	√	Traffic incidents involving trucks are usually more serious traffic accident
4	Trucks→Vehicles	√	Trucks are also the part of the vehicles involved in the incident
5	IncidentStyle→Trailer	√	Traffic accidents generally need a trailer for clearing the obstacles
6	Ambulance→Trailer	×	There is no clearly logical relationship, so will not be considered
7	StuckInCar→Tire	×	There is no clearly logical relationship, so will not be considered
8	Trailer→Tire	√	Trailer and tire repair vehicle usually joint operate

3.2 Bayesian network parameter learning

The network structure has been established, followed by the network parameter learning. The calculations of Bayesian network parameter mainly include batch learning and sequential learning. Batch learning is that usually at the beginning of the establishment of the network structure, we use the sample data to get the parameter estimation at a time; sequential learning is that in a period of time after training the history data, we use the new accumulated data to estimate the parameters again so as to ensure integrating the experience information of historical data and use the real-time fresh information of the new conditions. Batch learning usually uses the parameters calculation method of the maximum likelihood estimation, and sequential learning usually uses the Bayesian estimation method of which the parameter update is carried out on the basis of existing knowledge. This paper uses the batch learning of maximum likelihood estimation as an example and carries out the Bayesian network parameter learning.

On the basis of the Bayesian network structure based on expert knowledge, for the node X_i, assuming that its parent nodes set π_i is the j th possible value, we need to calculate the probability that node X_i is the kth value. We take node X_8 (the number of lane occupied by incident) as an example and use the maximum likelihood estimation to calculate the node parameter of $\theta_{8jk} = P(X_8^k \mid \pi_8^j)$, as shown in Table 3.

Table 3.Node parameter calculation of Bayesian network

Trucks	State0				State1				State2				State3				State4			
Crane	State0		State1		State0		State1		State0		State1		State0		State1		State0		State1	
Tranfer	State0	State1	State0	State1	State0	State1	State0	State1	State0	State1	State0	State1	State0	State1	State0	State1	State0	State1	State0	State1
State1	0.71	0.29	0.50	0.38	0.65	0.29	0.28	0.27	0.49	0.31	0.06	0.28	0.10	0.29	0.20	0.17	0.14	0.20	0.20	0.20
State2	0.26	0.53	0.39	0.38	0.29	0.47	0.59	0.48	0.40	0.31	0.63	0.44	0.40	0.29	0.20	0.17	0.43	0.20	0.20	0.20
State3	0.03	0.06	0.07	0.13	0.04	0.18	0.07	0.19	0.06	0.23	0.13	0.17	0.20	0.14	0.20	0.33	0.14	0.20	0.20	0.20
State4	0.00	0.06	0.02	0.06	0.01	0.03	0.04	0.04	0.02	0.08	0.06	0.06	0.20	0.14	0.20	0.17	0.14	0.20	0.20	0.20
State5	0.00	0.06	0.02	0.06	0.01	0.03	0.01	0.01	0.02	0.08	0.13	0.06	0.10	0.14	0.20	0.17	0.14	0.20	0.20	0.20

3.3 Bayesian network inference

Emergency response of freeway incident is a traffic management under abnormality. The previous rule reasoning, trigger condition reasoning and case-based reasoning is to reason in the condition of gaining explicit information and according to a prearranged rule or discriminant conditions, and which cannot meet the management requirements of real-time response to the incident. Along with the progress of events, information of incident tends to complete and accurate. And the reasoning process of Bayesian network can respond to the requirements of incomplete incident information and uncertain factors' changing and provide real-time emergency response intelligent decision support. The Bayesian network of traffic incident response decision obtained through loop learning is as shown in Figure 2.

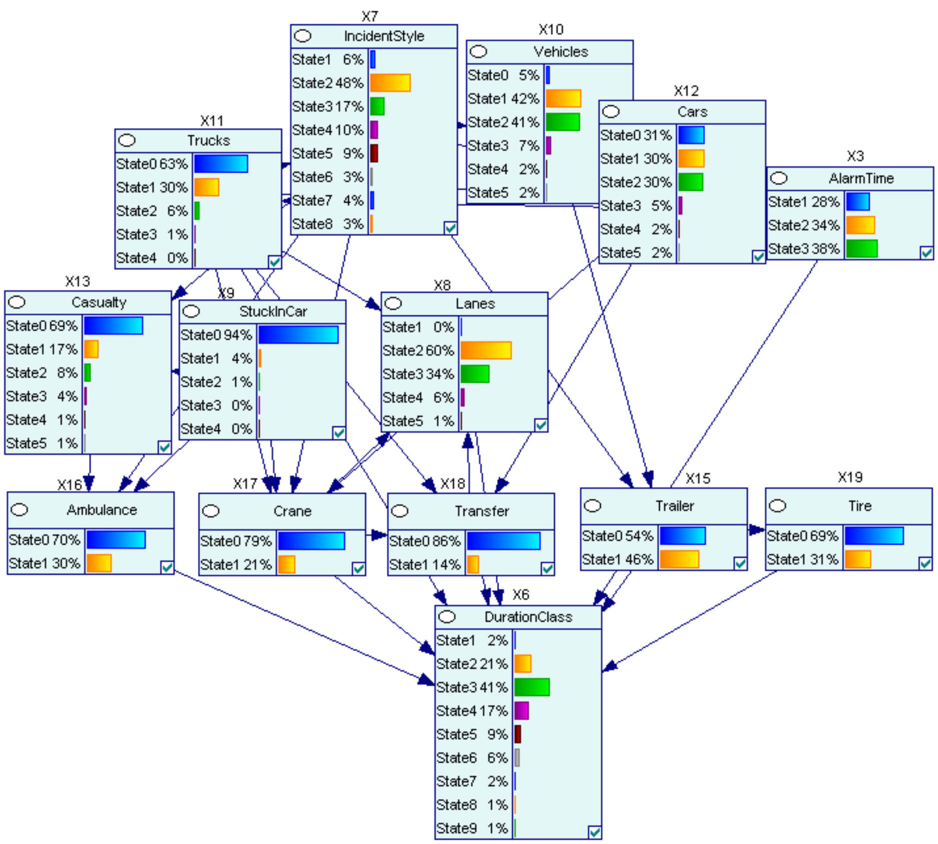

Figure 2.Loop learning Bayesian network of incident response plan

For traffic incident management, casualties caused by incident and expected duration are two very important aspects of incident management and index of reflecting the severity of the incident. Therefore, the prediction of the reasoning process from cause to effect of double learning Bayesian networks facing incident severity is as follows: firstly, we add the other parent node of the predicted nodes to the predicted nodes, keeping the conditions unchanged, and adds all states of new nodes. Then, we expand each item of sum formula by using the Bayesian rule, and will obtain the conditional probability $\theta_{ijk} = P(X_i^k \mid \pi_i^j)$ of predicted nodes.

Then we will illustrate a Bayesian network reasoning process of the incident's severity through a case analysis. The case description is: A rear-ends accident involving a car and a truck happened at night, causing 2 casualties and 2 lanes occupied. According to a series of processes of event detection, scene, disposal, we carry out a real-time analysis and reasoning as follows.

Discovery stage of the incident is: alarm time X3=3 night, incident style X7=1 rear-end collision, the number of vehicles involved in the incident X10=2, the number of trucks involved in the incident X11=1, the number of cars involved in the incident X12=1. At this point, X3, X7, X10, X11, X12 is the evidence variables, and other variables is predictor variables. We can reason that the probability of the number of casualties due to the incident being 2 is 16.2% and the probability of the number of people stuck in the car being 0 is 94.5% and probability of occupying two lanes is 50.6% and the probability of the expected duration of this stage being 60~90 minutes is 44.2% according to Bayesian network.

To-the-scene stage of the incident is: from receiving the alarm to arriving at the scene, under the conditions of the original evidence variables (we give tacit consent to that the original evidence variables are accurate and can amend the original evidence variables according to the site condition), we obtain the new real-time information, that is, casualties caused by the incident X13=2, the number of the people stuck in car X9=0, the number of lanes occupied by incident X8=2. At this point, X3, X7~X13 are evidence variables and other variables are predictor variables. We can reason that the probability of needing an ambulance is 91.4% and the probability of needing a crane is 27.4% and the probability of needing transfer is 25.6% and the probability of needing a trailer is 100% and the probability of needing a tire repair vehicle is 36.5% and the probability of the expected duration of this stage being 120~150 minutes is 60.9% according to Bayesian network.

Clean-up stage of the incident is: under the condition of having known the number of casualties, vehicle involved and the blocking lanes, we need the ambulance, crane, transfer and trailer for rescue and clearing. Therefore, we will get further real time information under the conditions of keeping the original evidence variables. The value of X15~X18 is 1, which means the ambulance, crane, transfer and trailers are needed and the tire repair vehicle X19=0 is not needed. The probability of the expected duration of this stage being 150~180 minutes is 40%. And the duration of this incident is 162 minutes, just falling in the interval. The Bayesian network reasoning results of the total expected duration of this incident's three stages are as shown in Table 4.

Table 4.Bayesian network reasoning results

Expected duration	Discovery stage	To-the-scene stage	Clean-up stage
State1: (0,30]	0.005	0	0
State2: (30,60]	0.195	0.029	0
State3: (60,90]	0.442	0.073	0
State4: (90,120]	0.113	0.199	0.2
State5: (120,150]	0.119	0.609	0.2
State6: (150,180]	0.078	0.062	0.4
State7: (180,210]	0.034	0.022	0.2
State8: (210,240]	0.01	0	0
State9:(240,+∞)	0.003	0.005	0

Acknowledgement:

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References

Adel W Sadek, Brian L Smith (2001). Aprototype case-based reasoning system for real-time freeway traffic routing. Trasportation Research Part C: Emerging Technologies, 9(5):353-380.

Asad Khattak，Adib Kanafani (1996).Case-based Reasoning：A Planning tool for intelligent transportation systems.Transportation Research Part C:Emerging Technologies,4(5)，267-288

Filippo Logi, Stephen G. Ritchie (2002). A Multi-agent Architecture for Cooperative Interjurisdictional Traffic Congestion Management. Transportation Research Part C, 10: 507-527

Fred Lin, Tarek Sayed, Paul Deleur (2003). Estimating Safety Benefits of Road Improvements: Case Based Approach. Journal of Transportation Engineering, ASCE, 2003, 8

Konstantions G. Zografos, Konstantions N. (2002). A Real-Time Decision Support System for Roadway Network Incident Response Logistics. Transportation Research Part C, 10: 1-18

Ritchie SG (1990). A Knowledge-based decision support architecture for advanced traffic management. Transportation Research Part A, 24(1):27-37.

Sadek AW，Smith BL (1998).Artificial intelligence-based architecture for real-time traffic flow management. TRB，National Research Council，Washington,DC

Railway Time Management System Based on the Beidou Navigation System

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Abstract: With the development of high-speed railway and the advancement of railway informatization, the inconformity of time has an impact on the railway operation management and security management. Following the principle of safety, advanced, practicability, reliability, easy maintenance and expansion, this paper designs the framework of railway time management system based on Beidou/GPS satellite navigation system, In-depth analysis of the internal configuration structure of timing node in Ministry of Railways, rail bureau and train deeply, And designs the main technical solution to provide technical support for the time unification of railway departments.
Keywords: BDS; Railway; Timing; Time management.

1 Introduction

At present, there are multiple information systems in China's railway and time system of each is individual, without unified management system. Systems are physical isolation, although a few system uses GPS to timing, there is still a larger error between layers. The inconformity of time brings a certain effect to the normal operation of railway, for example, which will lead to "fly line", "stay" in drawing the actual operation diagram, disorders of train number in statistics report of 18 O'clock, great difficulties in finding out the exact cause of fault when the accident occurs and so on.

In railway time management, some experts and scholars researched on the railway time synchronized net, the system of synchronous timing with satellite and time correcting with network, distributed timing synchronous clock and so on. Tang Jun and Liang Feng (2003) proposed using GPS system as a collecting source of railway time. Liu wei, and Dong Decun (2005) designed and developed a kind of letters type of distributed timing synchronous clock system with free adjustment based on GPS technology. Tang Huaidun and Zhou Shengyang (2007) introduces application of GPS satellite timing in railway time synchronized net. Gao Qing and Ma Xu (2006) studied the application of positioning with the information integration of "Beidou" satellite navigation system and railway transport system in the intelligent transportation construction of railway transportation. Fu Bin (2006) pointed out that the clock quantity traceability in the railway transportation system is related to the safety and accurate command and put forward the project of time unification in railway system by analyzing the principle of timing equipment and the present using situation of clock equipment in railway system. Liu Tianping (2007) introduced how to take the global positioning system (GPS) as a time reference to make sure the synchronization of time information in the driving clock among railway TMIS, railways DMIS, railways HMIS, voice recording computer network system and dispatch and command system. Wang Li and Wang Qian (2008) put forward to establish railway network time synchronized net on basis of Network Time Protocol （NTP） in a comprehensive dispatch system. Qu Bo (2010) reseached a kind of railway time synchronized net which consist of satellite receiving equipment, master clock equipment, time display devices, network management of equipment, and transmission channel. Dong Xueyuan and Gao Shibin (2006) proposed a clock synchronization solution based on the Precision Time Protocol (IEEE1588) by analyzing the demand of fault location and clock synchronization using electric traction line.

To sum up, among the current research achievements, the main time source in the railway timing system is GPS, and very few literature study on the “Beidou” timing system. It’s very necessary to research on the “Beidou” timing application in railways considering the national strategic security. As a result, this paper designs the framework of railway time management system based on Beidou/GPS satellite navigation system according to the principle of safety, advanced, practicability, reliability, easy maintenance and expansion, In-depth analysis of the internal configuration structure of timing node in Ministry of Railways, rail bureau and train deeply, And designs the main technical solution.

2 Designation of system framework

Referencing the time management mode in existing system at home and abroad and considering safety and reliability factors, the railway time management system is composed of space-base and ground-base, namely, the space-time-base rely mainly on Beidou while take GPS as secondary reliance and the ground-time-base is made up of a high accuracy and stable frequency source. Among them, the ground time management system consists of ministerial timing node setting in the dispatching center of railways ministry, bureau timing node setting in the dispatching station of railways bureau or passenger dedicated line and station timing node setting in station or depotor segment. The train time management system is set up in the train. Each of the ground time management system is mainly composed of satellite receiving equipment, atomic clock, time servicer and transmission channel and each of the train time management system consists of satellite receiver, punctual device of crystal oscillator and time servicer, having the functions, such as, time input, time output, time regulation, time calibration monitoring and management functions and so on. As shown in figure 1.

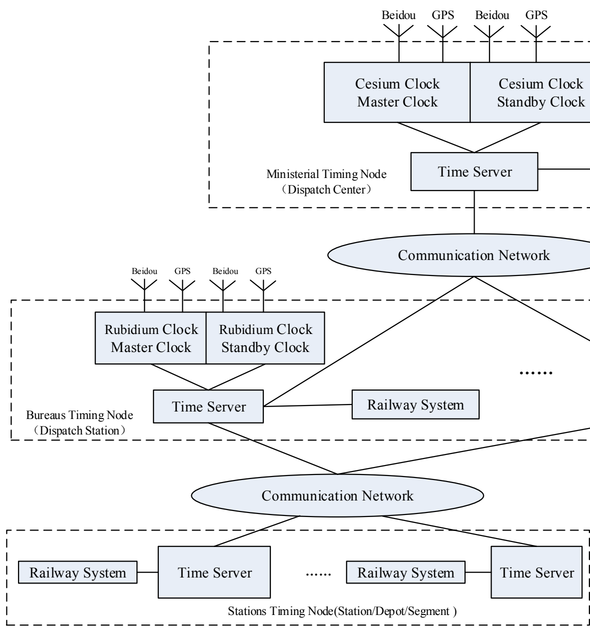

Figure 1. the Framework of Railway Time Management System

Timing center of railways ministry should set up Beidou/GPS satellite timing cesium atomic clocks with double redundancy (master/standby) and add external time server, when timing for systems such as TDCS/CTC, TMIS, freight transportation services, passenger transportation service and so on through interface RS422, the system can take use of the protocol NTP or PTP timing for the other system through network, and reserve extended interface. The time server of railway ministry should is connected with time server of each railway bureau through the transmission equipment such as network and so on. At ordinary times, the system timing for external by cesium atomic clocks in the standard clock timing device, and check the time for once an hour (later, adjust the frequency for time checking according to the actual need). If the difference between the cesium atomic clocks in the standard clock timing device and the clock of Beidou/GPS system is in excess of the prescribed deviation, the system will take Beidou/GPS clock as a standard clock, receive it, transmission it down, and correct the time for cesium atomic clocks in the standard clock timing device.

Timing center of railway bureau should set up Beidou/GPS satellite timing rubidium atomic clocks with double redundancy and add external time server, when timing for systems such as TDCS/CTC, TMIS, freight transportation services, passenger transportation service RBC、TSRS and so on through interface RS422, the system can take use of the protocol NTP timing for the other system through network, and reserve extended interface. The time server of railway bureau should is connected with time server of stations, such as traffic, maintenance, engineering, electricity, power supply and vehicle, through the professional transmission equipment, such as network. The time server of station timing for other system through interface RS422 or general protocol NTP.

Generally, the timing center of railway bureau timing for external by rubidium atomic clocks in the standard clock timing device, and check the time for once an hour (later, adjust the frequency for time checking according to the actual need). If the difference between the rubidium atomic clocks in the standard clock timing device and the clock of Beidou/GPS system is in excess of the prescribed deviation, the system will take Beidou/GPS clock as a standard clock, receive it, transmission it down, and correct the time for rubidium atomic clocks in the standard clock timing device. In addition, the timing center of railway bureau would compare the time with the timing center of railway ministry by rail private network, in order to verify if their own equipment and transmission system is normal, when the difference is more than a certain deviation or there is a breakdown, it will alarm and checking the time automatically or apply for manual intervention.

3 Technological Scheme Design

3.1 Way of guiding the time signal

The time service unit of the business systems of railway transportation should be able to get time signals from the ministerial or bureau time synchronization equipments through a variety of time interfaces, and can provide time services to many business network management systems and network equipments, and will use time keeping function of its business systems, when it can not receive the time synchronization signal of the server.

The time display device can get time signals from the corresponding ministerial , bureau and station time synchronization equipment through a variety of time interfaces, and should be able to display time information under the time signal output driven by the server. We can configure one or more time allocation unit at each level to provide time services for business network at the corresponding level (each service network can set their own VPN or firewall). The principle of guiding time signal of the time display device is guiding to the nearest, which means that the time display device access to the nearest time synchronized server equipment at all levels.

To guide the time source, business systems of railway transportation adopt centralized and decentralized way.

The time signal link of the server equipment at the corresponding level to business system of railway transportation and time display device can transmit time signal over coaxial cable, shielded control cable, audio communication cables and fiber.

3.2 Time synchronization monitoring system

You need to build a timing monitoring system to examine the performance of the railway time synchronization system. The time synchronization monitoring system deploy a lock monitoring device TMU at the center of all levels, the device can be connected to different time signal and clock information on the site through a variety of interface board by modular design. TMU achieves major time precision monitoring functions by comparing timing reference signals of a variety of time signal and core clock, and reports the information to the monitoring center through data networks, and will also report the body clock device working status and other information. The monitoring center takes a unified analysis and post-processing for the monitoring information reported form corresponding time monitoring device through a dedicated monitoring platform software, and provides a good man-machine interface management in a variety of forms. Monitoring system comprising the composition of structural elements, as shown in Figure 2.

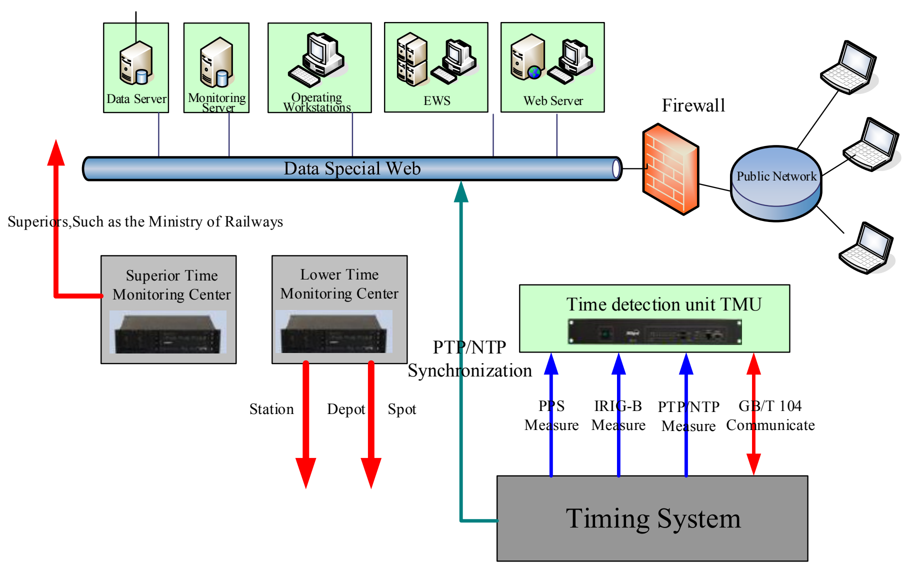

Figure 2. Diagram of Control Center of the Timing System

4 Conclusion

Compared with traditional methods, the railway time management system proposed by this paper has the following characteristics: First, the reliability, when the signal of Beidou/GPS is missing, the system takes the cesium / rubidium atomic clock as the standard time source of time servers, which improves the reliability of the time management system; Second, the security, the system adopts multilevel tree-model, is suitable for hierarchical distributed wide area network system, each layer connects through professional transmission equipment and plays a role of redundancy backup, and can automatically exclude information from wrong server to guarantee the security and practicability of the system; the third is easy to maintain and expandability, multiple subsystems in the railway system is physically isolated, it adopts the satellite timing, whose change is relatively small to the original system, besides, the system takes modular design and provides extended interface, which guarantees that the system is easy to maintain and extend; Fourth, transparency of management, we can observe the operation conditions of the time system , which can increase the stability and reliability of the system .

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References

Dong Xueyuan, Gao Shibin. *Precision time protocol realizes ranging clock synchronization in traction network fault*. Electrified railway. .2006.5: 13-16.

Fu Bin. *Research on problem of unified missing of railway transportation system*. West Rail Technology. 2006, 3: 7-8,4.

Gao Qing, Ma Xu, Qu Wenke, Tao Chunyan. *Application of Beidou satellite navigation system in the intelligent railway transport system*. Telecommunication Technology. 2006.4: 128-131.

Liu Tianping. *Development of the network clock synchronization timing system*. Railway Technical Supervision, 2007, 7: 29-30.

Liu Wei, Dong Decun. *Distributed timing synchronous clock based on GPS technology.* Develop and applications. 2005.5: 21-23.

Qu Bo. *Overview of railway time synchronized network*. Railway Signalling & Communication Engineering. 2010,7 (4): 43-45.

Tang Huaidun, Zhou Shengyang, Liang Feng. *Study and application of GPS satellite synchronization timing and network limitation system*. Computer Application of Railway. 2007.4: 40-51.

Wang Li, Wang Qian. *Discussion of applying the network time synchronization technology in integrated scheduling system*. Railway Transport and Economy. 2008, 30 (1): 49-51.

Yang Jun, Liang Feng. *GPS satellite synchronization standard timing system*. Diesel Locomotive. 2003.4: 45-46.

Network Access Solution in a High-Speed Railway Carriage

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Abstract: With rapid development of the high-speed railway and mobile communication technology, the high-speed railway passengers have an increasing demand for mobile information service. The mobile communication network is available in the high-speed railway today, where the mobile network is very unstable especially in the tunnel. With slow downloading speed, the passengers can not enjoy good communication and network service. Therefore, how to provide stable and high-efficient communication and network service in high-speed railway has become an urgent issue to be dealt with today. This paper has made a series research of the network access project in high-speed railway carriage. Through a great number of experiments on chengdu-chongqing motor car, the network access project with the main communication device and the extended communication device (referred to as the main device and the extended device hereinafter) in the double-carriage proposed in this paper can enable Received Signal Strength Indication (RSSI) to achieve a better result and cost saving.

Keywords: High-speed railway carriage; Network access; RSSI; Communication device.

1 Introduction

After our railway was sped up for six times and the high-speed railway entered into the era of rapid development , the railway hardware facilities are significantly improved, especially leading in the high-speed railway worldwide, setting a great example for global high-speed development. But the corresponding and affiliated passenger service system has lagged behind in construction, with one of its main parts demonstrated in the mobile information service in the high-speed railway *(Lu Jiajia,2008)*. As the survey published the 34th time by Chinese Network Information Center (CNNIC) showed, until today, the number of net citizen in China has reached 632 million, the mobile net citizens of which have reached 527 million in number, increasing by 26.99 million compared with that by the end of 2013. The scale of mobile net citizens has surpassed that of traditional PC net citizens for the first time(*Ren Yan, 2006*). The passengers (especially the passengers on the medium-and-long-distance railway) have an urgent demand for high-speed mobile communication and network service in the railway, such as surfing internet, watching movies, playing games, etc. Although China Mobile, China Unicom and China Telecom have covered the full range of communication area with 3G, yet the mobile network is still unstable in the high-speed railway and tunnel with slow downloading speed, resulting in unsatisfactory communication and network service*(Wang Zhilin,2010)* for the passengers.

In order to solve the mobile information service in the high-speed railway, we need to first solve how to get access to the high-speed network*(Qi Hongfeng,2012)* in the railway carriage. Therefore, the paper will make a research of the network access in the railway carriage by studying the common carriage network access methods to test various parameters and indicators*(Qin Huafeng,2012)* of WIFI for determining the network access project in the high-speed railway carriage*(Zhang Hesheng, 2006)*.

2 Research of network access solution in high-speed railway carriage

At present, many companies have put forward the mobile network access projects for the high-speed railway. But the main communication device deployed in single carriage is commonly used by deploying network device in single carriage of neighboring carriages to provide mobile network access service. This method can maximize the effect of the main device in communicating ability and connecting scale(Jiang Xinhua, 2007). But through testing and analysis, the method may have blind sport in network coverage, resulting in ineffective mobile network access or bad network signal in some areas of the neighboring carriages. In order to solve this problem, this paper has proposed a network access method by deploying the main device and the extended device in neighboring carriages at the same time, aiming to eliminate the network blind spot of neighboring carriages and realize an effective mobile network access by means of networking bridge. We have also made study and testing of the two deployment methods with the main testing parameters including Received Signal Strength Indication, RSSI of mobile information network. The bigger the value of RSSI, the better the wireless mobile network signal and the faster of the mobile device network used by the passenger; vice versa.

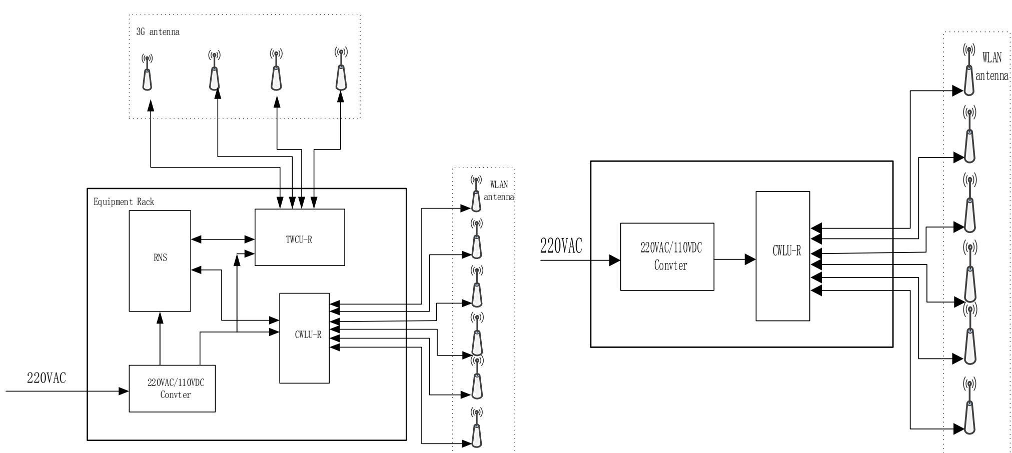
3 Environment deployment of network access solution in high-speed railway

The tested object is CRH1 motor car with 16 carriages located at one end of the railway, adjacent to the driver's cab. In the single-carriage testing mode, the main communicating device of the system is located in the middle of carriage 16 (with the location shooting picture seen in Fig.1); in the double-carriage testing mode, the main communicating device of the system is located in the middle of carriage 16, while the extended communicating network device of the system is located in the middle of carriage 15. The main device and the extended device are connected by means of 5.8G wireless signal. The device with RSSI strength adopts Trinity system device for testing.

a location map of main device b location map of main device

Fig 1. Location map of testing device

The three main devices of the system are located in the built-in erecting fixture in 6U height. The connecting relation between the three devices and the outside include power input and antenna connection. The electricity source is 220 VAC, which is supplied to the device after being transferred by AC/DC in the erecting fixture. The antennas include WLAN antenna and 3G antenna. WLAN antenna is located in the erecting fixture. The device is located in the part of the first carriage which is adjacent to the driver's cab, the electricity source socket with 220VAC is located above the rear part of the last seat. The WLAN extended coverage device of the system is located in the sanitary appliance cupboard between carriage one and carriage two. But we need to open the side gate of the sanitary appliance to facilitate putting the antenna outside the sanitary appliance cupboard.

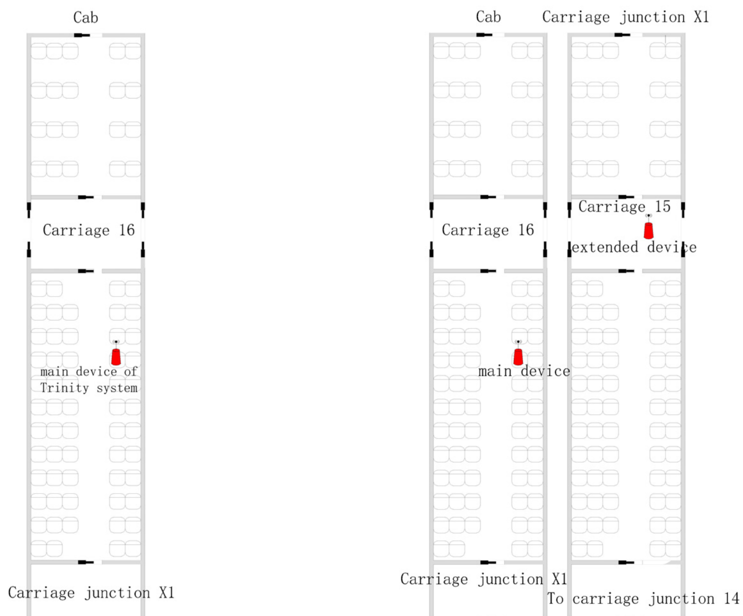


a Sketch map of main device installation b Sketch map of extended device installation

Figure 2. Sketch map of device installation

4 Testing of network access project in high-speed railway

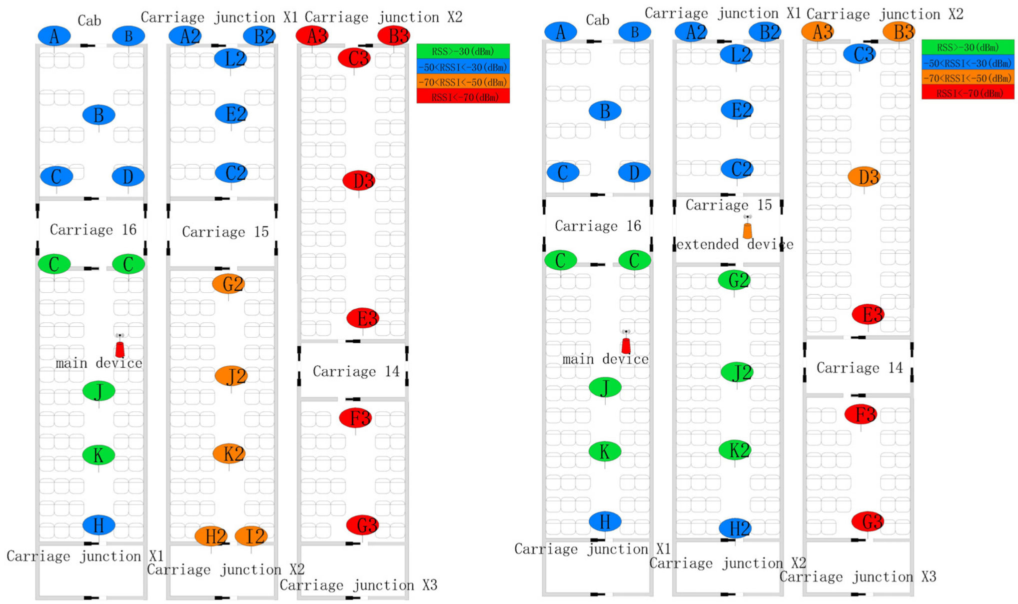
For the network access testing in the high-speed railway, this paper mainly makes the comparative testing between the network device deployed in single-carriage and the main device as well as the extended device deployed in double-carriage. The sketch maps of the two network access projects are shown in Fig. 3.



a Model map of single-carrigae system layout b Modle map of double-carriage system layout

Fig 3. Model map of network access project layout

For the two network access projects, their values of RSSI should be tested. The four kinds of colors stand for four different values of RSSI (the upper right of the following Figure). In the double-carriage testing mode, the main device of the system is located in the middle of carriage 16, while the extended device of the system is located in the middle of carriage 15. The main device and the extended device should be connected through 5.8G wireless signal. The results of the testing are as followed in Fig.4:



a RSSI sketch of single-carriage b RSSI sketch of double-carriage

Fig 4. Carriage location- signal strength coverage map

In the upper left of the coverage map, the green means that RSSI ＞-30(dBm), the blue means that -50(dBm)＜RSSI ＜-30(dBm), the orange means -70(dBm)＜RSSI ＜-50(dBm), the red means that RSSI ＜-70(dBm). The bigger the value of RSSI is, the better the wireless signal is and the faster of the mobile device network used by the passengers; vice versa. The relation of the carriage testing time and RSSI is shown in Fig.5 in the following:

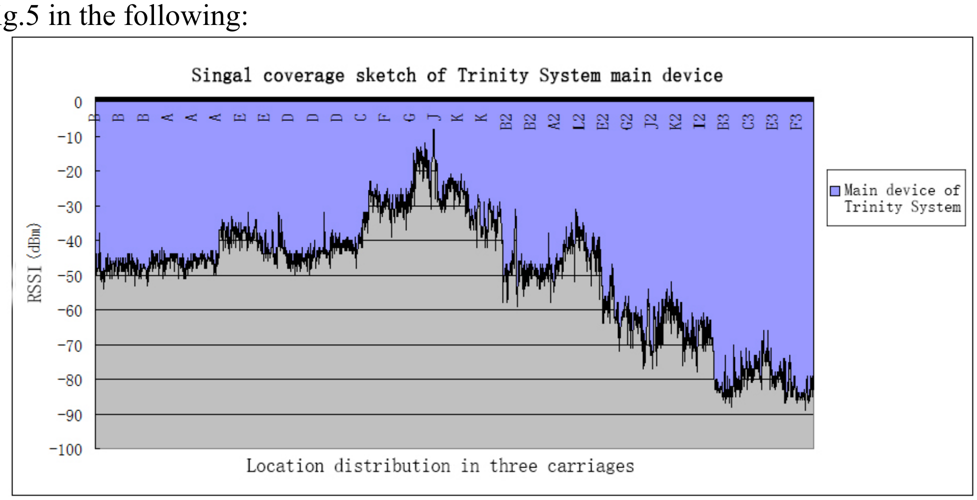


Fig 5. Testing time in carriage-RSSI

The detailed RSSI statistics corresponding to the figure of carriage location-RSSI map is as followed in Table 1:

Tab 1. WLAN strength coverage value statistics in single-carrigage and double-carriage

Carriage	Testing point	single-carriage RSSI [dBm]	double-carriage RSSI [dBm]
Carriage 16	B	-47.5	-47.5
	A	-46.0	-46.0
	E	-39.3	-39.3
	D	-43.4	-43.4
	C	-41.3	-41.3
	F	-29.8	-29.8
	G	-22.6	-22.6
	J (installation point of device)	-18.4	-18.4
	K	-28.9	-28.9
	H	-34.9	-34.9
Carriage 15	B2	-48.9	-48.9
	A2	-48.1	-48.1
	L2	-39.7	-39.7
	E2	-49.2	-49.2
	G2	-62.6	-19.5
	J2	-66.9	-24.3
	K2	-59.7	-27.7
	H2	-66.9	-37.6
Carriage 14	A3	-82.4	-60.2
	B3	-82.2	-46.7
	C3	-77.9	-62.6
	D3	-74.4	-65.7
	E3	-79.5	-73.4
	F3	-82.3	-72.5
	G3	-83.9	-70.9

From the coverage of the main device in the single-carriage, when the device is installed in the middle of the carriage, the maximum RSSI is -18.4dBm and the minimum RSSI is -47.5dBm in that carriage, matching perfectly with the requirements. When the main device is installed in the middle of the first carriage, the part adjacent to the first carriage in the second carriage such as the blue area is meeting the requirement, where the signal strength is between -39dBm and -49dBm. When the main device is installed in the middle of the first carriage, the part connecting the door of the second carriage with the third carriage such as the orange area is not meeting completely the requirements, where the signal strength is between -59dBm and -67dBm. In the double-carriage mode, the RSSI in the two carriages is between -18dBm and -49dBm, meeting the requirement.

With the testing results above, we can conclude: through a great number of testing results in the single-carriage mode and the double-carriage mode on chengdu-chongqing motor car, we can find out that the single-carriage mode uses one main device for coverage, but the mislocated layout of the main device results in unsatisfactory RSSI value in some areas of the carriage; while the double carriage modes deploy the main device and the extended device at the same time. In the testing, we find out that wherever the main device and the extended device are located, RSSI in two carriages can be more reliable compared with single carriage. With this method, we can provide an efficient and effective mobile network access for the passengers in any part of neighboring carriages, eliminating the blind spots of the carriage.

5 Conclusion

In order to provide better service for the high-speed railway passengers in terms of mobile information, this paper has made a research of network access in the railway carriage and its impact over the electromagnetic environment in the carriage. Through a great number of experimental tests on chengdu-chongqing motor car, it shows that the main device and the extended device network access projects proposed in this paper can enable RSSI to reach better results and cost saving. In addition, wireless signal in two carriages can be more reliable and stonger compared with single carriage wherever the devices are located.The researches above have laid a solid base for employing various mobile information services further in the high-speed railway.

Acknowledgement

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References

Jiang Xinhua, Zou Fumin, Lin Zhangxi, Wang Tongsen.(2007).“A Survey on the Internet Application on Passenger Trains”. Journal of the China Railway Society. Vol. 29: 103-110.

Lu Jiajia, Chen Ji.(2008). “Market Application of Mobile Network Based on Location Information Service”. Telecom Technology. Vol. 8: 21-24.

Qi Hongfeng.(2012). “Analysis of Medium-and-Low-Speed Magnetic Suspension Railway Operation Magnetic Environment”. Motor Electric Drive. Vol. 5: 62-65.

Qin Huafeng, Wang Jianhuai, Qian He.(2012). “Subway Railway Filter Reactor Structure and Magnetic Leakage Analysis”. Electric Motor and Urban Vehicles. Vol. 35: 48-51.

Ren Yan, Su Wei, Zhang Sidong, Zhang Hongke.(2006).“Research on Key Technology of Train-based Mobile Network”. Journal of the China Railway Society. Vol. 28: 121-124.

Wang Zhilin, Zheng Guoxin, Kai Kai, Ruan Yanrong.(2010). “Rail Transit Based on Communicating Railway Controlling Wireless Communication System Testing Platform”. Urban Transit Traffic Study. Vol. 10: 52-55.

Xu Yanfen.(2008).“Railway passenger train wireless transmission system”. Rolling Stock. Vol. 46: 33-34.
Zhang Hesheng, Zhang Yi, Hu Dongcheng.(2006). “Study on method of traffic state analysis for urban traffic network”. Intelligent Transportation System. Vol. 5: 23-27.

New Challenges in Managing Staff Competency for a Driverless Urban Rail Transit System

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Abstract: In order to fully realize the potential of Urban Rail Transit (URT) system in maintaining the viability of major cities, one of the key elements-- the competency of staff operating the URT system--must be managed effectively. As driverless URT systems have the ability to achieve higher efficiency while still maintaining the required safety standard, more driverless URT systems are being built and operated. When an URT becomes driverless, the operating concept of the URT will become significantly different from that of an URT with drivers as well. This has resulted in new challenges to the management of staff competency for a driverless URT system. This paper started off with discussions of the Competency Curve and then used the driverless Singapore North East Line (NEL) as a study case to examine the two main challenges faced when managing staff competency in a driverless URT context: the manual driving of a driverless train, and the driverless train control in the Operating Control Center (OCC). Strategies towards the handling of the above-mentioned new challenges were proposed based on the experiences gained on the ground.
Keywords: Urban rail transit; Driverless; Staff competency management.

1 Introduction

A driverless URT system can be defined as an URT with its trains being able to operate without a driver onboard. Driverless rail transit is not new, but there is a new trend that more and more driverless urban rail transit are being built or to be built in the near future, with the aim of reducing the operational costs and improving the frequency of service. Here are some examples.

(1) The Dubai Metro

As part of the driverless, fully automated metro network in the United Arab Emirates city of Dubai, the first section of the Red Line, covering 10 stations, was ceremonially inaugurated at 9:09:09 PM on September 9, 2009. With the line opening to the public at 6 AM on September 10, the Dubai Metro is the first urban train network in the Arabian Peninsula. The Green Line is under construction, and further lines are planned.

(2) The SkyTrain in Metro Vancouver

It is an urban rapid transit system in Metro Vancouver, British Columbia, Canada which uses fully automated trains running mostly on elevated tracks. The Expo Line was built in time for the Expo 86 World's Fair, the Millennium Line opened in 2002, and the Canada Line opened in 2009 in advance of the 2010 Winter Olympics.

(3) The San Pablo metro

June 16, 2010, a new driverless underground railway began operating in the network of San Pablo.

(4) The Singapore's Driverless Mass Rapid Transit (MRT)

The North East MRT Line (NEL) is the world's first fully-underground, automated and driverless, heavy rapid transit line and was opened on 20 June 2003 with 16 stations. The Circle Line (CCL) is also fully automated driverles metro line. Stage 3, a 5 kilometer five-station segment stretching from Bartley to Marymount, was the first section of the line opened on 28 May 2009. Stages 1 and 2 started operations on 17 April 2010.

(5) The Shanghai's Line 10

The trains on the Shanghai's Line 10 are designed to operate without drivers, but drivers are on board at the moment, since its official opening for restricted service on April 10, 2010.

2 Competency Curve

It has been understood that in general the following curve could well describe the stages that a person experiences when developing and maintaining his competency in a natural environment.

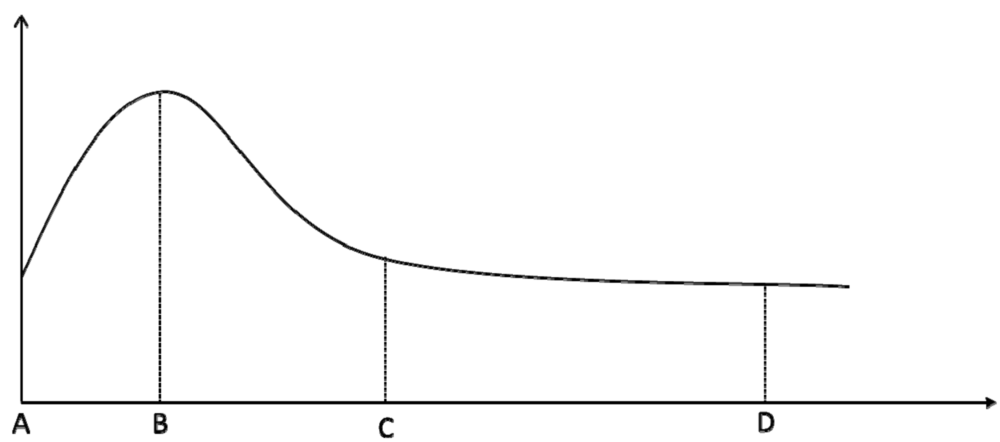

Figure 1. Person experiences stages

Stage (A-B): a person's competency quickly increases and reaches the required level through proper training.

Stage (B-C): his competency level drops when he starts to practice ONLY some skills that are normally required and no more training is provided.

Stage (C-D): his competency stabilizes at a level corresponding to the skills that he regularly practices.

It is obvious that the drop of competency level is a foot note to the old saying “if you do not use it, you will lose it.” And this drop creates a gap between the required Competence Level and his actual competence level. This implies that the staff is no longer competent in terms of some skills, good examples of which are handling rare equipment faults and other rare incidents like fire.

3 North East Line (NEL)

Trains in NEL are operated by computers on board and at wayside.

Based on the predefined Train Working Timetable, a central control computer Automatic Train Supervision (ATS) will trigger train Wake Up signal when the time comes. This signal will travel through various communication equipment including waveguide IAGO and eventually reach a designated sleeping train. A train in sleeping has one live device onboard to receive the train Wake Up signal and turn on the onboard computer and other train equipment.

After the train successfully completes its self-test, the train will be launched to mainline station for passenger service. This process and the subsequent movement/stopping along the mainline do not require any involvement of human driver under normal circumstance, although Traffic Controller (TC) in Operations Control Center (OCC) will monitor the whole process and take action when necessary. Train travel time between stations and dwell time at stations are also controlled by central computer.

Stand-by drivers are deployed inside trains as Customer Service Officers (CSO) with the main task of serving passengers in need such as wheelchair bound passengers. When necessary the stand-by driver is able to operate the train manually and/or handle certain equipment faults.

4 The New Challenges

Two major new challenges are faced when maintaining competency of operations staff of a driverless URT system. One of them relates to standby drivers.

As stand-by drivers seldom drive, their competency level and confidence level tend to drop, especially when manual train driving is concerned because: 1, usually a driverless train is not designed for manual driving, so driver’s comfort like driver’s seat is naturally not taken into account in design, as can be seen from the following picture. 2, no driving compartment is provisioned which means that a driver will have to drive in the presence of passengers close to him. This will inevitably affect the driver’s concentration which is essential to train driving task. 3, to stop a train accurately in manual requires skills and experiences that can only be obtained through practice.

Figure 2.Driving area of a driverless train

The other challenge involves traffic controllers. Unlike URT systems with train drivers readily available at driving console, TC of a driverless URT system will need longer time to find out what really went wrong on board the train and will in general need longer time to get a driver to the scene if a driver is needed.

5 The Strategy to take on the Challenges

The key is refresher training and the success requires that the refresher training is an integrated one which include actual driving, computer based simulation, table top exercise and drills at night when passengers service has stopped and the system is available for training.

Train drivers. Although refresher training through actual driving in Main line is the best and must not be skipped, this type of refresher training may cause train service delay due to the difficulties encountered in stopping a train accurately at stations, leading to the possible failure to achieve service performance requirement. Driving in depot without passengers can be used as compensation. Train driving simulator is good but could be too costly to be justified.

For refresher of train defect handling, Computer Based Simulation (CBS) can be very effective if defect handling exercises using actual train is provided in conjunction.

Traffic Controllers. As the key function of a Traffic Controller is coordination, scenario based table top exercise and drills using the real system at night involving various parties like driver and station staff have been proven to be very effective. Not only participants could regain their familiarity with the operating features of the system, the relevant rules and procedures, gaps among rules and procedures can be identified and filled up as a byproduct. Computer Based Simulation can be deployed for Traffic Controller's refresher training also.

6 Conclusions

Staff competence is one of the key elements needed for safe and efficient operations of an Urban Rail Transit system. However Stand-by drivers of a driverless urban rail transit will see their driving skills drop after the initial training due to the lack of driving practice. On the other hand, as train faults and other incidents are not every day events, both Stand-by driver and Traffic Controller have little chance to practice their incident handling knowledge and skills. In order to ensure they are always "Combat Ready", an "integrated refresher" strategy which includes actual train driving, Computer Based Simulation, table top exercise and drills at night must be adopted.

References

HE Jing(2007)."Urban Rail Transit Operation Management",China Railway Publishing House.

ZHU Haiyan(2009). "Urban Rail Transit Passenger Organization", China Railway Publishing House.

Zhang Guobao(2006). "Urban Rail Transit Passenger Organization",Shanghai Science and Technology Press.

Simulation of the Optimal Allocation of Self- Service Check-In Kiosks at the Airport

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Abstract: Passengers usually chose the traditional manual check-in or self-service check-in provided by the airport. Then, to confirm the optimal allocation of self-service check-in kiosks, the paper briefly introduced the current situation of self-service check-in and offered literature review of the research method of self-service check-in. Second, based on the method called ExtendSim simulation, the paper put forward assumptions, simulated process and the quantitatively allocated ways of appropriate number of self-CUSS. Third, taking some airport for example, the paper carried out a study on the passengers' arrival on some day and poached the passengers by adopting traditional ways and self-service ways. Finally, the article arrived at the conclusion which contained the briefly average queuing time in the different period of time, the most adaptive numbers of self-service kiosks on the highly utilized rate as well as the appropriate number of self-service kiosks in this airport. And the average value could be regarded as the proper number of self-service kiosks that should be equipped in the airport.
Keywords: Airport; Self-CUSS; ExtendSim simulation; Allocation of check-in.

1 Introduction

1.1 The present condition of Self-Service Check-in

The utilized rate of self-service check-in has been increasing by years (self-service check-in includes: check-in through online, phone and self-service kiosks), due to the more preferences from travelers.

However, there existed some questions relating to institution and standards for the development of self-service. Fast Travel meant a set of self-support process, which was not built on one day. Then, the diversification of self-service check-in only played a part in the whole process of Fast Travel, which required us to gain a better understanding of relevant questions. Through making massive investigations, analysis, conclusions, clear-up and practicing, the article proposed excellent, efficient, workable measures for the problems relating to the present operating mode. With the perpetual optimization, the implementation of Fast Travel could be put into effect. The problems of self-service check-in in our country could be listed in the following:

(1) The irrationality of the configured number of self-service kiosks

Just as Shang yao Y., Chin-Hui T., Miawjane C(2004) put, at present, the passengers still showed great preferences for artificial check-in, particularly for the travelers with registered luggage. However, due to the mere number of both types, if the peak period came, both of them could not meet the demands of passengers.

(2)In contrast, the number of domestic check-in kiosks was inferior to the foreign and most travelers are not guided, just like Yan S, Tang C.-H, Chen M(2004) put.

The majority of passengers remained low for the self-service kiosks, partly because of the inconvenience brought by registering luggage; partly on account of the anxiety; and partly due to the unfamiliarity with self-service kiosks.

(3)The insufficiency of uniform industry standards, as Liu Changyou, Deng Zhenning, Zhang Jinjing(2007) described.

For instance, the self-service check-in varied from different airports or airlines. For customers or enterprises, it would be a waste of resources brought by overlapping investment. Given the deficiency of relevant criterions, it leaded to the mixed self-service and did not accomplish the established target.

The article made explosive study on the dynamic configuration number of self-service kiosks, selected the configured mode of self-CUSS of airports as a major research object and obtained experience from the foreign, in order to solve practical problems.

1.2 The methodology on the allocated number of self-service check-in

1.2.1 The analysis of foreign research

In 1980s, the computer simulated technology, particularly the dispersed simulation, was applied into the airport information system by some space agency of Europe and America. And then, a great number of findings have been made. Some were listed in the following:

(1) On account of the travelers' behavior, Ahn SB and Park Y(2003) built the assigned optimization model for check-in counter. Specifically, by passengers' survey, the study determined to build a model according to the departure time and the arrival time. After that, deploying the passengers' arrival time distributions, it counted the most appropriate amounts of kiosks that should be open as well as the opening period of every counter. The model, not only provided a more economical way for airlines and enhanced customer experience, but also offered applied systems for the effective execution of the kiosks' actual-time assignment. What is more, it also provided effective long-term methods for settling the problem relating to the crowd of airport terminal caused by flight delays.

(2)When making study on the configuration and controlling of check-in kiosks, Nico M. van Dijk and Erik van der Sluis(2006) first computed the minimum number of kiosks needed for every flight. Then, given the constraint condition that the kiosks for the same flight should be adjacent, the study got the minimum amounts of counters for every period and the total open time of kiosks, with the adoption of 0-1 programming.

(3)Ueda, Keiich, and Setsuya Kurahashi.(2014) intended to propose "Self-Service Technology Adoption Model" by utilizing the knowledge and experiences of front line experts. The study also suggests the efficient practice of air–travel passenger handling with self-service kiosks in an international passenger terminal by the simulation of the proposed agent-based model. Through conducting the experiments, the scenario and the key factor are indicated, which may possibly accelerate the self-service usage rate with cost effective way and less impact for customer services.

1.2.2 The analysis of domestic research

(1)Zhu Jinfu, in the book called *Air Transportation Programming*, introduced suggestions for IATA (IATA: International Air Transportation Association) and derived the simplified calculation method based on the Queuing Theory, which were available for measuring the open amounts of check-in kiosks.

(2)Liu Changyou, Deng Zhenning and Zhang Jinjing(2007) made study on the influence of the arrival modes for the check-in service, with the application of Queuing Theory. Definitely, the due amounts of check-in kiosks, for the single flight, were presented for both the uniform arrival and non-uniform arrival of travelers. Then, for the minimum allocation of kiosks for multiple flights, the study, with practical flight data, made simulations for verifying the model and obtained the solutions by the Integer Programming.

(3)Tay-Lin Hwang, Chi-Ruey Jeng and Sin-Siang Wang(2012) established the operating pattern for airport check-in counter assignments by minimising the operational cost from incurred by the airline and maximising passenger service level with considering the use of kiosk machine and full/part-time duty counter staff. According to the experimental results and sensitivity analyses of actual airline operations data, employing part-time counter staff and using kiosk machines would significantly reduce counter operation cost and improve passenger service quality.

Simulation referred to a process for the experimental study of system, which operated with the construction of practical system model. It is worth noting that simulation technology and comprehensive simulation system stayed dispensable in analyzing, designing, evaluating, decision making and training. Especially for the configured number of self-service kiosks, simulation system had advantages that could not be ignored.

3 The construction of model: the configured number of self-service check-in

3.1 The hypothesis of simulation

The course of building a model was to make analysis, hypothesis, and induction for the system. Then, the most important was to make practical factors rational with some reasonable assumptions. According to check-in queuing system, the article carried out the following assumptions:

(1)Initially, both staff and kiosks were in the state of readiness, with no passengers in the system;

(2)All the facility worked normally in the simulation operation, and no breaks left to the staff at the interval;

(3)All the counters could be shared by users;

(4)The arrival time interval of travelers' from varied period complied with the Uniform distribution;

(5)During the permissible period, all the passengers finished the procedure for the check-in;

(6)The queuing rule referred to FIFO;

(7)The average check-in time was replaced by the check-in time; ($A = B + C$; A: the average check-in time; B: the mean time for check-in formalities; C: the mean time to for registering luggage)

(8)Every kiosk shared same traits and only could service one user at a time. The mean servicing time was employed to represent the service time of reception desk;

(9)In accordance with the combination of departure time and ahead of the arrival time, the data about passengers would be actually presented in the system;

(10)During the queuing period, passengers were not allowed to leave or switch the line;

(11)There existed no flight delays under the condition of all departure flights operating punctually for the schedule.

(12)The study did not divide the passengers into distinctive classes, such as first class, business class, and economic class. And it did not include transfer travelers.

3.2 The procedure of simulation

3.2.1 The introduction of simulation software: ExtendSim

For probing into the allocated number of self-service check-in kiosks at the airport, the discrete event simulation is employed for the article. For example, computer network, traffic management, social economic system and other communication system are parts of the discrete event system. Both time and space, relating to events of this system, are disperse. Normally, due the strong randomness of the event, it is difficult to study with conventional methods.

The simulation software is adopted by the paper, called ExtendSim. The ExtendSim is a part of computer simulation tools, which is used to construct models involving multiple kinds of production, service and system. What's more, through repeated argumentation and analysis, ExtendSim is the most appropriate for simulation.

The applied cases have been found in the foreign airports, for the registered luggage system being embedded into the self-service check-in kiosks. Nowadays, in the domestic airports, only T3 of Beijing Capital International Airport offered this kind of service. Its kiosks were to integrate the work of check-in counters into the self-service check-in. Afterwards, by self-support (Specifically, it meant integrating the luggage code printer into the self-service check-in and made data interaction with ELV system of airport.), the kiosks could provide solutions required for the passengers with baggage. In consequence, in the course of designing the simulation, the study neglected individual differences and took shape integration of check-in procedure and luggage transportation, in order to employ the mean time to check-in. Then, the process of simulation is demonstrated in the following, just like the figure 1.

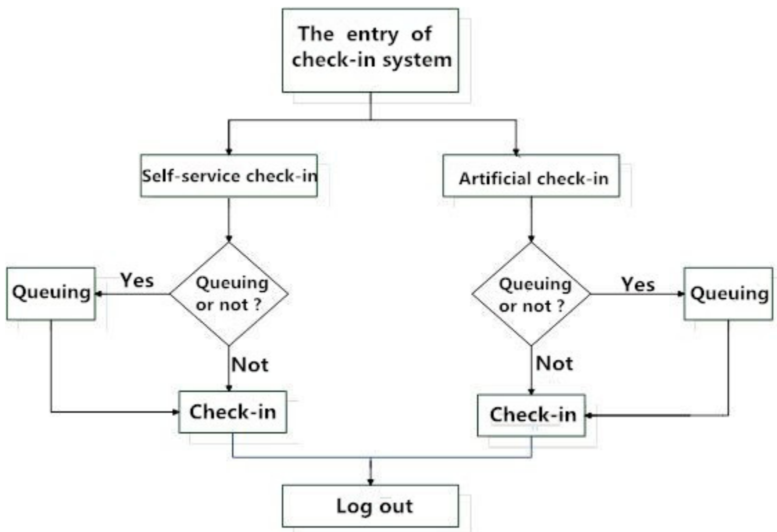


Figure 1. The procedure of simulation

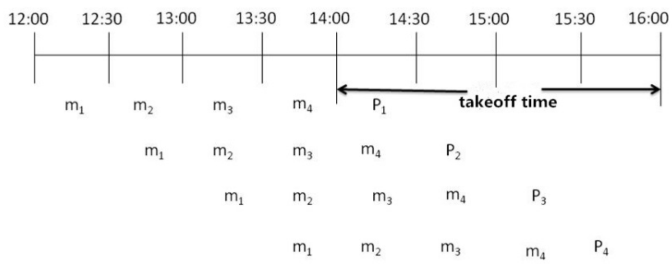
When the departure travelers entered into the check-in system, decisions on the ways of check-in were dependent on the personal preference or practical situation. After choosing, if leaving vacant kiosks, the passengers who selected the self-service would be in the state of check-in directly until logging out; if leaving no spare facility, the state of travelers would be in the state of queuing spontaneously, with the queuing rule called FIFO, until receiving service and then logging out. In the same way, it also could be applied to the artificial check-in.

4 The simulation of some airport terminal's self-service check-in kiosks

4.1 The arrival pattern of passengers

For the passengers, the arrival pattern was more dependent on the travelers' habits. And in the same period, the arrival amounts would vary on the basis of certain flight schedule and arrival rule. Therefore, according to the Arrival Pattern, how to calculate the actual numbers of passengers in some period would be one of the determinant factor for the allocated amounts of kiosks. But the arrival rule could not possibly comply with some specific distribution.

Hence, "Sliding Window" would be adopted as the calculating method, which divided time into the unit programming period and split the problems up into the set of sub-problem, in order to decrease the complexity of solution and avoid taking the large scale of sample assembled by passenger traffic into account. In detail, the study selected the interval, 14:00-16:00, as the programming period. P_i（i=1,2,3…n）was regarded as the amounts of departure passengers in the programming period, that's to say, the numbers of departure travelers at 14:00-14:30, 14:30-15:00, 15:00-15:30 and 15:30-16:00 would be replaced by P_1、P_2、P_3、P_4. Besides, from 30 minutes to 180 minutes before takeoff, the passengers would arrive at the airport, whose arrival time obey some distribution. Assuming that the amounts of passengers who arrive 180-120 minutes early would be m_1; 120-90 minutes early would be m_2; 90-60 minutes early would be m_3; 60-30 minutes early would be m_4; and m_i（i=1,2,3…n）refers to the percentage, so the study made the provision: $\sum_{i=1}^{n} m_i = 1$. In the next, for the programming period, the percentage of passengers arriving at the airport, performing in the matrix form, would be presented in the following:



M is the distributed matrix of passengers' arrival time and P is the vector of departure travelers in varied periods. And the time frame could be divided by different needs. If setting 30 minutes as a time slot, then M refers to a 7×4 matrix while P refers to a 4×4 matrix. The practical arrival amounts of departure passengers in programming period would be described by $W = M \times P$. So the passenger assignment model, performing in the matrix form, would be listed in the following:

$$M = \begin{bmatrix} m_1 & m_2 & m_3 & m_4 & 0 & 0 & 0 \\ 0 & m_1 & m_2 & m_3 & m_4 & 0 & 0 \\ 0 & 0 & m_1 & m_2 & m_3 & m_4 & 0 \\ 0 & 0 & 0 & m_1 & m_2 & m_3 & m_4 \end{bmatrix}$$

$$P = \begin{bmatrix} P_1 & 0 & 0 & 0 \\ 0 & P_2 & 0 & 0 \\ 0 & 0 & P_3 & 0 \\ 0 & 0 & 0 & P_4 \end{bmatrix}$$

$$W = M \times P$$

$$W=\begin{bmatrix} m_1P_1 & m_2P_1 & m_3P_1 & m_4P_1 & 0 & 0 & 0 \\ 0 & m_1p_2 & m_2p_2 & m_3p_2 & m_4p_2 & 0 & 0 \\ 0 & 0 & m_1p_3 & m_2p_3 & m_3p_3 & m_4p_3 & 0 \\ 0 & 0 & 0 & m_1p_4 & m_2p_4 & m_3p_4 & m_4p_4 \end{bmatrix}=(W_1\ W_2\ W_3\ W_4\ W_5\ W_6\ W_7)$$

Among it, $\sum_{j=1}^{4} W_j = W$ depicted the concrete arrival amounts of departure passengers in the programming period. By field survey and given the actual requirements, the study confirmed the m_i and P_i which would be put into effect. After that, the article obtained the estimated amounts of arrival passengers.

4.2 The settings of simulation

The beginning time of queuing system was at zero clock, January 1, 2013. And the unit of time was set to the seconds. In the initial state, both staff and kiosks were in the state of readiness, with no travelers being serviced. What's more, the simulation for queuing was measured by one hour. On the basis of departure flight schedule, combined with investigative analysis, the article would obtain the time distribution of passengers who arrived at ahead of time. Then, employing the calculation method called "Sliding Window" to ensure the average arrival interval of every passenger, the actual data about passengers would be generated through the Create module, as shown in the Figure 2.

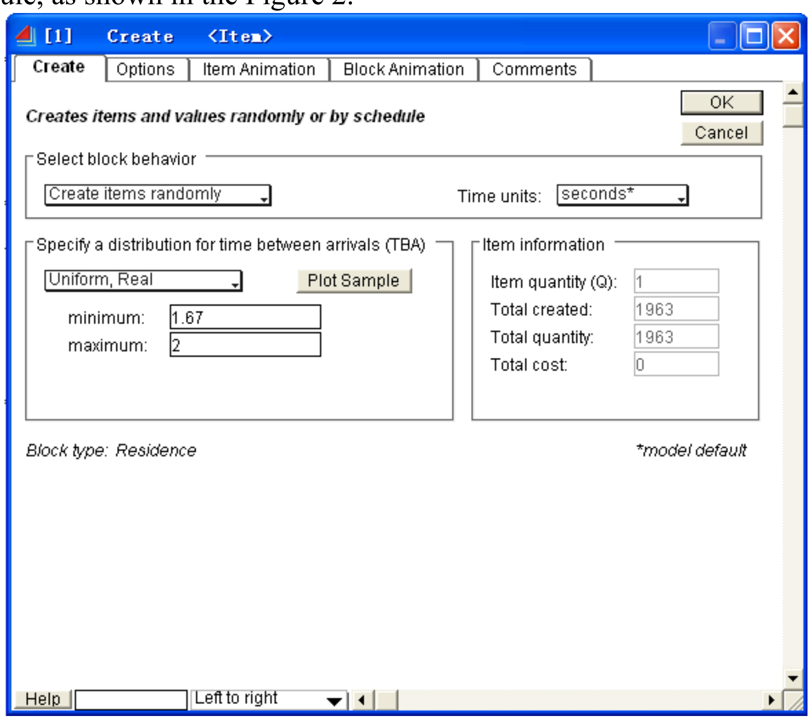


Figure 2. The settings of Create module

After that, to confirm the configured number of self-CUSS, in light of the allocated ratio of self-CUSS, the system would filter out the passengers employing the self-service from the whole travelers. And it required that the allocated ratio of both ways should be input the Probability where the apportionment of self-CUSS was 27%, the sharing ratio of manual check-in was 64%, and the other ways were 9%. Next, in the routing selection, the 27% of passengers generated by the system were arranged to use the self-CUSS; the 64% of travelers would employ self-CUSS; and the remaining selected other ways. The routing selection was presented in the following, just like figure 3.

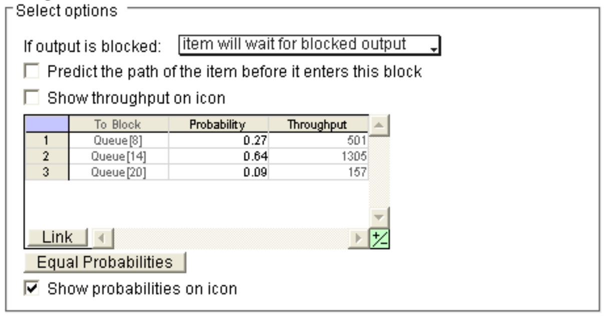


Figure 3. The setting of routing selection

The module of Queue was set to the ordered queue, and the queuing rule complied with FIFO.

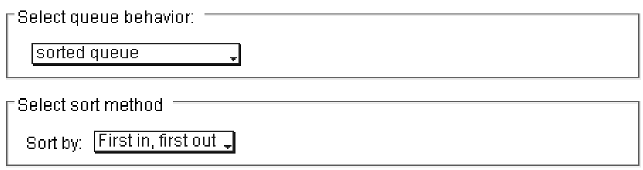


Figure 4. The module of Queue

The average time of check-in was adopted to describe the servicing time of self-CUSS and artificial check-in, which was relatively rigid. In the simulation, the processing time of self-CUSS was 180 seconds. That's to say, every passenger was allowed to spend 180 seconds for check-in, when time is over, it would let the users log out.

It was necessary to set the maximum items in activity to the number which is greater than one, on account of the similar kiosks operating parallelly in reality. Furthermore, the definite values would be adjusted by the parameters output by the simulation. After finishing the settings, the system would run multiple times, in order to gain the range of results. Eventually, the possible results would be appropriate for analyzing the model and observing the result of assessment.

The data of this article was derived from the departure flight, from August 29 to September 4 in 2013, due to the fact that the amounts of actual arriving passengers from varied periods could not be counted and that the alteration of scheduled departure flight in every day could not be neglected. After that, the paper would gain the practical numbers of departure travelers at varied periods, based on the percentage distribution of passengers who arrived ahead of time.

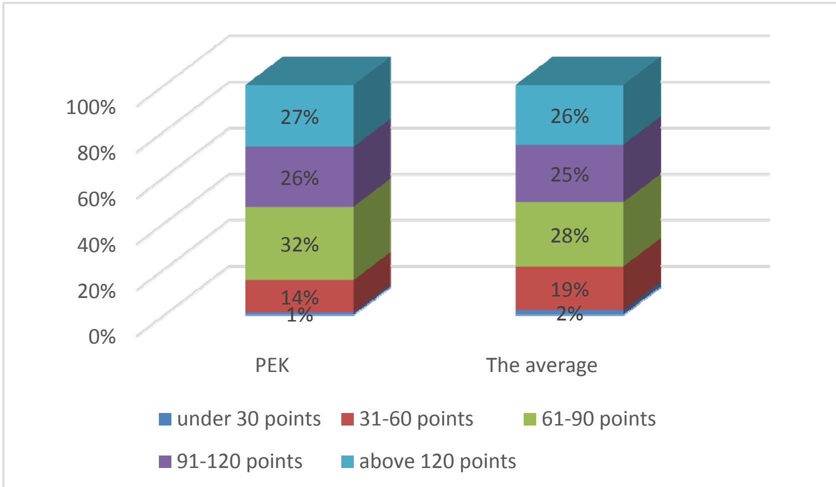


Figure 5. The arriving time distributions of departure passengers ahead of time The data source: PEK 2013 Total Traffic Report

Just as indicated in the figure 5, during 120 minutes, the percentage of arriving passengers, ahead of schedule, was around 73%. Additionally, above 120 minutes, the travelers who arrived ahead of time accounted for 27% of the total. Then, by the Sliding Window, at varied periods, the study would obtain the real-time number of arriving passengers from the foreign and domestic check-in area of T3.

Table 1. The actual amounts of departure passengers at varied periods

Time Quantum	Foreign check-in area	Time Quantum	Domestic check-in area
00:00-01:00	0	00:00-01:00	203
01:00-06:00	429	01:00-06:00	1,424
06:00-07:00	2,132	06:00-07:00	4,302
07:00-08:00	1,451	07:00-08:00	2,927
08:00-09:00	743	08:00-09:00	1,508
09:00-10:00	996	09:00-10:00	2,047
10:00-11:00	1,213	10:00-11:00	2,579
11:00-12:00	1,324	11:00-12:00	2,836
12:00-13:00	1,597	12:00-13:00	3,121
13:00-14:00	1,121	13:00-14:00	2,267
14:00-15:00	1,368	14:00-15:00	2,659
15:00-16:00	1,359	15:00-16:00	2,769
16:00-17:00	1,165	16:00-17:00	2,321
17:00-18:00	1,076	17:00-18:00	2,249
18:00-19:00	1,250	18:00-19:00	2,436

19:00-20:00	1,045	19:00-20:00	2,218
20:00-21:00	598	20:00-21:00	1,223
21:00-22:00	343	21:00-22:00	654
22:00-23:00	131	22:00-23:00	329
23:00-24:00	108	23:00-24:00	296
Total	19,449	Total	40,368

The explanatory note: Foreign check-in area refers to the number of passengers in the foreign check-in area; Domestic check-in area refers to the number of passengers in the domestic check-in area.

In the fifth figure, it was acquired that around twenty-seven percent of passengers chose self-CUSS. About forty-five percent of passengers selected the artificial check-in. The percentage of travelers who chose the Bag Drop Off Desk was nineteen. Thus, it was about sixty-four percent of passengers who elected the check-in counters. (Notably, the Bag Drop Off Desk is a part of check-in counters.) In sum, the number of passengers using the self-service check-in versus the number of travelers using the artificial check-in is 3:7.

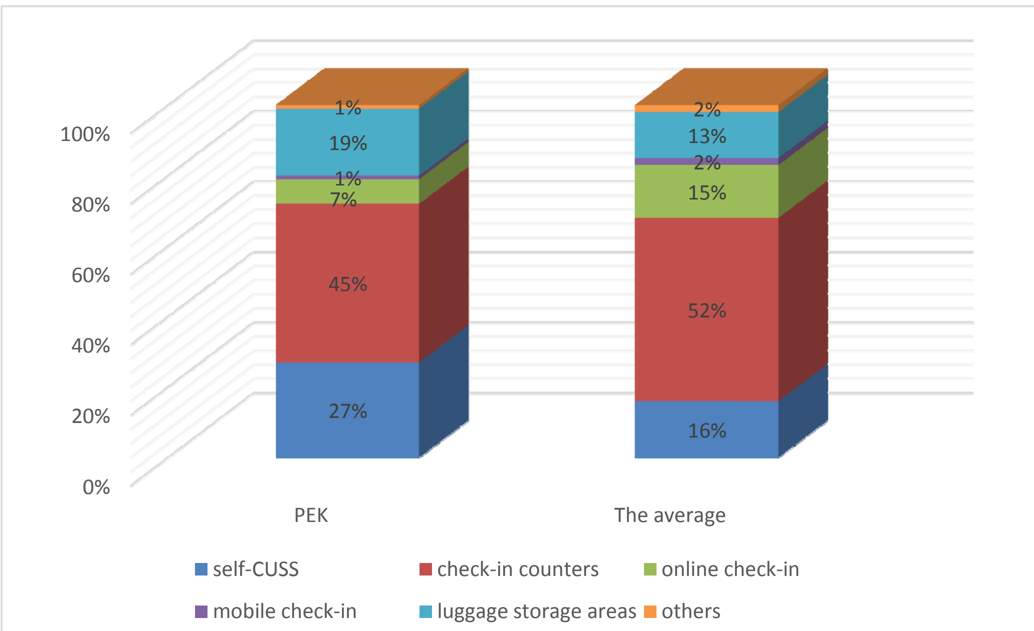


Figure 6. The percentage distribution of the modes of check-in
The data source: PEK 2013 Total Traffic Report

The sojourn time of check-in counters, servicing for the ninety-five percent of international routes, shouldn't be over twenty minutes, based on the Passenger Service Commitment. Meanwhile, the residence time of check-in counters, servicing for the ninety-five percent of domestic routes, shouldn't be over ten minutes. What's more, it must be ensured that the sojourn time for the passengers who adopt the self-CUSS, should not be beyond eight minutes. However, the commitment should be adjusted: the percentage of both international routes and domestic routes, serviced by the check-in counters, should be altered to a hundred. Meanwhile, the others stay invariant. The reason to make these adjustments is because of the limits of the simulation software. Then, the mean time of check-in would be presented through the data offered by some airport and on-the-spot investigation, just as illustrated in the second table.

Table 2. The mean time of check-in from varied passengers

Travelers / Check-in ways	International routes	Domestic routes
Artificial check-in	53 seconds	35 seconds
Self-CUSS	180 seconds	180 seconds

In the study, the article required to keep the utilized rate of self-service check-in and artificial check-in stay at the reasonable range and comply with the adjusted service commitment of Air China. And, by the incessant adjustments of parameters, the optimal dynamic amounts of self-service check-in kiosks would be acquired. Then, it was demonstrated as shown in the third and fourth table.

Table 3. The dynamic index of self-CUSS at varied periods from the domestic

Time Buckets	Opening numbers	The mean length of line	The longest line	The average time for waiting(Seconds)	The maximum time for waiting(Seconds)	The availability
00:00-01:00	3	0.18	3.9	37.21	206.26	0.81
01:00-06:00	21	0.44	7	4.32	64.05	0.83
06:00-07:00	64	2.29	18	6.91	46.54	0.91
07:00-08:00	40	3.87	16	17.96	76.75	0.95
08:00-09:00	23	0.64	7	5.52	61.80	0.90
09:00-10:00	34	0.72	10	4.17	50.02	0.89
10:00-11:00	34	3.91	20	10.51	102.25	0.93
11:00-12:00	34	3.74	26	19.26	136.82	0.93
12:00-13:00	43	1.14	10	5.08	36.51	0.89
13:00-14:00	31	3.52	16	20.85	87.87	0.95
14:00-15:00	36	5.97	19	29.81	83.58	0.96
15:00-16:00	36	7.98	34	38.15	162.67	0.94
16:00-17:00	31	5.18	17	30.08	90.75	0.96
17:00-18:00	31	1.85	14	11.42	81.25	0.93
18:00-19:00	31	5.95	20	34.52	114.64	0.97
19:00-20:00	31	2.04	13	12.41	67.19	0.93
20:00-21:00	18	3.48	13	36.28	121.20	0.93

21:00-22:00	10	1.00	7	20.27	134.82	0.86
22:00-23:00	4	1.08	6	51.06	238.57	0.87
23:00-24:00	4	3.38	10	162.41	414.40	0.90

From the above table, for the domestic routes, it acquired that the peak period of check-in zone arose from six o'clock to seven o'clock in the morning. According to the simulation results, it requires that sixty-four self-service check-in kiosks should be equipped, the utility rate would be nine-one percent, the average queuing length would be two point twenty-nine, the maximum queuing length would surmount to eighteen, the average queuing time would reach six point ninety-one seconds, and simultaneously the maximum queuing time would rise to forty-six point forty-four seconds. In the next, the detailed simulation would be presented, just as shown in the seventh figure.

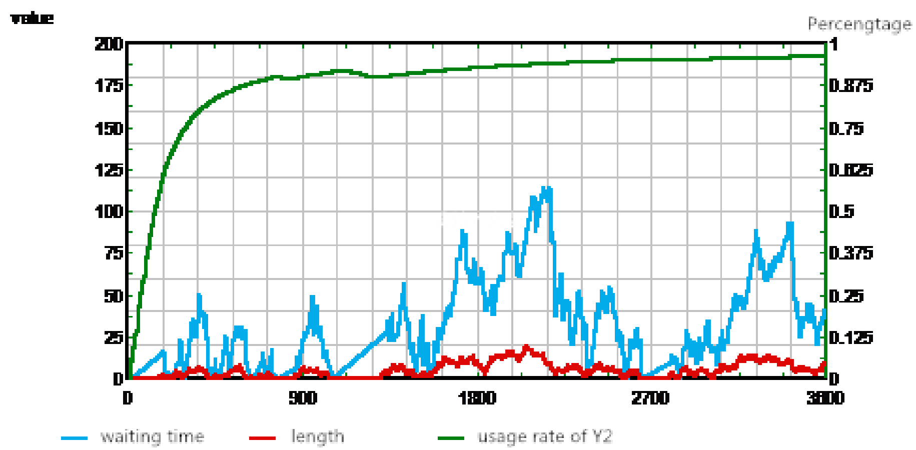


Figure 7. The usage of self-CUSS for domestic flights at 6:00-7:00

Figure 7: the utilized situation of self-CUSS for the domestic flights from 6:00 to 7:00. The fifth table: the dynamic and unrestricted indicators of self-CUSS in the international flights.

Table 4. The dynamic index of self-CUSS for international flights

Time Interval	Open Amounts	Average Queuing Lengths	Largest Queuing Lengths	Maximum Waiting Time(s)	Maximum Waiting Time(s)	Utilized Rate
00:00-01:00	0	0	0	0	0	0
01:00-06:00	1	0.51	2	100.04	243.49	0.88
06:00-07:00	28	3.77	19	24.57	100.85	0.96
07:00-08:00	20	0.52	7	5.32	61.10	0.86
08:00-09:00	12	0.52	5	9.23	67.76	0.84

09:00-10:00	12	3.43	14	51.60	215.15	0.89
10:00-11:00	20	1.38	8	13.24	70.20	0.90
11:00-12:00	20	2.81	12	27.29	115.20	0.91
12:00-13:00	20	0.58	8	6.06	80.75	0.83
13:00-14:00	20	1.08	8	10.70	67.97	0.88
14:00-15:00	20	1.50	10	15.33	79.85	0.85
15:00-16:00	20	7.60	22	68.50	193.98	0.93
16:00-17:00	18	1.45	11	16.22	105.36	0.87
17:00-18:00	18	1.58	11	17.66	88.89	0.87
18:00-19:00	18	1.52	11	16.50	110.52	0.90
19:00-20:00	18	1.16	8	12.52	102.44	0.87
20:00-21:00	7	4.17	12	107.72	295.13	0.95
21:00-22:00	7	1.82	8	49.45	207.44	0.92
22:00-23:00	2	0.88	5	70.75	229.42	0.88
23:00-24:00	2	1.22	5	104.71	427.64	0.88

For the international routes, it acquired that the peak period of check-in zone arose from six o'clock to seven o'clock in the morning. According to the simulation results, it required that twenty-eight self-service check-in kiosks should be equipped, the utility rate would be nine-six percent, the average queuing length would be three seventy-seven, the maximum queuing length would surmount to eighteen, the average queuing time would reach six point ninety-one seconds, and simultaneously the maximum queuing time would rise to forty-six point forty-four seconds. In the next, the detailed simulation would be presented, just as shown in the eighth figure.

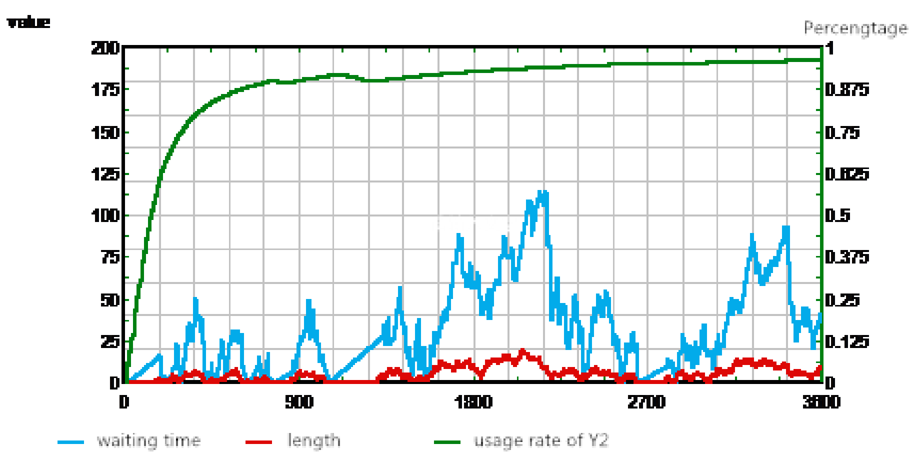


Figure 8. The usage of self-CUSS for international flights at 6:00-7:00

5 Conclusions

Given the fact that the queuing time should be cut down as much as possible and the utilized rate should be improved, the average values were employed as the number of self-service check-in kiosks, based on the amounts of kiosks described by the above. Besides, if both the international and the domestic check-in kiosks area were sliding into the state of heavy load, keeping the counters being in the condition of overloaded operation for a long time, it would lead to severe loss of facilities and then make evil impacts on the quality of travelers' service. Therefore, in order to ensure the service quality, it demands that the self-service check-in kiosks should be reasonably added especially in the peak period, on account of the fluctuation of flights and the increase of passengers' traffic. What's more, it is the ExtendSim simulation that may possibly improve the utilized rate of self-service check-in kiosks with cost effective way and less impact for customer services.

References

Ahn S.B. Park Y. (2003). Optimal assignment for check-in counters based on passenger arrival behaviour at an airport. *Transportation Planning and Technology*.

Hwang, T. L., Jeng, C. R., & Wang, S. S. (2012). Airport check-in counter assignment: a proposed solution. International Journal of Aviation Management, 1(4), 257-270.

Liu Changyou, Deng Zhenning, Zhang Jinjing. (2007). Study on the check-in in the terminals of airport. Chinese Control and Decision Conference

Nico M. van Dijk, Erik van der Sluis. (2006). Check-in computation and optimization by simulation and IP in combination, European Journal of Operational Research, 2006, 171: 1152~1168.

Shang yao Y., Chin-Hui T., Miawjane C. (2004). A Model and a Solution Algorithm for Airport Common Use Check-in Counter Assignments. Transportation Research Part A, 38; 101-125.

Sewell, E. C., Lee, A. J., & Jacobson, S. H. (2013). Optimal allocation of aviation security screening devices. Journal of Transportation Security, 6(2), 103-116.

Ueda, K., & Kurahashi, S. (2014). How passenger decides a check-in option in an airport. In Social Simulation Conference.

Xu, K., & Cheng, D. (2011, October). Modeling and analysis of check-in procedure by simulation. In Systems, Man, and Cybernetics (SMC), 2011 IEEE International Conference on (pp. 61-66). IEEE.

Yan, A., Solomon, S., Mirchandani, D., Lacity, M., & Porra, J. (2013). The Role of Service Agent, Service Quality, and User Satisfaction in Self-Service Technology.

Yan S, Tang C.-H, Chen M. (2004). A model and a solution algorithm for airport

common use check-in counter assignments. Transportation Research.
Zografos, K., Andreatta, G., & Odoni, A. (Eds.). (2013). Modelling and Managing Airport Performance. John Wiley & Sons.
Zhu Jinfu. (2007) Air Transportation Programming, Nanjing University of Aeronautics and Astronautics.

Internet of Things Technologies for Urban Public Transport Systems: A Case Application in Chengdu, China

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Abstract: Public transport is widely acknowledged as a high capacity transport mode which helps mitigate traffic congestion in urban road networks, reduce fuel consumption and improve air quality. In this paper, a review of the application of internet of things technologies, such as Radio Frequency Identification (RFID), GPS/GIS and GPRS/3G/4G, in public transport system is presented. Thereafter, a newly developed intelligent public transport system with application of Internet of things technologies in Chengdu city is analyzed. The effectiveness of the system is quantitatively analyzed. Results show that application of Internet of things technologies in Chengdu public transport system highly improves operational efficiency and level of service, and reduces total costs of operation and management.
Keywords: Public transport; Internet of things; RFID; GPS/GIS; Level of service.

1 Introduction

In big cities, urban roads become more and more congested, especially at rush hours. In order to mitigate traffic congestions, different traffic management measures have been or are being applied, such as congestion pricing, ITS measures, limit issuance of new car license plates, traffic restrictions based on the last digit of license plate numbers, etc. However, when car traffic demand highly exceeds road supply, the improvement of traffic conditions by applying some traditional traffic management measures appears marginal. In the past decades, more attention has been paid to develop public transport around the world. In China, public transport operators and authorities are trying to increase the public transport mode share by performing fare reform, improving public transport operational efficiency and level of service. In recent years, with the application of Internet of Things technologies in ITS, e.g., RFID technology, sensing technologies, GPS/GIS, GPRS/3G/4G, etc., more advanced public transport systems are being developed.

RFID is non-contact automatic identification technology that uses radio waves to identify and track groups or individual objects at distance. The application of RFID technology in public transport systems started in recent years. In the US and some European countries, the RFID enabled smart card is widely used in the transport field to perform revenue collection. It is perceived as a secure method of user validation and fare payment(Pelletier et al., 2011). Apart from fare collection, the data collected by RFID smart cards can be used for long-term network planning, travel behavior analysis, demand forecasting, schedule adjustment, and longitudinal and individual trip patterns(Pelletier et al., 2011). RFID technology can be applied for Automatic Vehicle Location (AVL) as well. In Beijing, RFID technology was applied for bus signal priority since 2008(Jiang et al., 2011). When a bus equipped with a RFID tag approaches the intersection, a roadside RFID reader captures the bus information and sends it to the traffic signaling system to control the traffic light(Lee et al., 2009). A simulation study conducted in (Wang et al., 2011) shows that the RFID enabled bus priority system has the potential to improve public bus service level by reducing congestion of bus traffic flow.

GPS/GIS and GSM/GPRS/3G technologies have been extensively applied in road transport systems for vehicle monitoring purpose. In the public transport context, data collected by GPS equipped buses can be used for bus fleet tracking and scheduling. In (Medagama et al., 2008) , a GPS/GIS/GPRS and web based system framework for large fleet (including bus fleet) tracking is proposed. In (Liao, 2011), a data driven tool was developed to fuse GPS data and fare collection data. Sun et al. (Sun et al., 2007) Proposed a method to predict bus arrival time at individual bus stops based on the bus location and speed data collected by GPS enabled buses. Besides, The GPS equipped AVL is commonly implemented along with signal priority systems for buses (Hounsell et al., 2005; Liao et al., 2006).

In this paper, Internet of Things technologies applied in public transport systems are reviewed in the next section. Then, intelligent public transport system of Chengdu city, which is composed of four subsystems with application of Internet of things technologies, is presented in section 3. In section 4, the effectiveness of the system is discussed. The last section concludes the paper.

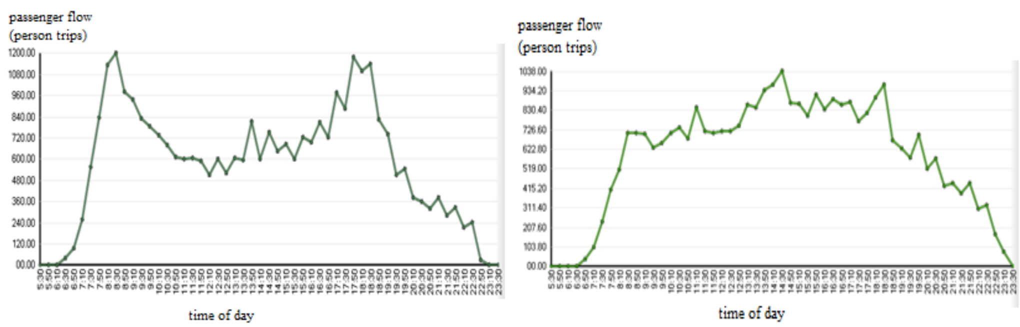
2 Intelligent public transport system in Chengdu

2.1 Background

Chengdu city is located in the southwest of China with a population of more than fourteen million. By the end of 2013, the car ownership in Chengdu is about three million, which ranks three among all cities in China. Traffic demand increases year by year, which leads to severe congestion, especially during rush hours. In the past five years, developing an intelligent public transport system is on the agenda of Chengdu municipality. The system started in 2008, and it is now in full operation. This system is composed of four parts: smart card system, bus monitoring system, bus scheduling system and bus information system. In the following, detailed information about these subsystems will be presented.

2.2 Smart card system

The smart card system (IC card system), has been implemented in Chengdu public transport system since 2004. Up to 2014, more than 7000 buses are equipped with contactless smart card readers that are linked to a GPS device. The preliminary purpose of this system is to realize no cash fare collection. The value stored on a smart card is mainly in the form of eCash and number of rides. Passengers who are onboard in the same bus or transfer less than three times within two hours pay a fixed amount of fare, independent of time of the day and trip distance. Therefore, unlike some systems, where passengers need to tap-on when get in the bus and tap-out when get out of the bus, this system requires passengers to 'tap-on' only when get onboard the bus and no 'tap-out' is required. On average, 75% of passengers use a smart card when traveling with public transport. This percentage goes up to 95% during peak hours. Apart from the role of effective revenue collection, ridership, boarding location and time can be collected as well. Figure 1 (a) illustrates ridership of bus line 47 at different periods of a weekday. Two peaks which are a morning peak between 7:30 and 9:30 and an afternoon peak between 17:00 and 19:00 can be clearly observed. Figure 1 (b) shows ridership of a weekend day, where passenger volumes are more evenly distributed along the day and no peaks can be observed.



(a) weekday (2nd, March 2011) (b) weekend (5th, March 2011)

Figure 1. Ridership of bus line 47 (aggregated in 20min)

The passenger flow data collected by a smart card system can be used to optimize bus line networks, scheduling plans and to improve bus operational efficiency. However, the smart card system now in use in Chengdu public transport company can only collect boarding information of passengers and no alighting information is available. Recently, a new card called "double-chip" (CPU chip and RFID chip) card has been developed. With this double-chip smart card system, passengers only need to tap on when they get onboard the bus, and the boarding information and fare can be collected. No tap out is needed since the alighting information is collected automatically by a RFID reader installed at the back door of the bus. The detailed ridership information collected can be used for long-term bus line network planning and scheduling adjustment. FIGURE 2 shows the structure of a RFID equipped smart card system and the data flow among components of the system.

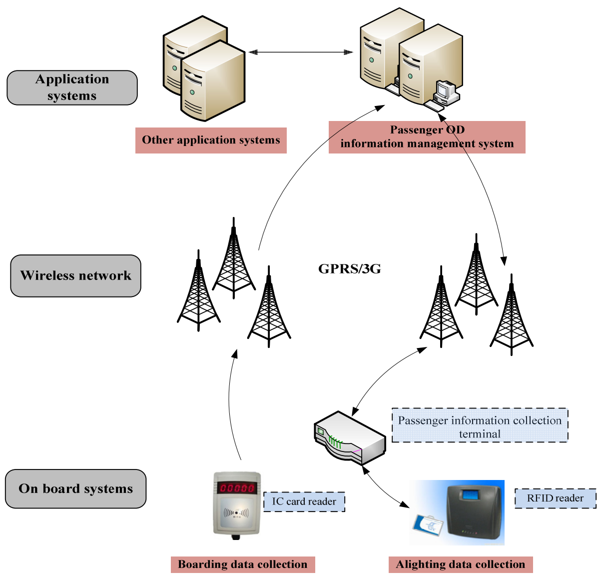


Figure 2. Simple representation of the 'double- chip' smart card system structure and data flow

2.3 Bus monitoring system

In Chengdu, the development of the bus monitoring system started since 2009. Some integrated sensing technologies such as RFID, GPS, GIS, 3G and video have been applied to monitor bus operations. The status of a bus running in the road network can be tracked by applying GPS/GIS/GPRS technologies. In Chengdu, more than 7000 buses are equipped with GPS receivers. The information of bus locations and speeds are sent to the bus monitoring center every 15s through GPRS network. Every bus has a mobile data terminal that allows drivers to send and receive messages and trigger alarms. If a bus driver does not take the right bus line or drives over the speed limit, a warning message will be sent to the driver by the monitoring center.

2.4 Bus scheduling system

A GPS based communication technology, together with GIS and GPRS/CDMA technologies are used to improve real-time tracking and scheduling of buses. On one hand, bus traveling distance collected by GPS is directly linked to the bonus of each bus driver, which helps improve working efficiency of bus drivers. On the other hand, the collected GPS data and passenger data collected by the IC card system are used for estimating ridership of each bus line. According to the estimated ridership, four categories of bus lines are identified as shown in Table 1.

Table 1. Categories of bus lines

Types of bus lines	A	B	C	D
Ridership (person trips/month)	≥ 1200,000	between 800,000 and 1200,000	between 300,000 and 800,000	≤ 300,000

2.5 Bus information system

This system helps travelers make better trip plan with public transport. Before trips, users can get access to the bus information website from computers or web-enabled wireless devices. The system is also combined with GPS based AVL system to provide information of bus arriving at or departing from a bus stop to travelers. Besides, more than 1200 Variable message signs have been installed at bus stops within the third ring road of Chengdu city. The bus arrival time information is displayed in the variable message sign. Recently, Chengdu public transport company has developed an 'app' for smartphones. The 'app' gives real-time bus arrival information for the user's selected bus stops or bus routes. Another new function of this 'app', which is the customized service of buses, has been provided to users.

3 Discussion

TABLE 2 compares the quantitative indexes of bus operation, safety and service before (in 2008) and after (in 2013) implementation of the intelligent public transport system. It is clear that the operational efficiency has been improved substantially in 2013 compared with that in 2008. The number of accidents and the number of bus drivers who drive over speed limit have decreased greatly in 2013 compared with those in 2008. Besides, the level of service has been improved as well after implementation of the system. TABLE 3 indicates operational cost savings after implementation of the system.

Table 2. Comparison of indexes between 2008 and 2013

Operation Indexes	2008	2013
Fare collected per thousand buses per kilometer (RMB)	3772	4260
Percentage of buses in operation during peak hours (%)	62%	93%
Safety Indexes	**2008**	**2013**
Number of over-speed limit (per month)	2136	695
Number of accidents (per month)	277	59
Service Indexes	**2008**	**2013**
Number of complaints (per 600,000 person trips)	207	0.793
Average Waiting time during peak hours (min)	9	3

Table 3. Cost savings after implementation of the system

Type of cost	Labor cost	Bus purchase cost	Invalid bus travel distance (converted to cost)	In total
Reduced amount of cost (10,000 RMB)	14,000	70,000	8,400	92,400

5 Conclusions

In big cities with large population, an efficient way to reduce traffic congestion and enhance efficiency of transportation systems is to develop public transport system as a priority. In this paper, application of Internet of Things technologies in Chengdu public transport system is presented. The comparison results between before and after development of the system show that the operational efficiency and the level of service are improved, and operational costs are reduced substantially. The public transport mode share increased by 7.5% since 2010 when the system started to perform its function.

Acknowledgement

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References

Hounsell, N.B. and Shrestha, B.P. (2005). AVL based Bus Priority at Traffic Signals: A Review and Case Study of Architectures *European Journal of Transport and Infrastructure Research*, 5(1):13-29.

Jiang, G., Liang, Y. and Guan, J. (2011). Application of RFID Technology in Bus Signal Priority Control at Intersections. *First International Conference on Transportation Information and Safety*, Wuhan, China.

Lee, E.-K., Yoo, Y.M. and Park, C.G. (2009). Installation and Evaluation of RFID Readers on Moving Vehicles. *VANET'09*,Beijing, China.

Liao, C. (2011). Data-Driven Support Tools for Transit Data Analysis, Scheduling and Planning. University of Minnesota, Minneapolis.

Liao, C. and Davis, G.A. (2006). Bus Signal Priority Based on GPS and Wireless Communications Phase I -Simulation Study. University of Minnesota, Minneapolis.

Medagama, M., Gamage, D., Wijesinghe, L., Leelaratna, N., Karunaratne, I. and Dias, D. (2008). GIS/GPS/GPRS and Web – based Framework for Fleet Tracking. *National conference on Geoinformatics Applications*,Sri Lanka

Pelletier, M.-P., Trépanier, M. and Morency, C. (2011). Smart card data use in public transit: A literature review. *Transport Research Part C: Emerging Technologies*, 19(2011):557-568.

Sun, D., Luo, H., Fu, L., Liu, W., Liao, X. and Zhao, M. (2007). Predicting Bus Arrival Time on the Basis of Global Positioning System Data. *Transportation Research Record: Journal of the Transportation Research Board*,(2034):62-72.

Wang, H., Cheu, R.k. and Lee, D.H. (2011). RFID Enabled Signal Priority Strategies for Bus Operations. *Applied Mechanics and Materials*, 55-57(2011):2169-2174.

Signal Priority Control Methods of Modern Trams at Intersections

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Abstract: In order to solve the serious problem of traffic congestion, many cities in China are developing urban public transportation systems and focusing on modern trams with the advantages of workload, cost performance and transportation efficiency. Based on analysis of the status quo, problems of tram signal control and operation efficiency, this paper tries to study signal priority control methods for trams under the condition of mixed traffic at intersections, proposed priority control principles of signals based on information perception as well as interaction at intersections, and achieve connection between signal control for trams and the existing urban signal control for other motor vehicles. Through the example application of 17 signal intersections along Suzhou tram lines 1 and 78 around the tramline, the result shows that coordinated priority strategy increases tram operation efficiency and reduces waiting time at intersections. It will provide reference for the reforming of Road Traffic Signal Controller and Road Traffic Signals, which are national mandatory standards in China.
Keywords: Modern tram; Signal control; Signal priority; Intersection.

1 Development situation of trams in the world

In the past ten years, more than 50 countries and 400 cities in Europe and the United States have developed modern trams for urban public transportation. European countries have adopted the system of Communication Based Train Control (CBTC) or Europe Train Control System (ETCS) to control them. In Europe, the CBTC system has independent tram operation control centers, such as SACEM of France and Siemens LZB of Germany, which are ideal for city areas with high volume of passenger flow. ETCS system for trams focuses on network connecting between tramways and railways around cities, so trams are controlled by the railway operation control center directly.

1.1 Trams construction and application status in China

In order to solve the urban traffic congestion and meet the increasing demand of public transportation, many cities in China set off an upsurge of modern tram construction. At present, 11 lines of trams in 7 cities have been put into operation, including: Changchun and Dalian city in which trams are transformed from the original traditional streetcars, and Shenyang, Suzhou, Nanjing, Guangzhou and Qingdao city, in which in which trams have been operating for nearly two years. Trams are under construction in ten cities, such as Shenzhen, Huaian, Zhuhai, and Foshan. More than 40 cities have planned more than 100 tram lines.

In the respect of signal control, both the traditional streetcar operating in Dalian and Changchun and the modern tram running in Binhai New District, Tianjin and Zhangjiang District, Shanghai use driver manual control mode, and travel by road traffic signals at intersections. The trams which have been put into operation in the past two years are designed with reference to technical standards of metro and light rail. Therefore, trams adopt CBTC with expensive cost and complex functions, such as automatic train supervision (ATS), automatic train protection (ATP), intersection priority system, and distributed control system (DCS).

1.2 Existing problems of trams in China

(1) Lack of regulations and standards of trams and unreasonable tram plans. According to the current classification code of motor vehicles and driving licenses, trams and trolleybuses are both classified as motor vehicles, but metros and light rail trains aren't. So tram driver must apply for Class P motor vehicle driving licenses. Trams in many cities are planned, designed and operated as metros or light rail transit. Operating routes, stops and other facilities of trams are designed with focus on the performance of tramcars and control centers rather than to features of mixed traffic conditions.

(2) Signal control is coordinated poorly at intersections and signal priority has not been realized. The technical standards of urban traffic control system (UTCS), built and operated by the department of traffic police, are different from the technical standards of CBTC and ETCS for metro and light rail. During tramline planning and construction, the compatibility with existing UTCS hasn't been considered, resulting in great difficulty in realization of tram signal priority. For this reason, trams opened in Shanghai, Shenyang and Nanjing didn't realize tram signal priority control.

(3) Trams operating efficiency is low and does not meet the design objectives. During plan-step of operating routes and stops, the planning department didn't consider mutual interference with other motor vehicles and pedestrians, collaboration and matching of trams with existing UTCS in these cities, and they designed some impractical and unreasonable principles, such as absolute signal priority.

2 Research on tram signal priority control

2.1 Selection of control strategies

Signal priority control strategies for trams are classified into absolute priority, exclusive phase, conditional priority and coordinated priority.

(1)Absolute priority strategy. When the arrival of a tram is detected, the road signal controller will interpose an exclusive signal phase, turn the current signal phase to a tram travel signal phase. After the tram is detected to have passed the intersection, the road signal controller will switch to the next signal phase. This strategy ensures that each tram will not be delayed for any reason when passing intersection. In spite of this, it has a serious impact on other flows and is very likely to bring traffic jams at intersections.

(2) Exclusive phase strategy. Setting up the exclusive phase for trams will depend on the average travel speed, the departure frequency, the location of stops and so on. It requires channelization and control at intersections to reduce the potential conflict of trams with other motor vehicles. This strategy doesn't need any tram detectors or other additional devices. Nevertheless, the delayed tram will waste the green light.

(3) Conditional priority strategy. By setting some conditions, UTCS provides priority signal only to selected trams. First, according to the tram running schedule, UTCS provides priority signals only to the punctual or delayed trams and not to the advanced trams. Second, UTCS provides priority signals only for trams at rush hours rather than those during flat-peak period. This strategy requires additional control parameters to be added in the existing UTCS.

(4) Coordinated priority strategy. Typically there are two basic control methods. One is turning off the red signal in advance- if the current phase is a red signal and a tram is approaching, the road signal controller will reduce the red signal time and turn the on green signal several seconds in advance. The other one is extending the green signal time- if the current green light is about to turn off and a tram is arriving, the road signal controller will extend the green signal time so that the tram can pass through intersection safely. However, it will lead to excessive adjustment of the signal phase and interfere with other traffic flows when trams come frequently.

We have compared four control strategies in terms of operating efficiency, cost and the influence to other vehicles, as shown in Table 1.

Table 1. The comparison on signal priority control strategies of urban tram

Control Strategy	Operation Efficiency	Cost	Influence to Other Vehicles	Applicable Conditions
Absolute Priority	Highest Efficiency with no delay	High cost, detectors needed	Huge influence to traffic flows and easy to congestion	Applied in the intersections with low traffic volume
Exclusive Phase	Low efficiency with severe delay	Lowest cost, no detectors needed	Relatively fixed signal phase with little influence to other vehicles	Applied in the intersections with low traffic volume
Conditional Priority	High efficiency with relatively low delay	Highest cost	Low influence to traffic flows	Under the coordinated signal control in adjacent intersections
Coordinated Priority	High efficiency with delay in particular	High cost, detectors needed	Low influence to traffic flows and frequent phase	Applicable to trams with less frequent schedule

	intersections		adjustment	

Judging from Table 1, it is obvious that four control strategies have their own merits and defects. In practice, it is needed to calculate the traffic volume of the intersections and investigate the traffic management level as well as the investment in the first place. Then, select an appropriate control strategy for each intersection. In the project of Suzhou Urban Tram, the selected control strategy is coordinated priority after considering that the majority of urban trams can receive priority with little influence to lateral traffic flow.

2.2 Coordinated signal priority control based on interaction

(1) Configuration of sensing equipment

To implement signal control with absolute priority and coordinated priority strategies, it is crucial to sense the arrival and departure of trams at intersections. Highly accurate and sensitive detectors are required for coordinated control and reliable operation. In application of Suzhou tram line 1, four sensing cycle detectors are used to detect and calculate the position of the tram (Figure 1). Specific positions of the tram detector shall determine the tram running speed, the crossing time, the safety braking distance and other factors.

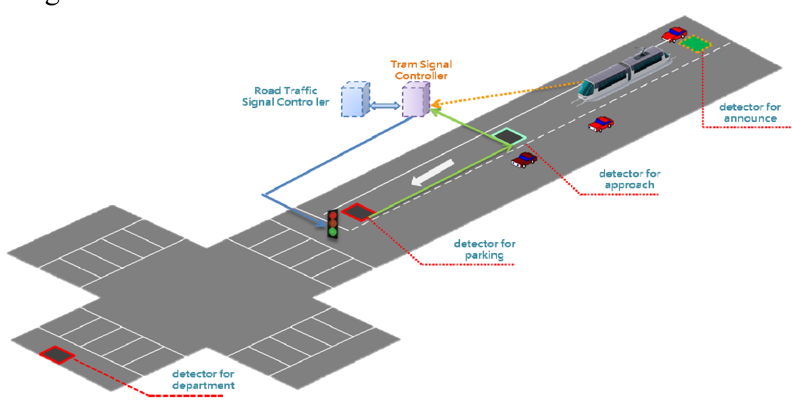


Figure 1. Tram detector layout example

(2)Coordinated control between road signal controller and tram signal controller

We communicate real-time information between the tram signal controller and road signal controller at the level of intersection to coordinate control. The road signal controller exchanges information with the tram signal controller, and the tram sends and receives the signals from signal controller via ports to control the tram signal (Figure 2). After a tram request signal triggers a priority phase, the road signal controller will make five basic responses as follows:

- Request in "front end" of green light: accept request and proceed with the priority phase
- Request in "back end" of green light: accept request and extend the priority phase

➢ Request in red light: accept request and terminate the non-priority phase in advance
➢ Mandatory request: interpose a priority phase
➢ Response lockout period (determined by strategy): do not accept request and wait for a priority phase

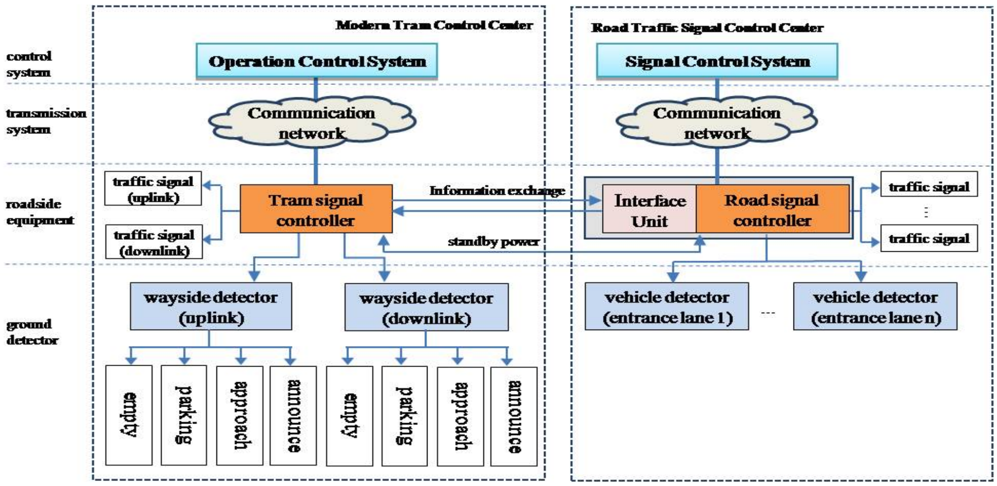


Figure 2. Communication between road signal controller and tram signal controller

2.3 Coordinated control for associated areas with tram signal priority

All intersections passing tram are designed as critical intersections. Considering that the reduction of phase green time for other motor vehicles as a result of tram priority may cause traffic flow queue-spillback upstream, it is necessary to implement signal control on the upstream intersection and select the "control arriving flow slowly and let departure flow quickly" strategy of arterial street coordinated control(Figure 3). Additionally, we implement coordinated control, such as “red-wave” and “green-wave” for main traffic flow on the lateral road.

Figure 3. Coordinate control for intersections in associated areas

(1) Red wave control in upstream intersections

Set the priority intersection as terminal point, establish red-wave band in the upstream intersections, which can make vehicles stop in the priority intersection and close partial traffic flow significantly. The fundamental principle is to close traffic flow and use existing system resources to alleviate the over-saturated traffic flow.

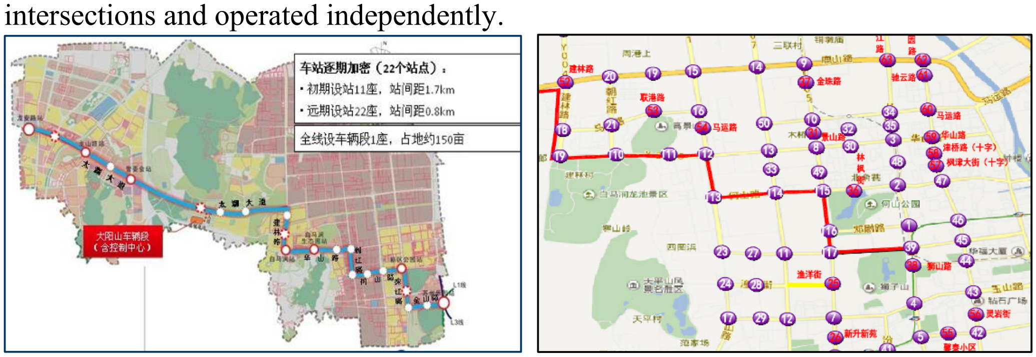
(2) Green wave control in downstream intersections

Set the priority intersection as the starting point, establish the green wave band in downstream intersections, which allows other vehicles in the priority intersections to pass the intersection with low stop ratio and alleviate the queuing in the target intersections. The fundamental principle is to allow fast passing and use existing resources to improve operating ratio.

3 Empirical application of modern tram signal control

The tram network in High-tech Zone, Suzhou, has 6 lines planned with a total length of about 80km. Tram Line 1 was opened in October 2014, and tram line 2 and line 3 are under construction now. Tram Line 1 is the first modern tram line approved by the National Development and Reform Commission in China. It has 22 stop-sites and a total length of 18km. Around tram line 1, there are 104 intersections with road traffic signal controllers installed, with HT-UTCS system provided by Wuxi HT Company, and 17 intersections installed tram signal controllers with CBTC system provided by Bombardier Company.

Coordinated priority Control strategies and proposals discussed above are applied to 17 signal control intersections of tram line 1 and 78 related grouped intersections for empirical study of the region's coordinated control. Before the construction of the tram， some road signal controllers are installed at some intersections and operated independently.



(a) Signal intersections along tram line 1 (b) Signal intersections at related area

Figure 4. Area for empirical application of modern tram

Measuring at morning peak and off-peak for two weeks, we compare operation effects before and after implementation of tram signal priority (Table 2 and 3). The result shows that the average travel speed increased from 21.7km/h to 25.6km/h and the congestion at related grouped intersections was improved after use of coordinated priority control strategy.

Table 2. Priority control effect evaluation of Suzhou Tram Line 1

Evaluation index	Before implementation of signal priority	After implementation of signal priority	Improvement percentage
Average number of parking	10	5	-50.0%
Total average stop delay	8′03″	4′46″	-40.8%
Average travel time, min	49	41	-16.3%
Average speed, km/h	21.7	25.6	+17.9%

Table 3. Coordinated control effect evaluation of related roads

Evaluation Item		Peak hour			Off-peak hour		
Road name	Average index	Before	After	Improve	Before	After	Improve
Zhujiang Rd. [Fenjin St. to Mayun Rd.]	travel time, min	2′40″	2′10″	12.5%	2′15″	1′40″	16.3%
	speed, km/h	25	29	14.3%	28	43	53.6%
Zhujiang Rd. [Yuyan St. to Xinshen Rd.]	travel time, min	3′42″	3′20″	14.9%	2′11″	1′50″	10%
	speed, km/h	21	25	17.5%	23	28	21.7%
Xiangjiang Rd. [Mayun Rd. to Majian Rd.]	travel time, min	5′08″	3′48″	23.6%	4′08″	3′17″	12.5%
	speed, km/h	25	36	45.1%	30	42	38.7%

4 Conclusion

Here we may draw the following conclusions.

(1) Coordinate priority strategy will significantly enhance operation efficiency of modern trams, and effectively reduce stop delays at intersections.

(2) Information exchange in real-time between tram signal controllers and road signal controllers at intersections can realize coordinated traffic control between CBTC and UTCS.

(3) In order to reduce the influence of tram operation vehicles to other motor vehicles, UTCS shall have good function of arterial street coordinated traffic control.

5 Recommendations for Future Research

UHF RFID labels will be used on modern trams and motor vehicles as sensors in 2015 with the hope to enhance the sensor ability of road controllers to the arrival of trams.

Some technical requirements of tram-related signal priority control functions and communication protocol will be added in modification of national standards for road traffic signal controllers and urban traffic control systems. We also suggest that tram-related laws and regulations about tramcar registration and safety inspection, driver training and testing should be established as soon as possible.

Acknowledgement

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References

Li K., Mao L. L. (2013). "Study on the control projects for modern tramcars at signal intersections." Urban Rapid Rail Transit, 26(2),104-107.

Lu X. M., Li N. (2013). "Rational and sustainable development of streetcars." Urban Traffic, 11(4),19-23.

Wei C., Gu B. N.(2008). "The typical modern tram systems in Europe." Urban Mass Transit, 11(1),11–14.

Wu Q. G. (2013). "Research on the emphasis and difficulties of modern tram system development and its countermeasures." Journal of Railway Engineering Society, 12, 89-92.

Zhu S. S. (2014). "Signal control technology of modern tramcar." Railway Signaling &Communication, 50(4),8-11.

Intelligent Transport Systems in the Big Cities of China Based on Public Service

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Abstract: In the field of traffic management, the development of traffic information technology has provided the technical support for ITS and has become an important means to the traffic manager, which does improve the government's administrative ability. This paper will analyze the intelligent transportation development mode of some representative cities in our country on the basis of the necessity of research of intelligent transportation system based on the public service of the big cities in our country, such as Peking Shanghai and Guangzhou through the method of systematic analysis, and advance some research methods for the big cities, and offer reference for the development of ITS in big cities in our country.
Keywords: Public service; Intelligent transportation; Development model; Systematic analysis.

1 Introduction

With the boom of global urbanization and the rapid development of our country's economy, the big cities of our country such as Peking, Shanghai, Guangzhou and Shenzhen have been deeply troubled by the traffic problems.

Sales growth rate in China's auto market in 2014 is 6.86% less than the data 8% to 10% forecast by the Automobile Association in early 2014 growth. From the data, the growth of passenger cars is still a major force in the overall growth of the automobile industry in 2014.But in all segments of the passenger car, the sales of the best selling car were accounting for 12,376,700, an increase of only 3.1 %; the sales of the SUV vehicle reached 4.08 million, an increase of 46.4%; the number of sales of the MPV is 1,914,300, a highest increase of 46.79%. Automobile Association expects the sales of China's auto will reach about 25.13 million, an increase of about 7%. The domestic sales of cars is about 24.27 million, exports is about 860,000 cars, among which the passenger car sales growth is about 8%; commercial vehicle sales increase is about 2.4 percent. It's obvious that it will cause great pressure for current road conditions in our country.

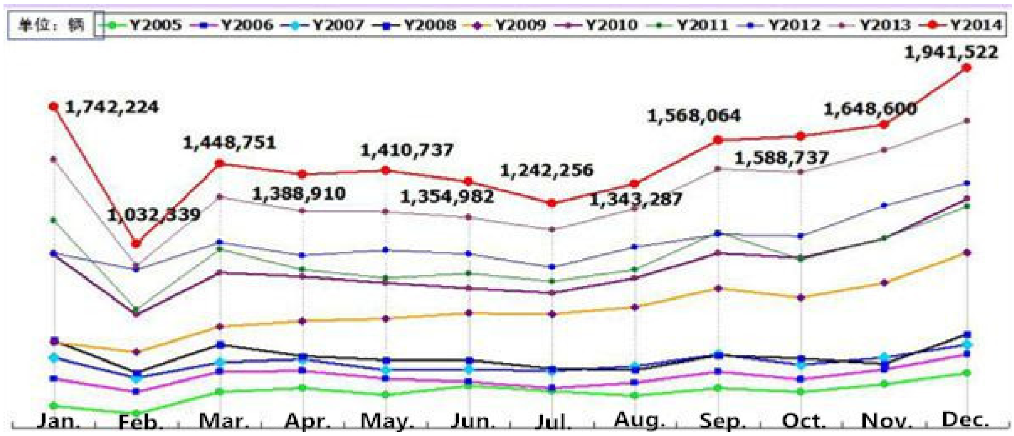

Figure 1. 2005-2014 domestic narrow passenger car monthly sales charts

2012, the ministry of transport released the "intelligent transportation development strategy (2012-2020) in the transportation industry", which pointed out: the development of intelligent transportation will not only support the transportation management,but also pay more attention to the services of public traveling and modern logistics. It will provide services for the car traveling, at the same time, pay more attention to the services of public transportation; it will focus on improving efficiency,at the same time, pay more attention to safety and healthy development; it will draw lessons of tracking technology from abroad and make full use of the new generation of information technology so as to advance the research,development and integrated application of intelligent transportation technology and product with independent intellectual property rights; it will encourage and guide the folk capital investment, as well as promote interagency and cross-industry cooperation, etc. Although intelligent transportation research is only in its infancy in China, it is bound to cause great attention from the related management departments as it is the trans-century economic growth engine and the inevitable choice of transport system construction.

2 Status at Home and Abroad

2.1Foreign research status

Governments in developed countries like the United States, Japan, Europe have put a lot of efforts and resources to the construction of intelligent traffic information services and applications, which has been regarded as a valid means of solving traffic congestion caused by urban sprawl.Dynamic traffic information service is developing into the direction of integration and platformization in order to provide better public services and improve the administrative efficiency of the government.

The United States points out seven major areas of intelligent transportation systems and 29 user services in National Intelligent Transportation System Project Planning, and develops quickly in navigation and safety monitoring system, vehicle toll collection systems, vehicle management systems.The VICS in Japan uses a variety of platform to release dynamic real-time traffic information, mainly used in navigation systems,security monitoring systems, traffic control systems and vehicle management system.The coverage of the intelligent transportation research in Europe is wider, which is currently involved in 11 countries and regions;the advanced traveler information service (ATIS), advanced vehicle control system (AVCS) and so in Europe are playing an irreplaceable role.

2.2Domestic research status

The study of intelligent transportation construction has increasingly become the focus of research scholars.The domestic first-tier cities and the SAR have developed a number of applications, which have facilitated the public to travel and got public recognition to a certain extent. These applications,however,are mainly conducted for the business of departments, which will result in phenomenons as follows.The content of information services will be confined within its business scope and the degree of information sharing is not high; the services of content, quality and range of various existing applications will need to improve and develop continuously; personalized information service approach is still in deficiency, in particular the lack of dynamic traffic information services and the main means of publication are websites and SMS.

3 Field Data

Big cities, which have a population of more than 5 million such as Beijing, Shanghai, Guangzhou , have the preliminary achievements in the field of intelligent transportation development.Analysis of development mode of these cities will provide reference to the development of other cities in the future.

Because of the economic development, which is a powerful driving force, car ownership in cities such as Beijing, Shanghai, Guangzhou is growing at an alarming rate each year.As a result, the traffic problem is increasingly complex, such as serious congestion during the peak, severe air pollution caused by automobile exhaust emissions and short supply of parking space.

As one of the cities that are the first batch of intelligent transport demonstrative cities, Guangzhou mainly exists these problems in traffic fields: lack of industrial regulatory means, inadequacy of infrastructure and regulation to drivers. For a decade,the traffic informatization in Guangzhou has realized the rapid development and a large number of traffic information infrastructure and business systems are widely used through the joint efforts from various departments, which are all the important supports for transportation industry management, enterprise production and management,as well as the travel service.

As a modern metropolis,Shanghai has set international economic, trade, financial and shipping all in one,which has also built urban traffic management control system based on the "cloud service" platform,such as Shanghai Traffic Information Center, road traffic information collection system infrastructure within the city, passenger transport services and management systems, urban traffic electronic toll collection system, the downtown parking, information services and management systems, traffic safety and emergency response management systems, and building intelligent traffic engineering research center in Shanghai.Although the development of intelligent transportation offers lots of convenience for traffic management department of Shanghai ,there still exists some shortcoming, mainly presented as the phenomenon of information island.

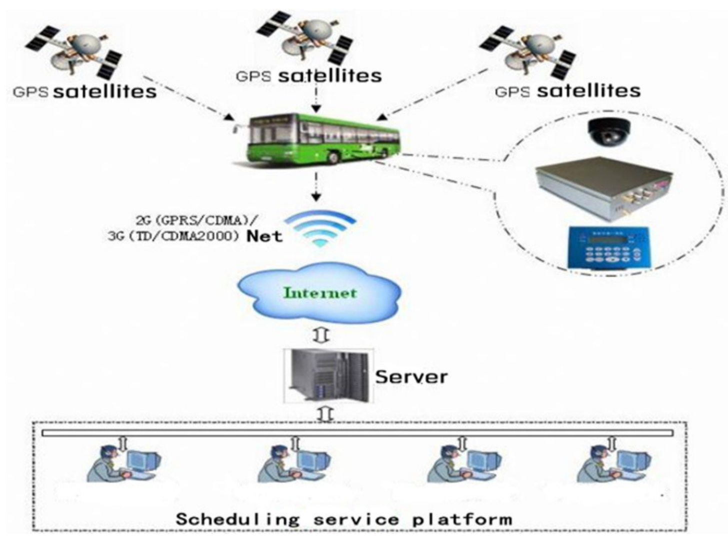

Figure 2. Urban Traffic Management Control System based on the "cloud service" platform

In Beijing, the capital of China,the vehicle ownership has constantly ranked the first around the whole country for many years. Beijing Traffic Development Outline, which has been promulgated,determines to focus on the building of the integrated information platform,aiming to improve scheduling command system, use intelligent transportation technology to build the new Beijing traffic system and realize intelligent road traffic.And this goal has been achieved to a certain degree: the completion of intelligent road traffic control management system; establishment of unified city highway information center;the opening of a municipal transportation card system construction within the city.At present, Beijing has almost built a complete intelligent transportation system, realized various operation such as gathering information intelligently, intelligent supervision, the optimal allocation of resources, which reduce the travel consumption of residents and the administrative burden of traffic department.

4 Data Analysis

Although China's major cities already have their own ITS frameworks, the use of traffic information technology is of low degree in fact. We must take the characteristics of these regions into account and use strict methods and measures to optimize the system in accordance with the government-oriented, business-oriented, market mechanisms operating mode,so as to ensure the government to deliver the optimal service.

4.1 Project needs analysis

ITS is an innovative traffic pattern developed on the basis of digital traffic and intelligent transportation, which is aiming at solving the problem of China's major cities are facing with. Therefore, it is necessary for our management department to provide the overall framework of ITS that is on the basis of public services and planned rationally in order to lay a solid foundation for the development of large cities.

4.2 Technical level to be achieved

The expected technical level is to build a management system that incorporates integrated command platform, traffic signal control system, series traffic check venting system, traffic information service system, traffic business management system as a whole.

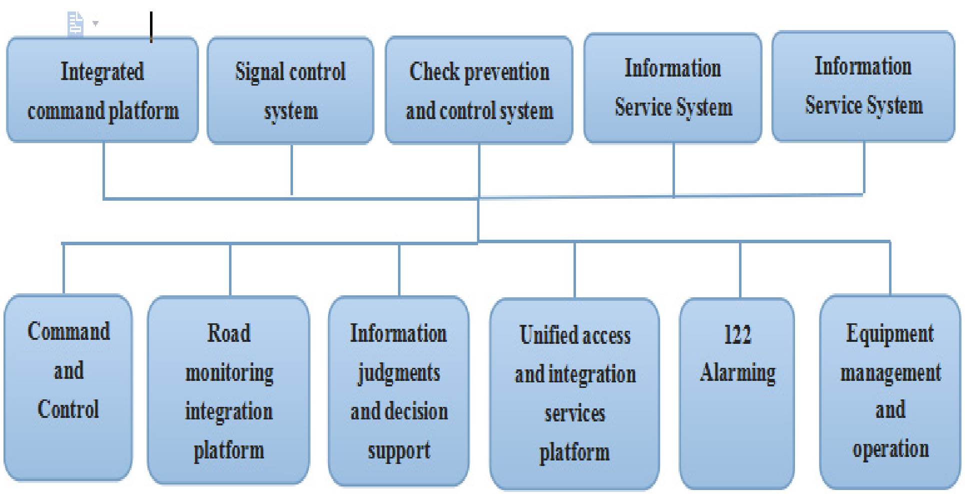

Figure 3. Intelligent traffic management system based on the metropolitan public service theory

4.3 Basic conditions for implementation of the system

(1)Foundation of preliminary work

In the foregoing, we detail the role of ITS in the public service and analyze the current development of ITS in Beijing, Shanghai, Guangzhou, which lays a foundation for the study of late.

(2) Existing study conditions

1) Policy support

Ministry of Transport in 2012 issued Intelligent Transportation Development Strategy In 2012-2020;Guangzhou in 2011 enacted Intelligent Transportation System Twelve Five-Year Development Plan (2011-2015); the Shanghai municipal government issued Action Plan To Promote The Construction Of Smart City In 2011-2013;Beijing promulgated the Beijing Transportation Development Program. All these major strategic plans are important milestones in the development of intelligent transportation. The development of intelligent transportation is genuinely related to people's lives and has a great impact for enhancing national life satisfaction. We ought to believe that the introduction of these government policies will support ITS to make considerable progress in our country, especially in the economically more developed cities.

2) Support from present situation

The development of ITS in our country started late,but with the progress of economy,science and technology,the researches on this system have made substantial progress and achievement.In early 2014, the major Internet giants made a crossover to internet of vehicles and arranged the transportation market. Our country initially established institutional mechanisms adapted to the integrated transport system,such as acceleration of the process of ETC national network, formally implement of new standards of electronic police GAT496-2014 and so on.

In March 2014, the official website of the Ministry of Transport announced that the adjustment related to responsibilities and organization in Ministry of Transport has been basically put in place, forming a large pattern of transport management department where the Ministry of Transport is responsible for managing the National Railway Bureau, China Civil Aviation Administration and the State Post Bureau. As a result,it will promote the effective convergence of various modes of transport and the integration of service.

3) Technology support

With the rapid development of internet of vehicles, cloud computing, car networking and etc,it has no problem to establish transportation systems that is closely linked by information in big cities in the future. Higher Institute of many large cities in China will also provide a steady stream of talent to support the development of this technology.

5 The Optimization Measures

According to the characteristics of the cities, here are specific project implementation plans, technical routes, the organizations and the task decomposition schemes as follows:

a.It has an advantage of low cost if using the program of combining self-developed high-speed MCU with embedded DSP network cameras .

The main chip can be made of just three dollars under the circumstance where performance parameters of HD 720p and H.264 encoding are supported to be unchanged, which is the low-cost advantage that the normal network cameras can not match .

b.Two image sensor lens share a webcam Motherboard

For the characteristic that general parking are arranged in parallel parking lane,we use the dual-lens design——one towards the left ,another towards the right,each HD lens regulators two parking spaces,further reducing the cost.

c. Abandon CCD, ues CMOS sensor

In general, industrial network cameras use CCD more, because its dynamic effect is good and it is not prone to motion image smear.However,CCD is more expensive, the general cost of the CCD network cameras is over a thousand dollars. For parking, the vehicle must be stopped, and thus can use lower-cost CMOS image sensor. CMOS has a huge amount of users in electronics market like digital cameras, so there exists an advantage of cost.

d.The recognition algorithm of camera embedded within the Slow car's license plate

In addition to the embodiment of the video detection terminal (webcam), you must also equipped with a multi-channel video processor (PC) every 25 video terminals to recognize license plate.It is no doubt that it will increase the cost of PC hardware and network cabling hardware. In this regard, for the characteristics that vehicles must stop when they are in traffic lights parking , we propose innovatively that the technical solutions to achieve slow car's license recognition in micro-controllers can complete one frame license plate recognition as long as 10 to 20 seconds, which can meet the requirements of parking license plate recognition and save the cost of PC,and network cabling.

It's no need to use Fast Gigabit Ethernet when there is no immediate transmission of HD video, but you can use WIFI wireless network,which can upload the recognized license plate information to the server.Further,it has no wiring, which is a greatly facilitate to the construction and maintenance.

e.Released real-time road information to car owner's mobile to let them master the relevant traffic situation ahead of time and avoid serious congestion.

6 Conclusions

In summary, the ITS research towards metropolis is a difficult and macroscopic systems engineering,which requires comprehensive planning and unity from the central to local and universities to enterprises.In this process, it's make great sense of leading and driving from government. Meantime, the new technology and management methods should be updated and applied continually.Lastly,it's necessary for private enterprises to enter this field. Only by this way,can we build, operate and manage traffic problems effectively, and get rid of the constraints of intelligent transportation industry development.

Reference

Ahuja,G.(2015) "Collaboration Networks,Structural Holes and Innovation:A longitudinal Study ."*Administrative Science Quarterly*，45 (3) : 425-453.

Chunmei Zhou.(2014) "Big data applications and development in intelligent transportation". *China Security*,(6): 33-36.

"Intelligent Transportation Transportation Industry Development Strategy (2012-2020)."

Jinmao Jing.(2014)"Chinese intelligent transportation systems technology development status quo and prospect" *Transport Information and Safety*, (05): 1-5.

Liu Jianguo.(2014) "Intelligent transportation industry standardization strategy of actor-network theory". *Chinese Science and Technology Forum*, (2): 52-56

Nonaka,I.(2006) "Objectivity and Subjectivity in Knowledge Management:A Review of 20 Top Articles. "*Knowledge and Process Management,*13(2) : 73－82.

Yue Jianming, (2012) "development and technical innovation model of intelligent transportation industry to explore" ,*China Soft Science*,(9):188-192 Liu Yingqi, Gao Hongwei.(2011) "Chinese New Energy Technology Development Alliance automotive industry trends and countermeasures" *scientific decision-making*, (2): 1-8.

Detecting the Synergy between Talent Accumulation and the Effect of Intelligent Transportation Systems

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Abstract: Talent accumulation plays a vital role in improving the comprehensive benefit of Intelligent Transportation System (ITS). Based on literature reviewing, this research analyzes the synergistic mechanism between talent accumulation and the effect of ITS. According to the synergistic model, the degree of synergy between talent accumulation and the effect of ITS has been tested by using related statistical data. The results reveals the developing tendency and the level of synergy between talent accumulation and the effect of ITS. In addition, the results have both theoretical and practical implications for strengthening the effect of talent accumulation and improving the comprehensive benefit of ITS effectively.
Keywords: Talent accumulation; Intelligent transportation system (ITS); Synergy.

1 Introduction

With the development of information technology, transportation has shown the trend of intelligent improvement. In many countries, Intelligent Transportation System (ITS) has been playing a very significant role in the growth of economy and society. Intelligent transportation is of the characteristics of high intelligence, high talent accumulation and high innovation, so talent accumulation is quite important for the sustainable development of intelligent transportation. In recent years, the research around the coordination relationship between talent accumulation and ITS has become the hotspot in the field of management and economics.

Talent accumulation is a kind of special situation in the process of human resource flowing. The term of talent accumulation can be defined as a process that the talent flows from one area or industry to another because of some affection（Zha, 2014）. Under the effect of talent accumulation, the economic output will exceed the summation of the output made by single talent (Niu, 2012).

As for ITS, it is a kind of advanced transportation system based on the development of information technology. ITS cannot only properly resolve the problems of transportation for people and goods, but also drive the development of relevant information services and information industries (Yang, 2006).

Since talent accumulation and ITS are very significant for the growth of economy, the harmonious synergy between them can also bring great improvement for the effect of both talent accumulation and ITS. This research will detect the mechanism of synergy between talent accumulation and ITS based on the theory of synergy. By establishing the synergy model, this research will evaluate the synergetic levels and the trend of talent accumulation and ITS, so as to taking proper measures to improve the effect of talent accumulation and ITS in the future.

2 Model Construction

The synergetic relationship in this research means the level of the synergy between talent accumulation and ITS. In the theory of synergy, the degree of order of each variable devotes greatly to the synergy relationship of systems. Hence, the first step is to construct the model for the degree of order of each variable. In this research, the two systems of talent accumulation and ITS can be shown as $S_i,\ i \in (1,2)$. The variables of the two systems are shown as $X_{ij},\ i = 1,2, j = 1,2, \ldots \ldots n$. n is the number of variables. The model for the degree of order of variables can be shown as:

$$u_{ij} = \begin{cases} (X_{ij} - \beta_{ij})/(\alpha_{ij} - \beta_{ij}) \\ (\alpha_{ij} - X_{ij})/(\alpha_{ij} - \beta_{ij}) \end{cases} \quad (1)$$

In this model, α_{ij} and β_{ij} are the upper limit value and lower limit value of each variable, and $X_{ij} \in (\alpha_{ij}, \beta_{ij})$.

The second step is to calculate the devotion of each variable to the synergetic relationship of systems. The formula is shown as:

$$u_i = \sum_{j=1}^{n} \lambda_{ij} \times u_{ij} \quad (2)$$

In this formula, λ_{ij} stands for the weight of variables.

The third step is to construct the model for the synergetic relationship between talent accumulation and ITS. The formula is shown as:

$$C_t = f(u_{1t}, u_{2t}) = 2\{(u_{1t} * u_{2t})/[(u_{1t} + u_{2t})(u_{1t} + u_{2t})]\}^{1/2} \quad (3)$$

The value of C_t reflects the level of synergy between talent accumulation and ITS in the year of *t (t*=1, 2, 3…T*)*. In this formula, $u_i \in [0,1]$, u_{1t} and u_{2t} stand for the devotion of each variable to the systems of talent accumulation and ITS.

3 Empirical Study

3.1 Variables and Data Resource

In order to comprehensively evaluate the effect of talent accumulation and ITS, this research chooses 6 variables to describe the two systems. As for talent accumulation, the number of employee in the industry of transportation, fixed-investment for transportation and the number of patent in the industry of transportation have been selected out as the indexes to measure talent accumulation in transportation (Niu, 2012; Zha, 2014). Meanwhile, length of city road, casualty in traffic accident (negative index) and greening rate in city are used to measure the effect of ITS (He, 2010). All these variables have been extensively used in former researches. They have also been tested to be effective in reflecting the two systems.

All the data applied in this research are from the statistical yearbook of both Sichuan province and the city of Chengdu from the year of 2005 to 2013. By taking the method of principal component analysis (PCA), the weight of every variable is shown in Table 1.

Table 1. Weight of variables

Talent accumulation	Weight	ITS	Weight
The number of employee in the industry of transportation	0.333528	Length of city road	0.333196
Fixed-investment for transportation	0.333225	Casualty in traffic accident	0.333436
The number of patent in the industry of transportation	0.333247	Greening rate in city	0.333368

3.2 Results Analysis

In order to judge the developing level of talent accumulation and ITS, and the synergetic level of talent accumulation and ITS, this research divided the degrees of evaluation and synergy into four levels. See Table 2.

Table 2. Evaluation and synergy levels

Statistical values	Evaluation levels
$u_{it}, C_t \in (0,0.25]$	Low
$u_{it}, C_t \in (0.25,0.5]$	Primary
$u_{it}, C_t \in (0.5,0.75]$	Medium
$u_{it}, C_t \in (0.75,1]$	Senior

Based on the category in Table 2 and the statistical results in Table 3, we can find that the effect of talent accumulation from 2005 to 2009 was at the low level, while in 2010 and 2011, it rose up the primary level. In the year of 2012, the effect of talent accumulation in Chengdu was at the level of medium. Since 2013, it rose up to the senior level. However, the developing level of talent accumulation in Chengdu has much more space to improve.

As to the effect of ITS, the level was low in 2005 and 2006. In the year of 2007 and 2008, the level of ITS effect was at the primary stage. After 2009, the level of ITS effect rose up to the senior level. All in all, ITS effect of Chengdu has been at the high level in recent years.

Although the developing level of talent accumulation was low from 2005 to 2008, the synergetic relationship between talent accumulation and ITS was at the level of primary and medium. Since 2009, the level of synergy for both of the two systems was senior. Hence, the synergetic level of talent accumulation and ITS in Chengdu has shown a good condition in recent years.

Table 3. Evaluation and synergy of systems

Years	Evaluation of talent accumulation	Evaluation of ITS	Synergy
2005	0.00	0.182912	0.00
2006	0.039541	0.202186	0.739781
2007	0.060391	0.290406	0.755027
2008	0.084399	0.500612	0.702723
2009	0.195863	0.666472	0.837956
2010	0.318956	0.756068	0.913603
2011	0.388546	0.799626	0.938243
2012	0.544546	0.908976	0.968059
2013	1.00	0.955014	0.999735

Figure 1 shows us the trend of evaluation for talent accumulation and ITS in nine years. From this figure, we can find that the developing level of ITS is higher than that of talent accumulation in Chengdu, though both of them show fast improvement during the last few years. Meanwhile, this figure shows that the synergetic level of both systems has been high enough at almost senior stages since 2006.

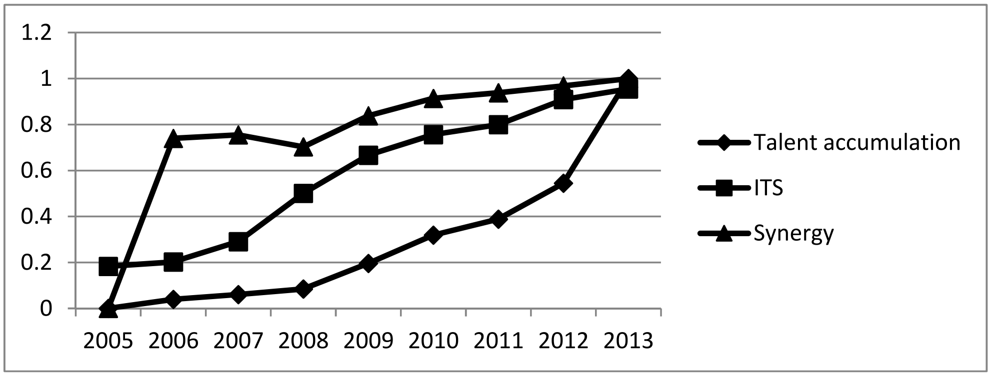

Figure 1. Trend of evaluation and synergy of systems

4 Conclusions

According to former studies, this research selected 6 indexes to describe talent accumulation and ITS. By using the model of synergy, the data which stem from the city of Chengdu from the year of 2005 to 2013 were used to evaluate the developing level to talent accumulation and ITS. The synergetic relationship between the two systems has also been detected in this research. The results clearly show that the level of synergetic relationship between the two systems was at the senior stage from 2006 to 2013. However, the underdeveloped talent accumulation in Chengdu will attract more attention to propose effective measures for improving the effect of talent in the industry of transportation.

References

He, J. W., Zeng, Z. X., Li, Z. H. (2010). "Benefit Evaluation Framework of Intelligent Transportation Systems". *Journal of Transportation Systems Engineering and Information Technology*, 1, 81-87.

Niu, C. H., Zhang, F., Feng, H. Y. (2012). "On the Relationship among Science and Technology Talent Accumulation, High-tech Industry Agglomeration and Regional Technologic Innovation". *Science and Technology Progress and Policy*, 15, 46-51.

Shi, F., Lu, J., Wang, W., et al. (2004). "Method and Application of Profit Estimated in Traffic Commanding Center". *Communication and Computer*, 22(2), 43-46.

Statistic bureau of Chengdu, (2005-2013). *Chengdu Statistical Yearbook 2005-2013*, Beijing, China Statistics Press.

Statistic bureau of Sichuan, (2005-2013). *Sichuan Statistical Yearbook 2005-2013*, Beijing, China Statistics Press.

Wang, W. (2004). "The Study of Urban Transportation System Sustained Development Evaluation Method". *China Civil Engineering Journal*, 37(3),

1-6.

Yang, X. G., et al. (2006). “Study on Evaluation Method for Intelligent Transportation Systems in China”. *Journal of Transportation Systems Engineering and Information Technology*, 6, 14-20.

Zha, C. W., Cheng, W. M., Tang, C. Y. (2014). “Synergy between R&D Talent Aggregation Effect and Technological Innovation in High-tech Industry”. *Science and Technology Progress and Policy*, 5, 1-6.

Traffic Flow Parameter Detection Based on Epipolar Plane Image

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Abstract: Traffic flow parameters detection is one of the most critical parts of the intelligent traffic management system in currently. With the continuous development of computer vision and image processing analysis technology constantly development, video detection technology in the traffic parameters testing is more and more attention. Video automatic detection technology utilization of computer vision, image processing and analysis, pattern recognition technology, compared with traditional detection technology induction loop detector, microwave radar detector and magnetometer detector, etc. The video automatic detection has many advantages, such as simple installation, convenient maintenance, not to harm the roadbed, low cost, high accuracy, and wide monitoring area. Firstly, the image sequence can be acquired through the video automatic detection equipment mounted over the road, and then two 2D spatial-temporal images, a panoramic view image and an epipolar plane image, are formed for each lane in this article. By using the methods of constructing a general epipolar plane image model, to reflect the vehicle surface characteristics and movement characteristics of the driveway. Then put forward the texture Canny texture edge detection algorithm of image based on Gabor filter, according to the texture edge detection of three steps: normalization processing, filtering processing and edge texture detection, analyzes the edge texture detection algorithm of epipolar plane image, and provides normalized epipolar plane image, presented the specific calculation method and formula of Canny texture edge detection based on Gabor filter. Finally, according to the graphics after processing, examines traffic flow parameters detection for traffic volume, vehicle speeds and lane occupancy and analyzes summary of the whole algorithm.
Keywords: Computer vision; Epipolar plane image; Traffic flow parameters; Canny edge detection.

1 Introduction

The traffic parameters mainly consist of traffic flow、traffic density ,velocity and the queuing length, etc. The detection of traffic parameters is a key segment of traffic control and management. Through detecting, analysis and controlling the traffic flow parameters, it can enhance the road transportation capacity, reduce the traffic accidents and adjust the traffic distribution of the road network (PG Michalopoulos, 1991; Brian Carlson, 1997).

There are lots of detection measures of the traffic parameters, such as ultrasonic, infrared detection, annular induction coils and computer vision. Ultrasonic detector is in low accuracy, easily influenced by vehicle barrier and pedestrian, and with short detecting distance (not more than 12 m in general); infrared detector is easily affected by heat source of the vehicle itself, and has low accuracy and resistance to the noise; annular induction coils detector has high accuracy, but it has to be set in the roadbed which will damage the roadbed and is inconvenient to the installation and construction. It also needs lots of loops; computer vision detector will use the technology of image processing, artificial intelligence, pattern recognition, etc. To collect the information of vehicle and traffic parameters from the video digital image.

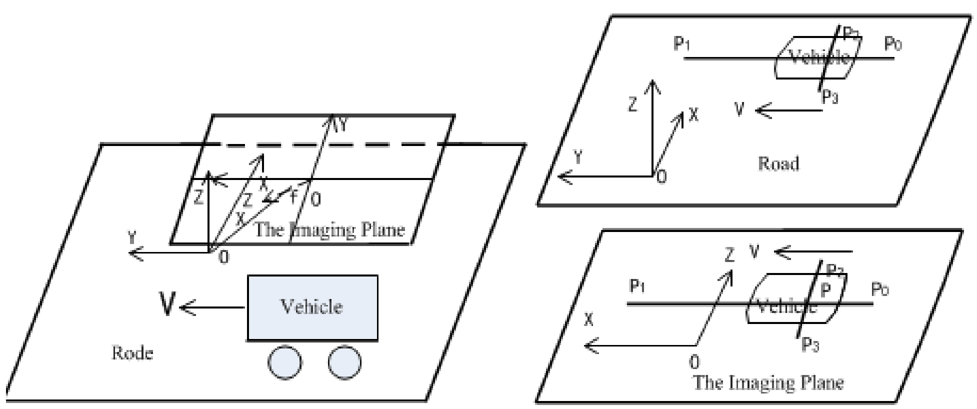
Traffic monitoring system based on video normally use the videos set on the roadside or above the road to acquire the relatively stable traffic scene images in a long distance, detection, vehicle tracking, and traffic flow parameters detection, etc. The vehicle detection methods based on video mainly have streamer method (PG Michalopoulos, 1991), adjacent frame differential method (Brian Carlson, 1997), background subtraction method (Barron J, 1994). Each method has the advantages and disadvantages. Streamer method has very good accuracy and large calculated amount; adjacent frame differential method can detect moving object under the variable background, but may easily lost the detection of slowly moving vehicles, and make one vehicle into several parts; background subtraction method is a commonly used method under the regular background. Its detective effect depends on background updates algorithm, so when background updates has high reliability, it has good effects. As it has characteristics in small calculated amount and high reliability, it has a good instantaneity and practical applicability. In some papers, the method of neural network and SVM (support vector machine) have been used to the traffic video detection field, such as Sun (Lipton A, 1998) use Gabor filter to collect various image characteristics and train SVM grader to realize the vehicle detection. But in these kind of the methods, as it first need to train the traffic image, the processing is complex and instantaneity is not good.

The vision detecting technique has been a hot spot of research in ITS with the particular advantages such as broad view, low cost and intelligence. In traffic monitoring system based on vision, the videos are set on the roadside or above roads to get the relatively stable traffic scene image in a long distance, which then are used image processing technique to conduct vehicle detection, vehicle tracking, and traffic flow parameters detection, etc. As the detection and track in the vision traffic monitoring is at the low level of the whole traffic monitoring system, it needs to collect vehicle information from video sequences image in real-time, constantly track them and provide the basis for the analysis of the traffic information in further. The most important part of the process is how to get good traffic background image from the vehicle operating. It is the key segment to gain the real-time traffic background image in the traffic vision monitoring system. And selecting the adaptive algorithm of background extraction is the most important part of the visual detection research.

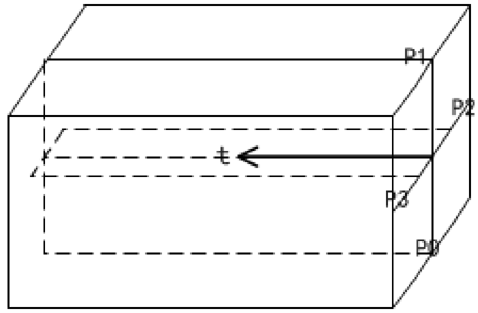
2 Acquisition of Epipolar plane image model of the vehicle motion

2.1 Epipolar plane image model under ideal conditions

The ideal imaging geometric model of the epipolar plane image is shown as Figure 1, in which the projection axis of surface X-axis and Y-axis in the image plane, respectively, is Y direction and X direction. Through stable image, a complex movement of vehicles can be effectively separated with complex background. Because the camera is stationary with the road, it can get a stable image, in which vehicles move or stay along the straight road. Suppose the vehicle is at $X=X_1$, and moves along Y-axis. As the projection of line $X=X_1$ at the image plane is $y=y_1$,the line segment on the vehicle along the Y direction at $X=X_1$ is the projection of the line plane. As in Figure 1(b), the vehicle on the road moves from point P_0 along P_0P_1. Suppose the image plane is paralleled with the road surface, so that on the image plane, the vehicle will travel along P_0P_1, and on the timer shaft, then to take the segment P_0P_1 paralleled with X-axis plane to produced the epipolar plane image. This is an ideal model between the road surface and he image plan. As in this model, the vision must be perpendicular to the road surface and need the higher installation accuracy, it is not often used.



(a) The vehicle motion model **(b) The relationship between the road plane and imaging plane**

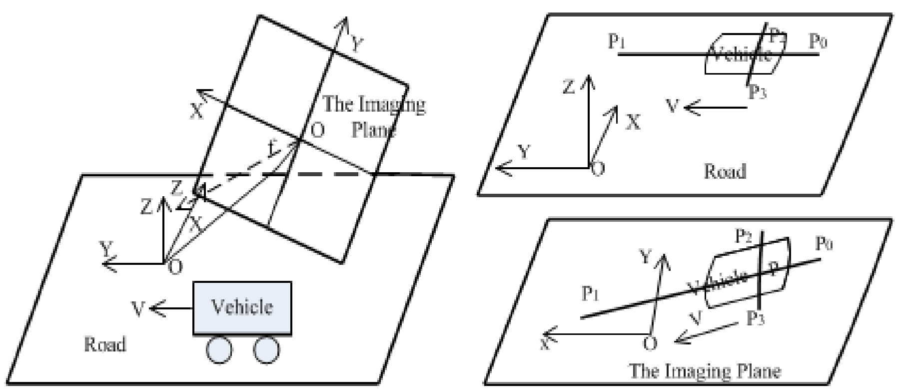


(c) The epipolar plane image of vehicle

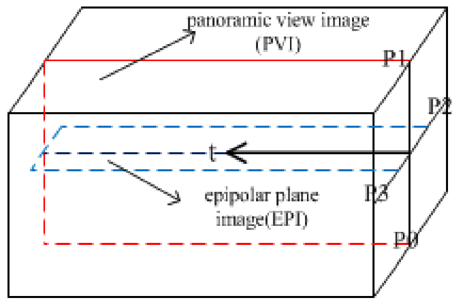
Figure 1.The imaging geometry of epipolar plane image under ideal conditions

2.2 Epipolar plane image model under actual conditions

In this paper, a detection model of road traffic parameter used for a real traffic scene is presented as Figure 2. Suppose the coordinates of the rode surface is XYZ, in which X, Y direction is on road surface. X-axis is perpendicular to the lane. Y direction is paralleled with the lane, Z direction is perpendicular to the road surface, as in Figure 2(a). As the vehicle usually drives along with the lane, this model is suitable for the traffic parameter detection of various flows. In the road coordinate system, as P_0P_1 along the lane, the projections of P_0P_1 and P_2P_3 on the image plane are P_0P_1, P_2P_3, but P_0P_1 is not paralleled to the X-axis(Figure 2(b) below). Suppose the vehicle on the road drives from point P_0 to point P_1 along P_0P_1, then on the image plane, the vehicle will drive along P_0P_1. And on the timer shaft the line segment P_0P_1 takes shape epipolar plane image (Figure 2(c) below). This is a general relationship model of the road plane and image plane. In order to prevent the blocking of vehicle, the video should be installed at a certain height above the lanes.



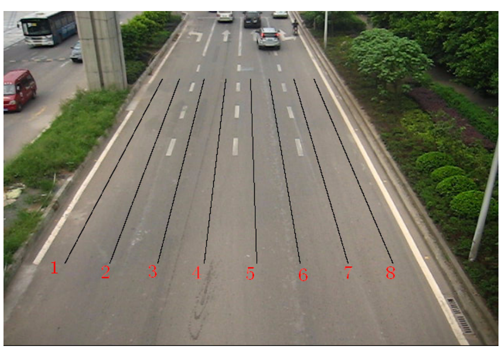
(a) The vehicle motion model **(b) The relationship between the road plane and imaging plane**



(c) The epipolar plane image of vehicle

Figure 2.The imaging geometry of epipolar plane image under actual conditions

In this paper, an example in Wuhan is taken. The video is installed above the road surface 6.5m. The taken image sequences of Four-lanes one-way are in 1280×720.In the middle of each lane, it is taken two line segment-t sections in a group. With about 1.5m, eight epipolar plane images are made up as Figure 3.Two epipolar plane images constructed by any straight segment-t section can detect the traffic parameters of one lane. Every epipolar plane image is plane projection of the contour of the vehicle on a line segment and camera projection center. The vehicles motion and the airspace feature of road surface formed directional texture. It basically reflects the characteristics of the surface and the movement of vehicle in each lane.



(a) The position of line-t section **(b) The epipolar plane image**

Figure 3.The panoramic view image and epipolar plane image of vehicle motion

3 Texture edge detection of epipolar plane image

Texture detection is active field in the research of the computer vision. In general, there are 6 characteristics of texture distribution: sparse, contrast, directional, contiguous, constant and roughness. Based on these characteristics, the existing texture segmentation method can be generally divided into the following categories: the measure methods based on the symbiotic, the method based on markov, the method based on Gabor filter and the method based on fractal. The first three image texture segmentation methods were based on the structural properties and the statistical properties. It is shown by Pentland (Jain R, 1984) that the fractal model effectively covers all the second order change information of the image. Fractal model can have more than three kinds of model ability in theory. There are two fractal characteristics commonly used: Fractal Dimension, FD and Lacunarity. The first one measures the vision roughness of texture to some degrees. The second one contains some information of the texture element.

The basic process in texture edge detection is divided into three steps: normalization dispose, filtering, and texture detection.

3.1 Normalization

The function of normalization can make gray value reach to a predetermined mean value and variance and also to strengthen the effect of the whole image contrast. The function which the normalization adopted is:

$$\mathrm{N(i,j)}=\begin{cases} M_0+\sqrt{\dfrac{V_0(I(i,j)-M)^2}{V}}, if\ \mathrm{I(i,j)>M} \\ M_0-\sqrt{\dfrac{V_0(I(i,j)-M)^2}{V}}, if\ \mathrm{I(i,j)\le M} \end{cases} \tag{1}$$

In which $I(i,j)$ for the gray value of the pixel M_0, for the average of the expected V_0, for the variance of the expected, M for the estimated means of the gray value of $I(i,j)$, V for the estimated variance of the gray value $I(i,j)$, and $N(i,j)$ for the gray value of the pixel spot $I(i,j)$ after normalization.

3.2Canny operator texture edge detection

Here Canny operator is used to detect the texture characteristic of epipolar plane image, which can make the color epipolar plane image to do the gray-scale and the normalized, as shown in Figure 4 show.

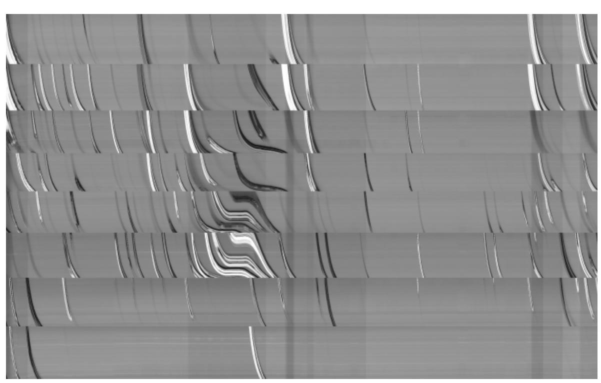


Figure 4.The epipolar plane image after gradation processing

To the epipolar plane image after gradation processing, after the texture is detected by Canny operator, Gabor filter is used to remove the noise points, then the field method is used to keep the edge of the high strength, and connectedness is used to eliminate the particles and the islands to obtain the binarization of epipolar plane image, as shown in Figure 5. This is used as the input graph of the traffic parameter detection and the standard graph of the traffic parameter detection follow-up.

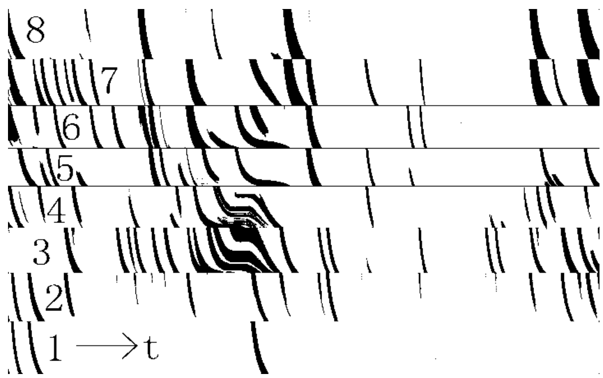


Figure 5.The input graph of the traffic parameter detection

3.3 Canny texture edge detection based on Gabor filter

Gabor transformation uses Gaussian function, $g(t) = \frac{1}{2\pi a} e^{-t^2/4a}$, in which $a > 0$ is contained as window function, Gabor transformation is:

$$G\left[f(b,v)\right] = \int_{-\infty}^{\infty} f(t) g^*(t-b) e^{-jwt} dt = \frac{1}{2\pi a} \int_{-\infty}^{\infty} f(t) e^{-(t-b)^2/4a} e^{-jwt} dt \qquad (2)$$

In the plane, Gabor transform is dense. Gabor wavelet has been widely used in the field of image processing and pattern recognition, especially in the feature extraction of texture image. Gabor wavelet is a plural sine function of rotating Gaussian modulation (Sun ZH, 2002). Commonly used even symmetric Gabor wavelet in two dimensions shown as type (1):

$$g(u,v,\theta) = \frac{1}{2\pi\sigma_u\sigma_v} \exp\left\{-\frac{1}{2}\left[\frac{u^2}{\sigma_u^2} + \frac{v^2}{\sigma_v^2}\right]\right\} \times \cos(\omega u) \qquad (3)$$

with $u = x\cos\theta + y\sin\theta$, $v = -x\sin\theta + y\cos\theta$

In which, θ for the parameters of the small wave direction angle; (x, y) and (u, v) for the original coordinate system and the transformed coordinate system; σ_u and σ_v respectively for Gaussian envelope constant; ω for The frequency of a small wave. In this paper, improved Canny operator, improved texture edge detection process shown in Figure 6.

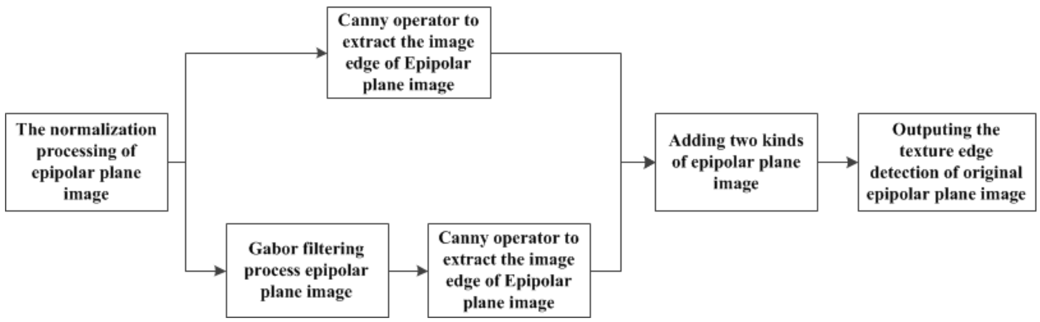


Figure 6.The processing of canny texture edge detection based on Gabor filter

In general, a planar Gabor wavelet consists of a band-pass filter at the direction of μ, and a low pass filter at the direction of ν (perpendicular to μ).The bigger σ_u and σ_v; the more slow attenuation of Gabor wavelet respectively on the direction of μ and ν. By type(1),it is known that the nature of the coordinate transformation from (x, y) to (u, v) is the original coordinate system rotated about $\theta + \pi / 2$ .This is because when vehicles is passing across the testing lines, it generally has a certain speed ,so that it leaves a outline texture on the epipolar plane image within $(0, \pi / 2)$. If $\theta = 45°$, $\sigma_u = 4$, $\sigma_v = 4$,the results of Gabor wavelet transform can be got as shown in Figure 7.

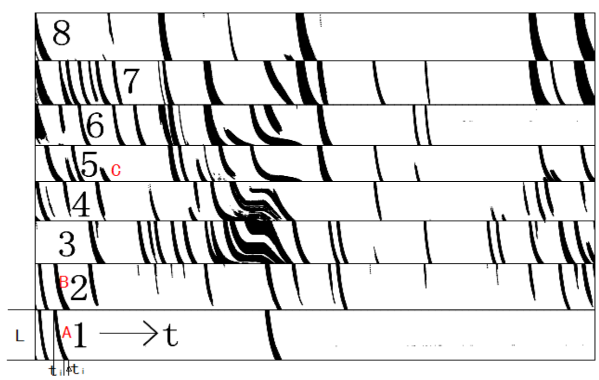


Figure 7.The input graph analyses of the traffic parameter detection

4 Traffic Flow Parameters Detection

The input graph of traffic parameter detection is shown as Figure 5 where every black curve shows that a vehicle is passing by a detection line of epipolar plane image. A part of the curve in the figure is not traversing the whole detection line of epipolar plane image, because the vehicle is deviate from the detection line of epipolar plane image sometime. According to Figure 7, the corresponding technical means are used to analysis various data of traffic detection. The traffic parameters analysis results are as follow:

4.1Model of vehicle detection

Because traffic is the important information in the acquisition of traffic data, the number of traffic section can be determined through detecting the vehicles exist and calculating it. It is shown from Figure 7 that, on a lane, a short black line shows the existing of vehicle. If there are two detection lines, the vehicle could be deviate from the lane, then there will be a half of short line on the detection line, or the repetitive lines on the corresponding lane. It needs filter to determine the number of vehicles. As shown in Figure 7, because C line in the fifth lane is only a short section, it can be deleted in statistics. Only when the length of line l≥l0, we consider it to be a existed vehicle, in which l0 is the shortest line as the statistical vehicle. In meantime, the two detection lines in the adjacent lane is close, the vehicle could be deviated from the lane. When the vehicle is driving in two lanes at the same time, it could be shown that there are two vehicles driving in two lanes while there is only one actually. In statistics, the repeated vehicle should be deleted. For example In Figure 7, the starting points of A in the first lane and B in the second lane are at the same time position, and their end points are at the same time position, and the widths of the two line are very close as well. It is shown that when there is only one vehicle, so in the statistics, it should get rid of the repeated one in the adjacent lane. Finally after calculating the total number of the lines in each lane, eliminating the repeated one and the one beyond the reach of the requirement, the remaining number will be the number of vehicle passing by.

4.2 The detection model of the speed

The speed of vehicle is the important data of the traffic data acquisition as well. Through the analysis of the input graph of the data detection, the speed at which the vehicle is passing by the detected area can also be detected. It can get the time of which the vehicle is passing by the detected area from Figure 7. Then get the speed of vehicle from the length of the detection line. As the A segment in the first lane, it shows there is a vehicle passing by. The time interval of the start point and end point of the segment is t_i. And the length of the detection line is *L*, then the speed of the vehicle is $V_i = L / t_i$.

4.3 The detection model of the time occupancy

The time occupancy is the percentage that the cumulative time of the vehicle passing by a certain section divided by the minute in the unit minute. It is known from the figure that if the time of the vehicle passing by a certain section is Δt_i, the statistic of traffic flow during t is n, the time occupancy can be obtained in.

$$R_s = \frac{1}{t}\sum_{i=1}^{n} \Delta t_i \left(\%\right) \tag{4}$$

In which, R_s :the time occupancy,%; t -the unit minute, s; Δt_i :the time s of the first car I passing by a certain section; n :the number of the vehicle through the observation section within the unit minute.

5 Conclusions

This paper presents a new traffic flow parameters based detection methods in computer vision-traffic flow parameters outside the pole face detection method based on image, the main idea is: first build to reflect each lane of the vehicle by the surface characteristics and kinematics Construction of the outer pole face image, the paper outside the Vehicle motion pole face image model gives a detailed analysis. Then, by its normalization process with improved Canny operator for texture detection, Canny improved operator to overcome the traditional Canny operator to detect the presence of the edge of the rough edges, noise-sensitive shortcomings. The calculation method is given Gabor texture edge detection operator. Finally illustrate the rationality and the specific implementation method based on detection of traffic flow parameters outside the vehicle treated pole face images. The practical application proved that the new method proposed in this paper not only has all the advantages of video detection technology, also has a fine edge extraction, strong noise immunity, etc., is a new traffic flow parameters.

Acknowledgement

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References

Brian Carlson. (1997). "Vision Makes Traffic Control Intelligent." *Advanced Imaging,* 12 (2): 54~56

Barron J. (1994). Performance of optical flow techniques. *International Journal Computer Vision*, 32 (12): 42~77.

Dunn D, W. (1995). Optimal Gabor filters for texture segmentation. *IEEE Transactions on Image Processing*, 4 (7): 947~964.

Jain R. (1984). Difference and accumulative difference pictures in dynamic scene analysis. *Image and Vision Computing*, 2(2): 99~108.

Lipton A, F. P. (1998). Moving target classification and tracking from real-time video//Proc of the Workshop on Application of Computer Vision, IEEE, New Jersey: Princeton, 8~14.

PG Michalopoulos. (1991). Vehicle Detection through Image Processing, *The Auto scope System, IEEE Trans. on Vehicular Technology*, 40 (1) :21~29.

Sun ZH, G. R. (2002). On-road vehicle detection using Gabor filters and support vector machines. *Digital Signal Processing*, 2: 1019~1022.

Traffic Guidance Strategy of Urban Freeways Based on Model Predictive Control

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Abstract: Urban freeway, as the important carrier of urban transportation, played the role of skeleton in the urban traffic network. It was of vital importance for the entire road network to induce traffic flow of urban freeway reasonably. Firstly, the traffic guidance strategy of urban freeway based on Model Predictive Control was explored. The strategy aimed at minimizing the total time spend. A dynamic expressway network traffic flow model was adopted as the process model. Finally, a simulation case study was presented under different scenarios .The results indicated that the traffic guidance strategy of urban freeway based on Model Predictive Control reduced the total time spent and improved the operational state with good stability and operability.
Keywords: Urban freeway; Model predictive control; Total time spend; Simulation case; Stability.

1 Introduction

Since the beginning of the 21st century, with the acceleration of urbanization and the rapid development of China's social economy, the city's size, population and vehicle fleet have showed significant growth trend. The main contradiction of urban transport is that the limited road resources can't meet the increasing traffic demand. There are more and more traffic congestion and accidents. This series of questions have restricted the sustainable development of cities seriously.

The guidance strategy of urban freeway is mainly by regulating traffic distribution in the network nodes to change the distribution of traffic from the perspective of space. Previous studies used accurate traffic flow model, taking the open-loop control strategy, allowing the system to maintain the optimal operating condition from the overall perspective. However, the volatility of this strategy is great, destabilizing the system. It is difficult to achieve in the actual guidance strategy. Based on this practical problem, this paper presents the guidance strategy of urban freeway based on model predictive control. It will induce strategy into the sliding window operation to increase the stability of the system. Model predictive control is the current research frontier. There are few studies abroad in the transport sector. The article describes the basic principles and mathematical model of model predictive control, process models, and so on. Finally, it studies the stability of model predictive control by analyzing the simulation results.

2 Mathematical models of model predictive control

The control is applied in a rolling horizon scheme: at each time instant k a new optimization is performed over the prediction horizon [k, . . ., k + Np - 1], and only the first value of the resulting control signal (the control signal for time instant k) is applied to the process. The next time instant k + 1 this procedure is repeated. To reduce complexity and improve stability often a control horizon Nc ($\leq$Np) is introduced, and after the control horizon has been passed the control signal is taken to be constant(Bellemans,2006). So there are two loops: the rolling horizon loop and the optimization loop inside the controller. The loop inside the controller of Figure1 is executed as many times as needed to find the optimal control signals at time instant k, for given Np, Nc, traffic state and expected demand. The loop connecting the controller and the traffic system is performed once for each k and provides the state feedback to the controller. Recall that this feedback is necessary to correct for (the ever present) prediction errors, and disturbance rejection (compensation for unexpected traffic demand variations). The advantage of this rolling horizon approach is that it results in an on-line adaptive control scheme that allows us to take changes in the system or in the system parameters into account by regularly updating the model of the system. In conventional MPC heuristic tuning rules have been developed to select appropriate values for Np and Nc(GAN Hongcheng,2011).

One of the main parameters of MPC is the length of the prediction horizon Np, the number of samples for which the behavior model is predicted (Hegyi, 2005). One should choose Np long enough to include all relevant system dynamics in the prediction.

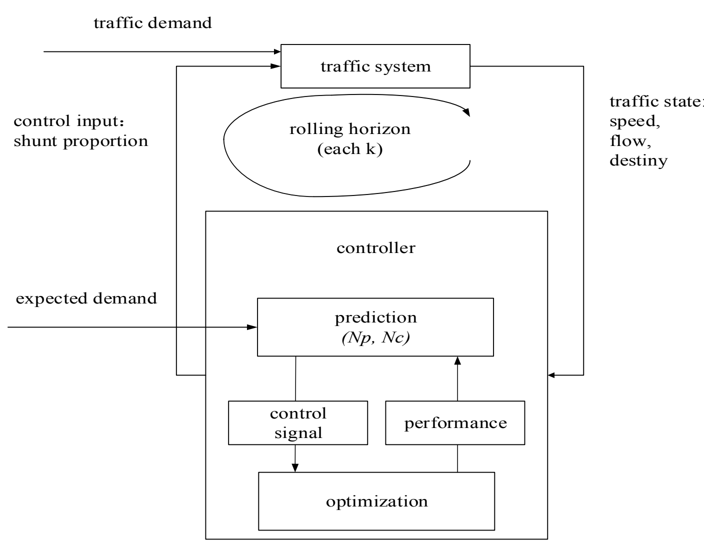

Figure 1. Schematic view of the model predictive control (MPC) structure.

3 Simulation

The benchmark network for the experiments is chosen as simple as possible (see Figure 2), since we want to focus on the relevant points of the approach presented in this paper. The network consists of a main-stream freeway with two origins and two destinations. There are two paths for drives to choose at node ②. "②-④-⑤"is defined as the main path L1. "②-④-⑤" is defined as the secondary path L2.Simulation time(see Figure 3) is chosen from 7: 00 am to 10: 00 am.

Dynamic expressway network traffic flow model (METANET)is adopted as the process model (Messmer, 1990; Papageorgiou, 1998).TTS, total time spend ,includes the total travel time and the total waiting time(Messmer, 1998; Sanwal,1993).

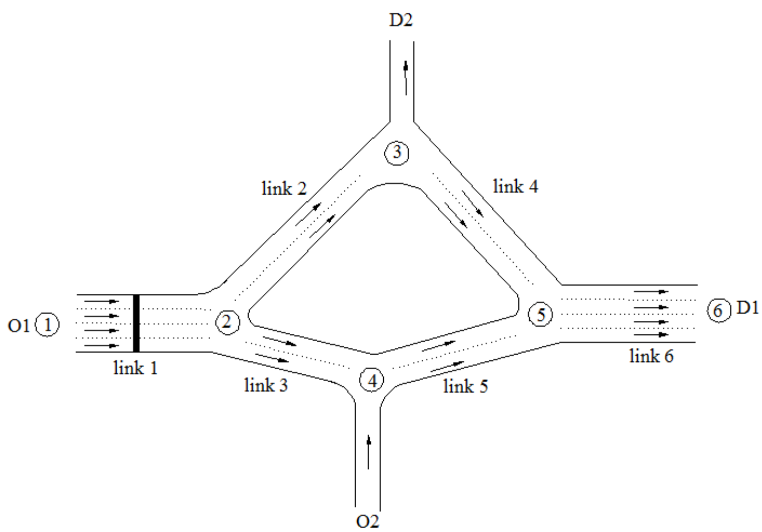

Figure 2. Benchmark network

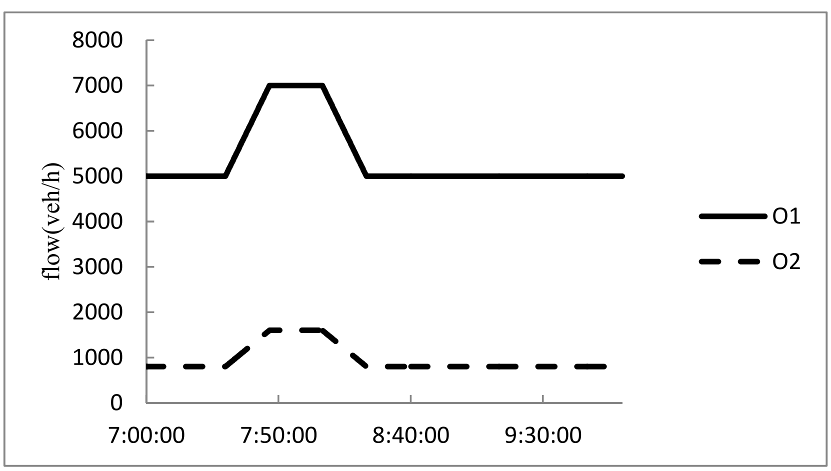

Figure 3. The demand scenario considered in the simulation experiments

3.1 Uncontrolled case

At the start of time, due to the low traffic demand, the road network is running in a smooth state. Traffic demand is increasing gradually. Downstream of the confluence node ④ appears congestion firstly. Traffic can not flow out of the road network successfully. Congestion begins to spread to the upstream. Since then, traffic demand begins to reduce and congestion begins to eliminate. Road network returns to smooth state gradually. The TTS in the uncontrolled case is 4778.0 veh * h.

3.2 Open-loop control case

Taking the urban freeway network as an example, traffic guidance strategy is divided into open-loop control strategy and model predictive control strategy. The strategy aims at minimizing the total time spend. For the node ②, we set shunt proportion $\beta_{D1}^{L1}(k)$ as the control variable, it stands for the proportion of traffic that select main path L1 at node ②, then $\beta_{D1}^{L2}(\mathrm{k}) = 1 - \beta_{D1}^{L1}(k)$. Optimization trajectory of shunt proportion is as follows.

$$\beta_{D1}^{L1}(k) = \{\beta_{D1}^{L1}(0), \beta_{D1}^{L1}(1), \beta_{D1}^{L1}(2), \ldots\ldots, \beta_{D1}^{L1}(K-1)\}$$

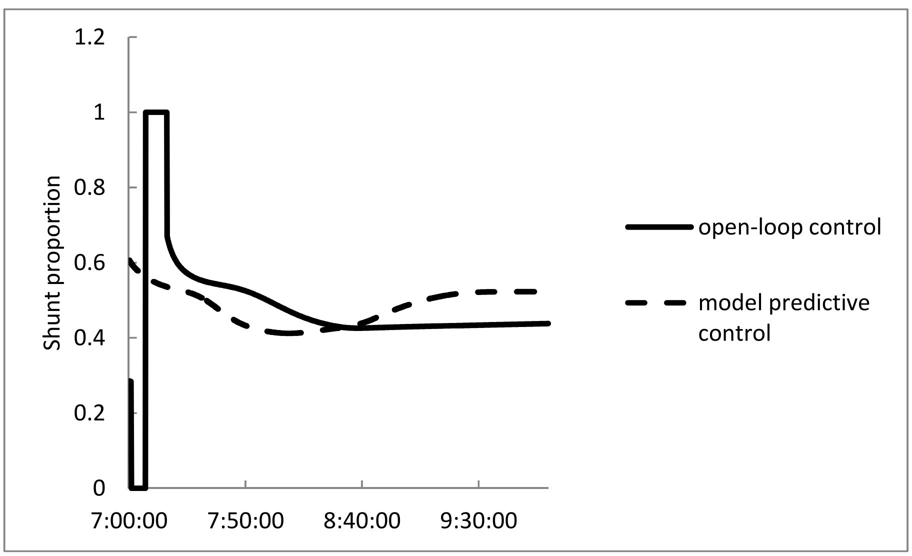

Figure 4. Optimization trajectory

As shown in Figure 4 , optimization trajectory of shunt proportion for open-loop control curves abrupt relatively and has large volatility. Under the open-loop control, in the 7:01: 00-7: 07 time period, shunt proportion is 0. At this point, all the drivers at node ② select the secondary path L2.The traffic of link 3 is zero. The traffic of O1 all flow into link 2.In the 7:07: 10-7: 16:10 time period, shunt proportion is 1.

Compared with the previous period, traffic distribution on the road network appears an opposite trend at this time. All the drivers at node ② select the main path.Traffic, including O1 and O2, loads on the main path fully. Secondary path, including link 2 and link 4, is idle. Shunt proportion is reducing gradually over the time. In the 7:50:00-8:05:40 time period, shunt proportion is 0.5.It indicates the equal probability for drivers to select the main path or the secondary path at node ②.The two paths share the traffic demand from O1 averagely.Finally, the shunt proportion maintains 0.43.Under the open-loop control, the shunt proportion changes from 0 to 1 suddenly, indicating the poor stability and difficulty of achieving. The TTS in the open-loop control case is 4100.5 veh*h, which is an improvement of 14.2%.

3.3 Model predictive control case

In the model predictive control case, the optimization trajectory of shunt proportion is as follows.

$$\beta_{D1}^{L1}(k) = \{\beta_{D1}^{L1}(0), \beta_{D1}^{L1}(0) \ldots \beta_{D1}^{L1}(k_s - 1), \beta_{D1}^{L1}(k_s), \beta_{D1}^{L1}(k_s) \ldots, \beta_{D1}^{L1}(2k_s - 1) \ldots \beta_{D1}^{L1}(K - 1)\}$$

As shown in Figure 4, compared with open-loop control, the shunt proportion of model predictive control changes gently, with less volatility, good continuity and operability. Trajectory curve shows the tendency of rise after the first drop. Finally, shunt proportion is 0.5, indicating the same possibility of two paths. The TTS in the open-loop control case is 4337.7 veh*h, which is an improvement of 9.2%.

In summary, the two traffic guidance strategies both reduce the TTS at varying degrees, improving the utilization efficiency of the road network in time and space. However, the open-loop control only considers the optimal control strategy in the current time. It achieves the best results in theory. But it is none of possibility to realize in reality. The model predictive control, as the real-time feedback control method, has more practical significance, though the improvement is reducing. During the model predictive control period, traffic flow changes smoothly.

4 Conclusions

This paper proposes the urban freeway guidance strategy based on model predictive control to solve the practical problems. The simulation results show that MPC eases road congestion effectively, with good stability and prospect.

5 Recommendations for Future Research

We will study artificial intelligence algorithms and robustness of MPC, aiming at providing theoretical basis and technical guidance for the management of urban freeway.

Acknowledgement

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References

Bellemans T, De Schutter B, De Moor B(2006). "Model predictive control for ramp metering of motorway traffic: A case study." *Control Engineering Practice*, 14(7): 757-767.

Gan Hongcheng(2011)."Expressway ramp matering strategy based on model predictive control."*J.University of Shanghai for Science and Technology,*33(3),268-273.

Hegyi A, De Schutter B, Hellendoorn H(2005). "Model predictive control for optimal coordination of ramp metering and variable speed limits." *Transportation Research Part C: Emerging Technologies*, 13(3): 185-209.

Messmer A.,Papagergiou M(1990). "METANET:a macroscopic simulation program for motorway networks."*Engineering and Control*, 31:466-470.

Messmer A.,Papageorgiou M.,Mackenzie N(1998). "Automatic control of variable message signs in the interurban Scottish highway network."*Transportation Research Part(C)*, 6(3):173-187.

Papageorgiou M.,Blosseville J(1990). " Modelling and realtime control of traffic flow on southern part of Blulevard Peripherique in Pairs."*Transportation Research Part(A)*, 24(5):221-228.

Sanwal K.,Petty K.,Walrand J(1993). "An extended macroscopic model for traffic flow."*Transportation Research Part(B)*, 27(2):97-107.

Model and Algorithm of Urban Road Discrete Network Design Based on CO Emissions

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Abstract: Network design is to optimize traffic network system performance by choosing to build or improve road sections under the given constraint conditions. This paper established a bi-level programming model of discrete traffic network design with optimization of environment protection and user goals, and designed a global optimization algorithm for solving the model based on the genetic optimization algorithm. This algorithm is simple and easy to implement, and the corresponding algorithm procedures have been developed in MATLAB platform. The validity of model and algorithm has been tested by Sioux Falls network and the results showed that the model and algorithm can be well applied to medium-sized network.

Keywords: CO emissions; Discrete network design; Bi-level programming; Genetic algorithm.

1 Introduction

Urban road network is the skeleton and infrastructure of a city, so a good network can relief the contradiction of supply and demand of urban traffic and promote sustainable and rapid development of urban social economy. The urban road network design problem (Network Design Problem, NDP) is an optimal investment problem: given certain constraints, by improving the capacity of existing roads or building new roads to make specific traffic system performance optimization. This paper presents a bi-level programming model with the upper model based on the minimization of co emissions and aggregate travel time of network system and the lower model based on user equilibrium traffic assignment. Basing on low-carbon urban road network design, with the combination of environment and network design, will not carry an important theoretical value but also a practical significance in solving problems of social and traffic.

2 Models and Algorithm

2.1 Models

Upper model in this paper is double objective programming model, as shown in formula 1. The objective of model is the minimization of CO emissions and a total travel time of network system under the constraints of investment budget, through the selection of road to widen or newly build by decision-makers.

$$\underset{y}{Min}\ E_S = w_1 \sum_a (167.154 - 5.2911 v_a + 0.0662 v_a{}^2 - 0.0003 v_a{}^3) \cdot l_a \cdot x_a + w_2 \bullet t_a \bullet x_a \quad (1)$$

$$\text{s.t.} \ \sum_a \tau_a \bullet y_a \le B \quad (2)$$

$$y_a \in (0,1), \forall a \in A \quad (3)$$

$x = x(\mathrm{y})$ can be obtained by the lower programming model. Lower model is user equilibrium traffic assignment model, as shown in formula 4.

$$\underset{x}{Min}\ Z(x) = \sum_a \int_0^{x_a} t_a(\omega) d\omega \quad (4)$$

$$\text{s.t.} \ \sum_k f_k^{rs} = q_{rs}, \forall r \in R, s \in S, k \in P \quad (5)$$

$$f_k^{rs} \ge 0, \forall r \in R, s \in S, k \in P \quad (6)$$

$$x_a = \sum_r \sum_s \sum_k f_k^{rs} \bullet \delta_{a,k}^{rs} \ge 0, \forall a \in A \quad (7)$$

$$t_a(x_a) = t_a \bullet [1 + 0.15(x_a / (c_a + y_a \bullet (pc_a - c_a)))^4] \quad (8)$$

Define:

w_1、w_2—weight of total CO emissions and total travel time, denotes degree of importance attached to different targets of network systems;

E_s、Z—objective function of upper model and lower model;

τ_a—construction cost of widening or building new road;

y_a—decision vector of whether to widen or newly build road;

B—investment budget in upper model;

R、S—sets of origin and destination in road network;

P—all of path sets in road network;

A—all of node sets in road network;

x_a—link flow of section a ;

l_a—link length of section a;

t_a—traffic impedance of section a, travel time;

$t_a(x_a)$—travel time function of section a;

c_a—traffic capacity of section a at present;

pc_a—traffic capacity of section a in the future;

f_k^{rs}—traffic flow of the k-th path between origin and destination of rs;

q_{rs}—traffic flow between origin and destination of rs;

$\delta_{a,k}^{rs}$—relation variables of section and path.

2.2 Algorithm

2.2.1 Algorithm Process

The road network in this upper model is established using GA, and it distributes UE traffic assignment in lower model to get traffic flow of each road according to the OD demand and the network obtained by upper model. Finally it puts the traffic flow into the upper model to determine fitness, as shown in figure 1:

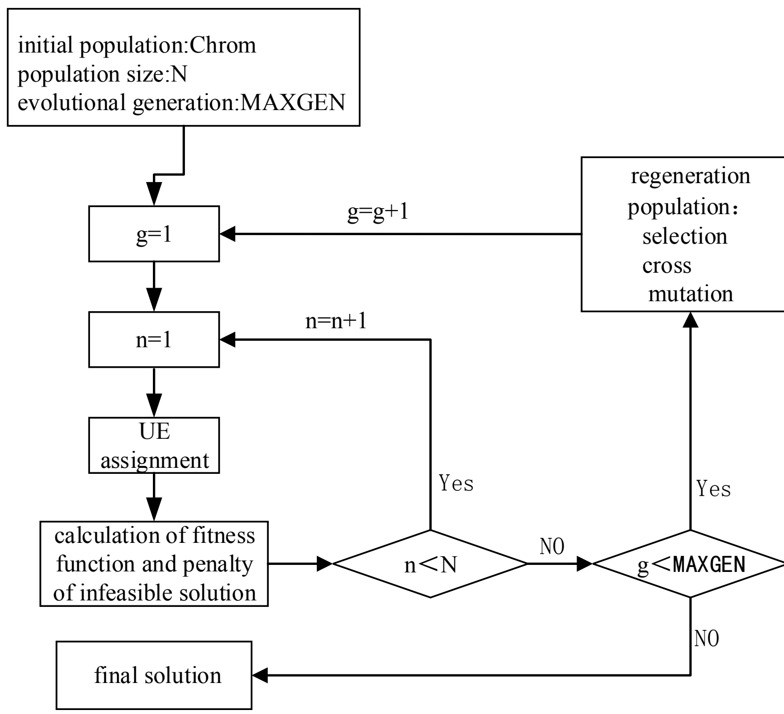

Figure 1. The Flowchart of NDP Model

2.2.2 Algorithm Steps

1. Road Network Coding. The original solution to the problem is mapped to chromosome, using the binary coding. If there are six roads in the road network, then use a variable of 0 or 1 with length of 6 to represent a chromosome, such as (110010). Number 1 indicates that the corresponding roads of 1, 2 and 5 will be newly built or expanded and Number 0 represents the corresponding roads status of 3, 4 and 6 will be maintained.

2. Initialize control parameters. Firstly it generates 40 chromosomes randomly as the initial population with binary encoding method, setting number of evolutionary generation as 100, value of cross probability as 0.9 and value of mutation probability as 0.01.Then the model with 40, 50 and 60 populations, cross probability of 0.8 and 0.9, and mutation probability of 0.01 are calculated again. Finally it comparatively analyze the results and adjust parameters reasonably.

3. UE assignment. According to the road network population obtained, we distribute algorithm of UE traffic assignment. The algorithm is discussed in Reference 3

4. Fitness evaluation. Calculate the objective function in the upper model after get road flow obtained in step 3. The larger the fitness value, the more superior individual, and the greater the probability that the individual is selected genetically to the next generation.

5. Constraint processing. Infeasible solutions not to meet the constraints will be deal with a penalty function, which can change a constraint problem into an unconstrained problem.

6. Selection strategy. Select the best individual and directly inherit to the next generation and then select the other individual using roulette method, which is based on the proportion of fitness selection strategy.

7. Cross operation. Select two individuals randomly from the population and get new fine individuals using double-cut point crossover method.

8. Mutation. Select individuals randomly from a population and change the coding by 0.01 mutation probability in order to maintain the diversity of population and avoid local optimum.

9. Algorithm terminates. Optimal solution cannot be determined by traditional methods, so we set the number of iterations as 100. When the program runs to 100, algorithm terminates; otherwise, returns to step 3.

3 Numerical Examples

3.1 Test Data

In this paper, Sioux Falls network (LeBlanc, 1975) is presented as a case study. There are 24 nodes (assuming that all nodes are occur-attraction spot), 76 sections (66 sections have been built and need expansion in the future, 10 sections need to be built) and 576 OD pairs (traffic demand of 48 OD pairs is 0) in the road network. The network structure is shown in Figure 2, where the solid line represents the existing road, blue dashed line represents the road need to be built.

All the basic parameters of Sioux Falls network can be obtained, referring to reference 1. Because the OD demand given by LeBlanc is for the daytime, it needs to be converted for peak hour. It's found that the 8th traffic flow of 24 hours in descending order is more stable and can be used as basic data for the control of traffic lights by long-term studies in US. So the traffic volume of peak hour is about 8.475% of a day.

3.2 Results and Analysis

Different values of the weight coefficients of w1 and w2 show the degree of deviation between the total travel time and urban traffic environment by planners and policy makers. Therefore, five different sets of weights were compared and different operation parameters in each group were taken in this paper. Each time the program running takes about 14 minutes and the results are as follows:

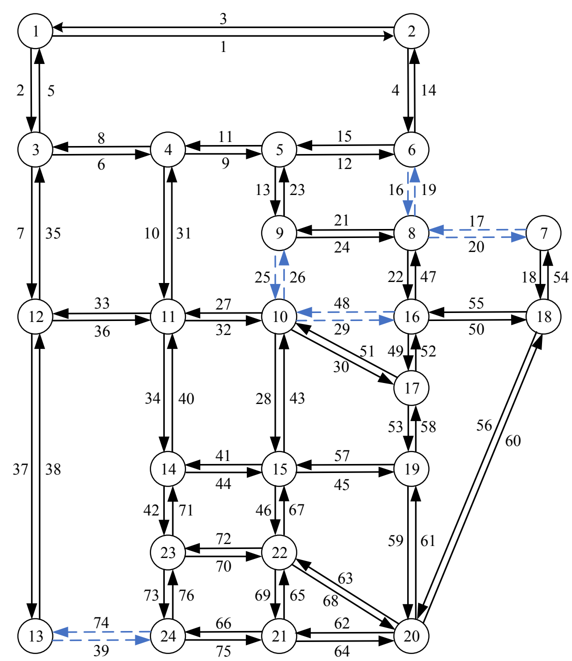

Figure 2. Test Network of Sioux Falls

Table 1. Road Network Design under Different Combination of Weights

Weight	Solution	Investment cost	Cross probability	population size	New Roads	Rebuilding Roads
w1=0, w2=1	3647	19500	0.9	60	16,7,19,25,26,39,48,74,	2,4,6,7,9,12,14,15,18,22,24,27,28,30,31,32,33,34,36,37,40,42,43,46,49,50,51,52,53,55,56,57,58,60,65,67,69,70,71,72,75
w1=0.2,w2=0.8	1045412	19800	0.9	60	16,17,19,25,26,39,74	2,5,6,7,12,15,21,22,23,27,28,30,32,33,34,35,36,37,38,40,41,42,43,44,46,47,49,50,51,52,53,57,58,59,61,63,65,67,71,72,73,75,76
w1=0.4,w2=0.6	2101638	18400	0.8	60	16,19,20,25,26,39,48	3,4,11,12,14,15,22,23,27,28,30,31,32,33,34,36,37,38,40,41,42,46,47,49,50,51,52,53,55,58,60,63,65,67,70,71,72,73,

						75,76
w1=0.6 ,w2=0. 4	3192 829	19700	0.9	60	16,17,1 9,20,25 ,26,29, 39,74	1,2,3,4,6,10,12,14,15,18,22,2 3,27,30,31,32,33,34,35,36,37 ,40,42,44,49,51,52,53,55,57, 58,59,61,62,64,66,67,69,72,7 4
w1=0.8 ,w2=0. 2	4201 091	19900	0.8	60	16,17,1 9,20,25 ,26,29, 39,74	1,2,3,8,12,13,15,22,27,30,31, 32,33,34,35,36,37,40,41,42,4 4,46,47,49,51,52,53,54,57,61 ,62,63,65,66,68,69,71,72,73, 74,75,76
w1=1, w2=0	5317 588	20000	0.9	40	16,17,1 9,20,25 ,26,29, 39,74	1,2,5,6,7,9,10,11,12,15,22,27 ,3031,33,34,36,37,40,42,44,4 5,46,4749,50,51,52,53,54,55, 57,58,59,61,63,64,65,66,67,6 8,72,75,76

From the above table it can be seen that it is easier to get a better result when the cross probability is 0.9 and the population size is 60. Some roads were always selected under different conditions, such as new roads 16, 19, 25, 26, 39 and rebuilt roads 12, 15, 27, 30, 33, 34, 40, 42, 49, 51, 52, 53. This shows that these selected roads are important to improve the system performance and should be the primary consideration in transportation planning.

4 Conclusions

A bi-level programming model for urban road network design problem based on environmental goals is established in this paper. The upper model aims at minimizing the CO exhaust emissions and total travel time to reduce traffic pollution and traffic congestion. The model is solved by GA and Frank-Wolfe algorithm and Sioux Falls network is taken as a numerical example to demonstrate the validity and effectiveness of the algorithm. The results showed that the algorithm has good convergence and the model and algorithm can provide a reference for traffic planning in practice.

References

LeBlanc L. J. (1975) *An algorithm for the discrete network design problem*, Transportation Science, Vol.9(3), 183-199.

Lu Huapu, Yu Xinxin, Bian Changzhi (2011) *Model and algorithm of discrete network design problem under OD demand uncertainty,* Journal of highway and transportation research and development, Vol.28(5), 128-132.

Lu Huapu (2006) *Theory and method of in Transportation planning,* Tsinghua University Press, Beijing.

Wang Dingwei. (2007) *Intelligent Optimization Methods,* China Higher Education Press, Beijing.

Wang Wei (2002) *Energy consumption and environmental impact analysis of urban transportation system,* Science Press, Beijing.

Yang Ming, Su Biao. (2014) *Model and algorithm of multi-objective discrete transportation Network design under stochastic demand among OD pairs,* Journal of southwest jiaotong university, Vol.49(1), 119-125.

A New Calculation Method of Bus Punctuality Based on AVL Data

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Abstract: An effective solution to traffic jam is to develop public traffic. According to GPS vehicle positioning system we get the bus operation data. Then on the basis of the analysis of the current research, we build a more accurate calculation model with extreme value theory, which is used to evaluate the bus running between adjacent sites based on the AVL data and data mining. The effectiveness of the model is evaluated by a computational example using the AVL data of Shanghai's No.49 bus. At last, we analyze the important role of this index for users and managers, and give some suggestions.
Keywords: Public transit; Punctuality; AVL.

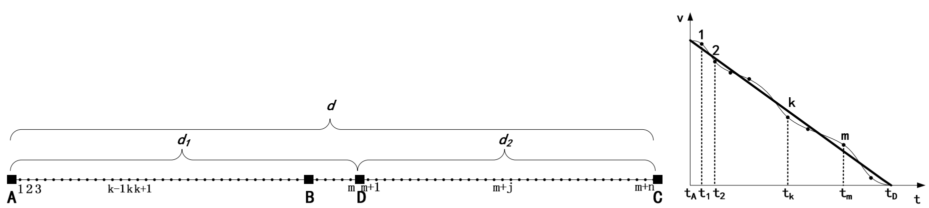
1 Introduction

Bus On-time Performance plays an important role in evaluation system of customers' satisfaction for public transport. In 2003, the Transport Research Institution in the US state of Texas introduced the Planning Time Index for evaluating the bus on-time performance in the Monitoring Report of American Transport Efficiency in 2003 compiled by federal agency. Professor Seung-Young Kho concluded that on-time performance was the most important evaluation index taking the bus operating conditions in Seoul, South Korea for example and put forward the concept of BMS-Bus Operation Management System. Early scholars mainly used the artificial survey data to study the bus service evaluation index, which had larger error. With the development of technology and the universal of the technique like GPS, more and more scholars begin to study the intelligent transport system. Chen put forward the Bus service reliability prediction simulation model based on the AVL-APC data; Joshua Greenfeld systematically elaborated various aspects in APTS which should be thought by the bus operators in his research, especially the Bus On-time Performance, and emphasized its importance; Ranhee Jeong, and Laurence R. Rilett put forward the method of predicting the bus arrival time based on the Artificial neural network model. Domestic scholars also had deeper research in this field. The research group of Professor Xiaoguang Yang systematically studied the deviation of bus intermediate arrival time and the concept and computational method of bus On-time Performance, and respectively analyzed the relationships between the both and passengers association; Professor Zhihua Xiong restructured the stochastic model of road network based on the APTS to evaluate the bus on-time performance and he put forward solving method by combining Frank-Wolfe Method and MSA-Method of Successive Average.

On the basis of understanding various scholars' researches, we found that most scholars only used mathematics method to study, fewer scholars applied the data mining technology to the field of bus research and early scholars only used travel time to study reliability index while reliability was a relatively large evaluation index. Therefore, this thesis bases on the reliability engineering thought, according to the Chinese recent condition of obtaining real-time transport data and its future development trend, using data collected by existing equipment to study bus on-time performance index. We classify and integrate the information of traffic database, on the basis of APTS technique and using the method of data mining, to get data for convenient study. Then taking 49 bus in Shanghai city for example, we fit certain operating road to validate the distribution model of travel time and establish evaluation model of bus on-time performance. At last, we analyze the important role of this index for users to improve travel efficiency and managers to make decisions according to the background of practical application and give some suggestions.

2 Model Develop

It is obvious that the data not get the accurate information about bus in-out site. In fact, only some nebulous statistics could be collected. Therefore it is necessary to calculate the actual information of stopping and leaving time at the site with the model and AVL data.



(a) (b)

Fig.1

In figure 1, D is the actual bus stop theoretically: d_1 indicates the actual pulling in distance; d_2 indicates the actual outbound distance; d is the total distance of into and out of sites; m and n respectively indicate that m pieces of information are returned from bus since pulling in to stopping and n pieces of information since restarting to leaving; k and j are respectively for the number k and j data point. A piece of information returned from GPS includes time (moment), speed, accumulated travel mileage. From this, its speed at point A and C, as well as the distance (d) between A and C can be informed.

This paper sets every two data points as a micro-element, so that the move between every two data points can be approximately treated as uniform variable move. Take the pulling in process for example, as shown in figure 1(b).

The formula to calculate stop time t_D is as follow:

$$\begin{cases} d_1 = \int_{t_A}^{t_D} v \cdot dt \approx v_A \cdot \frac{t_1 - t_A}{2} + \sum_{k=1}^{k=m-1} v_k \cdot \frac{t_{k+1} - t_{k-1}}{2} + v_m \cdot \frac{t_D - t_{m-1}}{2} \\ d_2 = \int_{t_D}^{t_C} v \cdot dt \approx v_D \cdot \frac{t_{m+1} - t_D}{2} + \sum_{j=1}^{j=n-1} v_{m+j} \cdot \frac{t_{m+j+1} - t_{m+j-1}}{2} + v_C \cdot \frac{t_C - t_n}{2} \\ d_1 + d_2 = d \end{cases} \tag{1}$$

Where,

d_1——actual pulling-in distance;

d_2——actual leaving distance;

d——total distance of pulling in and leaving;

v——actual speed;

t_A——pulling in time returned from the system;

t_B——stop time returned from the system;

t_C——leaving time returned from the system;

t_D——actual stop time;

m, n——amount of AVL data returned from bus from pulling in to stop and from restarting to leaving;

t_i——the time when No. i data point returned.

According to Eq. (1), there is

$$t_D = \frac{2\left(d - \sum_{k=1}^{k=m-1} v_k \cdot \frac{t_{k+1} - t_{k-1}}{2} - \sum_{j=1}^{j=n-1} v_{m+j} \cdot \frac{t_{m+j+1} - t_{m+j-1}}{2}\right) - v_A \cdot (t_1 - t_A) - v_C \cdot (t_C - t_n)}{v_m} + t_{m+1} \tag{2}$$

In general, there are obvious differences of bus travel time between periods of time. Therefore, it's not enough to force on the full bus travel time when evaluating the punctuality rate. For passengers, the punctuality rate between sites is more important, which is not a specific value, but a interval. The smaller the interval is, the more accurate the evaluation is.

For a better description for public transportation's punctuality situation, the paper introduces the concepts of Adjacent Sites Punctuality Rate on time (ASPR).

According to the above discussion, the travel time between every pair of neighboring stands can be calculated. Supposing $(t_1, t_2, \ldots\ldots, t_p)^T$ stands for the whole of the P elements. The No. j piece of data in the No. i section is recorded as $T_{ij} = (t_{ij1}, t_{ij2}, \ldots\ldots, t_{ijp})^T$, $T_i = (T_{i1}, T_{i2}, \ldots\ldots, T_{ip})^T$ is a $p \times n$ matrix. The No. k (k=1,2, ..., p) line of T_i respectively indicates the No. n_i travel time data of the No. k pair of neighboring sites, recorded as $T_{ik} = (t_{i1k}, t_{i2k}, \ldots\ldots, t_{in_ik})^T$.Then,

$$T_i = (T_{i1}, T_{i2}, \ldots\ldots, T_{ip})^T = \begin{pmatrix} t_{i1k} & \cdots & t_{in_ik} \\ \vdots & \ddots & \vdots \\ t_{i1p} & \cdots & t_{in_ip} \end{pmatrix} \tag{3}$$

Assume that ASPR of the No. k pair of adjacent sites in the No. i section is calculated by Eq.(5).

$$ASPR_{\mathrm{ik}} = P\left\{\overline{T_{ik}} - S_{ik} \le ti_{jk} \le \overline{T_{ik}} + S_{ik}\right\} \tag{4}$$

Where $\overline{T_{ik}}$ is the average value of the travel time and $\mathrm{S_{ik}}$ is the standard deviation. Thus among the n_i dates, there are m_i dates in the marked time range above. It could be thought that the $ASTT$ obeys binomial distribution. Assume the prior distribution of $ASPR$ is $\beta(a,b)$, and it is able to be inferred that the posterior distribution is $\pi(\mathrm{ASPR}|m) \sim \beta(m+a, n-m+b)\beta(a,b)$. With a given $1-\alpha$, there is

$$P(R_1 \le ASPR \le R_2 |\mathrm{m}) = \int_{R_1}^{R_2} \pi(\mathrm{ASPR}|m)\, daspr = F(R_2) - F(R_1) = 1-\alpha \tag{6}$$

Where $F(r), f(r)$ are distribution function and distribution density of $\beta(m+a, n-m+b)$. $[R_1, R_2]$ is the $1-\alpha$ confidence internal , and $L = R_2 - R_1$ is burst length. In order to get the shortest confidence interval, it is needed to get R_1^*, R_2^* in the following condition:

$$\begin{cases} \min L = R_2 - R_1 \\ \int_{R_1}^{R_2} \pi\left(\text{ASPR}\,|\,m\right) daspr = F\left(R_2\right) - F\left(R_1\right) \end{cases} \tag{6}$$

Considering the relationship of β distribution and binomial distribution, the result of Eq. (6) is equivalent to Eq. (7).

$$\begin{cases} \min L = R_2 - R_1 \\ \sum_{l=a+m}^{N} C_N^l R_2^{\,l} (1-R_2)^{N-l} - \sum_{l=a+m}^{N} C_N^l R_1^{\,l} (1-R_1)^{N-l} = 1-\alpha \\ R_1,\ R_2 \in (0,1) \\ R_2 \geq R_1 \end{cases} \tag{7}$$

Where， $N = a + b + n - 1$

It can be proved that this model has only one result (the the certification procedure is omitted). With MATLAB, the shortest interval $\left[R_1^*, R_2^*\right]$ can be got. The punctuality rate interval from this model is much more accurate than the one assumed, which is better for evaluating the bus running condition between adjacent stops.

3 Model verification

The intelligent transport information used in this thesis is real-time information data of all 49 buses in Shanghai. The basic information of 49 bus is as follows: The upside is from Shanghai Stadium to Hankou Road, the downside is from Hankou Road to Shanghai Stadium, there are 20 stations in all and departure interval is 5min.

The ASPR of all sites when $i = 1$ are shown in table 1.

Tab. 1 ASPR of all sites when $i = 1$

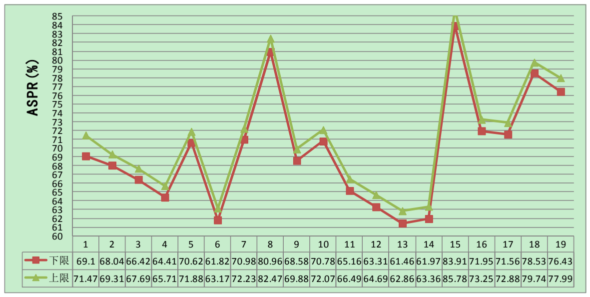


Table 1 indicates that: in morning peak, the punctuality rate is higher between the sites of Huashan Road-Changshu Road and NO.2 Company- Tumour Hospital while it is lower between the sites of North Shanxi Road-Tongren Road, Zhongshan Hospital-Fenglin Road and Fenglin Road-NO.2 Company. The result reflects the bus operation. Table 2 reflects the traffic road circumstance of sites above.

Tab. 2 Analysis of Influencing Factors of ASPR

NO. / Factors	8	15	6	13	14
Bus stop spacing(km)	0.34	0.64	0.55	0.77	0.48
Main road sections					
Intersection number/signal period(s)	2/(180+0)	1/(120)	2/(120+120)	5/(140+75 +75+75+1 20)	1/(120)
Bus lane	√	√	×	×	×
Platform form (A bus way，B not due)	A	A	A,B	A,B	A
Peak hour traffic(pcu/h)	2800	3310	4790	2430	5620
saturation	0.37	0.55	0.79	0.81	0.75

According to table 2, it can be informed that the bus stop spacing, main road sections, intersection number, signal period, bus lane, platform form, peak hour traffic and saturation affect the bus operation, in which bus lane, intersection number, signal period, peak hour traffic and saturation play a much more important role.

4. Conclusions

In this thesis, the study of bus punctuality is mainly discussed and we use GPS system to collect data, GIS technique to analyze data, data mining to handle the derived data. After analyzing the data, we tested that bus travel time basically obeys Beta distribution. Based on that, establish the evaluation model of bus punctuality. After analyzing the bus on-time performance of Shanghai Bus Faw's all 49 buses based on their real-time information data, evaluate it according to the classification table of the service level of bus roads' on-time performance. But this studying method's application has great limitation because of practical constraints; we should find more cost-effective and effective studying method to improve its practical value in the follow-up studies.

References

Agachai Sumalee , Zhijia Tan. Dynamic stochastic transit assignment with explicit seat allocation model. Transportation Research Part B 43 (2009) 895–912

C. Cirillo. Evidence on the distribution of values of travel time savings from a six-week diary. Transportation Research Part A 40 (2006) 444–457

Jan-Willem Grotenhuis,Bart W. Wiegmans. The desired quality of integrated multimodal travel information inpublic transport: Customer needs for time and effort savings. Transport Policy 14 (2007) 27–38

Justin S. Chang. Assessing travel time reliability in transport appraisal. Journal of Transport Geography 18 (2010) 419–425

Kittelson and Associates, et al. 2003. TCRP Report 100: Transit Capacity Quality of Service Manual, 2nd Edition. Washington DC: Transportation Research Board.

Laura Cecilia Cham.Understanding Bus Service Reliability: A Practice Framework Using AVL/APC Date.2005.

Mogens Fosgerau. The value of travel time variance. Transportation Research Part B 45 (2011) 1–8

Maged Dessouky, Randolph Ha. Real-time control of buses for schedule coordination at a terminal. Transportation Research Part A: Policy and Practice.Volume 37, Issue 2, February 2003, Pages 145-164

Seung-Young Kho .A Development of Punctuality Index for Bus Operation. Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, pp. 492 - 504, 2005

Zheng Li, David A. Hensher.Willingness to pay for travel time reliability in passenger transport: A review and some new empirical evidence. Transportation Research Part E 46 (2010) 384–403

Multiple-Depot Multiple-Type Vehicle Routing Problems Considering the Real Network

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Abstract: Vehicle Routing Problem (VRP) is a typical problem of urban distribution, multi-depot vehicle routing problem is a complex extension of vehicle routing problem. Reams of existing research of path optimization problems were assuming different customers have connected directly and using the straight-line distance between two points as the distance between two customers, it is possible in theory, but does not meet the reality of the road network structure, cannot be applied to the actual vehicle schedule.

In this paper, considering both customer's location within a specific service area and the actual road network structure, based on actual customer orders, research the optimal distribution path about multiple distribution centers with different types of vehicles, meet the needs of each customer, taking into account the loading rate of the vehicles, so that the total transport cost is minimal.

Considering the earliness of genetic algorithm, this paper combines simulated annealing algorithm, using an improved genetic algorithm and experimentally verify the feasibility and effectiveness of the algorithm, showing that the algorithm can be directly applied to the actual vehicle schedule.

Keywords: Transport planning; Vehicle routing problem; Road network structure; Multi-depo; Heterogeneous-vehicle.

1 Introduction

MDMTVRP is the extension of Vehicle Routing Problem, means there are many depots equipped a variety of types of vehicles, distribution to multiple clients in the same time, we need to arrange a suitable plan which ensure the needs of all customers are satisfied and lowest total cost of transportation (Yang Yuanfeng,2008). MDMTVSP is closer to reality than the VSP, but also more complex, the scholars (José Brandão, 2006; Teodorovic D, Kikuchi S, 1991; Jacques Renaud (1996) have discussed a series of issues about it. Wang Xiaobo (2009) used hybrid genetic algorithm to solve this kind of problem. Luo Hongbin (2014) used mutation ant colony algorithm to solve this kind of problem. However, the slow convergence of these algorithms make it is difficult to escape from local optimal solution (Li Xiangyong, 2007). Genetic algorithms has good global search ability; simulated annealing algorithm has asymptotic convergence, is a kind of global optimization algorithm converges in probability to a global optimal solution, so combine these two algorithms to solve MDMVVSP to find the optimal solution .

2 The mathematical model of MDMTVRP

MDMTVRP can be described as follows: M depots distribute to N (i = 1,2, ..., N) customers, each depot has K_{ml} units of load of Ql (l = 1,2, ..., L) of the vehicle, distribution cost of per vehicle is related to unit fuel and turnover volume (denoted as C_l), the demand of customer i is g_i and $g_i<Q_l$, the distance between customer i and customer j is d_{ij}, each customer can be distributed by any model of vehicle in any depot, and each customer has only one vehicle for distribution, each vehicle returns to original distribution depot after its task, designing a reasonable scheduling scheme, to meet all customers' requirements, so that the total cost is minimized.

Customer number set for 1, 2, ..., N, yard number is N + 1, N + 2, ..., N + M, define the variable as follows:

$$x_{ij}^{mlk} = \begin{cases} 1 & \text{l type vehicle k from depot m travelling from client i to client j} \\ 0 & \text{else} \end{cases} \tag{1}$$

Mathematical model as follows:

$$\min Z = \sum_{m=1}^{M}\sum_{l=1}^{L}\sum_{k=1}^{K_{ml}}\sum_{i=1}^{N+M}\sum_{j=1}^{N+M} d_{ij}x_{ij}^{mlk}C_l \tag{2}$$

Constraints as follows:

$$\sum_{j=1}^{N+M}\sum_{m=1}^{M}\sum_{k=1}^{K_{ml}}\sum_{l=1}^{L} x_{ij}^{mlk}=1, i\in\{1,2,...,N\} \tag{3}$$

$$\sum_{i=1}^{N+M}\sum_{m=1}^{M}\sum_{k=1}^{K_{ml}}\sum_{l=1}^{L} x_{ij}^{mlk}=1, j\in\{1,2,...,N\} \tag{4}$$

$$\sum_{i=1}^{N}\sum_{k=1}^{K_m} x_{ij}^{mlk} \le K_{ml} \tag{5}$$

$$\sum_{i=1}^{N} x_{ij}^{mlk} = \sum_{j=1}^{N} x_{ij}^{mlk} \le 1, m\in\{N+1, N+2,...,N+M\}, l\in\{1,2,...,L\}, k\in\{1,2,...,K_{ml}\} \tag{6}$$

$$\sum_{i=1}^{N} g_i \sum_{j=1}^{N+M} x_{ij}^{mlk} \le Q_l, m \in \{N+1, N+2, ..., N+M\}, l \in \{1,2,...,L\}, k \in \{1,2,...,K_l\} \quad (7)$$

$$\sum_{i=N+1}^{N+M} x_{ij}^{mlk} = \sum_{j=N+1}^{N+M} x_{ij}^{mlk} = 0, m \in \{N+1, N+2, ..., N+M\}, l \in \{1,2,...,L\}, k \in \{1,2,...,K_{ml}\} \quad (8)$$

In the above formulas, formula (2) is the objective function means the lowest cost of transportation; (3) and (4) ensure that each client can only be served by a vehicle once; formula (5) means vehicles participate in the distribution cannot exceed the total number of each depot; (6) means each vehicle distribute from a depot and return to the depot where it set out; (7) ensures each car's weight must not exceed its load limit; (8) represents the vehicle cannot travel directly from one depot to another.

3 Improved genetic algorithm

3.1 Encoded representation

In this paper, using natural number to code, chromosome structure is (g_1,g_2,…,g_N), g_i is constituted of depot_num and vehicle_num, customer whose number is i is distributed by vehicle vehicle_num in depot depot_num, depot_num and vehicle_num are randomly generated when initializing population. Then the problem is converted into n small-scale problem of TSP.

3.2 Cross reorganization

According to the actual structure of chromosomes, taking two-points crossover method, selecting two chromosomes, exchange genes between two points, and then exchange the head and the tail of each chromosome.

3.3 Mutation

Mutating the chromosomes in the probability of p_m, each gene is constituted of depot_num and vehicle_num, so mutation means changing the depot_num or vehicle_num.

3.4 Algorithm structure

Step 1 Find adjacency matrix of distance based on the actual road network, and use floyd algorithm to solve the shortest distance between any two points;

Step 2 Initialize algorithm: population size is G, the largest number of evolution is g, crossover probability is p_c, mutation probability is p_m, initial annealing temperature is t_0, cooling parameter is γ;

Step 3 Construct chromosomes, generating initial population;

Step 4 Find out the chromosome of largest fitness value in current population, and calculate the fitness value f(B);

Step 5 In the temperature of t_k, randomly select two individuals G_i and G_j with probability of p_c, after cross reorganization, generate two new individuals G_i' and G_j', both calculate fitness value f(i') and f(j'). For G_i', if f（i'）>f(B), accept i' as the new status. Otherwise, if $p_t = e^{-\frac{f(i')-f(B)}{t_k}}$ is bigger than random number belongs to [0,1) , accept B as current state; if not, reserve i as current state. For $G_j^{'}$ as well.

Step 6 Mutate chromosomes with the probability of p_m after crossing, based upon the method in step 4 to decide whether to accept the new state.

Step 7 Judge whether the condition is satisfied, if the optimal solution meet demand, then terminate and output f(B) ; otherwise, $t_{k+1} = \gamma t_k$, turn step 4.

4 Case analysis

In this paper, according to the actual road network, select a section of Chengdu downtown, design a case to test the feasibility and superiority of the algorithm.

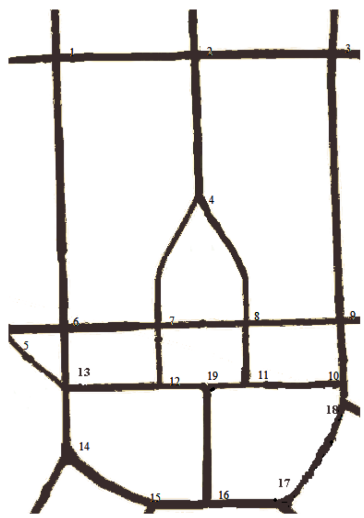

Figure 1. Actual road network

Suppose there are 16 clients and 3 depots, depots are located in positions of no.17, 18 and 19. All delivery is completed by the 3 types of vehicles in all depots, each depot has enough vehicles. Vehicle types and unit cost are in the following tables.

Table 1. Vehicles data

Vehicle	Capacity(t)	Cost of full-load (yuan/km)	Cost of no-load(yuan/km)
1	1	0.8	0.6
2	3	1.25	0.8
3	5	1.5	1.0

First find adjacency matrix of distance based on the actual road network, then use floyd algorithm to solve the shortest distance between any two points.

Table 2. Shortest distances

Km	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0	0.48	0.95	0.99	1.2	0.96	1.3	1.51	1.84	2.07	1.75	1.53	1.19	1.42	1.79	1.99	2.27	2.14	1.69
2	0.48	0	0.47	0.51	1.6	1.36	1.02	1.03	1.36	1.59	1.27	1.25	1.59	1.82	2.01	1.81	2.09	1.66	1.39
3	0.95	0.47	0	0.98	2.07	1.83	1.49	1.27	0.94	1.17	1.51	1.72	2.06	2.29	2.16	1.96	1.68	1.24	1.63
4	0.99	0.51	0.98	0	1.09	0.85	0.51	0.52	0.85	1.08	0.76	0.74	1.08	1.31	1.5	1.3	1.58	1.15	0.88
5	1.2	1.6	2.07	1.09	0	0.24	0.58	0.89	1.22	1.33	0.95	0.67	0.33	0.56	0.93	1.13	1.41	1.4	0.83
6	0.96	1.36	1.83	0.85	0.24	0	0.34	0.65	0.98	1.21	0.85	0.57	0.23	0.46	0.83	1.03	1.31	1.28	0.73
7	1.3	1.02	1.49	0.51	0.58	0.34	0	0.31	0.64	0.87	0.51	0.23	0.57	0.8	1.01	0.81	1.09	0.94	0.39
8	1.51	1.03	1.27	0.52	0.89	0.65	0.31	0	0.33	0.56	0.24	0.52	0.86	1.09	0.98	0.78	1.06	0.63	0.36
9	1.84	1.36	0.94	0.85	1.22	0.98	0.64	0.33	0	0.23	0.57	0.85	1.19	1.42	1.22	1.02	0.74	0.3	0.69
10	2.07	1.59	1.17	1.08	1.33	1.21	0.87	0.56	0.23	0	0.38	0.66	1	1.23	0.99	0.79	0.51	0.07	0.5
11	1.75	1.27	1.51	0.76	0.95	0.85	0.51	0.24	0.57	0.38	0	0.28	0.62	0.85	0.74	0.54	0.82	0.45	0.12
12	1.53	1.25	1.72	0.74	0.67	0.57	0.23	0.52	0.85	0.66	0.28	0	0.34	0.57	0.78	0.58	0.86	0.73	0.16
13	1.19	1.59	2.06	1.08	0.33	0.23	0.57	0.86	1.19	1	0.62	0.34	0	0.23	0.6	0.8	1.08	1.07	0.5
14	1.42	1.82	2.29	1.31	0.56	0.46	0.8	1.09	1.42	1.23	0.85	0.57	0.23	0	0.37	0.57	0.85	1.29	0.73
15	1.79	2.01	2.16	1.5	0.93	0.83	1.01	0.98	1.22	0.99	0.74	0.78	0.6	0.37	0	0.2	0.48	0.92	0.62
16	1.99	1.81	1.96	1.3	1.13	1.03	0.81	0.78	1.02	0.79	0.54	0.58	0.8	0.57	0.2	0	0.28	0.72	0.42
17	2.27	2.09	1.68	1.58	1.41	1.31	1.09	1.06	0.74	0.51	0.82	0.86	1.08	0.85	0.48	0.28	0	0.44	0.7
18	2.14	1.66	1.24	1.15	1.4	1.28	0.94	0.63	0.3	0.07	0.45	0.73	1.07	1.29	0.92	0.72	0.44	0	0.57
19	1.69	1.39	1.63	0.88	0.83	0.73	0.39	0.36	0.69	0.5	0.12	0.16	0.5	0.73	0.62	0.42	0.7	0.57	0

Table 3. Customer demands

Customer	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Demand	0.03	0.44	0.38	0.77	0.80	0.19	0.45	0.65	0.71	0.75	0.28	0.68	0.66	0.16	0.50	0.96

Using MATLAB to program and solve the problem, set population size N=20, predetermined evolution algebra is 100, p_c=0.8, p_m=0.1, initial temperature T=1000, cooling parameter γ=0.9.

By 50 times repeated calculation, get the minimum distribution cost 11.8162 yuan.

The best distribution scheme is:

17 depot：1t vehicle：14；
3t vehicle：15；
5t vehicle：none；
18 depot：1t vehicle：16；4；3 → 2 → 1；
3t vehicle：10 → 11；
5t vehicle：none；
19 depot：1t vehicle：12；13 → 6；

3t vehicle：8 ➔ 9 ➔ 7 ➔ 5；

5t vehicle：none；

The iteration process converges very quickly from Figure 1**:**

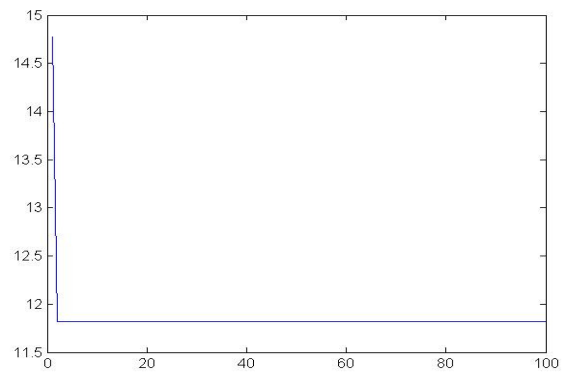

Figure 2. Convergence curve of best fitness

5 Conclusions

In this paper, considering the actual traffic conditions under MDMTVRP, make this kind of problems more practical. This paper combines the advantages of simulated annealing algorithm, improve the local convergence of genetic algorithm, accelerate the convergence rate of the algorithm, and has the ability to break away from local optimal solution. Therefore, the method mentioned in this paper can effectively solve MDMTVRP.

6 Recommendations for Future Research

In the future, time window should be adopted in the study, adjust the distribution route according to the real-time road congestion.

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References

Jacques Renaud.(1996).A tabu search heuristic for the multi-depot vehicle routing problem. *Computers and Operations Research.*

José Brandão.(2006).A new tabu search algorithm for the vehicle routing problem with backhauls. *European Journal of Operational Research* .

Li Xiangyong.(2007).Research on the model and algorithm of vehicle routing problem. *Shanghai Jiao Tong University*

Luo Hongbin.(2014).Improved particle swarm optimization algorithm for multi

depot multi type vehicle scheduling problem. *Computer engineering and Applications*
Teodorovic D,Kikuchi S.(1991).Application of fuzzy sets theory to the saving based vehicle routing algorithm. *Civil Engineering Systems*
Wang Xiaobo,Li Yijun.(2009).Multiple depot multi vehicle loading hybrid vehicle routing problem research. *Control and decision*
Yang Yuanfeng.(2008).An improved genetic algorithm for multi depot vehicle routing problem.*Computer and Modernization*

Maintenance Network Planning of RFID Facilities Considering the Validity of Communication Nodes

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Abstract: Maintenance network planning of RFID facilities is researched considering validity of communication nodes which is a necessary condition for the function of RFID system. Some impacts on the capacity of maintenance network such as number of maintenance resource nodes, coverage radius of maintenance resource nodes and operation expense are considered in this paper. On a certain RFID facilities layout, the maintenance network planning model of minimum the maintenance expense is proposed combining with set covering model constrained as validity of RFID communication nodes. And then the maintenance resource nodes can be determined by heuristic algorithm designed to solve the model. Sensitivity analysis of influencing factors on maintenance capacity is studied by using optimal simulation technology. Experimental simulation results show that the validity of communication nodes had an important impact on the maintenance network planning of RFID facilities. The number and coverage radius of maintenance resource nodes, operation expense of network are more sensitive to maintenance support capacity. Reference approach is offered for the future construction and operation practice of RFID facilities' maintenance network planning.
Keywords: Set covering model; Maintenance network planning; RFID facilities; Validity of communication nodes; Maintenance capacity.

1 Introduction

As the demonstration project, promotion and application of the emerging Internet of Things in the field of public security, civil aviation, transportation, environmental monitoring, smart grid and the agricultural and so on in China, RFID system, which is an essential perception technology of Internet of things, maintains a rapid growth. In 2009, Chinese RFID market share is about 8.03 billion yuans ranking as the third behind England and America. The share of 2012 has reached 12.45 billion yuans and the rate of growth was 18.3%. Just because RFID system play the essential roles in collecting , identifying the valuable information and recognizing environmental events in the various areas of Internet of things, RFID system is firstly promoted development from a single system, integration system into network.

In complex RFID system, the hardware includes tag, reader, communication middleware and backend server. Communication middleware, whose functions are strengthening and transforming signals between the reader and backend server as communication node, is a kind of transmission interface of optical fiber communication. The failure of the communication node may interrupt the information flow and lead to the failure of RFID system. Obviously, for improving performance of RFID system, it is necessary to protect the validity of the communication node from systematic failure. In the field of operation and maintenance of RFID system, planning and designing RFID facilities maintenance network (RFID-F-MN) based on the complex RFID system will be of important practical significance especially for improving reliability of RFID facilities, using maintenance resource effectively and reducing operation expense.

In this paper, we analyze RFID facility network by the complex network analysis method. This network is composed of nodes and edges with functions such as information identification, data collection and information process analysis, etc. Nodes represent different functional entities in the RFID system, such as tags, readers, communication middleware, backend server, etc. Edges represent the connection between the different function entities. The RFID-F-MN is a kind of concept network, whose nodes (i.e., functional entities) are defined as the demand nodes in the maintenance network. Those nodes with functions of maintenance designed as maintenance resources node (MRN) which cover the whole RFID facilities network. Edges refer to the maintenance vehicle path (MVP). The RFID-F-MN is imposed of MRN and MVP which give the maintenance service covering all maintenance demand nodes including communication node (CN), for instance, to detect, repair and maintenance the RFID system etc. In view of the characteristic of CN, once CN is failure, the "edge" which is connected to the CN will be total failure at the same time. Thereby while planning and designing the RFID-F-MN, the validity of the CN must be considered in priority.

RFID-F-MN is proposed to protect the normal system operation of RFID facility network. Xu Yuguo (2012) applied the description and analysis method of complex network to maintenance network planning, and combined with the graph theory to simplify the maintenance network as network with weight including weighted nodes and edges. Its dynamic evolution model was given by analyzing topological structure characteristics of the maintenance network. Su Ying (2012) pointed out that the maintenance network shows the similarity principle with the common network under this theory system of complex network. They are both composed of nodes and edges. Maintenance network is the development and improvement with certain service of common network which can be abstracted as a kind of service network composed of nodes, edges and flow. HAN Zhen & LU Yu (2014) put forward the different evaluation indicators of maintenance network, including node concentration, cluster coefficient and average path length. They tried to provide reference guide for evaluating objectively the structure characteristics and operation performance of maintenance network. Similarly, K.K.Shukla &S.Sah (2013) studied on the construction and maintenance of virtual backbone in wireless networks, and designed node allocation algorithm combined with genetic algorithm to solve the node failure problems. Their key evaluation indictors for maintenance network were selected by covering radius and average path length coming from set covering model.

The literatures above show that complex network analysis method was used for analyzing and planning RFID-F-MN much more practical applications. RFID-F-MN can be abstracted as a functional network including nodes, edges and flow. The clear research approach goes as below: to define and explore the maintenance network based on existed RFID facility network, and to give specific requests and measurement method for concept modeling including the choice of nodes and paths, the analysis of network and operation performance. However, compared with new characteristics of RFID technology, these studies did not indicate that the operation expense of maintenance network is much higher than the construction cost, higher operation expense influence deeply on the overall operation of maintenance network. Therefore, this paper takes operation expense as a decision-making point while planning RFID-F-MN. The validity of CN also should be considered because it directly reflects RFID technology characteristics. Besides, it is a decisive factor for systematic failure of function and good operation of overall network.

2 Formulation of problem

2.1 Modeling idea

Traditional set covering model is to cover all demand nodes satisfied with the minimum number of MRNs and then to allocate these MRNs meeting the demand of all over MDNs.

Set covering model in this paper for RFID-F-MN takes RFID facility network nodes as MDNs with objective function of minimum operation expense. The least quantity of MRNs and the shortest vehicle path are the basic constraints while choosing the MRNs. Coverage rate is used to measure the degree how much the MDNs are covered with MRDs (see formula (1)).

$$e = |\bar{V}| \big/ |V| \times 100\% \qquad (1)$$

$|\bar{V}|$ says the quantity of MDNs which are covered, |V| says the total number of MDNs. When e=100%, the MDNs are covered completely.

Three conditions for modeling are considered as follow:

(1) Classification covering principle is proposed. According to the importance, demand nodes are divided into two categories: communication nodes (CN) and the other support nodes without communication function (SN).

(2) Taking minimum operation expense instead of minimum construction cost as planning objective of RFID-F-MN. In this way, minimum construction cost problem is converted to minimum number of MRNs for this modeling.

(3) Besides, MDNs should be completely covered, at the same time, resource consumption are also considered as constrains in this model, i.e., the actual vehicle consumption for maintenance is combined with shortest path problem.

2.2 Basic assumptions

In the RFID-F-MN, the crossing of path is called node, all nodes are MDNs and can be regarded as alternative MRNs. The set of all nodes is written as V, whose size is m. The set of CNs is written as V_1 and the set of SNs is written as V_2.The set of MRNs is written as V', whose size is n.

e_{ij} says the edge between i and j in the RFID facility network. The set of edges is written as E, whose size is l. L_{ij} says the vehicle path between MRN j and MRN i, the set of paths is written as *Path*.

Assumption 1: The assigned MRNs and MDNs is 1, otherwise 0, see formula (5);

Assumption 2: The demand of all MDNs are same, and each MDN is only covered by the only MRN, there is no MDN is covered repeatedly, see formula (6);

Assumption 3: Cover FN firstly when FN and SN can be covered at the same time, see formula (7);

Assumption 4: MDNs should be covered by MRNs completely, see formula (8);

Assumption 5: Coverage radius is determined by average speed and response time, see formula (9);

Assumption 6: MDNs should be assigned to MRNs which have been selected, and the vehicle path between MRN and MDN should be shorter than coverage radius, see formula (10) and formula (11);

Assumption 7: When MDN i is assigned to MRN j, the path L_{ij} is also assigned to MRN j, see formula (12);

Assumption 8: The quantity of MDNs can be covered by MRN is restrained by its own service capacity, all MRNs have the same capacity, see formula (13).

Assumption 9: C, operation expense of RFID-F-MN, refers to the expense which is paid during the process of maintaining, which is divided into construction cost (C_1), maintenance resources (labor, spare parts, etc.) expense (C_2) and maintenance vehicle fuel cost (C_3).

Assumption 10: C_1, the construction cost of MRNs, is determined by the unit MRN construction cost and quantity. Assume that the construction cost of each MRN is same, C_1, which is one-time investment, is fixed cost.C_1 is only related to the quantity of MRNs, on the premise of meeting the demands of all MDNs, reducing unnecessary resource assignment by controlling the quantity of MRNs to achieve the goal of reducing construction cost.

Assumption 11: C_2, maintenance resource expense, is calculated by standard cost method, the labor cost (LC), vehicle cost (VC) and spare part cost (SPC) used to maintain each MDN can be written as formula (2):

$$C_2' = \sum_i LC_i \cdot Q_{LCi} + \sum_i VC_i \cdot Q_{VCi} + \sum_i SPC_i \cdot Q_{SPCi} \tag{2}$$

LC_i 、 VC_i and SPC_i say the unit labor cost, unit vehicle cost and unit spare part cost respectively (yuan), Q_{LCi} 、 Q_{VCi} and Q_{SPCi} say the quantity of employees, vehicles and spare parts respectively . C_2 is written as formula (3).

$$C_2 = \sum_i Q_i \cdot C_2' \tag{3}$$

Q_i says the quantity of CNs covered by i^{th} MRN.

Assumption 12: C_3, fuel cost, which refers to the cost of vehicles during the process of maintenance, is determined by the unit fuel consumption, distance and the quantity of vehicles. The distance can be converted into average speed and response time. If the road conditions are same, the fuel cost is associated with the actual distance, the cost can be reduced by shortening the distance. Therefore, the minimum cost problem can be converted into the shortest distance problem, namely choosing the shortest vehicle path under the condition that all MDNs be covered.

3 Maintenance network set covering model (MN-SCM)

The objective function of MN-SCM is established as formula (4) in this paper, constraints are written as (5) to (13).

$$MinC = \sum_{j=1}^{l} H_j \cdot p_1 + \sum_{i} Q_i \cdot C_2' + p_2 \cdot \sum Q_{CLi} \cdot \sum_{i=1}^{l} \sum_{j=1}^{l} W_{ji} \cdot L_{ji} \tag{4}$$

S.T.

$$H_j, W_{ji} \in \{0,1\}, \forall i, j \tag{5}$$

$$\sum_{j \in V'} W_{ji} = 1, \forall i \tag{6}$$

$$W_{jx} > W_{jy}, x \in V_1, y \in V_2 \tag{7}$$

$$e = 1 \tag{8}$$

$$R = v \cdot t \tag{9}$$

$$W_{ji} \le H_j, \forall j \tag{10}$$

$$W_{ji} \cdot d_{ji} \le R, \forall i, j \tag{11}$$

$$L_{ji} = W_{ji} \tag{12}$$

$$0 \le Q_i \le Q_{MAX}, \forall i \tag{13}$$

Relevant variables and parameters are defined as follows:

t	Response time of maintenance vehicle (h);
H_j	Choose node *j* as MRN;
W_{ji}	Allocate MDN *i* to MRN *j*;
Q_{MAX}	Maintenance service capacity of MRN;
$A(j)$	Set of nodes which are covered by node
$B(i)$	Set of nodes which can cover node *i*;
R	Coverage radius (km);
d_{ij}	Shortest distance between node *i* and node *j* (km);
p_1	Construction cost of each MRN (yuan/PC);
p_2	Fuel cost of each maintenance vehicle (yuan/ (PC· km));
v	Average speed (km/h);
m	Quantity of MRN (PC);
n	Quantity of edges (PC).

4 Heuristic algorithm designed for maintenance network set covering model

This paper uses heuristic algorithm to solve the MS-SCM, the logic diagram is shown in figure 1. Step 4 in figure 1 (b) is improved based on traditional HA for set covering model. The CNs are assigned prior to SNs, so the demand of CNs can be met.

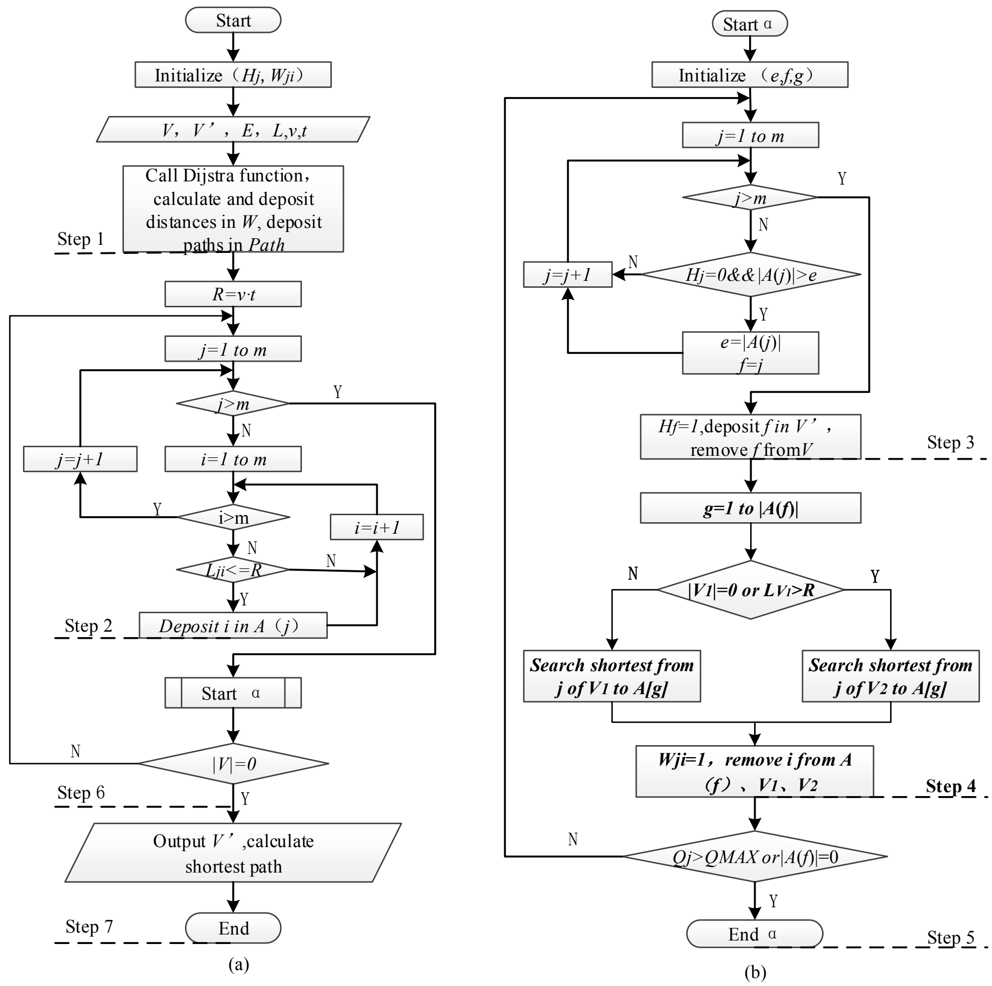

Figure 1. Heuristic algorithm for MS-SCM

Step 1: Initialization. $H_j = 0$, $W_{ji} = 0$.Input node matrix *E*, edge matrix *V*, vehicle speed *v* and response time *t*. Using Dijstra function to calculate the shortest distance between any two nodes, and deposite the distance in matrix *L*, at the same time deposited the paths in the matrix *Path*.

Step 2: Comparing the shortest distance between any two nodes with coverage radius, the serial number of node is deposited in matrix *A*(*j*) if the distance is shorter than coverage radius.

Step 3: Start α.Choose node *j* as MRN if $H_j=0$ and $|A(j)|$ is the max one. Deposited *j* in matrix *V'*, and remove *j* from *V*.

Step 4: Assigning *i*, which is included in *A*(*j*) and the distance between it and *j* is shortest, to *j* if there is undistributed node in V_1, $W_{ji} =1$ and remove *i* from *A*(*j*) and V_1; Otherwise assigning *i,* which is included in *A*(*j*) and the distance between it and *j* is shortest, to *j*, $W_{ji} = 1$ and remove *i* from *A* (*j*) and V_2.

Step 5: Repeat step 4 until $|A(j)|=0$ or $Q_i=0$.End α.

Step 6: Repeat steps 2, 3, 4 and 5 until $|V| = 0$.
Step 7: Output V' and the shortest path.

5 Simulation experiment for model effectiveness

5.1 Simulation network and experiment conditions

In order to verify the validity of the model, simulation experiment data combining with the actual example is analyzed. As shown in figure 2, RFID facility network is given, $|V|= 30$, $|E|= 48$.The quantity of CNs is 15, which is equal to the quantity of SNs. CNs should be covered firstly to ensure the validity of RFID-F-MN.

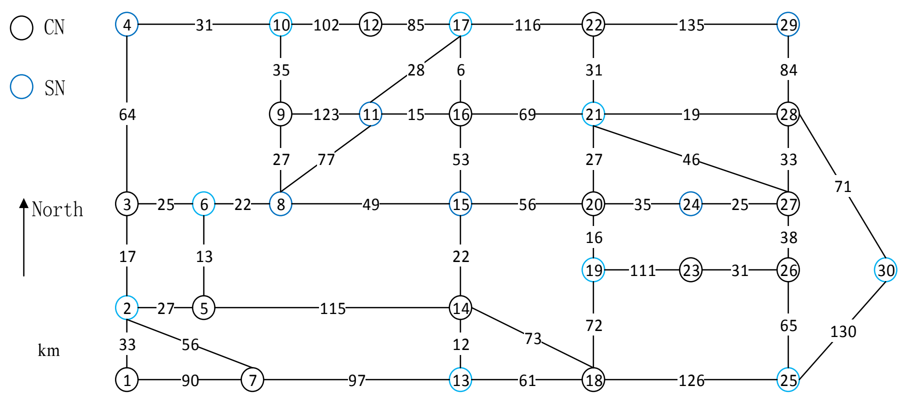

Figure 2. RFID facility maintenance network (RFID-F-MN)

5.2 Analysis of simulation results

R=120km, Q_{MAX} =5.Simulation results is shown in figure 3, the set of MRNs is V= {6, 8, 11, 15, 21, 27, 28 }, and all MDNs are covered, including:

$A(6)=\{4,10,11,13,15\}$; $A(8)=\{1, 2,6,7,8\}$; $A(11)=\{25,29,30\}$;
$A(15)=\{3,5,9,14,18\}$; $A(21)=\{16,20,22,27,28\}$; $A(27)=\{12,17\}$;
$A(28)=\{19,21,23, 24,26\}$。

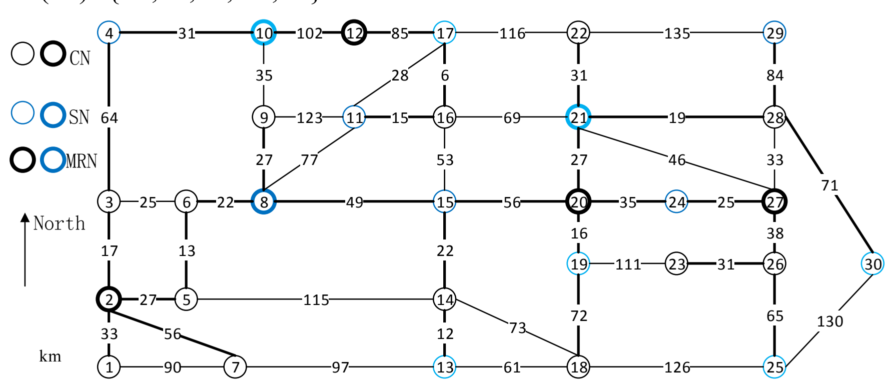

Figure 3. simulation result of MS-SCM

(1) Doesn't consider the validity of CN

R=120km, Q_{MAX}=5. If don't consider the validity of CNs, 7 MRNs are selected, too. V= {1, 8, 10, 20, 21, 23, 27 }, including:

A(1)={**1**,2,**3**,**5**,6}; *A*(8)={**3**,**5**,6,8,**9**}; *A*(10)={4,6,8,9,10};
A(20)={19,**20**,21,24,**28**}; *A*(21)={19,**20**,21,**22**,28}; *A*(23)={**23**,24,25,**26**,**27**};
A(27)={21,24,**26**,**27**,**28**}。

Table 1. Compare results of validity of CNs considered or not

Items	MRNs	MDNs covered	Path length（*km*）	Coverage rate（%）
considered	7	30	1111	100
Not considered	7	19	532	63

When the validity of CNs is considered, the path length is only 532 km, far shorter than 1111 km when not considered. But at the same time, only 19 nodes are covered, its coverage rate is only 63%. Visibly, MDNs are not completely covered by MRNs. There are some nodes are covered repeatedly or uncovered. Repeated cover will cause the waste of resources. Uncovered will lead to partial node unable to be maintained timely when node failure happening. More serious situation comes to extending the failure time of the network.

(2) Sensitivity analysis of coverage radius

In figure 3, coverage radius is 120 km. When coverage radius is changed, the quantity of MRN is also changed. When the coverage radius rank from 100km to 140km, the quantity of MRN is shown in table 2.With coverage radius increasing, the quantity of MRN is reducing gradually. But the path length is reducing with the number increasing firstly, but the length begin to increase when the coverage radius reaches a certain value. Visibly, when choosing the coverage radius, the quantity of MRN and path length should be considered at the same time.

Table 2. Sensitivity analysis of coverage radius

Coverage radius（*vt*，*km*）	MRNs	Serial number of MRNs	Path length（*km*）
100	8	3,6,15,16,20,21,25,28	1069
110	7	2,8,12,14,15,23,28	1061
120	7	2,8,10,12,20,21,27	1111
130	7	2,8,10,12,21,24,27	1219
140	6	9,14,15,16,20,28	1312

(3) Sensitivity analysis of Q_{MAX}

When Q_{MAX} ranking from 3 to 7 or there is no constraint to the service capacity, the quantity of MRN and path length is shown in table 3. For 21th node, if Q_{MAX}=4, due to the 19th MDN is farther than the other MDN, the 21th MRN must abandon it, then the layout of the entire network is affected.

Table 3. Sensitivity analysis of Q_{MAX}

Q_{MAX}	MRNs	Serial number of MRNs	Path length（*km*）
3	10	2,8,10,12,15,16,20,21,27,28	1312
4	8	2,8,10,16,20,21,23,27	1211
5	7	2,8,10,12,20,21,27	1111

6	6	8,10,12,20,21,27	1301
7	6	8,10,12,20,21,25	1145
∞	3	2,15,27	1080

The quantity of MRNs is reducing when the Q_{MAX} is increasing. The path length is reducing firstly, but begins to increase when the Q_{MAX} reaches a certain value. When Q_{MAX}=7, the path length is 1145km. It's only 156km shorter than 1145km when Q_{MAX}=6. But the quantities of MRNs are same 6. Therefore, when identifying Q_{MAX} during the process of planning MSNs, construction cost and operation expense should be in tradeoff together, i.e., we should ensure whether the operation expense reduced by shortening the path length can be made up by the construction cost increased through assigning more resource.

6 Conclusions

We put forward the maintenance network set covering model (MN-SCM) considered validity of CNs with minimum operation expense as objective function in this paper. By simulation experimental example, this model was solved by designing the heuristic algorithm suitable for this decision-making process. Comparative analysis is explored while validity of CNs considered or not is analyzed. Sensitivity analysis of coverage radius and Q_{MAX} to operation expense of RFID-F-MN is analyzed. Conclusions are as follow:

(1) When planning RFID facility maintenance network, the validity of CNs of RFID system should be considered. Main reasons are more clearly: it is indeed decisive factor for systematic failure of overall network function. It affects directly the selection decision of MRNs, and determines coverage rate e. Thereby it finally leads to the technology or function failure of RFID system.

(2) While choosing MRNs and assigning MDNs, on the one hand, the coverage radius should be shorten if the response time is strict. For example, for the emergency maintenance situation, the coverage radius of MRNs prefers to shorter to get quick response. But it will bring about new problems such as more MRNs planned and higher construction cost.

On the other hand, the smaller the Q_{MAX}, the bigger quantity of MRNs. The vehicle path length will be increased at the same time, which leading to operation expense increased.

(3) If the service capacity of MRNs is not considered, to identify MRN by sequence did not influence the quantities of MRNs, but it will cause the path length changed and further lead to the change of operation expense.

All in end, MN-SCM considered the validity of CNs and its heuristic algorithm designed are proved reasonable and valid in this paper. It provides reference in choosing MRNs reasonably and planning maintenance vehicle path efficiently. At the same time, applying the MN-SCM to the RFID-F-MN does not only draw on the experience of maintenance network planning method in military facilities field but more perspective approach goes to maintenance network for wireless network in the field of internet of Things in future.

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References

Ccid consulting co., LTD. (2010). the semiconductor industry research center，*the 13th China international expo and the fifth China international RFID smart card and smart card technology application peak BBS*，Beijing，2010-05-26

CHEN Yang. (2013). Study on the Security of Middleware Based RFID System. Nanning：Guangxi University, 2013：3-20.

Ferrer Geraldo, Dew Nicholas, Apte. (2010). When is RFID right for your service. *International Journal of Production Economics (S0925-5273)*, 2010, 124(2): 414-425.

HAN Zhen, LU Yu, GU Ping. (2014). Research on the Test of Maintenance Support Force System Based on the Theory of Complex Network. *IEEE*, 2014, (26): 2595-2598

K. K. Shukla, S. Sah. (2013) Construction and maintenance of virtual backbone in wireless networks. *Wireless Netw*, 2013, (19): 969-984

Samano-Robles, Ramiro, Gameiro, Atilio. (2009). Integration of RFID readers into wireless mobile telecommunication networks *.IEEE*, 2009, 2:327-330.

SU Ying. (2012). A Petri Net-based Approach for Evaluating the Capability of Equipment Maintenance Support Network. Changsha : National University of Defense Technology，2012

XU Yuguo, QIU Jing, LIU Guanjun. (2012) Optimization Design on Cooperation Effectiveness of Equipment Maintenance Support Network Based on Complex Network. *Acta Armamentarii*, 2012, 02:244-251.

XU Yuguo, QIU Jing, LIU Guanjun. (2012) Dynamic Evolution Model of Equipment Maintenance Organizational Structure Based on Multielement-Weighted Network. *Acta Armamentarii*, 2012, 04:488-496.

YAN Guangchao, SHEN Bin, ZHAO Hongfei, WANG Jiahai, YUAN Duanlei.(2012) Simulative Planning on Wire Between Devices of Complex RFID Network Considering Cost Constraint. *Journal of System Simulation*, 2012, 08:1660-1664.

YAN Jianmin. (2013). Design and Implementation of Embedded RFID Middleware. Dalian : Dalian Maritime University, 2013：1-14.

Prediction of the Traffic Volume of Henan Province with a BP Neural Network

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Abstract: This paper describes the construction of BP neural network model which was used to forecast highway Cargo traffic volume and predicts the highway cargo traffic volume in 2013, it was also used to predict the highway passenger traffic volume, railway cargo traffic volume, passenger traffic volume and their corresponding turn over. The purpose is to provide a scientific and objective reference for the construction of terminal layout and scale of investment of highway and railway traffic routes and stations in Henan province.
Keywords: BP neural network; Passenger and cargo traffic volume; Freight and passenger turnover; Prediction.

1 Introduction

Transportation must go first if the economics develops. This Sentence vividly describes the relationship between transportation and national economy, so we can clear see the important status and role that the transportation industry plays in the national economy. Along with the implementation of "Rise of central China" strategy, Henan province will usher in the golden period of the development of the transport industry (Li, C, 2010).

In order to realize the goal of traffic in the macro, some relevant microscopic traffic planning must be formulated. Traffic volume forecast is the foundation and basis of traffic planning, it has certain reference value for all of the government's planning work, therefore, a scientific and reasonable to predict the future traffic volume and its development trend has very important practical significance and practical value.

There are many forecasting method of traffic volume prediction methods early, such as regression analysis, exponential smoothing method, Markov analysis, elastic coefficient method, neural network model, grey prediction etc. But some of the aforementioned methods used in practice are not so convenient. However, the artificial neural network is a nonlinear system with collective computation, adaptive learning and recognition ability. Compared with the traditional modeling techniques, many scholars have used artificial neural network to build many models in the prediction of traffic and obtained certain achievements recent years.

2 BP Neural Network

BP (Back Propagation) is a kind of according to the error Back Propagation algorithm training of the multilayer feed forward network, is currently one of the most widely used neural network model 1.1 Number of trips. BP network can learn and store a lot of input - output model mapping relationship, without prior to reveal the mathematical equations to describe this mapping(H, L. Q,2007). Its learning rule is to use the steepest descent method, by back propagation to constantly adjust the network weights and threshold, minimize the error sum of squares of the network. Topology structure of BP neural network model includes input layer, hidden layer (input) (hide layer) and the output layer (output layer). Its structure is shown in figure 1. Each layer goes according to order, and finally output by output layers.

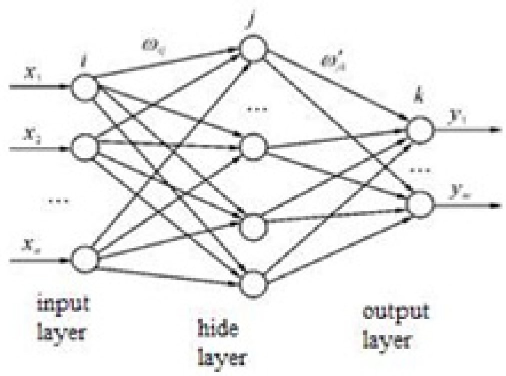

Figure 1.The structure of BP neural network

3 The BP Neural Network Design

Because there is no perfect theory to guide the design of neural network so far, the paper draw lessons from the experience of others on the basis of fully understand the traffic prediction, at the same time combined with heuristics, through continuous improvement and test, finally choose the better design of the BP Neural Network.

3.1 The Preparation of Neural Network Sample Set

Generalization refers to when the data of non sample input to the network is not seen in the training set, the network can output appropriate mapping. It is this ability of using the BP neural network that neural network can be used to predict traffic flow. Due to the increase in the number of samples can improve the generalization ability of the BP neural network, so this paper has collected 2001-2013(Henan Survey Organization National Bureau of Statistics Information Network, 2013), a total of 13 years of highway passenger and cargo traffic volume and turnover and railway passenger traffic volume and turnover, as a sample set table 1.

Table 1. Statistical data of Railway and highway passenger and freight volume and turnover volume from 2001-2013

Year	Highway				Railway			
	Freight transport		Passenger transport		Freight transport		Passenger transport	
	Volume	Turnover	Volume	Turnover	Volume	Turnover	Volume	Turnover
2001	53596	375.78	80259	369.41	4980	1185.36	11196	401.77
2002	55743	398.87	85078	390	5085	1234.77	12148	421
2003	56100	405.2	76301	350.02	4864	1463.2	12925	462.1
2004	58147	422.02	85016	395.4	5695	1650	14732	542
2005	62684	467	91920	437.84	5842	1759.77	14806	535.43
2006	69898	538.76	101345	492.72	6313	1810.8	15190	586.88
2007	83537	681.85	115460	601.8	6585	1962.93	16010	620.68
2008	118198	755.21	122414	808.32	7476	1985.84	16226	667.32
2009	151343	930.33	136278	914.8	7724	1955.36	13856	675.48
2010	183291	988	158630	1031.8	8399	1980.23	14224	747.2
2011	220122	1055.21	184213	1211.28	8952	2120.1	14312	766.45
2012	251772	1221.83	197785	1309.58	9628	2028.97	12779	779.57
2013	282970	1330.22	213900	1417.54	12762	2096.81	11160	853.38

3.2 The Structural Design of BP Network

The structure of the BP neural network design mainly includes the network layer, the number of neurons in each layer. Theoretical analysis has proved that a single hidden layer of BP neural network can be mapped to all continuous functions, only when a number of hidden nodes of hidden layer many still can't improve the network performance, the hidden layer were increased, so the forecast traffic network choose a hidden layer nodes. According to the sample data pare prepared, making the traffic volume and turnover of the previous three years of data as the input layer, transport volume and turnover of fourth years as output. There is no a good analytical formula to calculate the number of hidden neurons so far, at first the number of neurons in hidden layer training network is less, then increase the number of hidden nodes gradually, then use the same sample set for training, through continuous testing, finally choice of the network with smallest error corresponding to the number of hidden nodes.

So the main steps are following:

(1) At first, we should build a BP network structure according to the problem, include the number of layers and nodes.

(2) The selection of initial weight. The selection of initial value too big or too small will influence whether meet local optimum.

(3) The selection of training methods and parameters. According to different applications, BP network provides a variety of training and learning methods, convergence speed of function trainlm is the fastest when meet the tedious computation.

(4) Input the known data and output the unknown data.

4 The Example of Using BP Neural Network

4.1 Forecast of Highway Freight Volume

BP neural network in this paper uses the Matlab software to achieve, the specific steps:

(1) Using the traffic data of every three years to predict next year's data, the basic data for 13 groups, namely using the data from 2001 to 2003 to forecast data of 2004, using the data from 2002 to 2004 to forecast data of 2005, till 2014.

(2) Normalization processing of target vector. Because the output of the BP algorithm is "s" function whose output value between 0 and 1, so the target vector should be normalized before using the neural network model to train the freight volume.

(3) Using net=newff（minmax（p)，[s1，s2］,‘{ tansig’‘, logsig’}) to create the BP neural network. The training function, BP learning algorithm and the performance function use the default function, respectively "trainlm" "learngdm" and "mse".

(4) Using the function "init ()" to initialize the weights and thresholds.

(5) Setting the related parameters, the maximum number of learning for 15000 times, learning speed is 0.1, then the study goal is error sum of squares of 0.01.

(6) Calling the function net=train (net, P, t) to train the created BP neural network.

(7) If the training goals achieved, enter (8), else adjust parameters in step (5) and retrain until the training goals are reached.

(8) Taking simulation and computing the error between the actual value and

simulation value (see table 2).The main Matlab code is as follows (Yu, S. W,2014):

```
pmax=max(p);pmax1=max(pmax);
pmin=min(p);pmin1=min(pmin);
for i=1:9
p1(i,:)=(p(i,:)-pmin1)/(pmax1-pmin1);
end
```

```
t1=(t-pmin1)/(pmax1-pmin1);
t1=t1';
net=newff([01;01;01],[13,1],{'tansig','logsig'},'traingd');
for i=1:9
net.trainparam.epochs=500;
net.trainparam.goal=0.01;
LP.lr=0.1;
net=train(net,p1(i,:)',t1(i));
end
y=sim(net,[                    ]');
y1=y*(pmax1-pmin1)+pmin1;
```

The above program recognition rate stable at around 95%, about 100 times to achieve convergence of training, training curve as shown in figure2.

Table 2. The error of simulation value and actual value

Year	The error between the simulation value and actual value				
2004-2008	0.0006	-0.0013	-0.0009	0.0004	0.0063
2009-2013	0.0002	-0.0007	-0.0185	0.0081	0.0182

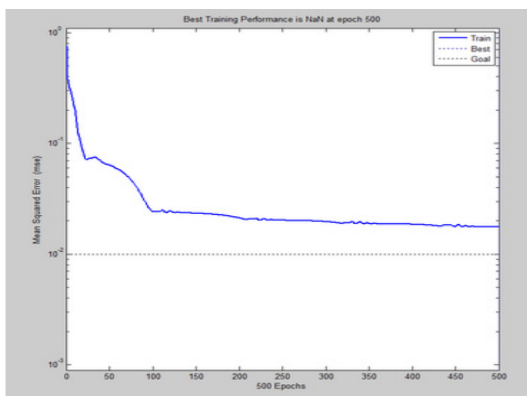

Figure 2.Training performance

(9) Prediction, input data of year 2011, 2012 and 2013 (220122 251772 282970) to calculate the highway freight volume of 2014.

(10) Comparison of actual and predicted values, the results are shown in table 3.

Table 3. Comparison of actual and predicted values，highway freight volume forecast in 2014

Year	Highway freight volume	
	Actual value	predicted values
2004	58147	58002
2005	62684	62127
2006	69898	68920
2007	83537	84001
2008	118198	118235
2009	151343	151301
2010	183291	183536
2011	220122	220185
2012	251772	251998
2013	282970	288116
2014		328452

According to the above steps, the BP neural network model consists of 3 layers, consisting of 15 neurons (1 × 13 ×1), the number of neurons in hidden layer is 13.This is determined by the repeated attempts to get the accuracy of the results (At this time the network convergence speed is the fastest, and the error is the smallest) (Li, Y. M, 2010).

4.2 Prediction of Other Traffic Volume and Turnover

BP neural network is constructed according to the above steps, by adjusting some parameters corresponding to the number of hidden layer neurons to forecast different kind of volume in 2004. The results are shown in following table 4.

Table 4. Highway, railway passenger and cargo volume and turnover volume prediction values in 2013

Year	Highway			Railway			
	Freight turnover	passenger traffic volume	passenger traffic turnover	cargo traffic volume	freight traffic turnover	passenger traffic volume	passenger traffic turnover
	Predictive value	Predictive value	Predictive value	Predictive value	Predictive value	Predictive value	Predictive value
2014	1449.94	231328	1534.40	15165	2166.92	13568	934.18

5 Conclusions

By using the BP neural network model to forecast traffic volume and turnover of passenger and freight volume, the model takes more attention on the simplicity and practicability when building the model under the premise of accurate results. Compared with other complex BP neural network model, it has many advantages. On the one hand, due to the construction of this model calls functions directly from Matlab software, it is simple to operation and easy to learn, on the other hand, the learning ability of this BP neural network is very strong, also after training, the error between target value and actual value is small.

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References

Henan (2008). Survey Organization National Bureau of Statistics Information Network, Henan Statistical Yearbook 2013. China Statistics Press, Beijing.

H. L. Q. (2007). The artificial neural network theory, design and Application, Chemical Industry Press, Beijing.

Li C. (2010). "The prediction of Stock Index Futures based on BP neural network." Ms D Thesis. Qingdao University.

Li Y. M. and Liang Q. O. (2010). "The prediction of Traffic Transportation Volume of Zhejiang Province with BP Neural Network." *Journal of Lishui University*, 32, 5, 21-25.

Yu S. W. (2014). MATLAB optimization algorithm and its application case, Tsinghua University Press, Beijing.

A Comparison Experiment of the Time Benefit between Bus Navigation and Car Navigation

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Abstract: In this paper, we carried out an experiment to compare navigation time benefit between bus and car. On the same OD (origin and destination) of 4 kilometers, public transit navigation saved an average of 18 minutes and car navigation saved just 4 minutes, time benefit of public transit navigation is about four times than car navigation. Look from large groups as a whole, and bus navigation time benefit will far exceed the car navigation. This paper illustrated that public transport navigation service should be vigorously encouraged.
Keywords: Experiment; Navigation; Time benefit.

1 Introduction

Satellite navigation and positioning technology for the private has been developed to an advanced level. Current research mainly focuses on bus routing choice, and there are not many studies on navigation time efficiency. Almost all navigation products are to face private car users. At present guidance service for public transport users is primarily through the PC network and station signs, users can only get the static, fixed-line guidance. Users can only be able to get where to travel, how to travel, but they don't know when to start, which bus to take. Especially when passengers meet more than one travel scheme, they may not know which project can save even more time. Because the user could not get dynamic information of the bus, and did not know the delay, did not know where the jam occurred, did not know which bus was full rate. So, it led public transit users to waste time and restricts the public transportation resources allocation effectively.

2 The experiment

We select the second ring road, Dashi street, Qinxi street, Xiaonan street, Chengdu city, as test area. We select 5:30-7:30 as the evening rush hour test period on Wednesday, departure from Huiyuan Building to Orthopaedic Hospital, at a distance of four kilometers. This article conducted experiments in two different conditions that travel with navigation and without navigation, and we organized forty people dividing into four groups, as the Table 1.

Table 1. Experiment groups

Model	Conditions	Number
Car	With navigation	10
	Without navigation	10
Public transport	With navigation	10
	Without navigation	10

2.1 Bus travel

There are three feasible choices for passengers, as the Figure 1 and Table 2.

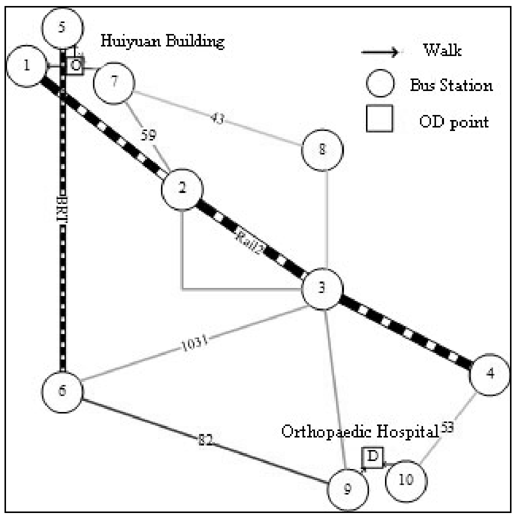

Figure 1. Public transportation routs

Table 2. Bus travel scheme

Project Number	Project（*means transfer point）
1	7-NO.59 Bus-9
2	1-Rail2-2*-NO.59 Bus-9
3	1-Rail2-4*-NO.53 Bus-10

Due to currently technology limit, we cannot get real-time bus dynamic information through user terminal. We used artificial method to obtain number of waiting, load factor, arrival time, and continuously sent them to passengers though mobile phones. Got dynamic bus data, according to saturation and arrival time passengers with navigation can choose the fast bus travel scheme. Meanwhile another group without navigation chose the travel scheme through station signs or internet.

2.2 Car travel

We choose Highmoralmap Navigation which can provides dynamic distance and road bypass scheme for drivers and synchronously record the travel time and route. Meanwhile we arrange the co-pilots recording road saturation.

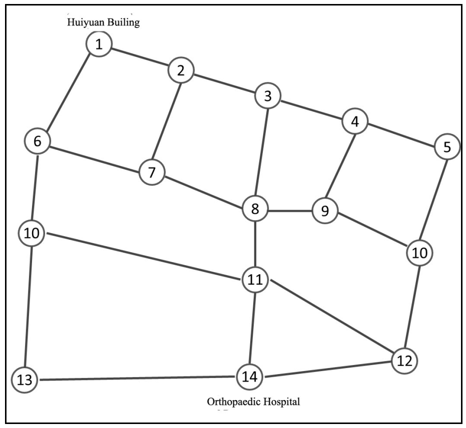

Figure 2. Car driving road network

Table 3. Car travel scheme

Project Number	Project
1	Fuqin Street to 1st Ring Road
2	2nd Ring Road to Dashi Street
3	Fuqin Street to Daqing street to Shudu road to 1st Ring Road
4	Fuqin Street to Yonglin street to Huaishu street to Changsun street to Dashi Street

3 Data Analysis

3.1 Bus data

Without navigation, 10 passengers choose option one, without transfer. Table 4 shows that all of the passenger choose project 1, and spend an average of 40 minutes. In Project 1, passengers can take the NO.59 Bus to reach their destination directly, but due to the high load factor, waiting time and in-vehicle time greatly increased, resulting in the overall travel time longer.

Table 4. Time of bus travel (without navigation)

Project Choice	Departure time	Walking time	Waiting time	Transfer time	Car time	Saturation	Totel time
1	6:05	8	9	0	27	80%	44
1	6:12	7	4	0	29	70%	40
1	6:20	7	7	0	29	90%	43
1	6:21	8	5	0	30	90%	43
1	6:40	7	15	0	35	100%	57
1	6:40	8	15	0	27	100%	50
1	6:40	7	16	0	35	100%	58
1	7:00	7	10	0	30	90%	47
1	7:04	7	6	0	30	90%	43
1	7:15	7	14	0	33	100%	54

With navigation, passengers get dynamic bus information and change travel plan. Table 5 shows that six passengers choose Project 2, three passengers choose Project 3, and according to the information, all of them chose appropriate departure time to make the travel more comfortable and faster.

Table 5. Time of bus travel (with navigation)

Project Choice	Departure time	Walking time	Waiting time	Transfer time	Car time	Saturation	Totel time
2	5:35	7	2	3	14	60%	26
1	5:45	6	2	4	14	55%	26
2	5:45	5	1	3	15	55%	24
2	5:50	5	2	3	15	50%	25
2	6:40	7	2	6	16	55%	31
2	6:45	8	1	5	17	50%	31
3	6:50	7	1	4	20	50%	32
3	6:56	9	0.5	4	16	50%	29.5
3	6:58	7	1	5	14	55%	27
2	7:15	7	1	3	14	65%	25

3.2 Car data

Without navigation, drivers had to choose their paths according experience. Table 6 shows the travel time and saturation of ten drivers.

Table 6. Time of car travel (without navigation)

Departure time	Project	Car time	Saturation
6:15	1	30	80%
6:20	1	29	80%
6:20	2	22	70%
6:30	1	27	95%
6:45	2	24	80%
6:45	1	30	80%
6:50	1	28	85%
6:50	1	27	85%
7:00	1	33	90%
7:00	2	32	80%

Under the conditions of dynamic travel guide, car drivers choose different project, and on the way they can change the paths according to the navigation. But in the course of the experiment, as Table 7 shows, because of the jam of all roads, even drivers change their paths, they could not find a genuine fast way.

Table 7. Time of car travel (with navigation)

Departure time	Project	Car time	Saturation
6:15	2	28	75%
6:19	2	27	80%
6:22	3	24	70%
6:30	3	27	95%
6:45	2	26	80%
7:00	2	23	80%
7:00	1	22	75%
7:10	2	20	70%
7:10	1	21	80%
7:15	3	24	75%

4 Discussion of Results

Because of the dynamic information and the bus lanes, even in rush hour and high network saturation, journey time is mainly under the influence of load factor. Passengers can acquire bus arrival information and load factor to decide when to start and which bus to take, reducing a lot of waiting time and car time, and they can select the bus of the lowest load factor to get the best comfort.

Table 8. Time efficiency comparison of buses

Bus travel	Change time	Waiting time	Car time	Saturation
Without navigation	0	10.1	30.6	91%
Navigation	4	1.35	15.5	55%

Table 9 shows that, private car travel time is mainly controlled by sections of saturation effects, as all roads are saturated, and dynamic navigation effect is very small.

Table 9. Time efficiency comparison of cars

Car travel	Car time	Saturation
Without navigation	28.2	83%
Navigation	24.2	78%

Table 10 shows that in the same OD, it is 18.3 minutes per capita for bus time efficiency, and 2.9 minutes for cars. Public transit navigation time efficiency is much higher than car navigation. Under the conditions of navigation, private cars than under the stochastic conditions saved 4 minutes.

Table 10. Time efficiency comparison between bus and car

	Navigation	Without navigation	Time efficiency
Bus	29.7	48.0	18.3
Car	24.2	28.2	4.0

5 Conclusions

Here we may draw the following conclusions. Relative to the car navigation, bus dynamic navigation will create greater time efficiency both from a personal and societal. It is important to improve the quality of bus navigation and promote it.

6 Recommendations for Future Research

Dynamic transit has not yet universal and related technology is not yet mature. In future work, we will further study of bus navigation technology. It is about that getting each bus driving information, identifying load factor, judging transfer point, and the most important thing is integrating this information and publishing them to user terminal.

Acknowledgement

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References

Bo Liu; Wenjia Wang. "Travel Time Enabled Bus Route Navigation System Experiment in Beijing". *Intelligent Transportation Systems Conference,2007.ITSC, 2007 IEEE.*

Chien S, LiuX, Ozbay K. "Predieting travel times for the south jersey real-time motorist information system". *Transportation Researeh Board，National Researeh Council，*Washington. D.C.

Pengfei Zhou, Yuanqing Zheng, Mo Li. "How Long to Wait? Predicting Bus Arrival Time with Mobile Phone based Participatory Sensing" *MobeSys'12 Proceedings of the 10th international conference on Mobile systems, applications, and services.*

Gray Markov Model in the Intersection of Short-Term Traffic Flow Prediction

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Abstract: With the rapid development of urbanization, the number of vehicles increased faster than urban roads in our city. The contradiction between supply and demand of urban transportation is increasingly sharp. Intelligent transportation system is an internationally recognized settlement of the best way to solve city traffic congestion. Traffic flow prediction, a key technology of the intelligent system, is the premise and key to traffic flow inducing and controlling. The intersection is the most vulnerable and most likely to appear problem in urban road traffic. Research on intelligent traffic conditions of intersection traffic characteristics, improve the capacity of the intersection is the key and main task of solving the city traffic problem. Short term traffic prediction model of previous research is still not perfect, low computational accuracy, need a large amount of data, the prediction model of complex, operation time is long, and so on. The grey prediction model has the advantages of simple model, less data is needed and short operation time. In this paper, based on the grey prediction model of these advantages combined with the Markov model, to establish a new method of grey model to forecast the short-term traffic flow prediction, and applied to the intersection of overcoming the insufficiency of the two kinds of prediction method, improve the prediction accuracy, carry on the forecast analysis.

Keywords: Intelligent transportation; Grey prediction model; Markov mode; Intersection flow.

1 Introduction

With the rapid development of social economy and the continuous expansion of city size, there's an increased demand for transportation both on its quality and quantity. Compared with the road that is unable to broaden, it's the increasingly crowded vehicles which lead to the worsen traffic situation that persecutes every country (ZHANG Yang,2009). It is a complex and comprehensive trouble to solve the traffic problems, just relying on the construction of roads or control vehicle to address the increasingly serious traffic problems is very difficult, and also it cannot solve traffic problems radically and avoid the growing accident rates. Thus, the Traffic Sensor Networks that is constituted by vehicles and roads that are synthesized by sensors, adopting computer data processing technology to solve the traffic problems of intelligent traffic control network came into being. It can achieve dynamic control signal through short-term forecasting of intersection traffic intersection to control intersection traffic flow more effectively and reduce traffic congestion, improve the safety of driving.

The change process of traffic state is a real, non-linear, non-stationary random one, the randomness and uncertainty of traffic state is growing along with the statistical period shortened. In intelligent traffic control network of traffic flow prediction process, in order to ensure the control efficiency of intelligent transportation and manner to control traffic and command timely, the time required to collect data from sensors in the network is as short as possible.

In other words, in order to ensure rapid completion prediction, we should take the traffic flow data that collected in a short time from the network sensors as predictive parameters. The basic process shown in Figure 1

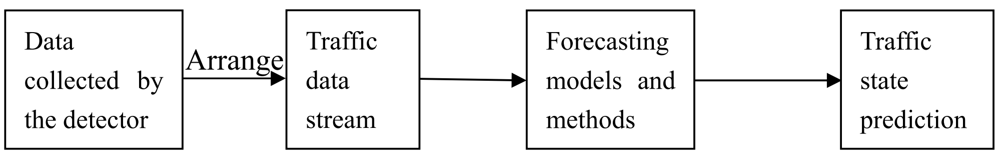

Figure 1.The basic flow of short-term traffic flow forecasting

The equilibrium point of forecasting accuracy and computational efficiency has been always the hotspot of short-term traffic flow prediction algorithm study. Generally the higher the accuracy, the larger the sample data needs to be calculated, and the more calculation time required. The current common short-term traffic flow prediction model as follows: Historical average model, its characteristic is the fast operation speed and modeling simple, but the accuracy is low and cannot solve the burst traffic conditions. Time series model, it simplify the modeling process and can be used to model complex system. If the data is fully, it would have higher prediction accuracy. But the algorithm cannot be transplanted and need the massive historical data to continuous support. Neural network model, with adaptive learning ability, it can make off-line training and on-line real-time forecasting, according to real-time traffic information to update the weights of the neural network. Because of the slow convergence speed, pre training process is complicated and many sample data supporting, it has poor generalization. Nonparametric regression model, the forecast precision is high, the mining information directly from the historical database, algorithm can be transplanted, but the nearest neighbor pattern matching complexity is high, the operation efficiency is low and need enough historical data. This article focuses on gray forecasting model; it has a simple algorithm, high calculation speed and can give good prediction effect of short-term prediction (CAI Yan,2006). The principle is based on the gray sequence generation operator weakens the random, mining potential rules, and the leap of using discrete data sequence dynamic differential equation of successive comes true by the exchange between difference equation and differential equation. Many other researchers conducted their work using Gray model for Short-Term traffic flow forecasting in the past. But separate grey forecasting accuracy is not high. It is difficult to predict with limited within a small range because of the ups and downs and disorder, and the limited number of original data. and leading to its original gray prediction model data under most circumstances is rough. This model also asked the accumulated generating data with index properties so that we can use differential equation fitting. The objects of Markov Prediction have characteristics such as stationary process etc., thus, prediction problem encountered in practice is the random and non-stationary process which shows some certain variation trend with the change of time. Therefore, if Gray model is used to fit these time series data, then identify and predict the development trend of the total sequence, the deficiencies of Markov prediction will be made up as a result. In this paper, combining with the Markova prediction model, and forms a more realistic prediction model, and applied to the intersection traffic flow short-time forecast.

2 Traffic Flow Forecasting Principles

2.1 Grey Prediction Model

Grey system theory is that, although due to the influence of various environmental factors on the system, make the discrete data of the system performance characteristic values exhibit chaos. But the system always has a whole function, it inevitably contains some intrinsic rules. So how to use the scientific method to collate original data and look for the true nature of its knowledge system by the rule of change is worthy of study. The grey system theory with the "generation" method getting a new series randomness weakened and regularity strengthened according to certain requirements for data processing or data transformation. Dig out the inherent characteristics of the original sequence.

Grey prediction model is established by time-series data accumulation generation module. From the process of building of GM (1, 1) forecast model can be seen that GM (1, 1) model is the most commonly used one kind of grey model.

2.1.1 Building of GM (1, 1) forecast model

Set the time series $X^{(0)}$ have n observations, $X^{(0)}=\{x^{(0)}(1), x^{(0)}(2),\ldots, x^{(0)}(n)\}$, Generate a new sequence by summing: $X^{(1)} = \{x^{(1)}(1), x^{(1)}(2),\ldots, x^{(1)}(n)\}$,

$$x^{(1)}(k)=\sum_{i=1}^{k} x^{(0)}(i) \quad (k=1，2，\ldots，n)$$

This sequence $X^{(1)}$ will exhibit certain regularity. Its rules can be obtained by solving the first-order linear differential equations. The definition:

$$\frac{dX^{(1)}}{dt}+aX^{(1)}=u \qquad (1)$$

Where a and u are parameters to be estimated. Set $\hat{\boldsymbol{a}}$ to be a vector of parameters to be estimated.

$$\hat{\boldsymbol{a}}=\begin{bmatrix} a \\ u \end{bmatrix} \quad (2)$$

Using least square method to calculate $\hat{\boldsymbol{a}}=(\boldsymbol{B}^T\boldsymbol{B})^{-1}\boldsymbol{B}^T\boldsymbol{Y}_n$

$$\boldsymbol{B}=\begin{bmatrix} -\frac{1}{2}\left[x^{(1)}(1)+x^{(1)}(2)\right] & 1 \\ -\frac{1}{2}\left[x^{(1)}(2)+x^{(1)}(3)\right] & 1 \\ \vdots & \\ -\frac{1}{2}\left[x^{(1)}(\mathrm{n}-1)+x^{(1)}(\mathrm{n})\right] & 1 \end{bmatrix}$$

$$\boldsymbol{Y}_n=\begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(\mathrm{n}) \end{bmatrix}$$

Where $\hat{x}^{(1)}(\mathrm{t})$ is defined as:

$$\hat{x}^{(1)}(\mathrm{t})=\left[x^{(0)}(1)-\frac{u}{a}\right]e^{-at}+\frac{u}{a}$$

Written in a discrete form is:

$$\hat{x}^{(1)}(\mathrm{k}+1)=\left[x^{(0)}(1)-\frac{u}{a}\right]e^{-ak}+\frac{u}{a} \quad (\mathrm{k}=0,1,2\cdots) \quad (3)$$

We can conclude that generating series $\mathrm{X}^{(1)}$ shows the change trend of exponential function by accumulated from (2) and (3).Then can be predicted by the two type of $\mathrm{X}^{(1)}$ model forecast. The changing rule of the original data sequence $\mathrm{X}^{(0)}$ can be generated by the regressive.

$$\hat{x}^{(0)}(\mathrm{k}+1)=\hat{x}^{(1)}(\mathrm{k}+1)-\hat{x}^{(1)}(\mathrm{k})$$

$$=(1-e^{a})\left[x^{(0)}(1)-\frac{u}{a}\right]e^{-ak} \quad (4)$$

That is

$$\hat{Y}(\mathrm{k})=\hat{x}^{(0)}(\mathrm{k}+1) \quad (5)$$

2.1.2 Residual test of the model

The actual value of k time for $x^{(0)}(\mathrm{k})$, Based on the test of time function obtained fitting prediction value is $\hat{x}^{(0)}(\mathrm{k})$(JIANG Zhihua, ZHU Guobao,2004). The residual sequence is defined as follows:

$$q^{(0)}(\mathrm{k})=x^{(0)}(\mathrm{k})-\hat{x}^{(0)}(\mathrm{k}) \quad (6)$$

The relative error:

$$\Delta_k = \frac{q^{(0)}(k)}{x^{(0)}(k)} \times 100\% \quad (7)$$

The average relative error:

$$\bar{\Delta} = \frac{1}{n}\sum_{k=1}^{n}|\Delta_k| \quad (8)$$

Grey prediction model due to the ups and downs and disorder, and the limited number of original data. It is difficult to predict with limited within a small range, and leading to its original gray prediction model data under most circumstances is rough. This model also asked the accumulated generating data with index properties so that we can use differential equation fitting. But the accumulation generation sequence of a nonnegative time sequence is not necessarily with exponential rule, this always leads to the grey model of using the exponential equation to fit is easy to produce very big error (CHEN Youxiao, LIN Xiaoyan,2005). This paper argues that these problems can be solved by improving the results of grey prediction model with Markov chain.

2.2 Markov Prediction Model

Markov Prediction is a method that applies the state transition law found by Russian mathematician Markov in the early 20th century. It analyses the random events in the future development trend and possible results, providing the decision analysis for decision makers.

The basic idea of Markov chain prediction method is a state transition matrix that is obtained through the original data. It estimates the future trend of state transition according to the matrix. One step state transition matrix form is

$$P = \begin{bmatrix} P_{11} & P_{12} & \cdots & P_{1n} \\ P_{21} & P_{22} & \cdots & P_{2n} \\ \vdots & & & \vdots \\ P_{n1} & P_{n2} & \cdots & P_{nn} \end{bmatrix}$$

It describes the probability distribution of n state mutual transfer. P_{ij} shows the probability that transfers form state S_i to state S_j of Markov chain. It's character is

$$0 \le P_{ij} \le 1; \quad \sum_{j=1}^{n} P_{ij} = 1 \qquad i, j = 1,2, \cdots, n$$

It is a key of prediction method of Markov chain to calculate a step transition probability state. The theoretical distribution of one step transition probability is unknown, so we can take the transferring frequency between states as estimation value of probability if we have enough sample data. Assuming that, the times n_i of the state appearance can be known on the basis of sample data. The transition number of times is n_{ij} from one state to another. Then $P_{ij} \approx \frac{n_{ij}}{n_i}$

The objects of Markov Prediction have characteristics such as stationary process etc., thus, prediction problem encountered in practice is the random and non-stationary process which shows some certain variation trend with the change of time. Time series data fluctuates and jumps around this trend due to the influence of random factors, exerting the divergence. Therefore, if GM (1, 1) is used to fit these time series data, then identify and predict the development trend of the total sequence, the deficiencies of Markov prediction will be made up as a result. Consequently,the Grey Markov Prediction model that is combined by two kinds of prediction model can make full use of the information given by historical data to provide a new method for the random and fluctuating data prediction task and improve the accuracy prediction.

Knowing about the status transferring rule is the key to predict development of future by taking the advantage of Markov chain. Therefore, the first step is to divide the state that is to divide the data sequence into a plurality of state to construct the state transition probability matrix. We can take it to be E_1, E_2, $\cdots$, E_n （The state transferring time is t_1, t_2, $\cdots$, t_n ）. The division the state E_n is based on coinciding with non-stationary Markov process and variation tendency. That is, regarding $\widehat{Y}(t) = \hat{x}^{(0)}(t+1)$ as reference curve, making several (determined by the number of state division) parallel to $\widehat{Y}(t)$ to achieve several bar areas of which each strip region represents a state, that is the state area to which it belongs. As shown on the right (JIANG Chengyi,1996).

The transition probability is

$$P_{ij} = \frac{n_{ij}}{n_i}$$

The sequence $\widehat{Y}(t)$ is divided into several States According to the specific situation, and each state (grey number), represented by grey element E_{1i}、E_{2i}:

$$E_i = [E_{1i},\ E_{2i}]$$

$$E_{1i} = \widehat{Y}(t) + A_i$$

$$E_{2i} = \widehat{Y}(t) + B_i \quad (A_i, B_i \text{ are suitable constant,i=1,2,…,n})$$

Thus the most likely predictive value Y(t) of the system future time can be obtained at the midpoint of the desirable for grey interval $[E_{1i},\ E_{2i}]$.

$$Y(t) = \frac{1}{2}(E_{1i} + E_{2i}) = \widehat{Y}(t) + \frac{1}{2}(A_i + B_i) \qquad (9)$$

3 Conclusions

In order to improve the prediction accuracy of short-term traffic of intersection, this paper uses the grey Markov prediction model. It is proved by the analysis of the data that grey Markov model has higher prediction accuracy than a single grey model. Because of the characteristic of the traffic itself, this model is only suitable for short time traffic forecast, and 5 to 10 minutes is better.

References

CHEN Youxiao, LIN Xiaoyan.(2005). Improved forecasting method of Grey Markov chain. The decision reference.

CAI Yan.(2006). Based on the grey forecasting model of short-term traffic flow forecasting research. Southwest Jiao Tong University master's degree thesis

JIANG Chengyi.(1996). Grey Markov forecasting model. *Journal of Chongqing Jianzhu University.*

JIANG Zhihua, ZHU Guobao.(2004). The gray prediction model GM (1,1) and its application in forecast of traffic. Journal of Wuhan University of Technology.

LIU Xiaoxu.(2009). Comparison of grey prediction and forecast of one element linear regression. *Journal of Sichuan University of Science and Engineering*.

ZHANG Yang.(2009). City road network traffic prediction model and its application.Doctoral Dissertation of Shanghai Jiao Tong University.

Establishment and Application of a Grey Forecasting Model

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Abstract: As a new transaction discipline, grey system theory which is an important branch of the science system, is a new method which researches little data, uncertainty and poor information. The grey system theory is based on incomplete information system .It use the perspective of the system to research the relationship of the information and create models .And by the part of the known information ,it can extract the valuable and meaningful information—how to use known information to reveal the unknown information. Gray model is the most important element of gray system theory. It is an important part both for the system to predict or control, and to establish the correct and accurate mathematical models. This paper will describe the principles of grey system and steps of establishing GM(1,1) model. Gray modeling theory has been widely applied in various fields such as industry, agriculture, social, economic, etc. This paper will use it to forecast the number of the car and analysis the accuracy.
Keywords: Grey forecast; Gray model; GM(1,1) model.

1 The Introduction of Grey Theory

Gray system theory is used to research the uncertain system of "part of the information known, part of information unknown," "little sample", "poor information". Gray was first put forward in field of the control systems, in control theory, people often use color to indicate the clear degree of system information, "black" means that the information is completely unknown, "white" means that the information is completely clear, "gray" means that part of the information known, part of the information is unknown. Accordingly, the information is completely unknown is called black system, information fully aware of the system is called white system, and the part of the information is clear, part of the information is not clear is called gray system.

2 The Principle of Model Establishment

2.1 Set $X^{(0)}$ as non-negative sequence

$$X^{(0)} = (x^{(0)}(1),\ x^{(0)}(2),\ \dots,\ x^{(0)}(n))$$

$X^{(1)}$is the cumulative sequence order of $X^{(0)}$

$$X^{(1)} = (x^{(1)}(1),\ x^{(1)}(2),\ \dots,\ x^{(1)}(n))$$

In the formula, $x^{(1)}(k)$=$\sum_{i=1}^{k} x^{(0)}(i)$(k=1,2, …, n),and $x^{(0)}(k) + ax^{(1)}(k) = b$ is the Original form of GM(1, 1) model.

2.2 Set $Z^{(1)}$ as the average generation sequence of $X^{(1)}$

$$Z^{(1)} = (z^{(1)}(1),\ z^{(1)}(2),\ \dots,\ z^{(1)}(n))$$

In the formula, $z^{(1)}(k) = 0.5(x^{(1)}(k) + x^{(1)}(k-1))$, and$x^{(0)}(k) + az^{(1)}(k) = b$ is the basic form of GM(1, 1) model.

2.3 If $\varphi = [a,\ b]^T$ is the parameters column, B= $\begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \vdots & \\ -z^{(1)}(n) & 1 \end{bmatrix}$,

Y=$(x^{(0)}(2),\ x^{(0)}(3),\ \dots,\ x^{(0)}(n))^T$,the Least Square estimation of the GM(1, 1) model is this,

$$\emptyset = [B^T B]^{-1} B^T Y$$

2.4 $X^{(0)}$ is the non-negative sequence, $X^{(1)}$is the cumulative sequence, $Z^{(1)}$ is the average generation sequence, $[a,\ b]^T = [B^T B]^{-1} B^T Y$,therefor, the albino equation is as follow:

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = b$$

2.5 The solution of the albino equation is as follow:

$$x^{(1)}(t) = \left(x^{(1)}(1) - \frac{b}{a}\right) e^{-at} + \frac{b}{a}$$

And the solution of the GM(1,1) model is:

$$p^{(1)}(k+1) = \left(x^{(0)}(1) - \frac{b}{a}\right)e^{-ak} + \frac{b}{a} \quad (k=1,\ 2,\ \ldots,\ n)$$

3 The Steps of Model Building

The first step: Accumulate $X^{(0)}$, to generate the $X^{(1)}$

$$X^{(1)} = (x^{(1)}(1),\ x^{(1)}(2),\ \ldots,\ x^{(1)}(n))$$

In the formula , $x^{(1)}(1) = x^{(0)}(1)$, $x^{(1)}(k)$=$\sum_{i=1}^{k} x^{(0)}(i)$(k=1，2，…，n)。

The second step: To get the albino equation

$$\frac{dx^{(1)}(t)}{dt} + ax^{(1)}(t) = b$$

In the formula , "a" is a development factor，"b" is the grey differential equations.

$$x^{(0)}(k) + az^{(1)}(k) = b,\ k=2,\ 3,\ \ldots$$

The third step: Solve parameters a and b. Parameters column $\varphi = [a,\ b]^T$ is identified by the Least Square estimation

$$\emptyset = [B^T B]^{-1} B^T Y$$

The forth step: To get generation data models:

$$p^{(1)}(k) = \left(x^{(0)}(1) - \frac{b}{a}\right)e^{-a(k-1)} + \frac{b}{a} \quad (k=1,\ 2,\ \ldots,\ n)$$

The fifth step: To get original data model:

$$p^{(0)}(k) = p^{(1)}(k) - p^{(1)}(k-1),\ (k=2,\ 3,\ \ldots,\ n)$$

Make k=2，3…，n , you can get the fitted values of the initial data. When k>n, you can get the predictive solution of the grey model

4 The Case

The first step :Structure the original car ownership data of Hangzhou .

$X^{(0)} = (x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(11))$

=（3.96 5.106 6.279 7.962 9.55 10.784 12.025 13.268 13.954 15.789 18.289 20.782）

The second step: Accumulate $X^{(0)}$,getting $X^{(1)}$=（3.96 ，9.066 ，15.345，23.307 ，32.857， 43.641， 55.666，68.934 ，82.888 ，98.677， 116.966 ，137.748）

The third step: Structure matrix B, and data vector Y:

$$B=\begin{bmatrix} -6.513 & 1 \\ -12.206 & 1 \\ -19.326 & 1 \\ -28.082 & 1 \\ -38.249 & 1 \\ -49.654 & 1 \\ -62.300 & 1 \\ -75.911 & 1 \\ -90.783 & 1 \\ -107.821 & 1 \\ -127.357 & 1 \end{bmatrix}$$

Y=
$(5.106\ 6.279\ 7.962\ 9.55\ 10.784\ 12.025\ 13.26813.954\ 15.789\ 18.289\ 20.782)^T$

Solve parameters a, b, $\varphi = [a, b]^T = \begin{bmatrix} -0.1205 \\ 5.3903 \end{bmatrix}$

Then the grey model is : $p^{(0)}(k) = (1 - e^{a})\left(x^{(0)}(1) - \frac{b}{a}\right) e^{-a(k-1)}$

$=5.5277e^{0.1205(k-1)}$

Table 1. Error analysis

Years	Fitted value （100000Veh）	Actual value (100000Veh)	Residual	Fitted relative error(%)
2000	3.96	3.96	0	0
2001	6.2356	5.106	-1.1296	-22.12
2002	7.0341	6.279	-0.7551	-12.03
2003	7.935	7.962	0.027	0.34
2004	8.951	9.55	0.599	6.27
2005	10.0973	10.784	0.6867	6.37
2006	11.3904	12.025	0.6346	5.28
2007	12.8491	13.268	0.4189	3.16
2008	14.4945	13.954	-0.5405	3.87
2009	16.3507	15.789	-0.5617	-3.56
2010	18.4446	18.289	-0.1556	-0.85
2011	20.8066	20.782	-0.0246	-0.12

The above table shows that, in addition to two relative error is greater than 10%, all other fitted relative error is below 10% . It indicates that the model has a better accuracy.

Table 2. The number of prediction

Years	2012	2013	2014	2015
Numbers （10000vel）	234.71	264.77	298.67	336.92

5 Conclusions

When use the GM (1,1) model to do prediction , although it has a lower requirement for original data, the prediction accuracy will be greatly affected by the following elements. First, the smoothness of the original data. The higher the smoothness of the original data, the more accurate prediction results will be. Second, the impact of “a”. “A “mainly affects the scope of the mode, and if it exceed this range, the error will be large, and the expected results will be different.

References

Chen Jie, Xu Changxin Improved Grey Prediction Model, Liaoning Normal University (Natural Science)

Deng Julong, Gray Forecasting and Decision-making, Wuhan: Huazhong Institute of Technology Pbress

Hangzhou Statistical Information Network .http://www.hzstats.gov.cn/web/

Li Xican Gray, GM (1,1) Model Extensional Scope, Systems Engineering Theory and Practice

Si Fong, Dang Yaoguo, Fang Zhigeng, Gray System Theory and Its application ,Beijing: Science Press

Xiao Xinping The study of Grey System Model Method , Huazhong University of Science and Engineering

Exploring Transit Use Regularity Using Smart Card Data of Students

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Abstract: With the popularity of Automated Fare Collection (AFC), transit operators and planners can make use of AFC data to have a better understanding of travelers behaviors, such not only provide meaningful guidance on public transport planning, but also for transit operators provide better services put forward a clear direction. In this paper, the main use of Chengdu on November 2nd to 8th one smart card. Using data mining technology to analysis the spatial and temporal regularity of students. Travel regularity analysis mainly include frequency of use, time of boarding, boarding intensity. This research shows that in a period of time, frequency of use, time of boarding and boarding intensity of student card presents regularity.
Keywords: Smart card; Transit system; Travel behavior; Regularity.

1 Introduction

Automated Fare Collection (AFC) system collects a large number of public transport network transaction of users every day, which includes the card number, type of card, boarding station and so on. Therefore, we can try to use data mining methods to dig out more interesting information in this huge data, such as the use of regular travelers on transit system in time and space, to help planners and operators to understand the behavior of travelers , so as to improving service.

This paper proposes to extract information from smart cards to describe travel behavior of students. The study focus on describing travel habits of students during peak hours on weekdays. The structure of the paper is the following. Firstly, in section 2, literature review focus on studying travel behavior by using smart card data. Then section 3 is a brief description of the data used. Section 4 shows the result of the regularity of student behavior. The last section is the conclusion of the paper and proposes directions for further research.

2 Literature review

This review focuses on analyzing travel behavior by using smart card data. Okamura(2004) analysis passenger boarding time and transfer behavior by using a month of smart card data from an AFC system. They find that boarding time is different from a questionnaire-based person trip survey. The authors also examine transfer wait time at important transfer points and classify cardholders according to some characteristic like boarding frequency, average on-board time. Bagchi & White (2004; 2005) analysis samples of public transit smart card data from Southport, Merseyside and Bradford, in the United Kingdom. The authors use rule-based processing to estimate trip rate per card and the proportion of linked trips by the samples. Tseytin et al.(2006) use the market basket data mining technique to extend the temporal coverage of travelers using weekly magnetic card by matching cards based on a similarity function between the travel patterns of two cards. Utsunomiya et al. (2006) use smart card registration and transaction data to analysis walk access distance from billing address to the first transit entry point, frequency of use, transfer trips, daily travel patterns, variation in transit mode, route and stop choice, and comparison of usage by area of residence. Morency et al. (2007) examine 2 million boarding transactions made within an 11-week period. Travel behavior are analyzed by frequency and time of transit use, fare type, number of boarding, and number of stops used. Bryan & Blythe (2007) use data from concessionary customers in Nottinghamshire County, United Kingdom, to analyze trip rates by user subgroups: elderly, disabled and school children. Mojica (2008) examines changes in travel behavior under deteriorated service conditions with smart card data and subsequently provides a modal shift model using a binary logit formulation. Asakura, Iryo, Nakajima & Kusakabe (2009) estimate change in behavior of train users after a schedule change with smart card data. Morency & Trépanier (2010) use smart card validation data from an extended period to assess loyalty of different segments of cardholders.

3 Data source and method

(1)Data source

From the analytical viewpoint, exploring the regularity of bus travel behaviors by using consecutive and multiple smart card data is very meaningful. This paper used the smart card data of student group as well as the information of the boarding stops in Chengdu from November 2nd to November 8th 2014 as exploratory research to analyze the bus travel behaviors of student group. The full dataset contains 703,014 transactions, collected from 128949 smart cards of students. Table 3-1 show that each transaction record matched with the information of boarding stops has 6 characteristics including card identification, card type, consume date, route identification, bus identification, and stop identification.

Table 3-1. The characteristics of the transaction record

CARD_ID	CARD_TYPE	DATE TIME	ROUTE_ID	BUS_ID	STOP_ID
0061324	4	2014-11-2 7:05:22	59	00700	03012

(2)Method

A transit smart-card fare collection system collects a huge amount of data. In the case of the system in use in Chengdu, for example, about 703,014 entries are collected each week.As the growing number of data generated on an everyday, new developments designed to automatically extract knowledge from that large amount of data have appeared. The term commonly employed to unify them is “data mining”, a technique which uses tools from statistics database management and visualization, as well as new methodologies specifically developed to extract patterns from large data sets.

In following section, the differences in bus travel behaviors of student group between weekdays and weekends as well as the indicators for describing the regularity of the travel behaviors will be explored by using the dataset.

4 The regularity of student travel behaviors

(1)Activity rate on the transit network

The paper defined the H as activity rate, which means the ratio of the number of days used by student card belongings (H_S) with the number of observation days (H_G). In general, the card belongings with high activity rate on the transit network perform relative more regular in travel tracks. Table 4-1 shows the value of the activity rate (H) for the student group in one week. It can be seen that 66% of cards belongings to the experimental sample have been used in the transit network on 60%-100% of the observed days, which reflects the student group is loyal user of transit system.

Table 4-1. The active day distribution of students cards

Activity day	1	2	3	4	5
Number of cards	26171	8568	8578	13322	45678
H	0.26	0.08	0.08	0.13	0.45

(2) Variability of travel behaviors for temporal distribution

Figure 4-1 shows the number of boardings as well as trip rate per card for student group. It can be seen that both the two measures keep a flat trend during the weekdays. However, the number of boardings on weekends is obvious less than it for the weekdays, while the trip rate per card is higher compared to the weekdays.

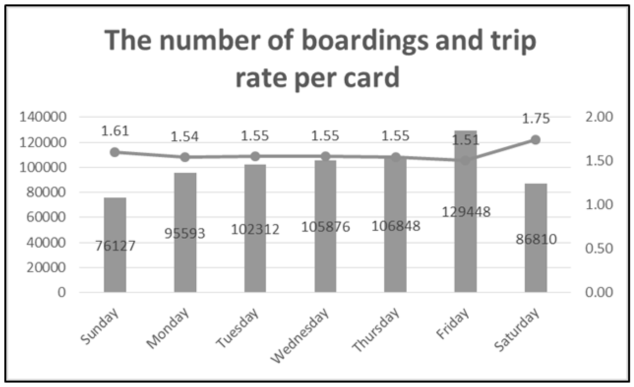


Figure 4-1. the number of boarding and trip rate per card

Figure 4-2 and Figure 4-3 represent the number of boardings for different time intervals for the weekdays and the weekends respectively. Figure 4-2 shows that the boarding time of the student group has a consistent trend for each weekday and has two peak hours including 7:00-8:00 a.m. in morning peak as well as 16:00-18:00 p.m. in evening peak. However, the regularity of the boarding time for the weekends is uncertain because of the flat trend for the different time intervals.

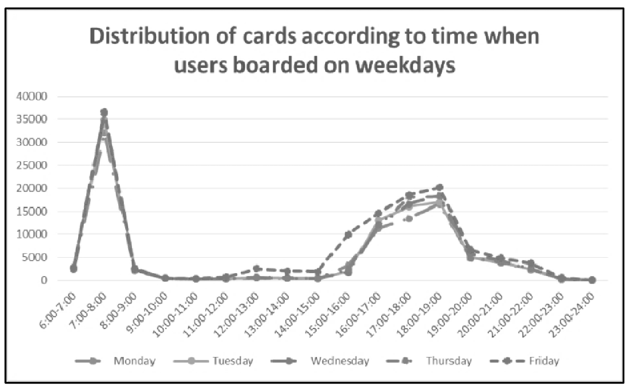


Figure 4-2. Distribution of cards according to time when users boarded on weekdays

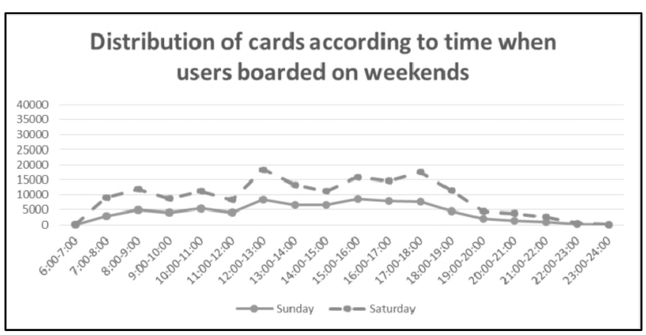


Figure 4-3. Distribution of cards according to time when users boarded on weekends

In addition, the coefficient of variation for the trip rate per card in weekdays is 0.19-0.23, which is lower than it for the weekends (0.33-0.34). It suggests the regularity of travel behaviors for the weekdays is more obvious than it for the weekends.

(3) Regularity of travel behaviors for spatial distribution

It can be seen from Figure 4-2 that the number of boardings is mainly in two time intervals including 7:00-8:00 a.m. and 16:00-18:00 p.m. and the number of boardings for 7:00-8:00 a.m. accounts for the one-third of the total number of the boardings. It dues to most of the students go to school in this period (7:00-8:00 a.m.). As a result of it, this paper selected this time interval (7:00-8:00 a.m.) to study the regularity of student travel behaviors in spatial distribution.

a. The number of the boarding stops

In this study, 7:00-8:00 a.m. interval was divided into four different time intervals for each 15 min to study the number of the boarding stops in every 15 min interval. The following figures (Figure 4-4-Figure 4-7) show the change of the distribution of the boarding stops in every 15 min interval on Monday.

Figure 4-4. 7:00~7:15

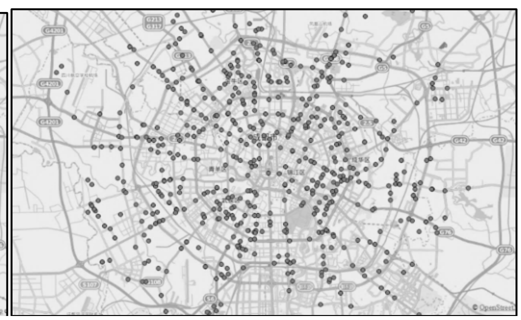


Figure 4-5. 7:15~7:30

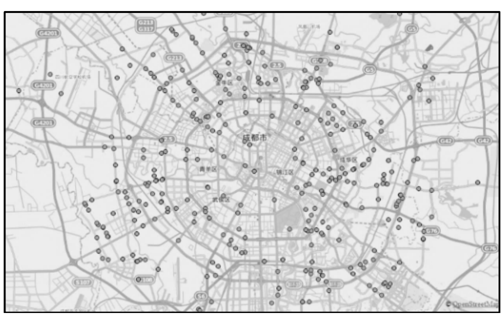


Figure 4-6. 7:30~7:45

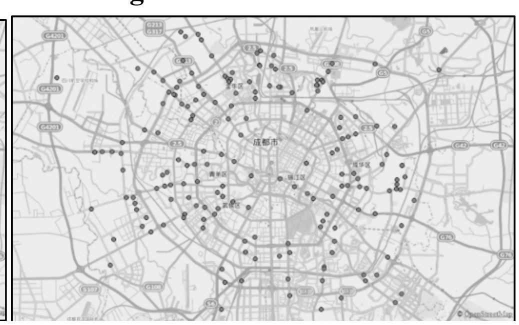


Figure 4-7. 7:45~8:00

Table 4-3. The numbers of boarding stops on weekdays

Time	7:00-7:15	7:15-7:30	7:30-7:45	7:45-8:00
Monday	1939	1842	1636	1272
Tuesday	2006	1894	1664	1318
Wednesday	2002	1924	1654	1299
Thursday	1985	1931	1660	1354
Friday	2015	1931	1679	1307
Decrease	-----	3%-5%	11%-14%	19%-22%

It can be seen from the figures that the number of the boarding stops has a decrease trend over time. Table 4-3 shows that the other weekdays perform the same regularity with the situation on Monday. On the whole, the number of boarding stops in the second interval (7:15-7:30 a.m.) decreases by 3%-5% compared to the first interval (7:00-7:15 a.m.) and the number in the third interval (7:30-7:45 a.m.) decreases by 11%-14% compared to the second interval. The rate of decline for the fourth interval (7:45-8:00 a.m.) compared to the previous interval is highest, which reaches 19%-22%.

b. The boardings of the stops

This paper selected top 30 boarding stops for the number of boardings in four intervals to analyze the boardings of the stops. The intervals include 7:00-7:15 a.m., 7:15-7:30 a.m., 7:30-7:45 a.m., and 7:45-8:00 a.m. There are steady 19,18,13,15 boardings stops in four intervals respectively during the weekdays by the result of data analysis.

Table 4-4 shows the boardings of the steady stops for each time intervals is 69 boardings per 15 min, 42 boardings per 15min, 29 boardings per 15min, and 20 boarding per 15 min respectively. It can be concluded that the boardings of the stops with high volume are relatively steady in the observation time interval for weekdays.

Table 4-4. The boardings of the stops in four intervals

Time	Max boarding	Min boarding	The number of stops	Average boarding intensity
7:00-7:15	148	45	19	69
7:15-7:30	103	30	18	42
7:30-7:45	47	20	13	29
7:45-8:00	27	14	15	20

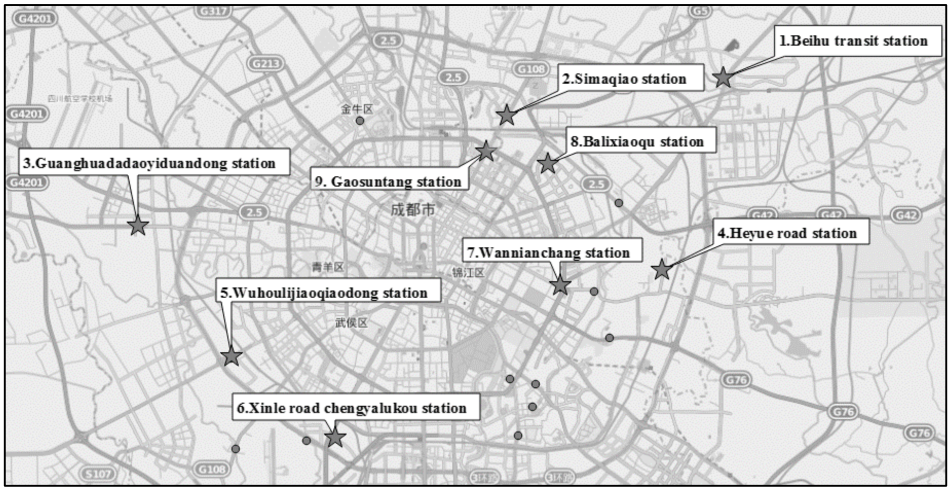


Figure 4-8. 7:00~7:15

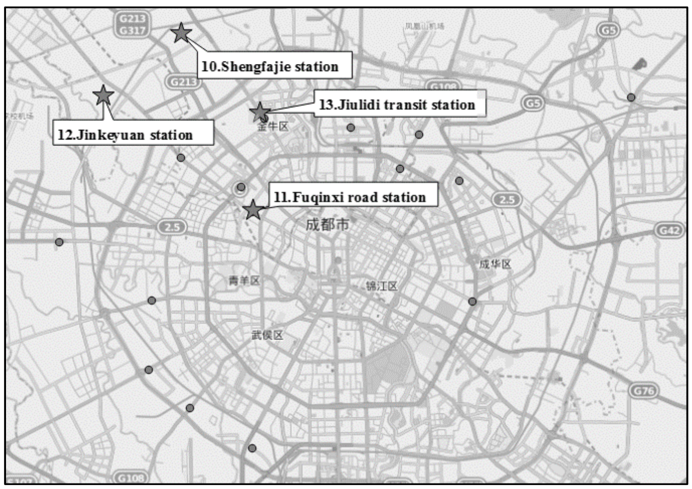
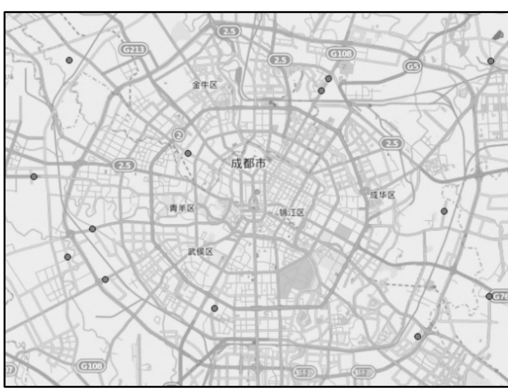


Figure 4-9. 7:15~7:30



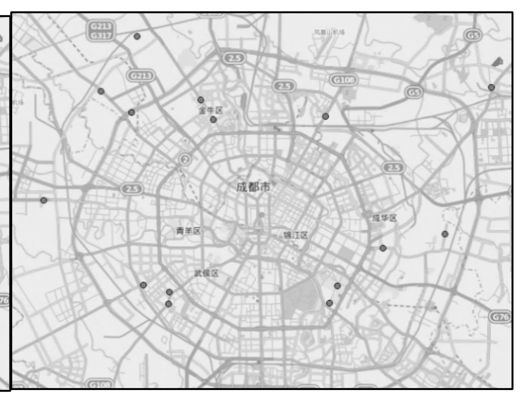


Figure 4-10. 7:30~7:45 Figure 4-11. 7:45~8:00

The above figures (Figure 4-8-Figure 4-11) show the spatial distribution of steady boarding stops in four intervals during weekdays respectively. We find that stop 1-5 with high boardings during 7:00-8:00 a.m. At stop 6-9 during 7:00-7:30 a.m. At stop 10-13 during 7:15-7:45 a.m.

Through analyzing students boarding stops, we find that the number of the boarding stops regularly decrease over time. We also find that most of top 30 boarding stops have stable boardings. It suggests the spatial regularity of travel behaviors.

5 Conclusion

With the popularity of the AFC system, it is reliable to use smart card data to reveal travelers behavior. Because smart card data can record cardholders various attributes in a long period, including boarding time, the stop of boarding and so on. By means of data fusion, smart card data can be combined according to the need of research, can depict the trajectory of travelers and can be found their temporal-spatial regularity.

This paper explain students are transit user with a high degree of loyalty during weekdays by active rate. We research trip rate per card and the number of boarding of students, found that students travel on weekdays higher stability than the weekend, mainly in the 7:00-8:00, 16:00-19:00during the weekdays. Then the number of boarding stops and the boarding of stop during peak hours on weekdays are examined, we found that the number of boarding stops presents an orderly decreasing trend, and the boarding of stop relatively stable. It is suggested that the students travel behavior have temporal-spatial regularity. If we are able to systematically analyze all types of travelers group, we can help transit operators to better understand transit demand. Then transit operators is able to adjust transit supply and provide better service.

Future experiments include the study of using the similar methods to analysis other types of cards and finding their travel regularity.

Acknowledgement

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References

Asakura, Y., Iryo T., Nakajima Y., & Kusakabe T. (2009). Estimation of behavioural change of railway passengers using smart card data. *Paper presented at CASPT 2009*, Hong Kong.

Bryan, H., & Blythe, P. (2007). Understanding behaviour through smartcard data analysis. *Proceedings of the Institution of Civil Engineers: Transport*, 160(4), 173-177.

Bagchi, M., White, P.R., (2004). What role for smart-card data from a bus system? *Municipal Engineer 157*, 39–46.

Bagchi, M., White, P.R., (2005). The potential of public transport smart card data. *Transport Policy 12*, 464–474.

Mojica, C. (2008). Examining changes in transit passenger travel behavior through a smart card activity analysis. M.S. Thesis, *Massachusetts Institute of Technology*, M.A, United States.

Morency, C., Trépanier M., & Agard, B. (2007). Measuring transit use variability with smart-card data. *Transport Policy*, 14(3), 193-203.

Morency, C., & Trépanier M. (2010). Assessing transit loyalty with smart card data. *Paper presented at the 12th Conference on Transport Research*, Lisbon, Portugal.

Okamura, T., Zhang J., & Akimasa F. (2004). Finding behavioral rules of urban public transport passengers by using boarding records of integrated stored fare card system. *Proceedings of the 10th World Conference on Transport Research*. Istanbul, Turkey.

Tseytin, G., Hofmann, M., O'Mahony, M., & Lyons, D. (2006). Tracing individual public transport customers from an anonymous transaction database. *Journal of Public Transportation*, 9(4), 47-60.

Utsunomiya, M., Attanucci, J., & Wilson, N. (2006). Potential uses of transit smart card registration and transaction data to improve transit planning. *Transportation Research Record: Journal of the Transportation Research Board*, No. 1971, 119-126.

Theory and Application Technology of Railway Intelligent Transportation Systems

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Abstract: Intelligent transportation system as a new technology and management system, has been a hotspot and frontier in the traffic research. In addition to the application of intelligent transportation system in road traffic, waterborne, aviation, it also played a huge role in the "high security, high efficiency, high service quality" railway transportation, the railway intelligent transportation system (RTIS). Paper starts from the connotation and essential characteristics of railway intelligent transportation system, and its core technology, development model and strategy, then analyses the main body by the user, the service main body, service framework, logic framework, physical framework and economic and technical evaluation of several parts of the system framework of railway intelligent transportation system theory. Then, we analysis foreign railway intelligent transportation system from the aspects of improving the service quality, enhancing the safety of railway transportation and improving the efficiency of railway transport. After that, the paper introduces the application technology of railway intelligent transportation system in the domestic, such as the Transportation Management Information System, Train Dispatch and Command Management Information System, Automatic Train Identification System and Railway Ticketing and Reservation System. Finally, we combine with the application and development of domestic and foreign railway intelligent transportation system and the analysis of the future vision of rationality in order to meeting the needs of different users and play its biggest role.

Keywords: Railway intelligent transportation system; System framework; Application technology.

1 Summary of railway intelligent transportation system

1.1 The concept and connotation of RITS

Railway Intelligent Transportation System(RITS) on condition that mobile and fixed infrastructure are certain by supporting high-tech information technology, communications technology, sensor technology, intelligent control and decision technology, modern science and technology to achieve information collection, transmission, processing and sharing based on the completion of high efficiency, high safety, high-quality passenger and cargo transport stream generation railway system.

The connotation of Railway Intelligent Transportation System lies in the integration of contemporary advanced science and technology, to realize information sharing, and strengthen the train control system and the safety guarantee system construction on the premise of completed information; At the same time ,making efforts to ensure road safety, to improve transport efficiency and quality of service; Strengthening of comprehensive intelligent decision support system based on management and control of construction, improve the efficiency of the decision-making and scientific.

1.2 Essential characteristics of RITS

RITS focus on enhancing the competitiveness of rail transport market, improve transport efficiency and improve the quality of transport services as the goal, to achieve the transport process through the supervision and management information system to integrate an economic, social, technological the railway system, so it has the essential characteristics as following:

（1） Open system, information sharing.
（2） The application technology, intelligent processing.
（3） According to the demand, dynamic configuration.

1.3 The core technology of RITS

RITS core technology mainly includes support layer perception of the Internet of things (sensor network) technology, support the communication layer of the large capacity of communication technology, support the fusion layer of cloud computing technology and interoperability technology, support implementation layer knowledge reasoning technology and network security technology to protect the safety of the whole system.

2 System framework of the RITS

Railway Intelligent Transportation System framework is used for identifying and describing all the Railway Intelligent Transportation System essential services to users, as well as subsystems to achieve these functions, interfaces and information between the various subsystems and flow between the external environment.

RITS framework consists of user principal, the service principal, the service framework, the logical framework, and economic and technical evaluation of the physical framework of several components.

2.1 The user and the service subject

User main body for service system is a system framework of subject, also putting forward the demand in certain areas of the subject; the main body of the service is to provide service to the user main body. They are the relationship between the service and the service, also in the field of RITS service supply and demand.

2.2 Service framework of RITS

Service framework is the foundation of the whole system framework of RITS. The purpose is to meet various requirements, and the goals are realizing the "high quality service, high safety, high efficiency" intelligent railway transport system. RITS could be divided into seven service system and figure1shows that.

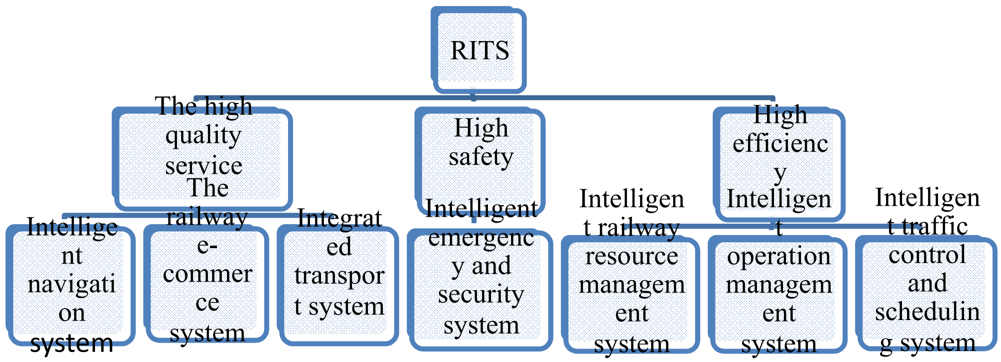

Figure 1. RITS service framework

2.3 Logical framework of RITS

The existence of the logical framework is mainly used to determine the main function of RITS system framework and accomplish the transmission between the information flow and data flow.

2.4 Physical framework of RITS

Physical framework is mainly used to make the each function substantial and modeling. Seven service systems which are divided from service framework as the central management subsystem links railway external user principals through the way of an external WAN wired or wireless communication, and via LAN or WAN, the central management sub the system can be connected to the station subsystem, subsystems and trackside train subsystems.

2.5 Common technology platform of RITS

RITS common technology platform integrates multi-source heterogeneous RITS subsystem information resources according to certain standards and becomes the carrier to collect, transmit, store, process, manage and release all kinds of railway transportation information. Its main function is that sharing data extracted from each business subsystem, and the multiple sources and inconsistent data fusion processing, performing multiple types of dynamic data and static data, time data, spatial data organization, ensuring the correctness of the relationship between the data, consistency and avoiding data redundancy, and provide decision support and information services.

3 Foreign RITS application technology research

3.1 RITS research on improving the service quality

Improve transport services in terms of quality, technology used in different countries vary. Europe via electronic data interchange (EDI) between modes of transport to build a multimodal transport system based on electronic markets, in order to achieve e-freight market positioning, seamless movement of cargo tracking, intermodal convergence operation and automated cargo handling and other stations to reach high efficiency, low consumption, sustainable standard door transport of goods between the integrated transport chain; the United States is also working on the promotion of compatible EDI systems and ITS technologies, and cargo tracking information and treatment, coordination and seamless connectivity between different modes of transport, improve the efficiency and flexibility of operating transport corridor between the public and private between the states; Japan Railway is gradually provide ticket information for travelers by means of e-commerce, service stations along the route, hotel, ticket reservations and other travel information service, at the same time, Japan established e @ train system provides a cheaper, safer, on time information sharing platform to meet the needs of different users.

3.2 RITS research on strengthening the railway transport safety

The research on strengthening the railway transport safety mainly relies on traffic safety inspection system, maintaining of the level crossing safety systems and rail disaster prevention system. First, the traffic safety monitoring is the use of onboard equipment and ground equipment for real-time train running status parameter tracking and detection, fault finding by parametric analysis and troubleshooting, in order to achieve security monitoring. Level crossing safety system is a level crossing in addition to the conventional signal flags, but also the addition of intelligent crossing equipment, real-time monitoring of the crossing, and the timely delivery of information to the crossing near the crossing of trains. Japan's railway disaster prediction and disaster prevention system is divided into two types of disaster monitoring system, the former using scientific methods to predict flooding line, tower defense and other disasters, forecasting, and take appropriate disaster warning and disaster developed under traffic rules to take preventive measures, while the latter is used for detecting those disasters which are difficult to predict, test run of the train to stop in time.

3.3 RITS research on improving the efficiency of railway transport

We must take train lines and operations management into consideration with scientific means to improve the efficiency of rail transport. European Rail Traffic Management System (ERTMS) is a typical foreign representative in improving the efficiency of rail transport. With the developing of European railway, in the late 1980s, European established a unified European Train Control System (ETCS) in order to ensure interoperability train operators, and later established the European Rail Traffic Management Project (ERTMS). ETCS system is the standard of ERTMS, railway communication system (GSM-R) as a platform, European point transponder as the positioning means, wherein ETCS is the most basic level, the use of conventional ground signal system, with fixed closed run, by Ground point transponder will pass the train traffic command, use the track circuit to check the integrity of the train and the train location. Increase traffic in the first stage, based on the command wireless transmission function, the entire range of two-way communications, driving the train from the command passed to the RBC (Radio Block Center), and using balise to position the trains. The third level has completely abolished the ground signal and increased vehicle equipment positioning trains.

4 Domestic RITS application technology

4.1 Transportation Management Information System（TMIS）

In order to improve the quality of services and transport railway transportation efficiency and achieve national railway transport management, information technology, Chinese railway development after decades of the most complex and the most massive, nationwide railway transport management information system (TMIS). TMIS system selects over 2000 main railway stations through a computer network , and collects trains, locomotives, vehicles, containers and cargo dynamic information, to achieve the train, cargo, rolling stock, real-time tracking of container node management, national railway transportation and production personnel at all levels to provide timely and accurate, and complete information and decision management solutions.

4.2 Train dispatch and command management information system（DMIS）

DMIS is a nationwide large-scale computer network signaling system, which uses digital technology, networking, information technology, within the national railway system related to train running, data sharing statistics, operational adjustments and data, and automated processing and inquiry, is a revolutionary breakthrough to the traditional dispatching mode. It greatly reduces the dispatcher's labor intensity and improve the efficiency of transportation and traffic control production level of technology and modernization of Railway Traffic Control.

4.3 Automatic train number identification system（ATIS）

ATIS aims to install an electronic tag on all locomotives and wagons (TAG), in all segments stations, marshalling yard, a large freight station and placed ground stations to identify the boundaries set (AEI), to train and run for accurate vehicle information identification, after computer processing systems to provide for TMIS trains, vehicles, containers real-time tracking information, provide a guarantee for accurate statistical boundaries station wagon, authorities can achieve real-time management of the car now.

4.4 Train railway ticket sale and reserve system（TRS）

TRS is to rely on computer management system, the full realization of the ticket, refund, booking, planning, scheduling, billing, statistics, query and other services for railway customer service provides an effective means of regulation, which marks the beginning of informational Chinese railway. The ultimate goal is to establish a TRS system covering the national railway network computer ticketing, ticket management and sale of work to achieve modernization, so as to facilitate passenger ticket and travel, passenger rail operators to improve the level and quality of service.

5 Recommendations for Future Research

From the departure from the whole railway development in our integrated transportation management system, providing customers with high efficiency, high security, high quality service: in terms of efficiency, to build integrated operational management system, to realize the passenger and cargo transportation efficiently; In terms of safety, should be intelligent construction of emergency rescue and security systems, real-time monitoring and safety evaluation for all kinds of disasters; In terms of service, should focus on building advanced user information system, for the passenger and cargo to provide detailed information and electronic secretary function.

Automatic Train number Identification System plays an important role in the railway intelligent transportation system, and railway freight transportation also plays an important role in the railway transportation. For the past 20 years, the scale and the flow rate of the railway freight trains increased significantly. It is difficult for the rail vehicle management center to make railway vehicle registration, records, statistics, scheduling, maintenance and tracking, and the traditional manual copy train number can't satisfy the demand of a new age. So the Automatic Train number Identification System arises at the historic moment. Imagining, if the Automatic Train number Identification System is not only applied to railway freight train, but throughout the railway train on each piece of goods, thereby it is convenient for railway staff to realize the running track of every piece of goods, and every owner can query logistics situation of their goods constantly. This will avoid the condition of missing goods and raise owner's satisfaction. But, at present still need to solve the problem is that the electronic tag cost highly. If there has a kind of cheap products which can replace the electronic tag and can also be identified by RFID technology . This is the key of the current, and the direction of future research.

Acknowledgement

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References

Borges H ,Knapp G ,Eisenhart B.(2010) *Development of Canadian architecture for intelligent transportation system[EB/OL]*.

JIA Limin , Qin Yong and Zhang Yuan.(2011)*Railway intelligent transportation system and its application* ,Changsha.

LIU Zhihong and Wei Minghua .(2006) *The Development of Intelligent Railway Trainsport System,* Nanchang.

SHEN Haiyan.(2005)*Rail car number automatic identification system implementation technologies.*www.3edu.net.

SONG Min , *Research and Development of Railway vehicle ATIS Systems*, Tianjin.

Route Optimization of Multimodal Military Logistics Transportation

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Abstract: This paper discussed the methods to build up multimodal military logistics transportation networks, defined the topological structures of two-dimensional combined transportation networks without multiple edges and the expression of transportation networks' attribute values. A route optimization model for multimodal transportation based on military supply was established, which turned out to be a high-order model due to the fact that safety attribute was a multiplicative parameter. To solve this problem, this paper proposed two improvement methods, respectively simplifying the original non-linear high- order 0-1 programming model into second-order 0-1 model and linear 0-1 model, which made it far less complicate to get the solutions. For further demonstration, this paper chose a case scenario which involved 74 nodes for simulation analysis, using Lingo 9.0 for programming to get the solutions of the high-order model, the second-order model and the linear model. The consistent results proved the models' correctness and feasibility in getting solutions. It was specially worth noting that the improved linear 0-1 programming model was able to get real-time overall optimum solutions, demonstrating very good real-time performance, stability and solution-getting ability.
Keywords: Military logistics; Multimodal transportation; Non-linear 0-1 programming; Route optimization.

Multimodal military logistics transportation is a transport mode used by army troops to transit personnel, material and equipment. Analysis has showed that applying multimodal transport in military transportation can greatly improve its efficacy, optimize its structure, enhance its rationality and economical efficiency (JIN, Z. H., 2005 and LIU, J., 2011) . Therefore, in order to strength armies' logistics distribution capabilities in an IT-based environment and raise armies' economic benefits, it is of practical significance that we should strength multimodal military logistics transportation, and especially look into its core issue – route optimization.

1 Current Research Review

There have been a few research results on multimodal transportation concerning military logistics, mainly including: ZHANG Jin(ZHANG, J., 2013) proposed a method to convert high-order 0-1 programming models into second-order 0-1 models and validate the method through a simulation case to solve the problem that safety attribute usually results in high-order multimodal military logistics transportation models; YANG Xirui(YANG, X. R., 2008) employed Lagrangian relaxation method into his study, simplified this issue to cargo flow and traffic flow issues, respectively using multiple cargo flow and minimum cost circulation algorithm to get solutions; ZHANG Jiaying(ZHANG, J. Y., 2010) chose cost and time as his optimization objectives, established a model which took into account of time and transport capacity constraints, demonstrated the method to use genetic algorithm for programming and solution; LIU Huaxia(LIU, H. X., 2010) discussed the difficulties in developing multimodal military logistics transportation from organization structure and regulation levels; Akgün(İBRAHIM, A., 2007) proposed a mixed integer programming model for multimodal transport to solve Turkish armies' Deployment Planning Problem (DPP) and discussed the method to use CELPX for solutions; Yıldırım(UĞUR, Z. Y., 2009) also made a analysis study on DPP by applying Discrete-Event Simulation (DES) method.

2 Problem Description and Assumed Conditions

A certain battle zone plans to transport some materials (generalized concept) from a strategic logistics center to a front-line distribution center. Transference is allowed among existing transporting vehicles, but the process of transferring will occur cost and time. Transport capacity of any section should not be smaller than the transport volume. The whole process should comply with specified requirements in terms of time, cost and safety probability. The problem is to choose optimization objectives based upon military demands and decide the best transport route Γ.

In order to clearly clarify and reasonably simplify the problem, assumed conditions are as follows:

(1) If conflicting with civil transportation, military transportation has absolute priority, including the priority to assign transport vehicles and the priority of access;

(2) Sufficient prewar preparation and adequate vehicles (such as automobiles used for transference), which means that there are waiting vehicles during the whole process of unloading;

(3) In the process of transference and transportation, stagnation won't occurred by traffic jam or throughput limits of terminal yards.

3 Multimodal Military Logistics Transportation Network

Modern military transportation has a significant networking feature. Multimodal military logistics transportation network indicates the geographical distribution of all transport routes within a certain battle zone for military materials. It relies on a nation's regional space and is comprised by four types of transport sub-networks, including railway, highway, waterway and air (pipeline is not considered here). It constitutes the basis for military material transport and a fundamental condition for developing rapid reaction and comprehensive support capabilities. It is an ensemble of logistics centers, supporting objects (military clients), supporting pathways (transport routes), supporting facilities (loading and unloading equipment), all kinds of terminal yards (including railway stations, airports, harbors and bus stations).

3.1 The Topological Structure of a Combined Transport Network

Multimodal combined transport network is the basis of a route optimization model. Its topological structure can greatly affect a model's expression form and solution. Typical topological structures for such networks are as follows:

(1) Three-dimensional Combined Transport Network

Such a network puts the transportation nets of multiple transport modes on several parallel two-dimensional combined transport networks, adding transference edges between corresponding nodes (cities), and thus establishes a three-dimensional network which is comprised by many two-dimensional networks(ZHANG, Y. H., 2006). See Graph 1.

(2) Multi-edge Two-dimensional Combined Transport Network

Each node in a network like this indicates a transportation hub which provides many transport modes, and any transference process is completed within this hub. Multiple edges are added between two hubs to indicate that there are more than one transport mode. See Graph 2.

(3) Two-dimensional Combined Transport Network without Multiple Edges

Nodes in such a network indicates logistics centers, military clients and all kinds of terminal yards. Edges are added between linked nodes and a two-dimensional combined transport network without multiple edges is thus created. See Graph 3.

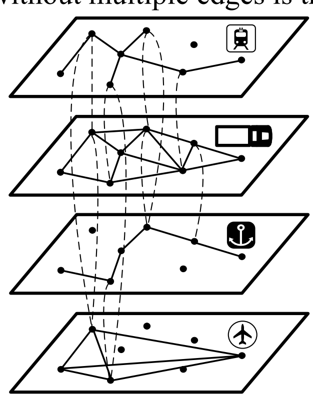

Figure 1. Three-dimensional combined transport network

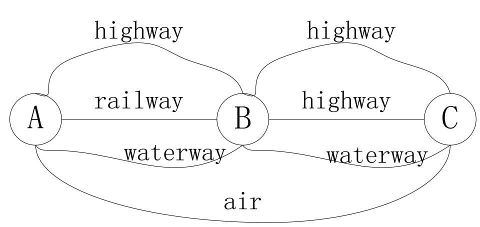

Figure 2. Multi-edge two-dimensional combined transport network unit

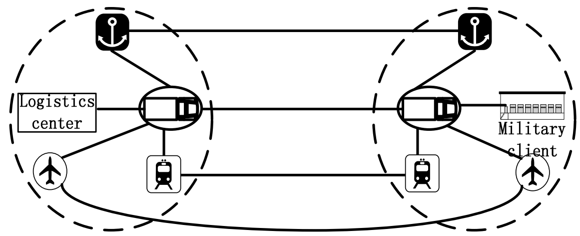

Figure 3. Two-dimensional combined transport network unit without multiple edges

In building up route optimization models, three-dimensional network and multi-edge two-dimensional network need to incorporate 0-1 decision variable $x_{ijk} \in X$, which means that transport mode k is used from city node i to city node j. As a result, the total number of this decision variable will be n×n×4, which is far too more than the number of a network's actual edges. For two-dimensional network without multiple edges, 0-1 decision variable $x_{ij} \in X$ needs to be considered, which means from terminal yard node i to j.The total number of this decision variable equals a network's actual edges.

3.2 The Definition of a Network's Attribute Value

More decision variables will cause the model to be more complicate. It is more advisable to establish a directed graph $G(V, E, T, C, P)$ for a two-dimensional network without multiple edges as the network's topological structure. In this directed graph, V is a point set and its total number is n; $v_i \in V$ indicates a point in the graph, and v_i=[1,2,3,4,5,6] respectively represent logistics center, train station, bus station (i.e. city express way or national highway's exit or entrance), airports, harbor and military client; E is an edge set, $e_{ij} \in E$ means that there are routes linking v_i and v_j; T is E's time attribute matrix, $t_{ij} \in T$ means that the time taken from v_i to v_j is t_{ij}; C is E's cost attribute matrix, $c_{ij} \in C$ means that the cost incurred from v_i to v_j is c_{ij}; P is E's safety attribute matrix, $p_{ij} \in P$ means safety probability in section e_{ij} is p_{ij}.

Establishing edge set attribute matrix T, C, P is fundamental to the establishing of a mathematic model. When $e_{ij} \notin E$, we define $t_{ij}=+\infty$, $c_{ij}=+\infty$, $p_{ij}=1$; when $e_{ij} \in E$, we need to discuss each matrix separately. Before discussion, we need to bring in homogeneity judgment matrix $B=[b_{ij}]_{n\times n}$:

$$b_{ij}=sgn[(v_i-v_j)^2] \quad \forall i,j \in [1,2,\cdots,n] \tag{1}$$

$sgn[]$ is a sign function, during homogeneous transport, $v_i=v_j$, $b_{ij}=0$; during non-homogenous transport, $v_i \neq v_j$, $b_{ij}=1$.

(1) Time Attribute

t_{ij}, as e_{ij}'s time attribute, indicates the time interval between the time when the first transport vehicle arrives at v_i and leaves v_j. During homogeneous transport, time attribute only relates to the time length of transportation, which means:

$$t_{ij} = s_{ij} / \mu_{ij} \tag{2}$$

In this equation, s_{ij} is edge e_{ij}'s mileage. When $e_{ij} \notin E$ *or* $e_{ij} \in E$ is interrupted by attacks, s_{ij} is $+\infty$, and μ_{ij} is e_{ij}'s average running speed.

During homogeneous transportation, transference process is completed via highway transport. Its time attribute includes the time for unloading (the time taken for unloading materials from v_i and transporting to transferring vehicles), the time for transferring, and the time for loading (the time taken for unloading materials from transferring vehicles and transporting to v_j). If unloading speed is faster than loading speed, then,

$$t_{ij} = \alpha_i g_i + s_{ij} / \mu_{ij} + \beta_j \cdot \min\{d_j, M\} \tag{3}$$

In this equation, α_i is v_i's unloading time coefficient (the time used for unloading unit material), and β_j is v_j's loading time coefficient (the time used for loading unit material); g_i represents transferring vehicles' (normally automobiles) standard loading capacity in v_i; M represents the total volume of distributed materials (valuation metric ton). For light goods, the volume will be converted according to relevant standards. d_j is the standard loading capacity of one single transporting vehicle.

If loading speed is faster than unloading speed, then

$$t_{ij} = \alpha_i \cdot \min\{d_j, M\} + s_{ij} / \mu_{ij} + \beta_j \cdot g_i \tag{4}$$

To sum up, the calculation formula for time attribute is:

$$\begin{aligned} t_{ij} = s_{ij} / \mu_{ij} + b_{ij}[\min\{\alpha_i, \beta_j\} \cdot g_i + \\ \max\{\alpha_i, \beta_j\} \cdot \min\{d_j, M\}] \quad \forall i, j \in [1, 2, \cdots, n] \end{aligned} \tag{5}$$

Further explanation for some special situations is as follows:

1) When e_{ij} is non-homogeneous transportation and v_i is a bus station, automobiles don't need to unload materials in v_i and will directly leave v_i for v_j. So α_i becomes 0.

2) When e_{ij} is non-homogeneous transportation and v_j is a bus station, β_j becomes 0.

3) When there is a railway directly linking train station v_i to harbor v_j, to calculate the result for t_{ij}, α_i is 0; to calculate the result for t_{ji}, β_i is 0.

4) When v_j is a military client, β_j is 0, and d_j equals g_i (transporting mission is completed when the first batch of materials arrive at their destination).

(2) Cost Attribute

Cost attribute c_{ij} indicates the direct economic cost incurred during e_{ij}'s transporting, loading and unloading process. It is comprised by transporting cost, loading and unlading cost. Transporting cost includes start-up cost and operation cost (start-up cost is usually ignored by highway and air transport, and operation cost of these two modes are directly determined by distance; start-up cost for shipping is mainly incurred by harbor pierage). During homogeneous transportation, c_{ij} is only about operation cost, and is related to transporting distance and volume. So,

$$c_{ij} = \gamma_{ij} \cdot s_{ij} \cdot M \tag{6}$$

In this equation, γ_{ij} represents operational base price, and its calculation unit is CNY/t*km.

During non-homogeneous transportation, c_{ij} includes transferring cost, loading and unloading cost, and transporting vehicles' start-up cost in v_j. So,

$$c_{ij} = (\eta_i + \gamma_{ij} \cdot s_{ij} + \lambda_j + \theta_j)M \tag{7}$$

In this equation, η_i represents v_i's unloading cost coefficient (CNY/t); λ_j represents v_j's loading cost coefficient; θ_j represents v_j's delivery base price ((CNY/t).

To sum up, the calculation formula for cost attribute is:

$$c_{ij} = [\gamma_{ij} \cdot s_{ij} + b_{ij}(\eta_i + \lambda_j + \theta_j)]M \qquad \forall i, j \in [1, 2, \cdots, n] \tag{8}$$

Further explanation for some special situations is as follows:

1) When e_{ij} is non-homogeneous transportation and v_i is a bus station, automobiles don't need to unload materials in v_i and will directly leave v_i for v_j. So η_i becomes 0.

2) When e_{ij} is non-homogeneous transportation and v_j is a bus station, λ_j becomes 0.

3) When there is a railway directly linking train station v_i to harbor v_j, to calculate the result for c_{ij}, η_i is 0; to calculate the result for c_{ji}, θ_i is 0.

4) When v_j is a military client, θ_j is 0.

(3) Safety Attribute

To define safety attribute p_{ij} for each section within a certain transporting network, it needs experts to make a comprehensive evaluation based on enemies attacking range and precision, surveillance technology and our armies' defense capability and transport facility's disguising level. As a result, this paper won't make too much discussion to define safety attribute's value. The value used in simulation analysis is only applied to prove the realizability of getting a model's solutions.

(4) Transport Capacity Constraints

When e_{ij} is homogeneous transportation, transport capacity constraint is not considered. When e_{ij} is non-homogeneous transportation, which means there will be transference, transport capacity constraint is comprised by three factors:

1) Vehicles' standard load capacity d_j in v_j is no less than the volume of the materials' minimum split cell, which means:

$$d_j \geq m \quad (9)$$

2) Vehicles' physical volume in length/width/Height ($l_j^1/l_j^2/l_j^3$) is larger than that of the materials' minimum split cell ($l_j^1/l_j^2/l_j^3$), which means:

$$\begin{cases} l_j^1 > l^1 \\ l_j^2 > l^2 \\ l_j^3 > l^3 \end{cases} \quad (10)$$

3) Total load capacity D_j of all vehicles in v_j is no less than the materials' total weight M, which means:

$$D_j \geq M \quad (11)$$

4 Route Optimization Model for Multimodal Military Logistics Transportation

A battle zone needs to choose route Γ to transport materials from strategic logistics center v_l to frontline distribution center or military client v_n. The total volume of these materials is M, and the entire process should not consume more *TIME* than W_t. In addition, the total *COST* should not exceed W_c, and safety probability *SAFETY* should not be smaller than W_p.

Optimization objectives vary from different battle fields. In order to keep the study's generality, the paper respectively choose total *TIME*, total COST and the whole SAFETY probability as objective functions to build a multi-objective route optimization model.

$$min \qquad TIME = \sum_{i=1}^{n}\sum_{j=1}^{n} t_{ij}x_{ij} \tag{12}$$

$$min \qquad COST = \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}x_{ij} \tag{13}$$

$$max \qquad SAFETY = \prod_{i=1}^{n}\prod_{j=1}^{n} q_{ij} \tag{14}$$

$$s.t \quad x_{ij} = \begin{cases} 0 & represnetse_{ij} \notin \Gamma \\ 1 & representse_{ij} \in \Gamma \end{cases} \forall i, j \in [1,2,\cdots,n] \tag{15}$$

$$\sum_{j=1}^{n} x_{1j} = 1 \qquad \forall j \in [2,3,\cdots,n] \tag{16}$$

$$\sum_{i=1}^{n} x_{in} = 1 \qquad \forall i \in [1,2,\cdots,n-1] \tag{17}$$

$$\sum_{i=1}^{n} x_{ik} = \sum_{j=1}^{n} x_{kj} \qquad \forall k \in [2,3,\cdots,n-1] \tag{18}$$

$$u_i - u_j + n \cdot x_{ij} \le n-1 \quad \forall i, j \in [1,2,\cdots,n] \tag{19}$$

$$v_i \in [1,2,3,4,5,6] \ \forall i \in [1,2,\cdots,n] \tag{20}$$

$$b_{ij} = \operatorname{sgn}\left[(v_i - v_j)^2\right] \forall i, j \in [1,2,\cdots,n] \tag{21}$$

$$t_{ij} = s_{ij} / \mu_{ij} + b_{ij}\Big[\min\{\alpha_i, \beta_j\} \cdot g_i + \max\{\alpha_i, \beta_j\} \cdot \min\{d_j, M\}\Big] \qquad \forall i, j \in [1,2,\cdots,n] \tag{22}$$

$$c_{ij} = \left[\gamma_{ij} \cdot s_{ij} + b_{ij}(\eta_i + \lambda_j + \theta_j)\right] M \ \forall i, j \in [1,2,\cdots,n] \tag{23}$$

$$(m - d_j)\sum_{i=1}^{n}(b_{ij}x_{ij}) \le 0 \qquad \forall j \in [1,2,\cdots,n-1] \tag{24}$$

$$(M - D_j)\sum_{i=1}^{n}(b_{ij}x_{ij}) \le 0 \qquad \forall j \in [1,2,\cdots,n-1] \tag{25}$$

$$(l^k - l_j^k)\sum_{i=1}^{n}(b_{ij}x_{ij}) \le 0 \quad \forall j \in [1,2,\cdots,n-1], \forall k \in [1,2,3] \tag{26}$$

$$q_{ij} = \lfloor (p_{ij} - 1)x_{ij} + 1 \rfloor \quad \forall i, j \in [1, 2, \cdots, n] \tag{27}$$

$$TIME \leq W_t \tag{28}$$

$$COST \leq Wc \tag{29}$$

$$AFETY \geq Wp \tag{30}$$

This model is a 0-1 non-linear programming model, and its decision variable is x_{ij}; equation (15)-(19) specify that feasible solution for this model is the route Γ starting from v_l and ending in v_n, and give out the necessary sufficient condition that this route doesn't include any other sections. u_i can ban any real number(YUAN, X. S., 2006). equation (24)-(26) indicate sections' capacity constraint; in equation (27), q_{ij} represents the mission's safety probability, which means, when $e_{ij} \in \Gamma$, $q_{ij} = p_{ij}$; otherwise, q_{ij}=1.

Equation (14) is the expression of safety probability, which is a multiplicative parameter. It is a high-order equation, causing the whole model to be a far more complicated non-linear one. It will take a great deal of time to get the solution and enhance the uncertainty to obtain the overall optimum solution. To improve this model, we bring in decision variable – phase safety probability p_j, which indicates the safety probability from starting point v_l to v_j on distributing route Γ. It is not hard to find out that:

$$p_l = 1 \tag{31}$$

$$p_j = \sum_{i=1}^{n} p_i p_{ij} x_{ij} \quad \forall j \in [2, 3, \cdots, n] \tag{32}$$

Then ,a new expression equation for *SAFETY* is:

$$SAFETY = \sum_{i=1}^{n} p_i p_{in} x_{in} \tag{33}$$

After replacing equation (14) and (27) with equation (31) to (33), the power value of *SAFETY* equation is reduced from n^2 to 2. The original 0-1 non-linear programming model thus becomes a less complicated 0-1 second-order model.

However, after simplification, this model is still a non-linear one. In order to further simplify it to a linear 0-1 model, given the monotonicity of logarithmic function $ln()$, we replace *SAFETY with* $ln(SAFETY)$ as the optimization objective, and change the mission's equation of safety probability q_{ij}. After replacing equation (14) and (27) in the original model with equation (34) and (35), the model completely becomes a 0-1 programming model.

$$\ln(SAFETY) = \ln\left(\prod_{i=1}^{n}\prod_{j=1}^{n} q_{ij}\right) = \sum_{i=1}^{n}\sum_{j=1}^{n}\left(x_{ij} \ln p_{ij}\right) \tag{34}$$

$$q_{ij} = \exp\left(x_{ij} \cdot \ln p_{ij}\right) \quad \forall i, j \in [1,2,\cdots,n] \tag{35}$$

5 Case Scenario Simulation Analysis

This part will give a case scenario, describe a military logistics network, and discuss its route planning problem. The analysis will choose the improved one-order 0-1 programming model, using calculating software LINGO 9.0 for programming and solution to optimize distribution plans and prove the model's correctness and feasibility.

5.1 Case Mission

Authorities send out the order to make a thorough distribution plan to transport 1000 tons of materials from a strategic logistics center to a frontline distribution center within 40 hours. After successfully delivery, it is required to send special forces to protect essential traffic sections and facilities, repair damaged logistics security facilities, and improve the network's traffic capacity.

5.2 Military Logistics Combined Transport Network

In this network, there are traffic lines between any two harbors and any two airports. To make the graph less complicated, air and maritime lines as well as transferring edges are not marked out. See Figure 4.

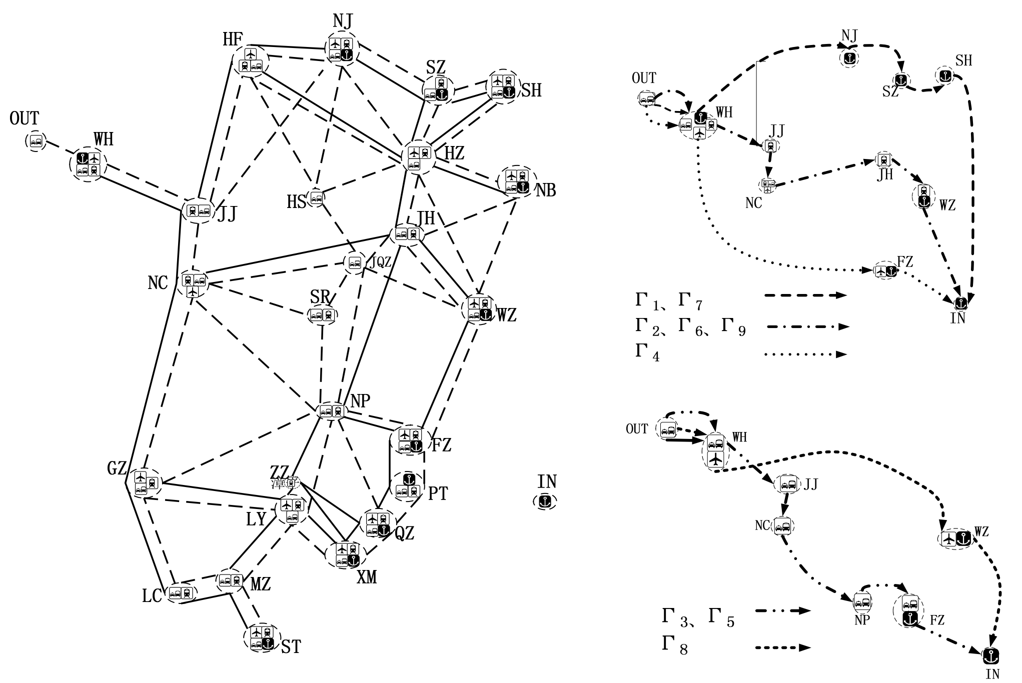

Figure 4. Military logistics supporting network

The military logistics combined transport network involves city nodes WH, NJ, HF, NB, NP, FZ, PT, XM, MZ, LY, SZ, JH, NC, JJ, FT, GZ, HS, JQZ, ZP, HZ, SR, ST, WZ, QZ, SH, LC, a strategic logistics warehouse (starting point/OUT), and a frontline distribution center (finishing point/IN). Each edge's attributes such as mileage, speed and safety probability can be obtained through measurement and statistic study, and attributes such as cost and time can be obtained calculation(LIU, S., 2008). Specific parameters are as follows:

1) Transport capacity

Transport capacity of one train carriage is 60 tons (the exact number of carriages depends on specific situations, but should be no more than 25). Transport capacity of an automobile is 10 tons. A ship can transport 1000 tons of materials and an airplane can transport 100 tons.

2) Time

On railway, transporting speed is 120 km/h, loading and unloading speed is 200 ton/h; On highway, transporting speed is 90 km/h, and transferring speed is 60 km/h; when using ships for transport, operation speed is 25 km/h, and loading and unloading speed is 150 ton/h; when using airplanes for transport, operation speed is 800 km/h, and loading and unloading speed is 100 ton/h.

3) Mileage

Table 1 specifies mileage between every city terminal yards. In the meantime, in order to simplify initial condition, the analysis assumes that transference mileage between any terminal yards within on city is 10 km.

4) Transference

The analysis assumes that automobiles can directly drive into other terminal yards for consecutive transport; that in cities which has the conditions for both railway and waterway transport, all harbors are directly linked with train stations by railways; that transference between railway and airway and that between waterway and airway can be realized through highway transport.

Table 1. Mileage and Safety Probability of This Military Logistics Combined Transport Network

e_{ij}	s_{ij}	p_{ij}	e_{ij}	s_{ij}	p_{ij}	e_{ij}	s_{ij}	p_{ij}	e_{ij}	s_{ij}	p_{ij}	e_{ij}	s_{ij}	p_{ij}	e_{ij}	s_{ij}	p_{ij}
WZK,STK	730	0.95	WZS,QZS	562	0.85	HFT,HFG	10	1	IN,QZS	379	0.85	HZG,JQZG	223	1	HFT,HZT	445	1
WZK,LYK	580	0.9	WZS,XMS	694	0.85	HFT,HFK	10	1	IN,PTS	359	0.85	HZG,JHG	177	1	SZT,HZT	254	1
WZK,GZK	716	1	WZS,STS	959	0.85	HFG,HFK	10	1	QZS,QZK	10	0.85	HZG,NBG	156	0.9	SZT,SHT	83	0.9
NCK,FZK	565	0.85	FZS,PTS	142	0.85	HZT,HZG	10	1	NJK,QZK	863	0.85	HZG,WZG	317	0.9	SHT,HZT	173	0.9
NCK,QZK	600	0.85	FZS,QZS	260	0.85	HZT,HZK	10	1	NJK,XMK	929	0.85	NCG,JQZG	356	1	HZT,NBT	176	0.9
NCK,XMK	542	0.85	FZS,XMS	372	0.85	HZG,HZK	10	1	NJK,STK	1154	0.95	NCG,SRG	274	1	HZT,JHT	172	1
NCK,STK	693	0.95	FZS,STS	637	0.85	NBT,NBG	10	0.95	NJK,LYK	892	0.9	NCG,NPG	436	0.95	JHT,WZT	262	0.9
NCK,LYK	516	0.9	PTS,QZS	118	0.85	NBT,NBS	10	0.95	NJK,GZK	885	1	NCG,GZG	390	1	JHT,NCT	457	1

e_{ij}	s_{ij}	p_{ij}	e_{ij}	s_{ij}	p_{ij}	e_{ij}	s_{ij}	p_{ij}	e_{ij}	s_{ij}	p_{ij}	e_{ij}	s_{ij}	p_{ij}	e_{ij}	s_{ij}	p_{ij}
NCK,GZK	412	0.85	PTS,XMS	112	0.85	NBT,NBK	10	0.95	SHK,NBK	160	0.95	SRG,NPG	272	1	JHT,SRT	197	1
FZK,XMK	219	0.85	PTS,STS	377	0.85	NBG,NBS	10	0.95	SHK,NCK	644	1	JQZG,SRG	124	1	SRT,NPT	280	0.95
FZK,STK	390	0.85	QZS,XMS	110	0.85	NBG,NBK	10	0.95	SHK,FZK	687	0.85	JQZG,NPG	356	0.95	NCT,GZT	412	1
FZK,LYK	350	0.85	QZS,STS	375	0.85	NBS,NBK	10	0.95	SHK,QZK	828	0.85	JQZG,WZG	287	0.9	GZT,LCT	241	1
FZK,GZK	560	0.85	XMS,STS	265	0.85	JHT,JHG	10	1	SHK,XMK	878	0.85	JQZG,JHG	91	1	GZT,LYT	297	0.95
GZK,QZK	482	0.85	WHT,WHS	10	1	WZT,WZG	10	0.95	SHK,STK	1046	0.95	JHG,NBG	248	0.95	LCT,MZT	131	1
GZK,XMK	400	0.85	WHT,WHG	10	1	WZT,WZS	10	0.95	SHK,LYK	902	0.9	WHK,STK	900	0.95	STT,STG	10	0.95
GZK,STK	450	0.95	WHT,WHK	10	1	WZT,WZK	10	0.95	SHK,GZK	790	1	WHK,LYK	800	0.95	ZPT,NPT	256	0.95
GZK,LYK	328	0.9	WHS,WHG	10	1	WZG,WZS	10	0.95	SHK,WZK	418	0.95	WHK,QZK	860	0.85	NPT,FZT	437	0.85
WHS,NJS	695	1	WHS,WHK	20	1	WZG,WZK	10	0.95	SHK,HZK	210	0.95	HFK,SHK	515	0.95	WZT,FZT	380	0.85
NJS,SZS	260	1	WHG,WHK	10	1	WZS,WZK	10	0.95	HZK,WZK	416	0.95	HFK,HZK	476	0.95	FZT,PTT	105	0.85
SZS,SHS	88.1	0.95	JJT,JJG	10	1	NCT,NCG	10	1	HZK,NCK	502	1	HFK,NBK	565	0.95	XMT,XMG	10	0.85
SHS,NBS	252	0.95	NJT,NJG	10	1	NCT,NCK	10	1	HZK,FZK	519	0.85	HFK,FZK	781	0.85	XMT,XMS	10	0.85
SHS,WZS	520	0.95	NJT,NJS	10	1	NCG,NCK	10	1	HZK,QZK	650	0.85	HFK,XMK	900	0.85	XMT,XMK	10	0.85
SHS,FZS	802	0.85	NJT,NJK	10	1	NPT,NPG	10	1	HZK,XMK	717	0.85	HFK,QZK	890	0.85	NPG,QZG	335	0.85
SHS,XMS	1045	0.85	NJG.NJS	10	1	SRT,SRG	10	1	HZK,STK	930	0.95	HFK.LYK	863	0.9	NPG,LYG	310	0.9
SHS,STS	1121	0.85	NJG,NJK	10	1	FZT,FZG	10	0.85	HZK,LYK	703	0.9	HFK,NCK	482	1	QZT,QZK	10	0.85
SHS,PTS	897	0.85	NJS,NJK	10	1	FZT,FZS	10	0.85	HZK,GZK	801	1	JHG,WZG	231	0.9	QZG,QZS	10	0.85
SHS,QZS	932	0.85	SZT,SZG	10	1	FZT,FZK	10	0.85	NBK,WZK	309	0.95	WZG,FZG	337	0.85	QZG,QZK	10	0.85
NBS,WZS	346	0.95	SZT,SZS	10	1	FZG,FZS	10	0.85	NBK,NCK	592	0.95	GZG,NPG	456	0.95	NPG,FZG	182	0.85
NBS,FZS	648	0.85	SZG,SZS	10	1	FZG,FZK	10	0.85	NBK,FZK	612	0.85	HFG,HZG	421	1	QZG,XMG	87	0.85
NBS,PTS	743	0.85	SHT,HSG	10	0.95	FZS,FZK	10	0.85	NBK,QZK	750	0.85	NJG,SZG	191	1	QZG,PTG	93	0.85
NBS,QZS	778	0.85	SHT,SHS	10	0.95	PTT,PTG	10	0.85	NBK,XMK	828	0.85	NJG,HSG	360	1	PTG,FZG	112	0.85
NBS,XMS	893	0.85	SHT,SHK	10	0.95	PTT,PTS	10	0.85	NBK,STK	1150	0.95	NJG,HZG	237	1	NBG,WZG	269	0.9
NBS,STS	1058	0.85	SHG,SHS	10	0.95	PTG,PTS	10	0.85	NBK,LYK	779	0.9	HSG,HZG	223	1	WHT,JJT	252	1
WZS,FZS	322	0.85	SHG,SHK	10	0.95	QZT,QZG	10	0.85	NBK,GZK	867	1	SZG,HSG	83	1	JJT,HFT	327	1
WZS,PTS	427	0.85	SHS,SHK	10	0.95	QZT,QZS	10	0.85	WZK,NCK	548	0.95	SZG,HZG	159	1	JJT,NCT	135	1
MZT,MZG	10	1	GZT,GZG	10	1	IN,SHS	776	0.85	WZK,FZK	312	0.85	SHG,HZG	177	0.9	HFT,NJT	156	1
LYT,LYG	10	0.95	GZT,GZK	10	1	IN,NBS	580	0.85	WZK,QZK	530	0.85	HSG,JQZG	149	1	NJT,SZT	217	1
LYT,LYK	10	0.95	GZG,GZK	10	1	IN,WZS	412	0.85	WZK,XMK	577	0.85	WHK,NJK	504	1	HFK,GZK	805	1
LYG,LYK	10	0.95	LCT,LCG	10	1	IN,FZS	276	0.85	STT,STK	10	0.95	WHK,SHK	761	0.95	NJK,SHK	273	0.95
OUT,WHG	10	1	IN,STS	608	0.85	IN,XMS	411	0.85	STG,STS	10	0.95	WHK,HZK	656	1	NJK,HZK	280	0.95
WHG,JJG	190	1	GZG,LYG	295	0.95	PTT,QZT	69	0.85	STG,STK	10	0.95	WHK,NBK	754	0.95	NJK,NBK	373	0.95
JJG,HFG	307	1	GZG,LCG	326	1	ZPT,QZT	184	0.85	STS,STK	10	0.95	WHK,FZK	780	0.85	NJK,WZK	655	0.95
JJG,NJG	360	1	LCG,MZG	108	1	ZPT,XMT	187	0.85	STT,STS	10	0.95	WHK,XMK	910	0.85	NJK,NCK	583	1
JJG,NCG	130	1	LYG,XMG	155	0.85	XMT,QZT	102	0.85	XMG,XMS	10	0.85	WHK,HFK	390	1	NJK,FZK	747	0.85
HFG,NJG	134	1	LYG,MZG	221	0.95	LYT,XMT	179	0.85	HFK,STK	950	0.95	WHK.NCK	343	1	XMG,XMK	10	0.85

e_{ij}	s_{ij}	p_{ij}	e_{ij}	s_{ij}	p_{ij}	e_{ij}	s_{ij}	p_{ij}	e_{ij}	s_{ij}	p_{ij}	e_{ij}	s_{ij}	p_{ij}	e_{ij}	s_{ij}	p_{ij}
HFG,HSG	320	1	MZG,STG	159	0.9	WHK,WZK	750	0.95	HFK,WZK	977	0.95	WHK,GZK	600	1	XMS,XMK	10	0.85
LYT,ZPT	68	0.95	MZT,LYT	175	0.95												

Note: the last letter indicates transport mode (T-Railway, G-Highway, S-Waterway, k-Air), the other letters indicate cities. For instance, WHG means a highway nodes in city WH.

5) Cost

Cost for railway transport is decided in accordance with authority standard issued by the Ministry of Railways. Commodity code is 2334 (quilt/mattress/tent/), delivery base price for carload freight is 10.4 CNY/t, operation base price is 0.0897 CNY//t*km (including railway construction fund), loading and unloading cost is 4.3 CNY/t. Cost for highway transport is decided with the reference of *2008 Xinjiang Commodity Transporting Rate.* Considering price inflation, operation base price is decided as 0.45 CNY//t*km (delivery base price can be ignored), loading price is 2.0 CNY/t, unloading price is 1.5 CNY/t. Cost for waterway transport is decided with the reference of *2008 Jiangxi Waterway Shipping Price Regulation*. Considering price inflation, delivery base price is decided as 5.0 CNY/t (means pierage base price), operation base price is 0.08 CNY//t*km, and according to the data issued by Chinese Harbor Association, loading and unloading cost is 20 CNY/t. Cost for air transport is decided with the reference of *the Rate for Air Transportation from Chongqing to other Cities in China*. Based on the price for transporting 1000 tons of materials from Chongqing to Nanning and from Chongqin to Shanghai, delivery base price is decided as 1097 CNY/t, operation base price is decided as 1.628 CNY//t*km, loading and unloading cost is 500 CNY/t (including fuel fee).

6) Safety probability

Safety probability is directly decided by expert grading method. See Table 1.

5.3 Plan Optimization

BY applying single-route multimodal transport route optimization model, choosing different optimizing objectives, giving different constraint conditions, using LINGO to simulate high-order, second-order and linear models, the solutions we get are consistent. For high-order model, it takes about 10 minutes to get the solution, and for second-order model, it takes about 1 minutes. The linear model is capable of real-time solution. According to the solution status demonstrated by LINGO, all solutions are overall optimum solution.

6 Conclusion

Multimodal combined transport has high reliability, lost cost, good flexibility and high efficiency. It is an important research area for military logistics distribution patterns. This paper focuses on the study of linear 0-1 programming model in multimodal military logistics transportation, finds out a suitable method to solve the non-linear problem caused by safety attribute's multiplicative feature. It simulates and verifies the method through case scenario, and the result of which shows that the improved linear model can greatly increase calculation speed, possessing very good real-time efficiency.

Table 2. Case Scenario Pre-act

Pre-act		Optimizing Objective	Total Mileage (Km)	Cost(ten thousand CNY)	Time (h)	Safety Probability	Constraining Conditions
Γ_1	OUT-WHG-WHS-HFS-NJS-SZS-SHS-IN	Cost	1839	17.95	79.77	0.808	none
Γ_2	OUT-WHG-WHT-JJT-NCT-JHT-WZT-WZS-IN		1548	18.18	36.11	0.727	Less than 40h，Safety Probability bigger than 0.7
Γ_3	OUT-WHG-JJG-NCG-NPG-FZG-FZS-IN		1234	47.82	28.45	0.583	Less than 30h
Γ_4	OUT-WHG-WHK-FZK-FZS-IN	Time	1086	342.74	23.58	0.613	none
Γ_5	The same as Γ3						Cost Less than 50
Γ_6	The same asΓ2						Cost less than 50，Safety Probability bigger than 0.7
Γ_7	The same asΓ1	Constraining Conditions					none
Γ_8	OUT-WHG-WHK-WZK-WZS-IN		1192	338.95	28.98	0.767	Less than 30h，Cost less than 350
Γ_9	The same asΓ2						Less than 40h，Cost less than 100

References

İBRAHIM, A., and BARBAROS, Ç. T. (2007). "Optimization of transportation requirements in the deployment of military units. " Computers & Operations Research, (34), 1158–1176.

JIN, Z. H., and PIAO, H. S. (2005). "YANG Hualong. Optimization of Co-ordinated Container Loading and Transportation in the Multimodal Transportation System." Systems Engineering, 23(11), 1-6.

LIU, H. X., and YANG, X. L., and ZHANG, C. B. (2010). "Application of multimodal transportation in military transportation under the military logistical environment." Logistics Sci-Tech, (12), 111-112.

LIU, J., and HE, S. W., and SONG, R., and LI, H. D. (2011). "Study on optimization of dynamic paths of intermodal transportation network based on alternative set of transport modes." Journal of the China Railway Society, 33(10): 1-6.

LIU, S., and WANG, Z. H., and JIN X. M. (2008). "A Preliminary Discussion on the Cost Model of Net-based Military Logistics ." Military Purchase and Logistics, 67-70.

UĞUR, Z. Y., and BARBAROS, Ç. T., and İHSAN, S. (2009). "A multi-modal discrete-event simulation model for military deployment." Simulation Modelling Practice and Theory, (17), 597-611.

YUAN, X. S., and SHAO, D. H., and YU, S. L. (2006). "Section 6: The Application of LINGO and Excel in Mathematic Modeling." Science Publishing House, Beijing, 6.3.
YANG, X. R., and SONG, C. P. (2008). "Optimizing model design for military transportation based on multimode transportation." Journal of Academy of Military Transportation, 10(6): 65-69.
ZHANG, J. Y., and FENG, J., and HU, J. S. (2010). "Research into optimizing the transportation mode combination of multimodal military transportation." Traffic Engineering and Technology for National Defence, (6), 24-27.
ZHANG, J., and WANG S. X., and SHEN J. (2013) "A Study on Path Optimization of Multimodal Military Transportation Based on Road Transfer." Proceedings of the 32nd Chinese Control Conference, 8097-8101.
ZHANG, Y. H., and LIN B. L., and LIANG, D., and GAO, H. Y. (2006). "Research on a generalized shortest path method of optimizing intermodal transportation problems." Journal of the China Railway Society, 28(4), 22-26.

Analysis of Logistics Network Equilibrium Assignment Framework Based on User Equilibrium

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Abstract: Logistics Network Assignment Problem is an important research field on logistics optimization. According to User Equilibrium theory, The equilibrium assignment framework of logistics network is a basic problem for it. The framework structure of logistics network consisted of carriers, logistics service providers, the shippers, and the modified Wardrop User Equilibrium of logistics network is proposed. Based on the modified UE condition, the optimum condition/equilibrium status of carriers, logistics service providers and the shippers in the equilibrium situation are analyzed.
Keywords: Logistics network; Modified user equilibrium; Equilibrium assignment framework.

1 Introduction

How to assign the flow rate and price among logistics subjects for maximizing the benefit, minimizing the cost and meeting the logistics needs in a logistics network is an important problem in logistics optimization design sector. The problem could be called Logistics Network Assignment Problem, LNAP.

The Network Assignment Problem, NAP, exists in sectors of economy, traffic, electronic power and information and raises concern of scholars. The Wardrop theory was applied in supply chain network at the first time according to the characters of traffic assignment problem (Nagurney and Dong et al., 2002). Nagurney (2003) provided a method to find out the winner supply chain in a supply chain network consisted of suppliers, manufacturers, retailers and demand markets. The super-network was used to discuss the equivalence problem between the supply chain network equilibrium and traffic network equilibrium (Nagurney, 2006). The supply chain network equilibrium problem with stochastic demand of retails was researched through a supply chain network model consisted of manufacturers and retailers (Dong and Zhang et al., 2004). The supply chain network equilibrium problem with multi-criteria decision maker was still researched (Dong and Zhang et al., 2002). The multi-commodity flow supply chain network equilibrium model with stochastic choice (Xu and Zhu, 2007), the multi-commodity flow supply chain network equilibrium model with random demand (Teng and Yao et al., 2007) and the supply chain network equilibrium model with multiclass multi-criteria stochastic choice (Xu and Zhu, 2008) were researched one by one. Zhang (2004) proposed that the assignment of logistics flow rate in logistics network should be researched via time and cost in the network.

In conclusion, there is a little research on LNAP. But LNAP has important value for recognizing the essence of logistics network and directing the logistics management and engineering in practice. This paper analyzes the equilibrium assignment framework of logistics according to the User Equilibrium theory. This is a basic problem for LNAP.

2 The Framework Structure of Logistics Network

Let the logistics network include 3 layers which are carriers, logistics service providers and shippers. The logistics network framework structure is shown as figure 1.

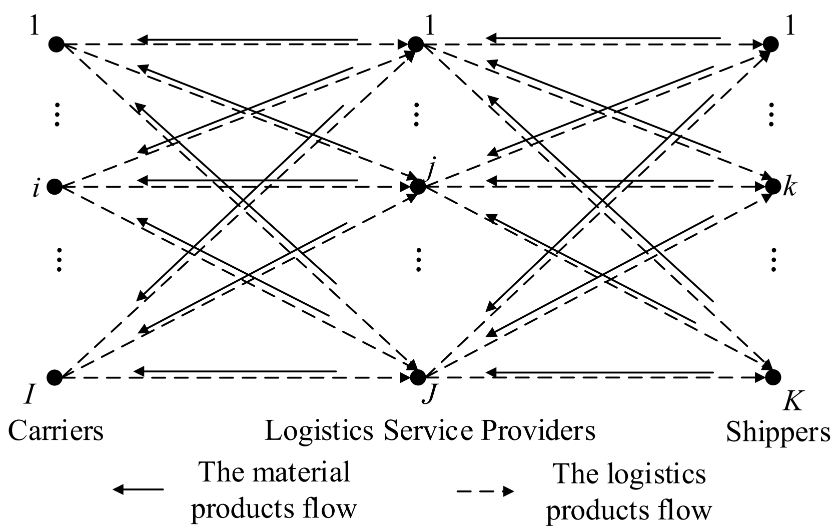

Figure 1. the Logistics Network Framework Structure

The nodes mean logistics activity participants. The directed arcs mean there are connections between the nodes which are connected by the arc. And the arcs also mean there are the flow of material product or the flow of logistics product between them.

Because the participants in the same layer provide the same products or services, there are competition relationships among them. For accomplishing the trade, consuming the logistics products and forming the flow of the material products, there are cooperation relationships among the participants in the adjacent layer. The Nash equilibrium could be used to describe the competition status of the participants in the same layer. They have the equilibrium status or optimum condition if they are in the Nash equilibrium points. The modified Wardrop User Equilibrium could be used to describe the status of whole logistics network, which is *the shippers in logistics network will choose the minimum cost path and make the network to reach the equilibrium status in which the cost of the used paths will be equal and not more than the cost of the unused*. The participants in every layer have the equilibrium status or optimum condition in the equilibrium status according to the equilibrium theory and competition/cooperation situation. The carriers and the logistics service providers pursue the minimum cost and reach the optimum condition. The shippers choose the minimum price of logistics products provided by different logistics service providers and reach the equilibrium status. The whole logistics network reach the equilibrium status if the participants in 3 layers reach the equilibrium status/optimum condition at the same time.

3 The Equilibrium Status/Optimum Condition of Participants in Logistics Network

3.1 The Optimum Condition of Carriers

Assume the carriers obey the rational-economic assumption. Let q_i be logistics product output of the carrier i, then the output of all carriers could be denoted by column vector $q \in R_+^I$, $q = (q_1,\ldots,q_i,\ldots,q_I)^T$. The carrier i will spend product cost f_i for manufacturing logistics products. Because of the competition among the carriers, the product cost function of the carrier i has relationships with output q of all carriers and product time t. then the f_i is

$$f_i = f_i(q,t), \forall i \in I \tag{1}$$

Every carrier would trade with every logistics service provider of the adjacent layer in logistics network. Then there are logistics product volume q_{ij} between the carrier i and the logistics service provider j. carriers must ensure all logistics products could be sold to logistics service providers for the maximum profit. In other word, carriers must ensure flow conservation between them and logistics service providers. That is

$$q_i = \sum_{j=1}^{J} q_{ij} \tag{2}$$

So the logistics product trade volume between all carriers and logistics service providers could be denoted by IJ dimension column vector Q^1, $Q^1 = \left(Q_1^1, \ldots, Q_i^1, \ldots, Q_I^1\right)^T$, $Q_i^1 = \left(q_{i1}, \ldots, q_{ij}, \ldots, q_{iJ}\right)^T$.

The trade cost c_{ij} of the carrier i is

$$c_{ij} = c_{ij}\left(q_{ij}\right) \tag{3}$$

The c_{ij} could be all cost that the carrier i spends for the successful trade with the logistics service provider j.

According to the rational-economic assumption, the objective of the carrier i is the maximum profit. Let P_{1ij} be the product price of the carrier i who sales the product to logistics service provider j, then the optimizing model is

$$\max z_1 = \sum_{j=1}^{J} p_{1ij} q_{ij} - f_i(q, w^1) - \sum_{j=1}^{J} c_{ij}\left(q_{ij}\right) \tag{4}$$

$$\text{s.t.} \quad q_{ij} \geq 0, \forall j \tag{5}$$

Equation (5) shows that the trade volume between the carrier i and the logistics service provider j is non-negative.

3.2 The Optimum Condition of Logistics Service Provider

Logistics service providers trade with carriers and shippers at the same time. They satisfy the demands of carriers and shippers depend on their understanding of the supply and demands in the logistics market. Logistics service providers purchase logistics products from carriers, and sale these things to shippers according to their demands. The logistics service provider j should spend management cost c_j for doing these things. And c_j has relationship with $\sum_{i=1}^{I} q_{ij}$ obviously, then c_j is

$$c_j = c_j(Q^1), \forall j \in J \tag{6}$$

According to the rational-economic assumption, the objective of the logistics service provider j is the maximum profit. Let p_{2j} be product sale price of the logistics service provider j who provides logistics products to shippers, and q_{jk} be logistics product volume between the logistics service provider j and the shipper k, then the optimizing model is

$$\max z_2 = \sum_{k=1}^{K} p_{2j} q_{jk} - c_j(Q^1) - \sum_{i=1}^{I} p_{1ij} q_{ij} \tag{7}$$

$$\text{s.t.} \quad \sum_{k=1}^{K} q_{jk} = \sum_{i=1}^{I} q_{ij} \tag{8}$$

$$q_{ij} \geq 0, q_{jk} \geq 0, \forall i, k \tag{9}$$

Equation (8) shows that the logistics product volume which the logistics service provider j sales to all shippers equal to the volume which is purchased from the carriers. Equation (9) shows that q_{ij}, q_{jk} is non-negative.

3.3 The Equilibrium Status of Shippers

Shippers obtain logistics products with the minimum price by obeying the spatial price equilibrium theory. The shipper k could reach the equilibrium status described by the modified UE equilibrium condition between them and logistics service providers. The condition is *the prices with which the shipper purchases logistics products from the logistics service providers are equal and not more than the prices with which the shipper does not purchase the products if the shipper and all logistics service providers are in the equilibrium status*.

The trading volume of logistics products between all logistics service providers and all shippers could be denoted by JK dimension column vector Q^2, $Q^2 = \left(Q_1^2, ..., Q_j^2, ..., Q_J^2\right)^T$, $Q_j^2 = \left(q_{j1}, ..., q_{jk}, ..., q_{jK}\right)^T$. Let c_{jk} be trade cost which the shipper k spends for logistics products. And c_{jk} has relationship with $\sum_{j=1}^{J} q_{jk}$ obviously, then c_{jk} is

$$c_{jk} = c_{jk}(Q^2), \forall j \in J, \forall k \in K \tag{10}$$

Let p_{3k} be the price which the shipper k is willing to spend for logistics products, set p_3 be the prices which all shippers are willing to spend for, $p_3 = \left(p_{31}, ..., p_{3k}, ..., p_{3K}\right)$, d_k be demands of the shipper k. Because d_k has relationship with the shipper k and all other shippers, d_k is

$$d_k = d_k\left(p_3\right), \forall k \in K \tag{11}$$

If the shipper k is in the equilibrium status, the situation could be denoted by complementarity problems, that is

$$\begin{cases} \left[p_{2j} + c_{jk}\left(Q^2\right) - p_{3k}\right] \times q_{jk} = 0 \\ p_{2j} + c_{jk}\left(Q^2\right) - p_{3k} \geq 0 \\ q_{jk} \geq 0 \end{cases} \tag{12}$$

and

$$\begin{cases} \left[\sum_{j=1}^{J} q_{jk} - d_k \left(p_3 \right) \right] \times p_{3k} = 0 \\ \sum_{j=1}^{J} q_{jk} - d_k \left(p_3 \right) \geq 0 \\ p_{3k} \geq 0 \end{cases} \quad (13)$$

Equation (12) shows that if the shipper *k* chooses the logistics service provider *j* to trade in the equilibrium status, $q_{jk} > 0$ between them, the practice price of the logistics products from the logistics service provider *j* to the shipper *k* is the minimum price, then the sale price of the logistics service provider *j* p_{2j} plus the transaction cost $c_{jk}\left(Q^2\right)$ equal to the price p_{3k} which the shipper *k* is willing to pay for logistics products. On the contrary, if p_{2j} plus $c_{jk}\left(Q^2\right)$ is more than p_{3k}, the shipper *k* does not want to buy logistics products from the logistics service provider *j*, that is q_{jk}=0.

Equation (13) shows that if the shipper *k* chooses the logistics service provider *j* to trade in the equilibrium status, $p_{3k} > 0$ exists, then the trade volume between the shipper *k* and all logistics service providers is the minimum demand of the shipper *k*. Otherwise, if the shipper *k* does not want to pay for logistics products, that is p_{3k}=0, then demands of the shipper *k* is not more than logistics products volume it purchases from all logistics service providers or the logistics products could be treated as free goods. The situation is impossible in practice.

4 Conclusion

The equilibrium assignment framework of logistics network is analyzed in this paper. If logistics network is in the equilibrium status, carriers, logistics service providers must reach the optimum condition and shippers must reach the equilibrium status. Though the equilibrium status/optimum condition is proposed, the equilibrium status of whole logistics network and the model which could describe the state still need to be researched in the future.

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References

Dong, J. and D. Zhang, et al. (2002). Transp ortation and Traffic Theory in the 21st

Century. Pergamon, M. A. P. Taylor.

Dong, J. and D. Zhang, et al. (2004). "A supply chain network equilibrium model with random demands." European Journal of Operational Research 156 (1): 194-212.

Nagurney, A. (2003). Innovations in financial and economic networks. Cheltenham, England, Edward Elgar Publishing.

Nagurney, A. (2006). "On the relationship between supply chain and transportation network equilibria: A supernetwork equivalence with computations." Transportation Research Part E 42 (4): 293-316.

Nagurney, A. and J. Dong, et al. (2002). "A supply chain network equilibrium model." Transportation Research Part E 38 (5): 281–303.

Teng, C. and F. Yao, et al. (2007). "Study on Mult-i Commodity Flow Supply Chain Network Study on Mult-i Commodity Flow Supply Chain Network Equilibrium Model with Random Demand." Systems Engineering-Theory & Practice(10): 77-83.

Xu, B. and D. Zhu (2007). "A Multi-commodity Flow Supply Chain Network Equilibrium Model with Stochastic Choice." Systems Engineering - Theory & Practice(3): 82-90.

Xu, B. and D. Zhu (2008). "Supply Chain Network Equilibrium Model with Multiclass Multicriteria Stochastic Choice." Journal of System Engineering 23 (5): 547-553.

Zhang, J. (2004). Research on Theory and Methods of Forecasting & Planning Based on L-OD in Modern Logistics. Chengdu, Southwest Jiaotong University. Ph. D.

Strategy of Constructing a Green Logistics System for the Pearl River Delta

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Abstract: The paper focuses on the research of green logistics. It studies on how to constructing a green logistics system in the Pearl River Delta in detailed. It points out that only constructing an effective green logistics system in the Pearl River Delta can improve the overall development level of logistics in this area. This paper gives some suggestions on how to build a green logistics system in the Pearl River Delta in order to improve the development of green logistics. These suggestions may be include as perfecting green logistics legal system, constructing comprehensive transport system, improving green logistics technology and so on.
Keywords: The Pearl River Delta; Green logistics; Strategy; Transport system.

1 Introduction

The paper describes the definition of green logistics firstly. And the paper completely analyses the problems which exist in the development of green logistics in the Pearl River Delta, such as imperfect regional comprehensive transport system, backward green logistics technology and so on secondly. At last the paper points out some measures on how to construct a green logistics system in the Pearl River Delta in order to improve the development of green logistics. These measures may be include as perfecting green logistics legal system, constructing comprehensive transport system, improving green logistics technology and so on.

2 Connotation of Green Logistics

The rapid development of logistics industry has made positive effects on the social economy. But it also brings a series of environmental problems which seriously affected the living environment of human beings. Under this background, the idea and the method of the sustainable development theory, the circulation economic theory, the social responsibility of enterprise theory, the supply chain management theory, the government regulation theory and other basic theory are gradually introduced to the studied field of logistics. So the concept of green logistics was appeared. At present, the concept of green logistics has no uniform definition. The professor WANG (WANG Changqiong) of China defined green logistics as the process of planning, implementing, managing and controlling logistics system through advanced logistics technology and environment oriented management concept with the goals of reducing pollution emissions and resource consumptions.

The connotation of green logistics can be described as the process of establishing the environmental friendly logistics system with the participation of governments, enterprises and all social public, which can reduce consumption and pollution with the method of re-planning, reorganizing, coordinating and controlling the whole life cycle of product. The goal of the system is to improve the further development of circular economy and sustainable development. Based on the theory of corporate social responsibility and government regulation, the system integrates the ecological economy and ecological ethics thoughts into supply chain management practice.

3 Current Situation and Problems of the Development of Green Logistics in the Pearl River Delta

3.1 Current Situation of the Logistics in the Pearl River Delta

The Pearl River Delta Economic Region includes 9 cities, they are Guangzhou, Shenzhen, Zhuhai, Huizhou, Zhaoqing, Foshan, Jiangmen, Zhongshan and Dongguan and with a total area of 41600 square kilometers. The level of the logistics service in the Pearl River Delta is the most advanced among the three major economic regions, including the Pearl River Delta Region, the Yangtze River Delta Region and Bohai Region. The Pearl River Delta is gathered with the nation's largest port group, such as Guangzhou port, Shenzhen port, Zhongshan port, Zhuhai port, Humen port, Huizhou port. And among these ports, Guangzhou port and Shenzhen port are the famous international port. The Pearl River Delta has developed Airport facilities. Taking Guangzhou as the center within 200 km, there are five international airports gathered in this region. They are Guangzhou, Shenzhen, Zhuhai airport. Macau Airport and Hong Kong Airport are adjacent to this region. The Pearl River Delta has widely highway network, such as Guangzhou-Shenzhen highway, Guangzhou-Foshan highway, Foshan-Kaiping highway and so on. The two main railway lines (Beijing-Guangzhou Line and Beijing-Kowloon Line) traverse this region. These two lines are also the transportation artery of China. The Pearl River Delta has formed a comprehensive transportation system which motor and water transport are the main ways of transportation while railway and air transport are the secondary ways of transportation. Logistics enterprises in the Pearl River Delta have grown up, such as Sinotrans Guangdong Branch and PGL and so on. A number of intensive and large scale logistics distribution centers and the third party logistics enterprises have appeared.

The Pearl River Delta logistics industry has improved the regional economic development but it also has caused serious pollution to the environment. The exhaust emissions of motor vehicle, the release of noise and traffic congestion pollute the air. Excessive packaging consumes a large amount of natural resources, resulting in more and more packaging waste remained on the earth. Chemical pesticides used in the process of storage and inflammable and explosive dangerous goods moved in the process of logistics can cause pollution or damage to the surrounding environment. These factors have become invisible killer in the field of the environment.

3.2 Current Situation and Problems of the Development of Green Logistics in the Pearl River Delta

Plan (Program) for Reform and Development of the Pearl River Delta Region (2008-2020) (short for PRD) and the Twelfth Five-Year Plan for National Economic and Social Development of Guangdong Province (short for The Twelfth Five-Year Plan) provide the policy support for the development of green logistics in the Pearl River Delta. But there are still some problems exist in the development of green logistics. The main problems are the following:

(1) Imperfect legal system of green logistics

At present, there has no uniform and systemic law for green logistics in the Pearl River Delta. Each of the nine cities in the Pearl River Delta has its environmental rules, such as Guangzhou Environmental Rules, Shenzhen Environmental Rules and so on. And now there has no green logistics laws for each city, only has some relevant policies for green logistics, such as Rules on Accelerating the Development of Circular Economy for Guangzhou, Rules on Promoting Circular Economy for Shenzhen Special Economic Zone, Rules on Promoting Ecological Civilization Construction for Zhuhai Special Economic Zone and so on. These fragmentary rules can not form an effective constraint mechanism to improve the healthy development of green logistics in the Pearl River Delta.

(2) Imperfect inter-city comprehensive transportation system

The inter-city comprehensive transportation system in the Pearl River Delta is not perfect, and the regional traffic has not formed the unified planning, unified management and overall construction. On the aspect of traffic infrastructure construction, the cities constructed respectively with the result that the transportation network is uncoordinated and imperfect and the construction of the roads is redundant. For instance, the number of port, waterway, railway, air and the other transportation facilities are more than the number of the road facilities in the Pearl River Delta Region. The expressway network has already formed in the Region, but still not perfect, resulting in the partial congestion of Guangzhou-Shenzhen expressway and Guangzhou-Foshan expressway. This reduces the development speed of logistics greatly and increases the cost of logistics. In addition, the construction of transportation hubs is not perfect and the ports facilities do not have complementary advantages either on hardware or on software. This greatly weakened the comprehensive competitiveness of the Pearl River Delta port cluster. It is difficult for the Region to form a coordinated development "win-win" situation between hub ports and feeder ports.

Transportation service system in the Pearl River Delta lacks the coordinated and unified management mechanism, such as non-standard logistics technology and logistics service, poor information transfer and so on. Integration of the regional transport market has not formed. The independent development and the vicious competition between the cities prevent the orderly development of regional traffic integration of Pearl River Delta. Every departments of the comprehensive transportation are managed by different administration agencies. For instance, motor and water transport are administrated by Traffic Authority, rail transport is administrated by the Ministry of Railway, air transport is administrated by the Civil Aviation authority, municipal road, rail transit and public transport are administrated by the local governments. Although these departments are worked with higher enthusiasm, management mechanism of regional integration transportation has not been formed because of the difference on the management system and technical standards.

(3) Backward in green logistics technology

Green logistics technology refers to the greening of logistics equipment, logistics facilities, logistics technology and logistics information. At present, green logistics technology of the Pearl River Delta is backward. Unreasonable and low efficiency of energy consumption is the main problem for motor vehicles, which leads to the higher level of carbon emissions. The standards of equipments of various transport modes are not unified, such as railway containers and shipping containers with different standards, which prevent the development of multimodal transport. The standards between logistics equipment are not matched, as packaging standards and facilities standards are different, which results in the goods cannot be effectively moved in the process of transportation, warehousing, loading and unloading. At the same time, a lower mechanization and automation in logistics activities results in poor environmental performance of logistics equipment.

The current planning and construction of logistics facilities in the Pearl River Delta has less consideration on the environmental protection and sustainable development requirements. In addition, there are some problems such as redundant construction, unreasonable site selection, low efficiency in the process of the construction of ports, stations, distribution centers and other facilities and so on.

Logistics process is refers to the process that organizes each functional elements and between the functional elements of logistics, including transportation, warehousing, packaging etc.. At present, there are some problems exist in the logistics process of the Pearl River Delta, such as empty backhaul transport, repeat construction and unreasonable site selection of warehouse, excessive packaging and so on.

The problems of logistics information technology prevent the development of green logistics in the Pearl River Delta. These problems include low information acquisition speed and high error rate of Bar Code technology, high cost and poor economic performance of RFID (the technology of radio frequency identification), nonstandard format of EDI (the technology of electronic data interchange), unobvious advantages of GPS (the global positioning system) in the goods tracking and scheduling optimization of vehicle etc..

(4) Ineffectively Green supply chain system

There has no unified definition for Green supply chain now. The typical definition of green supply chain management in China is: A comprehensive modern management mode with the consideration of environmental impact and resource efficiency in the entire supply chain, which is based on green manufacturing theory and technology of supply chain management, involving the suppliers, manufacturers, retailers and users, its purpose is to make the products with the lest impact on the environment (negative effects) and the highest resource efficiency in the whole process from the material acquisition, processing, packaging, storage, transport, usage to scrap processing. At present, the greening awareness of the enterprises in the supply chain is weak. Each enterprise focuses on the economic benefits without effective measures to greening the environment. In addition, the green reverse logistics system is not perfect.

4 The Strategy for Constructing a Green Logistics System in the Pearl River Delta

4.1 To Construct the Green Logistics Law System

Perfect law system is helpful to the development of green logistics in the Pearl River Delta. The government at all levels in the Pearl River Delta should construct the green logistics law system in two aspects. One aspect is to construct the regional green logistics law system and perfect constraint mechanism and incentive mechanism. The government should strengthen the comprehensive management and coordination in production, circulation, environmental, ecological and other aspects. Some environmental laws should be promulgated, such as Recovery & Recycling law, Law of Air Pollution Control, Law of Noise Control, Law of Solid Waste Pollution Prevention and Control. The government should strengthen the enforcement of current regulations, such as Comprehensive Utilization of Resources Regulations, Packaging Materials Recycling Approach, the Old Household Appliances and Electronic Products Recovery & Recycling Regulations, Traffic Industry Environmental Protection Regulations, and so on. On the other hand, the region should innovate government administrated mechanism, especially in perfecting mechanism of logistics pollution source, mechanism of environment bearing capacity for logistics, and mechanism of logistics waste material, according to its' advantages and disadvantages, with the domestic and foreign advanced experience. Some measures can be taken in order to innovating government administrated mechanism. For example, the Pollution Levy System and License System can be implemented in the enterprises of the Pearl River Delta. The Pollution

Levy System is the system that the government charging pollution discharge fee for all kinds of enterprises, according to the amount of emission. This system has been successfully implemented in foreign countries with the good results. The License system means that the government ruled the total amount of sewage in a certain period for all enterprises, according to the environmental resources carrying capacity. The ruled total amounts of sewage are assigned to the quota way among enterprises, emission of each enterprise can be assigned to the reserved for their own use, also can be sold in the market. License system is a kind of total quantity control system, which can effectively control the cost of pollution by adopting market mechanism without the governmental intervention behavior. This system has been developed for more than ten years in the developed countries.

4.2 To Construct the Comprehensive Transportation System

The comprehensive transportation system can be constructed for the following steps in the Pearl River Delta. Firstly, the governments should overall plan and improve the infrastructure network of the regional comprehensive transportation. The region should integrate the existing transportation resources and improve the service level of integrated transportation and promote the service ability with reducing the investment. To construct the highway network, rail and intercity rail transit network, the combination of port group in the Pearl River Delta in order to promote the service ability of traffic hub. Secondly, the governments should formulate a unified regional traffic management system and standards to provide institutional guarantee for the implementation of traffic integration. To eliminate administrative barriers and make for Pearl River Delta regional transportation regulations, to break local protectionism and unify punishment standards and market access system in order to form opened transparent and unified regional transportation market. To stipulate technical standards in order to facilitate communication and coordination in the municipalities unified technology platform. For instance, the government can stipulate technical or operational standards of logistics industry in order to form standards system of logistics. Thirdly, the government should construct service system of integrated transportation. To construct international transport channels with the major coastal ports as the center and the international logistics transportation network with the airport as the center. To improve domestic logistics network, the regional distribution and courier service network. Lastly, the government should implement the integrated traffic mechanism. The region should integrate the existing traffic management departments and set up Traffic Bureau (provincial and municipal etc.). The Bureau should be a rational division of labor, well defined power and responsibility, scientific decision-making, effective supervision and implementation of the traffic management system. To form the standardized procedures for deliberation and coordination and establish the permanent coordinating office in the Pearl River Delta Region, which can resolve the problems of the integrated traffic.

4.3 To Construct the Innovation System of Green Logistics Technology

The clean energy engine should be promoted in the Pearl River Delta in order to achieve low carbon emission of the vehicle. The governments can take the following measures for constructing the innovation system of green logistics technology:

(1) To research and develop methanol, ethanol, liquefied petroleum gas (LPG), compressed natural gas (CNG) vehicles in the market.

(2) To develop the multimodal transportation greatly, increase the market coverage of railway transport, water transport and pipeline transport appropriately, reduce the amount of water transport as less as possible.

(3) To overall plan and construct logistics facilities in order to avoid the repeat construction of station, port, logistics centers and other facilities and the reasonable choice for the regional logistics nodes.

(4) To promote the development of greening organizational processes of logistics. Two steps can be taken: the first step is to realizing the greening organizational processes for each functional element of logistics. Such as green transportation, green packaging, green warehousing and so on. The second step is to realizing the greening organizational processes between different functional elements of logistics. These may be include eliminating the barrier between the functional elements of logistics, realizing the seamless connection between the elements, reducing invalid activities, effectively achieving green organization process.

(5) To improve the development of logistics information technology. The governments at all levels should encourage and support enterprises to introduce advanced information technology and management technology in order to improve the service level of logistics enterprises in the Pearl River Delta. The governments should improve the current logistics information technologies as EDI, BC, ERP, RFID, GPS and other information technology in order to solve the problems of the existing system, realize resource sharing, information exchange and data sharing among the Logistics enterprises and promote the development of green logistics in the Pearl River Delta.

4.4 To Construct the System of Green Supply Chain

Green supply chain system can be constructed in the following ways:

The first is to construct the forward green supply chain system. The enterprises should choose the green partners, which can implement the greening process of the whole product life cycle from product design, production, packaging, transport, usage to recovery. The green partners may include green suppliers, green wholesalers, green retailers and green final customers. The enterprises of the green supply chain should implement intensive, high efficiency and pollution-free operation mode. The second is to construct the recycling logistics system. Enterprises should improve the system of reverse logistics and build processing center of reverse logistics. The waste materials which produced in the process of production by the numbers of supply chain can be recovered and transported to the processing center. The recovered materials are classified in the processing center. Harmful and useless goods are eliminated timely. Recyclable goods are reprocessed into new materials which flow from the point of origin to the point of consumption and form the recycling and reuse closed-loop circulation system (as shown in Figure 1).

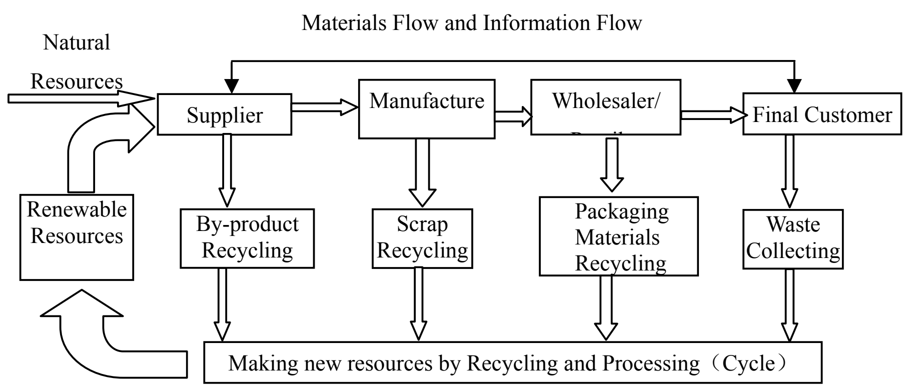

Figure 1. Recycling Logistics System

5 Conclusions

Here we may draw the following conclusions.

The government should play a vital role in improving the development of green logistics in the Pearl River Delta. It needs the joint efforts of governments, enterprises and customers.

(1) To Construct the Green Logistics Law System

(2) To Construct the Comprehensive Transportation System

(3) To Construct the Innovation System of Green Logistics Technology

(4) To Construct the System of Green Supply Chain

References

DENG Huanbin (2012). Research on Coordination Development of Regional Transport integration in the Pearl River Delta. *Doctoral Dissertation of Tsinghua University*. 118-120.

Green Supply Chain (2013). http://baike.baidu.com/view/961214.htm?fr=aladdin

SU Ming, LIN Junjie (2011). Discussion of Logistics Industry Development Strategic in Pearl River Delta. *Logistics Engineering and Management*. Vol (8):7-8.

WANG Changqiong (2009). Green Logistics. Beijing: Chemical Industry Press: 21-23, 96.

XU Xiaoping (2012). Research on Barrier Mechanism on Greening Enterprise

Logistics and the Promote Strategy. Beijing: Tsinghua University press: 24-25.

ZHENG Kejun (2009). Study on the Development of Green Logistics Based on SWOT Analysing in the Pearl River Delta. Logistics Sci-Tech. Vol (10): 29-30.

ZHONG Yonggang (2012). To Integrate Resources and Promote the Integration Traffic in the Pearl River Delta Region. *Comprehensive Transportation*. Vol (2): 32-34.

A Location Method for a Distribution Center Based on the Gravity Model and the Bi-Level Programming Model

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Abstract: This paper proposes a new method which fully considers the interests of logistics planning department and the clients. This method can define the initial solution of the Bi-level programming model by gravity model, and simplify the calculation of bi-level programming model. The numerical experiment results show that the proposed method are feasible and effective.
Keywords: Distribution center; Location; Gravity model; Bi-level model.

1 Introduction

Distribution center location has a great influence on modern logistics activities. Well located distribution centers can reduce transportation costs and improve operation efficiency. Therefore, locating distribution centers is an important decision-making problem. So far, there have been many methods and models for distribution center location. Aikens proposed 9 basic models after he had generalized the location problem of distribution center. Gravity model which is a typical continuous location model has the advantages of simple modeling and calculation, but it only considers the delivery expense without the variable costs and fixed costs based on distribution center construction and management. And the location of distribution center calculated by gravity model sometimes is unreasonable because of ignoring geographical constraints. Bi-level programming model belongs to discrete location model, it fully considers both logistics planning department and the interests of customers. The result deduced by Bi-level programming is in line with the actual situation because the alternative locations considered geographical constraints. The disadvantages of this model include uncertainty in the initial positions and complex computational procedure.

Considering the advantages and disadvantages of both models, this paper proposes a new method based on gravity model and Bi-level programming model to optimize the location of the distribution centers. The optimization process is summarized as follows:

(1) Investigate and analyze client demands and positions and unit delivery price.

(2) Establish a gravity model with the aim of minimizing total delivery expense and get a theoretical optimal solution.

(3) Considering land use planning and principle of distribution center locating, determine the finite optional positons according to the above result, which are the initial positions of bi-level programming model.

(4) Present a bi-level programming model taking into account the relationships of the distribution center layout and the service expenditure, and get an optimal solution.

2 Gravity model

2.1 Model description

Given there are n clients and client $\mathrm{j}(\mathrm{j}=1,2,\cdots \mathrm{n})$ is located at the location of (x_j, y_j). The distribution center location (x_0, y_0) is unknown, and a gravity model is presented with the aim of minimizing total delivery expense.

$$\min \mathrm{S}=\sum_{j=1}^{n} p_j d_j z_j \tag{1}$$

d_j can be calculated by equation 2.

$$d_j=\sqrt{(x_0-x_j)^2+(y_0-y_j)^2} \tag{2}$$

Where, p_j is the delivery price of per unit amount and unit distance from client j to distribution center; z_j is the demand of client j; d_j is the distance from distribution center to client j.

2.2 Model solution

The specific calculation process is described as follows:

(1) The coordinates of the center of gravity for all users is the initial location of distribution center.

$$x_0^{(0)}=\frac{\sum_{j=1}^{n} p_j z_j x_j}{\sum_{j=1}^{n} p_j z_j}, \quad y_0^{(0)}=\frac{\sum_{j=1}^{n} p_j z_j y_j}{\sum_{j=1}^{n} p_j z_j} \tag{3}$$

(2) Substitute $x_0^{(0)}$ and $y_0^{(0)}$ in equation (1) and (2), and calculate the total delivery cost $S^{(0)}$.

(3) Substitute $x_0^{(0)}$ and $y_0^{(0)}$ in equation (2) and (3), calculate a new distribution center position$(x_0^{(1)}, y_0^{(1)})$.

(4) Substitute $x_0^{(1)}$ and $y_0^{(1)}$ in equation (1) and (2), and calculate the total delivery cost $S^{(1)}$.

(5) Compare the data of $S^{(0)}$ and $S^{(1)}$: if $S^{(1)} > S^{(0)}$, return to step 3, otherwise, stop calculation. Repeat iteration until the optimal solution is found out.

3 Bi-level programming model

3.1 Model description

When determining distribution center locations, the upper-level model takes into account the interests of the decision maker, the cost of the construction of distribution centers is under investment constraint, and the goal is to minimize the general cost. The lower level model is established to minimize the clients' cost.

(1) The upper-level model

From the perspective of policy makers, the first thing is to consider the total cost, which consist of two parts: fixed cost and variable cost. At the same time, it should be considered to attract demand as much as possible.

$$\min F = \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}(X_{ij})X_{ij} + \sum_{j=1}^{n} f_j k_j - \theta \sum_{i=1}^{m}\sum_{j=1}^{n} k_j X_{ij}$$

$$\text{s.t.}\begin{cases} \sum_{j=1}^{n} f_j k_j \le B \\ \sum_{j=1}^{n} k_j \ge 1 \\ k_j = 0 \text{ 或 } 1 \end{cases} \tag{4}$$

Where, $C_{ij}(X_{ij})$ is the general service price of per unit amount and unit distance from client i to distribution center j, it increases with the increase of demand, so it is treated as a demand function. X_{ij} is the demand of client i from distribution center j. f_j is the fixed construction cost of distribution center j. B is the total investment budget. $k_j = 1$ represents to construct a distribution center in site j. $k_j = 0$ represents not to construct a distribution center in site j. θ is the coefficient of matching the total cost with customer demand for the unit.

(2) lower-level model

In the real distribution system, the demand of a certain client for a distribution center is influenced by the amount of this distribution center need delivery for all clients. For example, when a distribution center services for multiple clients, then the general service price will increase, and some clients maybe choice another distribution center. In order to describe this phenomenon, a demand function is proposed.

$$X_{ij} = D_{ij}(u_{ij}) \tag{5}$$

Where, u_{ij} is the minimum service cost of distribution center j for client i.

Normally, the form of every client's demand function is same, power function and logarithmic function are the most common forms. But for different client, the parameters are different, which can rely on data statistics.

The lower-level model is as follows:

$$\min T = \sum_{i=1}^{m}\sum_{j=1}^{n}\int_{0}^{X_{ij}} D^{-1}(t)dt$$

$$\text{s.t.}\begin{cases} \sum_{j=1}^{n} X_{ij} = W_{ij}, \quad \forall i = 1,2,\cdots,m \\ \sum_{i=1}^{m} X_{ij} \le s_j, \quad \forall j = 1,2,\cdots,n \\ X_{ij} \le Mk_j, \forall i = 1,2,\cdots,m, j = 1,2,\cdots,n \\ X_{ij} \ge 0 \end{cases} \tag{6}$$

Where: $D^{-1}(t)$ is the negative function of demand function. W_i is the total demand of client i. s_j is the supplying capacity of distribution center j. M is an arbitrarily large positive number.

3.2 Model solution

The constraint $X_{ij} \le Mk_j$ shows the relationship between the demand of clients in each distribution center and the location of the distribution centers in the equilibrium state. If $k_j = 0$ which is determined by the upper-level model, then $X_{ij} = 0$, and if $k_j = 1$, then $X_{ij} \le M$, M is an arbitrarily large positive number, it is certain this constraint can be met, it seems this constraint is unnecessary. But in order to get the reaction function, this constraint can be turned into the following form:

$$X_{ij} = Mk_j - y_{ij} \tag{7}$$

Where, y_{ij} is a slack variable. When $k_j = 0$, it is easy to determine the value of X_{ij} and y_{ij}; when $k_j = 1$, it is necessary to solve upper-level model firstly, get the value of X_{ij} in the equilibrium state, and then the value of y_{ij} is determined, it is y_{ij}^*, so all of reaction functions can be deduced:

$$X_{ij} = Mk_j - y_{ij}^* \qquad i = 1,2,\cdots,m, j = 1,2,\cdots,n \tag{8}$$

Substitute function (8) in the upper-level model, a new distribution center layout scheme is obtained, repeat the above ideas, it will be closer to the optimal solution. The specific procedure is as follows:

(1) Let $s = 0$, s is the number of iterations. Let $k_j^0 = 1, (j = 1,2,\cdots,n)$, it means all the optional positions will construct distribution centers.

(2) Substitute k_j^s in the lower-level model, and to find out the optimal solution for this model, they are X_{ij}^s $(i = 1,2,\cdots,m, j = 1,2,\cdots,n)$.

(3) Calculate the general service price C_{ij}^s according to X_{ij}^s.

(4) Calculate y_{ij}^s, substitute $X_{ij} = Mk_j - y_{ij}^s$ and C_{ij}^s in the upper-level model, and then find out a set of new optimal solutions $k_j^{s+1}, (j = 1,2,\cdots,n)$.

(5) If $|F_{s+1} - F_s| < \varepsilon$, end. Otherwise, let $s = s + 1$, and then turn to step 2. ε is the computing accuracy.

4 A practical example

4.1 Problem description

Select Dalian three largest supermarket chains Enterprise: Carrefour, Wal-Mart and the New Mart supermarket, plan to build distribution centers to the joint distribution of food for them, and the positions of the 11 clients related are shown in figure 1.

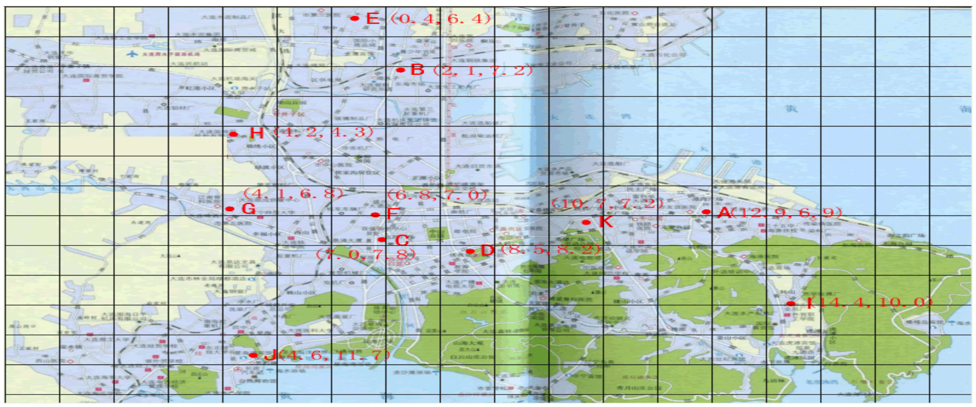

Figure 1. the positions of 11 branches

In this practical example, most of the delivery packaging is carton, the weight of these foods is light, which must be able to meet the load limit of van. But it is necessary to consider the volume of these carton. According to the characteristics of the goods, the pallet can be used in the process of logistics. Because these foods require lower bearing capacity, in order to save cost and convenient for stacking, use four-way double-faced plastic pallet is the best choice, and in order to adapt to van, the size of the pallet is 1200 x1000 (GB/T 2934-1996). Stacking height can reach 1100mm, so the unit volume is 1.32 cubic meters.

The main source of goods is other city, so it doesn't matter without respect to the positions of the upstream suppliers. The clients' demands are stable and predictable. The means of delivery is van, body size is 5300×2270×2400, and the volume is 28.87 cubic meters. Distribution centers have enough supply capacity to satisfy the clients' requirements. There are no other distribution centers have built in this region.

According to statistical data, the demands of clients are as follows (Table 1):

Table 1 the demands and coordinates of clients

NO.	A	B	C	D	E	F
coordinate	(12.9,10.0)	(2.1,7.2)	(7.0,7.8)	(8.5,8.2)	(0.4,6.4)	(6.8,7.0)
demand	13420	25440	12550	13780	16250	17890
NO.	G	H	I	J	K	
coordinate	(4.1,6.8)	(4.2,4.3)	(14.4,10.0)	(4.6,11.7)	(10.7,7.2)	
demand	10200	8600	12750	9360	15230	

4.2 The model and solution of gravity model

$$S = \sum_{j=1}^{n} p_j d_j z_j \tag{9}$$

Where, p_j is the delivery price of per unit volume and unit distance from client j to distribution center; z_j is the demand of client j; d_j is the distance from distribution center to client j.

Obviously, different from the regional distribution planning, the routes are constrained by the urban roads in city distribution, so it is unreasonable to regard straight line distance as the delivery distance. In order to correct this deviation, the delivery distance d_j is defined as linear distance multiplying by 1.41.

$$d_j = 1.41 \times \sqrt{(x_0 - x_1)^2 + (y_0 - y)^2} \tag{10}$$

Let the barycentric coordinates as initial solution based on the coordinates and demands of 11 clients, it is (6.61,7.78). And iterate aided by VB, the results are as follows (table 2):

Table 2 The results of iteration

iteration times	0	1	2	3	4	5	6	7
X	6.607	6.651	6.678	6.696	6.709	6.719	6.726	6.732
Y	7.786	7.713	7.673	7.649	7.632	7.620	7.610	7.603
S		247127	246517	246246	246102	246016	245961	245922

In fact, excessive iteration accuracy has no practical significance, so the iteration precision is 0.001, and then the end result is (6.7,7.6).

As you can see, the optimal location is near to the crossing of Xi'an road and Changjiang road, where is the busiest business district of Dalian, so it is not the suitable position for constructing a large distribution center.

4.3 The determination of optional locations

Combining with the characteristics of Dalian, it is necessary to consider the following aspects:

(1) Distribution centers should close to public transport hub, such as railway stations, highways and ports.

(2) It should be near to the main road of city.

(3) It should comply with the requirements of land use planning in Dalian.

So, four optional locations are proposed:

(1) K1 is near to Dalian locomotive plant, it is close to Shahekou railway and Xiang Lujiao overpass, where is an important transportation hub in Dalian, and there are large areas of land for construction.

(2) .K2 is near to the crossing of Changjiang road and Popular street, where is close to Dalian Port Railway Freight Station, The transportation is convenient, and there are large areas of land for construction.

(3) K3 is located in near the crossing of Xibei road and Yingke road, where is close to Zhou Shuizi Railway Station and international airport, and there are idle lands.

(4) K4 is near to heavy machinery plant, where is close to Xi'nan road, and there are large areas of land for construction.

4.4 Bi-level programming model

The lower-level model: Under the relatively single traffic environment in city, it is reasonable that the demands of clients are only under the influence of transportation cost. So the inverse function of demand function $D^{-1}(t)$ is a constant for every client and distribution centers.

$$D^{-1}(t) = A_{ij}, \quad A_{ij} = d_{ij}p \tag{11}$$

Where, p is the general service price of per unit volume and unit distance from client i to distribution center j.

The lower-level model can be written as:

$$\min T = \sum_{i=1}^{m}\sum_{j=1}^{n}\int_{0}^{X_{ij}} D^{-1}(t)dt = \sum_{i=1}^{m}\sum_{j=1}^{n} A_{ij}X_{ij} \tag{12}$$

Now, the lower-level model is transformed into a linear programming problem, it provides convenience for us to solve the model.

Let $m = 11$, $n = 4$, then calculate A_{ij}, the value is shown in table 3.

Table 3 the value of A_{ij}

A_{ij}	i = 1	2	3	4	5	6	7	8	9	10	11
j = 1	2.837	1.897	0.637	1.036	2.528	0.316	1.092	1.271	3.355	2.339	1.590
2	1.391	4.430	2.540	2.010	5.093	2.574	3.634	3.696	1.448	4.002	1.063
3	4.211	1.829	2.013	2.472	2.061	1.699	1.396	0.425	4.687	3.316	2.858
4	3.190	1.225	0.814	1.382	1.965	0.877	0.691	1.610	3.771	1.352	2.292

Due to assuming the size of distribution centers is enough to meet the demand of all clients, the constraints of lower-level model can be written as follows:

$$\text{s.t.}\begin{cases} EX = W \\ X_{ij} \le Mk_j, \forall j = 1,2,3,4; i = 1,2\cdots,11 \\ X_{ij} \ge 0, \forall j = 1,2,3,4; i = 1,2\cdots,11 \end{cases} \tag{13}$$

Where, E is a 11×44 order matrix, X is a 44×1 matrix, and W is a 11×1matrix.

$$E = \begin{pmatrix} 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & \cdots & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdots & 1 & 1 & 1 & 1 \end{pmatrix}$$

$$X^T = (X_{11,}X_{12,}X_{13,}X_{14,} \cdots, X_{11,4})$$

$$W^T = (13420, 25440, 12550, 13780, 16250, 17890, 10200, 8600, 12750, 9360, 15230)$$

Let $k_1^{(0)} = k_2^{(0)} = k_3^{(0)} = k_4^{(0)} = 1$, and substituted them in the lower-level model, the results are shown in table 4.

Table 4 the results of lower-level model

X_{ij}	i = 1	2	3	4	5	6	7	8	9	10	11
j = 1	3274	5145	1331	2069	3527	1034	1635	1561	3225	1989	3103
2	1605	12015	5309	4014	7106	8424	5441	4539	1393	3402	2075
3	4860	4960	4209	4937	2875	5563	2090	522	4506	2820	5579
4	3681	3321	1701	2760	2741	2869	1034	1978	3626	1149	4473

Then it is able to estimate the clients' distribution costs according to the above data, and the value is shown as follows (table 5):

Table 5 the clients' distribution costs

C_{ij}	i = 1	2	3	4	5	6	7	8	9	10	11
j = 1	9290	9760	847	2144	8916	327	1785	1985	10820	4651	4932
2	2232	53230	13483	8070	36191	21682	19774	16777	2017	13615	2206
3	20465	9071	8475	12206	5926	9454	2917	222	21120	9351	15948
4	11745	4066	1385	3815	5387	2515	714	3185	13675	1553	10253

It's obvious that the construction costs of distribution centers are much more than the distribution costs, according to relevant data, assume that the construction costs of each distribution center are 20000000 yuan, (f_j = 20000000). And substituted f_j = 20000000 in the upper-level model, the results of upper-level model can be obtained: $k_1^{(1)} = 1, k_2^{(1)} = 0, k_3^{(1)} = 0, k_4^{(1)} = 0$.

Because of $|F_1 - F_0| \geq 0.1$, so substitute $k_1^{(1)} = 1, k_2^{(1)} = 0, k_3^{(1)} = 0, k_4^{(1)} = 0$ in the lower-level model, and continue to the second iteration, the results are $k_1^{(2)} = 1, k_2^{(2)} = 0, k_3^{(2)} = 0, k_4^{(2)} = 0$, the iteration is end. The results show that one distribution center will be constructed , the location is K1.

5 Conclusions

This paper proposes a new method which fully considers the interests of logistics planning department and the clients. At the same time, this method can define the initial solution of the Bi-level programming model by gravity model, simplifies the calculation process of bi-level programming model. Through the example, the experiment results show that the method and the model and algorithm proposed by the authors is feasible and effective.

References

AIKENS C H. Facility. (1985). Location models for distribution planning. European Journal of Operational Research.

SUN Huijun, GAO Ziyou. (2003). Bi-level programming model and solution algorithm for the location of logistics distribution centers based on the routing problem. China Journal of Highway and Transport.

ZHAO Yangyang, ZHANG Yuxian. (2008). Optimization and application of self-owned distribution center’s location of chain supermarkets based on gravity method. Logistics Technology.

Selection of Enterprise Logistics Mode Based on Two-Tuple Linguistic and Grey Correlation Analysis

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Abstract: The manufacturing enterprise logistics is the most important part of logistics service, therefore it is of great significance to choose a reasonable logistics mode to optimize logistics activities in manufacturing enterprise. According to the results of all index evaluation on alternative logistics modes in semantics given by the experts, this paper proposes a logistics mode evaluation method based on group two-tuple linguistic and grey relational analysis. This method overcomes the defect of information distortion and loss caused in information integration and calculation. Finally, results from numerous examples show that the method presented in this paper is feasible and effective.
Keywords: Grey relational analysis; Two-tuple linguistic; Manufacturing enterprise; Logistics mode.

1 Introduction

Facing the downtrend of total profit, it is strategically decisive that a manufacturing enterprise determine a matching mode after an evaluation of different logistics modes so as to improve the logistics service efficiency. Hou and Zhang (2005) thought that the influence factors affecting selection of logistics mode were generally considered from the perspectives of balance between successful criticality and logistics management ability of the enterprise and balance between logistics service and logistics service. Zhao and others (2009) made a modeling study for three modes including self-support logistics, logistics outsourcing and combination of self-support logistics and logistics outsourcing of the enterprises, and the results indicate that profits of manufacturing enterprises and the third-party logistics enterprises increase as the outsourcing proportion increases. Regarding the selection method of logistics mode, Fei and the others (2012) analyzed factors affecting logistics mode selection of manufacturing enterprises through fuzzy comprehensive evaluation. Zhao and Luo (2013) endowed each objective with weight and found a programming solver for the model by establishing membership functions using maximum and minimum operators.

These researches were mainly on the logistics mode selection of manufacturing enterprises, and rare consideration is given directly to uncertainties in filtering logistics modes. Thus, this paper proposes an evaluation method of logistics mode based on group two-tuple linguistic and grey relational analysis model to provide manufacturing enterprises with a practical and effective guidance and assistance when selecting their logistic modes.

Analysis indicated that research on logistics mode selection of manufacturing enterprises rare consideration is given directly to uncertainties existing in filtering of logistics modes. Thus, this paper proposes an evaluation method of logistics mode based on group two-tuple linguistic and grey relational analysis model to provide practical and effective guidance and assistance in selection of manufacturing enterprises' logistics mode.

2 Factors Affecting Selection of Enterprise Logistics Mode

According to the references, main influence factors discussed in this paper are as below:

(1) Scale and strength of the enterprise. In general, enterprises with large scale and strong power will have self-built logistics systems, and ordinary small and medium-sized enterprises are more likely to select logistics outsourcing.

(2) Logistics cost. Enterprises will select a proper logistics mode to reduce their logistics cost , considering their operational characteristics and capital strength.

(3) Logistics strategic position. If an enterprise does not think its core competitiveness lies in logistics and wants to concentrate its energy and resources on the development of its core business, it will select a mode of third party logistics.

(4) Level of informatization. No matter how consumers or the main body select the mode, manufacturing enterprises themselves will propose new requirements on the application of information technology abreast of the times.

(5) Ability of logistics service. This factor directly affects consumers' comments on logistics companies, and logistics companies would work ceaselessly to improve their services to satisfy consumers' needs.

(6) Scale and strength of the third-party logistics enterprises. Enterprises have to make careful qualification and certification investigations about the scale and strength of the third-party logistics enterprise before outsourcing.

3 Two-tuple linguistic and grey correlation method

The two-tuple semantic methodology was proposed by Herrera, a Spanish scholar, for the first time in 2000. Detailed contents of **Definition1 to Definition 6** (Herrera, 2000; Herrera, 2005; Alcalá, 2007) are given below:

Definition1: If $s_k \in S$ is a language phrase, then function θ can be used to express $s_k \in S$ as corresponding two-tuple semantic form:

$$\theta : S \to S \times [-0.5, 0.5) \quad (1)$$

i.e.

$$\theta(s_k) = (s_k, 0),\ s_k \in S \tag{2}$$

Definition2: Assuming that a certain aggregation method is used to process language evaluation set S and obtain real number $\beta \in [0,T]$, there into, T represents number of elements in S, then β can represent the following two-tuple semantic information by means of function Δ:

$$\Delta: [0,T] \rightarrow S \times [-0.5, 0.5) \tag{3}$$

i.e.

$$\Delta(\beta) = \begin{cases} s_k & k = \text{round}(\beta) \\ a_k = \beta - k & a_k \in [-0.5, 0.5) \end{cases} \tag{4}$$

There into, round represents integral operator taken by rounding-off.

Definition 3: Assuming that (s_k, a_k) represents a two-tuple semantic phrase, s_k represents the k^{th} element in S and $a_k \in [-0.5, 0.5)$, then there must be an inverse function Δ^{-1} which shall be converted into a corresponding numerical value $\beta \in [0,T]$.

$$\Delta^{-1}: S \times [-0.5, 0.5) \rightarrow [0,T] \tag{5}$$

i.e.

$$\Delta^{-1}(s_k, a_k) = k + a_k = \beta \tag{6}$$

Assuming that (s_k, a_k) and (s_l, a_k) represent two-tuple semantic phrase, comparison of (s_k, a_k) and (s_l, a_k) must satisfy the following provisions:

(1) If $k < l$, then $(s_k, a_k) < (s_l, a_k)$;

(2) If $k = l$,

$a_k = a_l$, then $(s_k, a_k) = (s_l, a_k)$;

$a_k < a_l$, then $(s_k, a_k) < (s_l, a_k)$;

$a_k > a_l$, then $(s_k, a_k) > (s_l, a_k)$

Definition 4: Assuming that $\{(s_1,a_1),(s_2,a_2),\cdots,(s_n,a_n)\}$ is a set of two-tuple semantic information, then two-tuple semantic can be expressed as

$$(s,a)=\Delta\left(\frac{1}{n}\sum_{j=1}^{n}\Delta^{-1}(s_j,a_j)\right), s\in S, a\in[-0.5,0.5) \tag{7}$$

Definition 5: Assuming that a set of two-tuple semantic information is expressed as $\{(s_1,a_1),(s_2,a_2),\cdots,(s_n,a_n)\}$ and corresponding two-tuple semantic weight vector is expressed as $\boldsymbol{W}=\{(\omega_1,\beta_1),(\omega_2,\beta_2),\cdots,(\omega_n,\beta_n)\}$, then two-tuple semantic based weighted arithmetic averaging can be expressed as:

$$(s,a)=\Delta\left(\frac{\sum_{j=1}^{n}\Delta^{-1}(\omega_j,\beta_j)\times\Delta^{-1}(s_j,a_j)}{\sum_{j=1}^{n}\Delta^{-1}(\omega_j,\beta_j)}\right), s\in S, a\in[-0.5,0.5) \tag{8}$$

Definition 6: Assuming that (s_α,a_α) and (s_β,a_β) represent two pieces of two-tuple semantic information, then their distance is defined as:

$$d\left((s_\alpha,a_\alpha),(s_\beta,a_\beta)\right)=\Delta\left(\left|\Delta^{-1}(s_\alpha,a_\alpha)-\Delta^{-1}(s_\beta,a_\beta)\right|\right) \tag{9}$$

Assuming that decision maker $\mathrm{EXP}_k\in EXP(k\in T)$ properly measures alternative logistics mode $\mathrm{MO}_i\in MO(i\in M)$ relevant to evaluation indicator $\mathrm{EG}_j\in EG(j\in N)$ and obtains that attribute value of MO_i relevant to EG_j is $r_{ij}^{(k)}\in S$, and then builds language decision-making matrix $\boldsymbol{R}_k=\left[r_{ij}^{(k)}\right]_{m\times n}$ accordingly. Decision maker $\mathrm{EXP}_k\in EXP(k\in T)$ evaluates weight of indicator $\mathrm{EG}_j\in EG(j\in N)$ and estimates that weight of MO_i relevant to EG_j is $\boldsymbol{W}_k=\omega_j^{(k)}(\omega_j^{(k)}\in S)$. According to Definition1, convert matrix $\boldsymbol{R}_k=\left[r_{ij}^{(k)}\right]_{m\times n}$ into corresponding two-tuple semantic decision-making matrix $\boldsymbol{R}_k=\left[r_{ij}^{(k)},0\right]_{m\times n}$, at the same time, convert language weight $\boldsymbol{W}_k=\omega_j^{(k)}(\omega_j^{(k)}\in S)$ into corresponding two-tuple semantic weight $\boldsymbol{W}_k = \left(\omega_j^{(k)}, 0\right)$.

4 Specific Calculating Steps

Step 1: Aggregate evaluation information in two-tuple semantic form into group comprehensive evaluation information. Use equation of two-tuple semantic arithmetic averaging to obtain group comprehensive evaluation matrix $\boldsymbol{MIR} = \left[r_{ij}, a_{ij}\right]_{m\times n}$ and group attribute weight $\boldsymbol{MW} = \left\{(\omega_1, \beta_1), (\omega_2, \beta_2), \cdots, (\omega_n, \beta_n)\right\}$ respectively. Define computational equation of $\boldsymbol{MIR} = \left[r_{ij}, a_{ij}\right]_{m\times n}$ as:

$$\left(r_{ij}, a_{ij}\right) = \Delta\left(\frac{1}{t}\sum_{k=1}^{t}\Delta^{-1}\left(r_{ij}^{(k)}, a_{ij}^{(k)}\right)\right), i \in M;\ j \in N \tag{10}$$

Meanwhile, define computational equation of $\boldsymbol{MW}$ as:

$$\left(\omega_j, \beta_j\right) = \Delta\left(\frac{1}{t}\sum_{k=1}^{t}\Delta^{-1}\left(\omega_j^{(k)}, \beta_j^{(k)}\right)\right), j \in N \tag{11}$$

There into, $\left(r_{ij}, a_{ij}\right)$ represents group comprehensive evaluation value of MO_i relevant to EG_j, and $\left(\omega_j, \beta_j\right)$ represents importance of each individual in the group relevant to EG_j.

Step 2: Estimate a positive ideal solution according to each solution. Express positive ideal solution of each solution as:

$$\left(r^+, a^+\right) = \left(\left(r_1^+, a_1^+\right), \left(r_2^+, a_2^+\right), \cdots, \left(r_n^+, a_n^+\right)\right)^{\mathrm{T}} \tag{12}$$

Thereinto:

$$\left(r_j^+, a_j^+\right) = \max_i \left\{\left(r_{ij}, a_{ij}\right)\right\}, j \in N \tag{13}$$

Step 3: Corresponding to the positive ideal solution, estimate correlation coefficient of each alternative solution. Define the correlation coefficient as

$$\left(\xi_{ij}^+, \eta_{ij}^+\right) = \Delta\left(\frac{\min\limits_i \min\limits_j \left|\Delta^{-1}\left(r_{ij}, a_{ij}\right) - \Delta^{-1}\left(r_j^+, a_j^+\right)\right| + \rho \max\limits_i \max\limits_j \left|\Delta^{-1}\left(r_{ij}, a_{ij}\right) - \Delta^{-1}\left(r_j^+, a_j^+\right)\right|}{\left|\Delta^{-1}\left(r_{ij}, a_{ij}\right) - \Delta^{-1}\left(r_j^+, a_j^+\right)\right| + \rho \max\limits_i \max\limits_j \left|\Delta^{-1}\left(r_{ij}, a_{ij}\right) - \Delta^{-1}\left(r_j^+, a_j^+\right)\right|}\right) \tag{14}$$

Thereinto, $\left(\xi_{ij}^+, \eta_{ij}^+\right)$ represents correlation coefficient between a certain alternative solution and the positive ideal solution, and $\rho\left(\rho \in [0,1]\right)$ represents resolution ratio which is taken as $\rho = 0.5$ in general.

Step 4: Determine degree of correlation of each alternative mode relevant to the positive ideal solution.

$$\left(\xi_i^+,\eta_i^+\right) = \Delta\left(\frac{\sum_{j=1}^{n}\Delta^{-1}\left(\omega_j,\beta_j\right)\times\Delta^{-1}\left(\xi_{ij}^+,\eta_{ij}^+\right)}{\sum_{j=1}^{n}\Delta^{-1}\left(\omega_j,\beta_j\right)}\right), i \in M \tag{15}$$

Step 5: Prioritize the alternative solutions according to the above degree of correlation. Prioritize the alternative solutions according to two-tuple semantic nature: the larger the $\left(\xi_i^+,\eta_i^+\right)$ of a certain solution is, the more precedent the corresponding solution will be.

5 Calculation Example

A large-scale daily consumer goods production enterprise finds that when the uncertainty of customers' demands increases, an enterprise should also speed up its product response accordingly. In order to further improve its logistics management level, the enterprise invites specialists and scholars from relevant sectors to research on selection of logistics mode.

Based on an analytical research of its expert team, the enterprise plans to evaluate and select among self-built logistics mode $\left(\mathrm{MO}_1\right)$, logistics outsourcing mode $\left(\mathrm{MO}_2\right)$ and logistics alliance mode $\left(\mathrm{MO}_3\right)$, and then to establish alternative mode collection $MO = \left\{\mathrm{MO}_1,\ \mathrm{MO}_2,\ \mathrm{MO}_3\right\}$ accordingly. For the purpose of evaluating the above three logistics modes accurately, the enterprise engages five experts $\mathrm{EXP}_k \in EXP\left(k = 1,2,3,4,5\right)$ from product research and development, production and marketing departments, etc., to participate in evaluation of the logistics modes. According to the research conclusions, the following six evaluation attributes are selected: enterprise's scale and strength $\left(\mathrm{EG}_1\right)$, logistics cost $\left(\mathrm{EG}_2\right)$, logistics strategic position $\left(\mathrm{EG}_3\right)$, level of informatization $\left(\mathrm{EG}_4\right)$, ability of logistics service $\left(\mathrm{EG}_5\right)$ and the third-party logistics enterprise's scale and strength

(EG_6), based on which, evaluation attribute collection $EG=\{\mathrm{EG}_1,\ \mathrm{EG}_2,\ \mathrm{EG}_3,\ \mathrm{EG}_4,\ \mathrm{EG}_5,\ \mathrm{EG}_6\}$ is developed, and used by experts as natural language scale with granularity of 7, that is $S^7=\{S_0,S_1,S_2,S_3,S_4,S_5,S_6\}$, Set evaluation criterion used by experts as a set of evaluation language phrase (FC-extremely bad, HC- very bad, C- bad, YB- just so so, Z-important, HZ- very important, FZ- extremely important). Then, expert $\mathrm{EXP}_k \in EXP(k=1,2,\cdots,5)$ properly evaluates weight of $\mathrm{EG}_j\ (j=1,2,\cdots,6)$ first to obtain weight vector of each expert.

$$\boldsymbol{W}_1=(C,HZ,HC,Z,HZ,FZ)^{\mathrm{T}};\quad \boldsymbol{W}_2=(YB,HZ,HC,Z,Z,C)^{\mathrm{T}};$$

$$\boldsymbol{W}_3=(YB,C,YB,Z,YB,Z)^{\mathrm{T}};\quad \boldsymbol{W}_4=(HC,YB,HC,C,YB,Z)^{\mathrm{T}};$$

$$\boldsymbol{W}_5=(C,Z,C,YB,HZ,YB)^{\mathrm{T}}。$$

Carry out two-tuple semantic based evaluation $r_{ij}^{(1)}\ (i=1,2,3,\quad j=1,2,\cdots,6)$ of MO_1, MO_2 and MO_3 relevant to EG_1、EG_2、EG_3、EG_4、EG_5 and EG_6. Build a language evaluation matrix corresponding to EXP_k based on this.

$$\boldsymbol{R}_1=\begin{bmatrix} C & C & HZ & YB & Z & Z \\ FZ & FC & YB & Z & C & FC \\ Z & YB & FC & C & Z & YB \end{bmatrix}$$

Similar to $\boldsymbol{R}_1$, build a language evaluation matrix corresponding to $\mathrm{EXP}_k\ (k=2,3,4,5)$.

$$\boldsymbol{R}_2=\begin{bmatrix} C & HZ & C & Z & YB & Z \\ HZ & YB & HC & Z & Z & YB \\ HZ & FZ & C & YB & YB & C \end{bmatrix}\quad \boldsymbol{R}_3=\begin{bmatrix} YB & YB & HC & FC & Z & HC \\ FZ & FZ & C & YB & Z & FZ \\ HC & HZ & YB & HC & FZ & YB \end{bmatrix}$$

$$\boldsymbol{R}_4=\begin{bmatrix} Z & YB & C & Z & Z & YB \\ HZ & Z & C & HZ & YB & HZ \\ Z & HZ & Z & HZ & C & Z \end{bmatrix} \qquad \boldsymbol{R}_5=\begin{bmatrix} YB & YB & HZ & HC & Z & HC \\ YB & YB & YB & C & HZ & YB \\ FZ & HZ & C & HC & YB & HZ \end{bmatrix}$$

In order to determine the most appropriate logistics mode, the improved grey correlation analysis method mentioned herein will be used for processing and analysis.

Step 1: According to equation (10), determine that group comprehensive evaluation matrix $\boldsymbol{MIR}$ is

$$\boldsymbol{MIR}=\begin{bmatrix} (YB,-0.2) & (YB,0.2) & (YB,0) & (C,0.4) & (Z,-0.2) & (YB,-0.4) \\ (HZ,0) & (YB,0.2) & (C,0.2) & (Z,-0.4) & (Z,-0.4) & (YB,0.4) \\ (Z,0) & (HZ,-0.2) & (C,0.2) & (C,0.4) & (Z,-0.4) & (YB,0.4) \end{bmatrix}$$

According to equation (11), determine that group attribute weight $\boldsymbol{MW}$ is

$$\boldsymbol{MW}=\big((C,0.2),(Z,-0.2),(C,-0.4),(YB,0.4),(Z,0),(Z,-0.2)\big)^{\mathrm{T}}$$

Step 2: Estimate positive ideal solution of each logistics mode according to equation (12)-(13).

$$\left(r^{+},a^{+}\right)=\big((HZ,0),(HZ,-0.2),(YB,0),(Z,-0.4),(Z,-0.2),(YB,0.4)\big)^{\mathrm{T}}$$

Step 3: Estimate degree of correlation between the three alternative logistics modes and the positive ideal solution according to equation (14).

$$\boldsymbol{MRA}=\begin{bmatrix} (FC,0.33) & (FC,0.41) & (HC,0) & (FC,0.48) & (HC,0) & (HC,-0.42) \\ (HC,0) & (FC,0.41) & (HC,-0.42) & (HC,0) & (HC,-0.15) & (HC,0) \\ (HC,-0.48) & (HC,0) & (HC,-0.42) & (FC,0.48) & (HC,-0.15) & (HC,0) \end{bmatrix}$$

Step 4: Prioritize the three logistics modes according to equation (15), the numerical value of $\left(\xi_i^{+},\eta_i^{+}\right)(i=1,2,3)$ as

$$\left(\xi_1^{+},\eta_1^{+}\right)=(HC,-0.3773);$$

$$\left(\xi_2^{+},\eta_2^{+}\right)=(HC,-0.1883);$$

$$\left(\xi_3^{+},\eta_3^{+}\right)=(HC,-0.2186).$$

Step 5: According to numerical value of $\left(\xi_i^{+},\eta_i^{+}\right)(i=1,2,3)$, prioritize the three logistics modes as

$$\mathrm{MO}_2 \succ \mathrm{MO}_3 \succ \mathrm{MO}_1$$

Therefore, the enterprise believes that the third party logistics is the optimal one.

6 Conclusions

Logistics mode is an important driver which ensures effective logistics of manufacturing enterprises. The paper puts forward an logistics evaluation method based on an analysis of group two-tuple linguistic and grey correlation. According to the core idea of traditional analysis method of grey correlation, the paper calculates the grey correlation degree of semantics between each alternative logistics mode and positive ideal point, and determines an optimal scheme according to the size of the correlation, to ensure that the scheme has the greatest degree of correlation. The method can treat the two-tuple linguistic information effectively, and can avoid defects such as information distortion and loss caused in information integration and calculation. The results of numerous experiments show that all the proposed methods are feasible and effective.

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References

Alcalá R, Alcalá-Fdez J, Herrera F, Otero J. (2007). “Genetic learning of accurate and compact fuzzy rule based systems based on the 2-tuples linguistic representation”. *International Journal of Approximate Reasoning*. 44(1):45-64.

Fei X. Y., Tang G. Y., Cao L. G.. (2012). “Study on Logistics Mode Selection for Manufacturing Enterprises in Stripping of Peripheral Businesses”. *Logistics Technology*. 31(8): 243-247.

Hou R., Zhang B. X..(2005). “Enterprises Logistics Mode and Its Dynamic Selecting Mechanism and Procedure.” *Logistics Technology*. (2): 77-79.

Herrera F, Martinez L. (2000). “A 2-tuple fuzzy linguistic represent model for computing with words”. *IEEE Transactions on Fuzzy Systems*. 8(6):746-752.

Herrera F, Martinez L, Sanchez. (2005). “Managing non-homogeneous information in group decisionmaking”. *European Journal of Operational Research*. 166(11):115-132.

Zhao F., Ma H. S., Zhang J.. (2009). “Economic Analysis of Logistics Operation by Itself and Outsourcing in Manufacturing Enterprise.” *Journal of Highway*

and Transportation Research and Development. 26(5): 142-150.
Zhao H. Y., Luo S. Q.. (2013) "Fuzzy Multi-objective Decision Model for Selection of Logistics Modes." *Logistics Technology*. 32(6): 104-107.

Buyback Contracts Considering Return Logistics Costs

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Abstract: Suppliers do not always choose the buy-back contract to achieve coordination facing with different return logistics costs. In this paper we discuss the impact of return logistics cost on supply chain coordination and effectiveness of supply chain members based on the classic newsboy model. When the retailer and the supplier have the same return logistics cost, three kinds of buy-back contract models with return logistics cost burdened by the retailer, the supplier and both parties are respectively discussed, and these three cases achieve the supply chain coordination with the same optimal quantity. When the retailer and the supplier have the different return logistics cost, we propose the member of supply chain who has lower return logistics cost undertakes the return delivery to achieve the supply chain coordination.

Keywords: Return logistics cost; Buy-back contract; Coordination.

1 Introduction

Nowadays with rapid development of electronic commerce, customer returns gradually become a kind of effective marketing tools for retailers to attract customers, while a large number of customer returns is likely to lead large retailers returns at the end of selling season. Because of that, suppliers try to change return strategies to deal with growing retailers returns.

In the decentralized supply chain, the purposes of interest among the supply chain members are conflicting, which will lead to reducing the expected profit of the supply chain, while supply chain contract can reduce the total cost of supply chain and increase the overall supply chain efficiency.

Pastemack(1985), Taylor(2001) and Webster (2000) have pointed out that the buy-back contract can encourage retailers to increase order quantity, further increasing the supplier's benefits. Jing Chen, and Ravneet Grewal (2013) show that customer returns policies can be used as competing marketing strategies. YeFei(2007) simply discussed the buyback contract with considering Return Logistics cost.

From the viewpoint of return logistics cost, we discuss its impact of supply chain coordination and effectiveness of supply chain members base on classic newsboy model.

2. Model

In this paper, we analyze retailer's return policy considering return logistics cost through a supply chain consisting of a single supplier and a single retailer. To meet market demand D, the retailer orders Q unit products from the supplier. Suppose the market demand for a non-negative continuous random variables, and.The density function of market demand D is $f(x)$, the distribution function is $F(x)$, $F(x)$ is differentiable, strictly increasing and $F(0)=0$.

Table 1. Model basic parameters

p	retail price per unit
w	supplier's wholesale price of per unit
v	the salvage value per unit
c	product cost per unit
b	the buy-back price per unit, $v<b<w$
l_r	the return logistics cost per unit that the retailer undertakes
l_s	the return logistics cost per unit that the supplier undertakes
π_{sc}	the overall supply chain expected return profit
π_s	supplier 's expected profit
π_r	retailer's expected profit

The supplier as the leader of the game firstly decides the wholesale price w and the buy-back price b, then the retailer determines its order quantity Q and sells the product at p per unit; at last the supplier arranges production based on the retailer's order quantity Q. At the end of the selling season, the supplier will buy back unsold product at b per unit, then there exists $v<b<w$. In this return process, the retailer undertakes $\varphi I(Q)$ unit unsalable product and the supplier undertakes $(1-\varphi)I(Q)$, $0\le\varphi\le 1$, while φ is the distribution rate of unsalable product between the retailer and the supplier.

Base on classic model, we define the expected sales $S(Q)=Q-\int_0^Q F(x)dx$, the expected inventory $I(Q)=Q-S(Q)$ .On the other hand, only when $l_r\varphi I(Q)+l_s(1-\varphi)I(Q)<vI(Q)$ or $l_r\varphi+l_s(1-\varphi)<v$, the supplier will choose the buyback contract, and we do our research in this rage.

The retailer's expected profit is

$$\begin{aligned}\pi_r &= pS(Q)+bI(Q)-l_r\varphi I(Q)-wQ \\ &= (\mathrm{p}-b+\varphi l_r)S(Q)+(b-\varphi l_r-w)Q\end{aligned} \tag{2-1}$$

The supplier's expected profit is

$$\begin{aligned}\pi_s &= (w-c)Q-(b-v)I(Q)-(1-\varphi)l_sI(Q) \\ &= [b-v+(1-\varphi)l_s]S(Q)+[w-c-b+v-(1-\varphi)l_s]Q\end{aligned} \tag{2-2}$$

The expected profit function of supply chain is

$$\begin{aligned}\pi_{sc} &= \pi_r+\pi_s \\ &= [p-v+\varphi l_r+(1-\varphi)l_s]S(Q)+[v-c-\varphi l_r-(1-\varphi)l_s]Q\end{aligned} \tag{2-3}$$

Since $F(x)$ is strictly increasing, π_{sc} is strictly concave. The optimal order quantity of the supply chain satisfies:

$$Q_{sc}^* = F^{-1}\left(\frac{p-c}{p-v+\varphi l_r+(1-\varphi)l_s}\right) \tag{2-4}$$

The retailer's optimal order quantity satisfies:

$$Q_r^* = F^{-1}\left(\frac{p-w}{p-b+\varphi l_r}\right) \tag{2-5}$$

To simplify the model, we suppose the return logistics cost per unit represents the efficiency of logistics system. We discuss the effect of return logistics cost from two cases: the first one is when the retailer and the supplier have the same logistics efficiency, that means $l_r=l_s=l$; the second is they have different logistics efficiency, that is $l_r\neq l_s$ .We will discuss the two situations in the following parts.

3. Return logistics cost is same

In this case, three kinds of buy-back contract models are discussed in coordination with return logistics cost burdened by the retailer, the supplier or partnership. When $\varphi=1$,the retailer undertakes the cost only; When $\varphi=0$, the retailer undertakes the cost only; when $0<\varphi<1$,the retailer and the supplier share the return logistics cost.

3.1 The retailer undertakes the cost only

In this case, the retailer's expected profit:

$$\pi_r^{(1)} = pS(Q) + b_1 I(Q) - lI(Q) - wQ \\ = (p - b_1 + l)S(Q) - (w - b_1 + l)Q \tag{3-1}$$

The supplier's expected profit:

$$\pi_s^{(1)} = (w - c)Q - (b_1 - v)I(Q) \\ = (b_1 - v)S(Q) + (w - c + v - b_1)Q \tag{3-2}$$

Because $\pi_r^{(1)}$ is strictly concave and the retailer's optimal order quantity is unique. Further, $Q_r^{(1)*}$ satisfies:

$$Q_r^{(1)*} = F^{-1}\left(\frac{p - w}{p - b_1 + l}\right) \tag{3-3}$$

It is obvious the retailer's optimal order quantity decreases in the return logistics cost. In order to make the supply chain achieve coordination, it is necessary to make $Q_r^{(1)*}=Q_{sc}^*$, and we can obtain:

$$b_1 = \frac{v(p - w) + (w - c)(p + l)}{p - c} \tag{3-4}$$

When return logistics cost is burdened by the retailer only, the buy-back price increases as the return logistics cost increasing and buy-back contract can coordinate the channel only if parameters satisfy the formula (3-4).We observe the buy-back price is not related to the buy-back contract demands, but depends on the cost structure of the supply chain system.

3.2 The supplier undertakes the cost only

In this case, the retailer's expected profit:

$$\pi_r^{(2)} = (p - b_2)S(Q) - (w - b_2)Q \tag{3-6}$$

The supplier's expected profit:

$$\pi_s^{(2)} = (b_2 - v + l)S(Q) + (w - c - b_2 + v - l)Q \tag{3-7}$$

Because $\pi_r^{(2)}$ is strictly concave and the retailer's optimal order quantity is unique. Further, $Q_r^{(2)*}$ satisfies:

$$Q_r^{(2)*} = F^{-1}\left(\frac{p - w}{p - b_2}\right) \tag{3-8}$$

In order to make the supply chain achieve coordination, it is necessary to make $Q_r^{(2)*}=Q_{sc}^*$, and we obtain:

$$b_2 = \frac{(v - l)(p - w) + p(w - c)}{p - c} \tag{3-9}$$

When return logistics cost is burdened by the supplier, the supply chain cost structure satisfies formula (3-9), it can achieve supply chain coordination, and make the retailer, the supplier and supply chain profits maximized. It is inferred that the buy-back price will increase as the return logistics cost increasing from formula (3-9), and the supplier's expected profit reduces as return logistics costs increases.

3.3 Partnership share the logistics cost

In this case, the retailer's expected profit：

$$\pi_r^{(3)} = (p - b_3 + \varphi l)S(Q) - (w - b_3 + \varphi l)Q \tag{3-11}$$

The supplier's expected profit：

$$\pi_s^{(3)} = [b_3 - v + (1-\varphi)l]S(Q) + [w - c - b_3 + v - (1-\varphi)l]Q \tag{3-12}$$

Because $\pi_r^{(3)}$ is strictly concave and the retailer's optimal order quantity is unique. Further, $Q_r^{(3)*}$ satisfies:

$$Q_r^{(3)*} = F^{-1}\left(\frac{p - w}{p - b_3 + \varphi l}\right) \tag{3-13}$$

In order to make the supply chain to achieve coordination，it is necessary to make $Q_r^{(3)*}=Q_{sc}^*$, and we obtain :

$$b_3 = \frac{v(p-w) + p(w-c) + l(w - c\varphi) + l(p\varphi - p)}{p - c} \tag{3-14}$$

In this case, the overall profit of the supply chain and the profit distribution between the retailer and supplier is not related to logistics costs. While the buy-back price reduces as return logistics cost increasing, but decrease width becomes smaller, which is due to the supplier as a leader who decides the buy-back price, its impact on the buy-back price must be greater than retailers

Through 3.1-3.3, we observe that the three cases will achieve coordination with the same optimal quatity Q_{sc}^*, so we let $Q_r^{(1)*} = Q_r^{(2)*}=Q_{sc}^*$ and $Q_r^{(2)*} = Q_r^{(3)*}=Q_{sc}^*$ to obtain the relationship between b_1, b_2 and b_3.We obtain : $b_2 = b_1 - l$, $b_2 = b_3 - \varphi l$.

When the logistics efficiency is same between the retailer and the supplier, we observe that the supplier can just change the buyback price properly to make the supply chain achieve coordination.

Corollary 1: when the retailer and the supplier have the same return logistics cost, the condition of supply chain coordination is irrelevant to φ, that means no matter who undertakes the return logistics cost ,the supply chain will be coordinated at the same optimal quantity.

4. Return logistics cost is different

When the retailer and the supplier have different logistics efficiency, we analyze the problem from two aspects: the retailer has higher logistics efficiency, that is $l_r > l_s$; the supplier has higher logistics efficiency, that is $l_r < l_s$.

When $l_r < l_s$,that means the retailer has higher logistics efficiency, we analyze the formula (2-4) about Q_{sc}^*, φl_r and $(1-\varphi)l_s$ are both parts of the denominator, Q_{sc}^* will increase as the increase of φ ,we should make the value of φ larger enough and to confirm the maximum Q_{sc}^* which maximize the supply chain profit. On the other hand, we analyze the formula (2-5) and observe that when $l_r < l_s$, the retailer sacrifices some profit to achieve the supply chain coordination. Hence, we let $\varphi = 1\,(0 \le \varphi \le 1)$, the retailer who has higher logistics efficiency but lower return logistics cost undertakes the return delivery only to make the supply chain achieve the optimal.

When $l_r > l_s$,,that means the supplier has higher logistics efficiency,we analyze the formula (2-4) about Q_{sc}^*, φl_r and $(1-\varphi)l_s$ are both parts of the denominator, Q_{sc}^* will decrease as the increase of φ ,we should make the value of φ smaller enough and to confirm the maximum Q_{sc}^* which maximize the supply chain profit. On the other hand, we analyze the formula (2-5),when $l_r > l_s$, φ should be smaller enough to make the value of Q_r^* larger enough to insure the retailer's expected profit maximum. Hence, we let $\varphi = 0\,(0 \le \varphi \le 1)$, the supplier who has higher logistics efficiency but lower return logistics cost undertakes the return delivery only to make the supply chain achieve the optimal at the expense of the supplier's profit.

Corollary 2: When the retailer and the supplier have different logistics efficiency, the supply chain will achieve the maximum profit through regulating the value of φ,that means the member who has higher logistics efficiency or lower return logistics cost will undertake the return delivery.

Conclusions

We discussed the condition that the supplier chooses buyback contract from the viewpoint of the return logistics cost.

Three buy-back contract models of supply chain are discussed in coordination with return logistics cost burdened by the retailer, the supplier or partnership share when the members have the same return logistics cost. In this case, we observe that the supply chain will be coordinated with the same optimal quantity, which is irrelevant with the distribution of the return logistics cost between the members.

In this case, when the retailer undertakes the cost, it will inevitably require suppliers to raise the buy-back price to reduce the loss of profit caused by the return logistics cost. However, because the supplier's profit reduces followed by the return logistics cost increasing, then the supplier compensates for the loss of profits through reducing the buy-back price. As a leader of supply chain, the supplier's impact on the buy-back price is greater than the retailer.

When the retailer has higher logistics efficiency, the supply chain will choose the retailer to undertake the return delivery for reducing the loss caused by the return logistics cost. We observe some examples in the supply chains that cover large or mighty retailers like the Wal-Mart and Su-Ning electronics, in those supply chains, the retailers have systematic logistics systems which insure the high logistics efficiency of the supply chain.

When the supplier has higher logistics efficiency, the supply chain will choose the supplier to undertake the return delivery in order to reduce the loss caused by the return logistics cost. In this case, there are still some examples in the real market trade. Some large-scale suppliers like the automobile-suppliers will undertake the return delivery to confirm the maximum profit and efficiency of the supply chain because of the scale economies effect and their efficient logistics system.

In the end, the models show that no matter who undertakes the return logistics cost, it will make the overall profit of the supply chain reduced as the cost increases, so it is necessary to establish a reasonable and efficient logistics system for the supply chain.

References

Jing Chen, Ravneet Grewal (2013). "Competing in a supply chain via full-refund and no-refund customer returns policies" *Int. J. Production Economics* 146

Pastemack B A (1985). Optimal pricing and retrun policies for perishable commodities Management Science,4(2)166-176.

Tsay A A. (2001). “Managing retail channel, overstock: Markdown money and return policies” *Journal of Retailing*,77(2): 457-492.

V. P. L. Padmanabhan, P. L. Png.(2003). “Manufacturer' s Returns Policies and Retail Competition ” *Marketing Science*, 56(1): 81-94.

Webster S,Z K Weng (2000). A risk-free perishable item returns policy. Manufacturing &Service Operations Management 2(1):100-07.

YeFei(2007) The buy-back contract mechanism of supply chain collaboration with considering return logistics cost .Industrial Engineering Journal. 02:22-25.

Evaluation and Selection of a Third Party Logistics Supplier in a Chemical Company

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Abstract: This paper takes Chemical Company an the research subjecet, the purpose of the study is the third party logistics supplier selection of Chemical Company. This paper establishes an evaluation index system of chemical enterprises of third party logistics providers based on the study of logistics provider selection. The index system includes the the enterprise strength,the quality of service,logistics cost and service capability., including 14 detailed indicators. this paper put forward some problems in the cooperation in order to improve the performance of logistics service providers and improve the market competitiveness of Chemical Company.
Keywords: Chemical company; Third party logistics; Evaluation system.

1 Introduction

In recent years, more and more manufacturing companies have outsourced logistics services to the professional third party logistics company, therefore, professional logistics supplier's logistics service quality is directly related to both the enterprise and the customer satisfaction. Nowadays, logistics service providers offer the uneven quality of service. Enterprises need to build a suitable supplier performance evaluation index and methods of its own in the logistics supplier selection, selection and enterprise development goals of logistics service providers, build a win-win cooperation relationship, to realize the reasonable utilization of enterprise resources, so as to improve the enterprise benefits. Enterprises choose logistics service providers in accordance with enterprise development goals, build a win-win cooperation relationship, to realize the reasonable utilization of enterprise resources, so as to improve the efficiency of enterprises.

Along with the enterprise pay more and more attention to the selection of suppliers, research on logistics supplier evaluation and selection is also increasing, but the majority of these studies is to explore for supplier selection and evaluation method. Evaluation method of logistics supplier has been continuously improved, from the early according to experience, to establish quantitative mathematical model of the late selection, supplier evaluation and selection method of combining qualitative and quantitative now. Continuous research and development makes the selection method of logistics service providers become more and more, but also makes the evaluation method of suppliers is partial to theory and complexity, causes the appraisal method of the logistics service provider is not practical when it is difficult to use in practice. A simple method is not convincing, and complex method is difficult to understand and unrealistic, so how to choose an effective logistics supplier performance evaluation and selection method is the key.

2 The selection steps of third party logistics supplier

Specifically, the third party logistics supplier selection has the following steps:

(1) the demand analysis and selection of target.

Enterprises need to analyze the internal demand and the external environment before the third party logistics provider selection. Based on the demand analysis, enterprises will choose to outsource non core business, at the same time choose outsourcing business scope, finally, determine logistics supplier's ability according to the logistics demand of enterprise. The third party logistics supplier selection is not a simple process, good choice can bring a series of benefits for the enterprise, therefore the demand analysis and target selection is the foundation.

(2) the construction of evaluation index system.

The third party logistics supplier evaluation index system is the main basis to evaluate suppliers. The index system is a collection of different levels that it mainly reflects the different attributes of logistics suppliers. According to the principles of index system, this paper set up the third party logistics supplier evaluation system. All sectors of the logistics supplier evaluation index system is not the same, but to sum up, is the basic assessment from several indicators of cost, performance, customer satisfaction, delivery etc.

(3) select the candidate logistics supplier.

The team in charge of third party logistics supplier's evaluation and selection should closely connect with the purchasing, production and other departments, according to the internal and external demand, provide professional service evaluation. Assessment team lists third party logistics supplier candidates, according to the demand analysis, index system and analysis of the survey results. The candidate should be able to meet the enterprise's logistics service requirements, at the same time they should also have the intention to cooperate with enterprises.

(4) issued tenders.

After determining the third party logistics supplier, evaluation team should contact the candidates and determine whether they have the intention to cooperate with enterprises. Companies can issue bidding book to have the intention of cooperation which should indicate the specific requirements of cooperation. The tender should also indicate the service ability, quotation model and other information. Because of limited resource and energy, the candidate should not be too much. According to the actual situation, the enterprise will inspect the bidding enterprises, further understand the tender, in order to choose supplier better.

(5) the evaluation of supplier.

The supplier evaluation is based on the evaluation index system, through the investigation of related information of supplier, evaluate and select the third party logistics supplier using certain evaluation method. After evaluation, if choose success, both sides can carry out cooperation; if the choice is not successful, enterprises need to re-select.

(6) the implementation of cooperation.

The enterprise's demand is changing in the process of cooperation with logistics supplier. If the selection criteria have great change, it should be re-select logistics supplier and the original logistics suppliers should be given some time to adjust.

3. Establish the third party logistics supplier evaluation index system

3.1 selection of evaluation index

According to the actual need, enterprise which decides to outsource logistics business to the professional logistics companies should first choose supplier evaluation index. Supplier evaluation index should be selected to fit with the goal of enterprise development, also can reflect the service ability and level of supplier. Based on the research at home and abroad, combined with the actual situation of chemical industry, this paper selects the strength of enterprises, service quality, service ability and the logistics cost as a chemical industry third party logistics supplier evaluation index. Specific indicators are as follows:

(1) Strength of enterprises

Logistics enterprise's strength being strong or not is the basis of logistics service capabilities and service quality, only with strong fixed asset, financial condition, advanced information technology, it can ensure that the third party logistics companies have the ability to complete the high efficient logistics business. In a period of rapid development, the requirements of enterprise logistics service is more and more high, only powerful logistics suppliers can meet the demand of enterprise logistics.

(2) Service quality

Service quality is a very important assessment index when enterprises choose logistics outsourcing. Logistics companies only provide high quality services that can improve customer satisfaction. Enterprises that choose the high quality logistics suppliers mean that improve the operational efficiency and can improve customer satisfaction which can enhance competitiveness. Service quality is better, the possibility of further cooperation between enterprises and logistics providers is larger. Combined with the actual situation of chemical industry, this paper selects four indicators as accuracy, safety rate, loss rate, response rate.

(3) Logistics cost

Logistics cost is used to measure the service fee of logistics supplier produces in the process. Cost is the logistics supplier's largest expenditure, so reduce the logistics cost is very important. Relevant statistics show that the logistics cost in the total cost accounted for about forty percent that it is the third profit source of enterprises, thus reducing the logistics cost means to reduce the production cost that can manifest the price advantage.

(4) Service ability

The service capacity is third party logistics supplier's service skills and technology that can complete the enterprise's logistics demand. The service capacity is an important influencing factor if Logistics enterprises can complete the shipper's logistics requirements. Chemicals logistics is more dangerous so logistics providers must have stronger service ability. This paper selects four indicators as ability of emergency management, service network, cooperation ability, improvement of service ability

3.2 Test evaluation index importance

Inspection of the third party logistics supplier evaluation index can remove the index which has little influence on the evaluation results. If a certain level have m index in evaluation system, k experts were invited to review, and then analyze its opinion on statistics. Mainly in the following aspects:

（1）concentration degree ： $\tilde{E}_j = \frac{1}{k}\sum_{i=1}^{k} E_j n_{ij}$

Where $\tilde{E}_j$ denotes the concentration degree of expert evaluation for i indexes;

E_j is i index for the j level of importance degree value; n_{ij} denotes j numbers when expert evaluate i index.

（2）Discrete degree： $\delta_j = \sqrt{\frac{1}{k=1}\sum_{j=1}^{5} n_{ij}(E_j - \tilde{E}_j)}$

Where δ_j denotes the discrete degree of expert evaluation for i indexes; Contrary to the centralized degree index, if the more concentrated the expert evaluation, δ_j is relatively small, on the other hand, δ_j is relatively large.

（3） coordination degree:

Where $\tilde{E}_j$ denotes the expert's evaluation of index, the value is bigger, that the index is more important. δ_j is the concentration degree of expert opinions, the smaller the value represents the opinions of experts more concentrated. $\tilde{E}_j$ and δ_j are absolute indicators, the two value represents that the results sometimes are not entirely consistent, then use V_j to judge. The indicator is more important while V_j is smaller.

3.3 Establishment of evaluation index system

According to the actual situation of chemical industry, choose evaluation indexes of the third party logistics provider, then test the selected indicators, finally set up the third party logistics supplier evaluation index system as shown in table 1:

Table 1. Third party logistics supplier evaluation index system

Evaluation target	First level	Second levels
The third party logistics supplier selection	Enterprise Strength	Total assets
		Financial stability
		level of information technology
	Service Quality	accuracy rate
		safety rate
		response rate
		rate of loss
	Logistics Cost	transportation cost
		Warehousing cost
		Order processing cost
	Service Ability	emergency handling ability
		Service network
		cooperation ability
		improvement of service ability

The third party logistics supplier evaluation index system is a multi-level system of indicators. In this paper, the third party logistics supplier evaluation system is divided into three levels, each level indicator is the concrete development of a hierarchical index, a hierarchical index value and also by calculating the next level indicator. In this paper, the third party logistics supplier evaluation system is divided into three levels, each level indicator is the concrete development of a hierarchical index, a hierarchical index value is obtained by the next level index calculation. The third party logistics supplier selection is the object that is the target layer. The strength of the enterprise, service quality, logistics cost and service ability is second level index. The decomposition of these four indicators is third level index

.

4 Conclusions

After selecting the logistics supplier, it is the beginning of the cooperation between the two sides, but not the end. In the process of cooperation, the production enterprises must avoid leakage of internal information to external companies, at the same time in order to cooperation between the two sides can be carried out smoothly, enterprises should establish a contract with third party logistics providers.

(1) signed a valid contract

The contract should be clear formulation of the terms of the contract, try to fill with cooperation regulations in the contract, to avoid in the process of cooperation appear unclear responsibility and the enterprise internal information leakage problem. The risk of some unforeseen circumstances should also make corresponding provisions in the contract, so prevent no chapter when problems arise.

(2) Establish an information sharing mechanism

In the process of cooperation with logistics suppliers, information asymmetry is one of the most common risks that it would lead to a no-smooth cooperative information communication between the two sides. In order to reduce the risk of asymmetric information, cooperation between the two sides should establish information sharing mechanism.Through information sharing, the two sides also master the transportation planning, transportation demand, costs and other information.

References

Ellinger A E(2000) .“Improving Marketing/Logistics Cross-Functional Collaboration In the Supply Chain.” *Industrial Marketing Management,29(1):85-96.*

Wang huizhen(2011).“Evaluation of Model of Logistics Providers from the Perspective of Transaction Cost.” *Value Engineering,*Jan.15.

Wu zhe(2012).“Evaluation on Customer Satisfaction of Automatic Industry Based on AHP.” *Tianjin University,Tianjin,China.*

Yang zhensong(2013).“Research on Credit Risk Assessment of A Rural Credit Cooperative Based on AHP.” *Huazhong University of Science & Technology*

Zhou yufen(2009).“Review of Researches on theThird-Party Logistics Supplier Selection.” *Chongqing Technol Business Uniy,*Oct.11.

Logistics Cost Control Performance Evaluation of Third Party Logistics Enterprises

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Abstract: This paper brings forward the third party logistics cost management performance evaluation system, choose the transport department, storage department, information department and management department as one class index for the performance evaluation, in the foundation of one class index, choosing the appropriate level 2 index, constructing cost performance evaluation system, analyzing the logistics cost management performance.
Keywords: Logistics cost control; Performance evaluation; Third party logistics enterprises.

1 Introduction

The logistics enterprises can get the cost information of enterprise sector, besides, it can get customer cost information of enterprises through the department and customer Activity-Based Costing. The final purpose of any cost accounting method is not only to get a set of cost data. The purpose of department cost information is the internal cost control. The purpose of customer cost information is the foreign customer analysis. Thus, cost performance evaluation is the bridge of internal and external customers cost analysis of cost control. The essence of logistics cost performance evaluation is logistics cost benefit analysis which can provide valuable information for the enterprise management decision. Therefore, after the accounting of the enterprise department cost and customer cost, this article puts forward the evaluation index system based on department cost performance that its purpose is to provide the basis for the department cost control and reduce customer cost through the internal effective cost management.

2 Selection of third party logistics enterprises performance evaluation index

Many domestic and foreign scholars have done a lot of research on the choice of enterprise performance index. Objective evaluation method emphasizes the preset working target, finally compare job performance with the preset goals for comparison, find the gap, then draw a conclusion. Key performance indicators evaluation method is mainly through the clear indicators focus, select a few representative indicators of performance evaluation. The advantages of the balanced scorecard is to appraisal target localization in four dimensions of financial, customer, internal business, learning and growth which is a combination of financial factors and non-financial factors of enterprises. This paper added considerations of the target evaluation method, key performance index evaluation method and the balanced scorecard's charactics when selecting the performance evaluation indicators

(1) the selection of first level index

According to the general logistics department settings and co-ordination principle between departments of objective evaluation method, this selects the transportation department, warehousing department, information departments and administrative department as one class index of the third party logistics enterprise's performance evaluation. Objective assessment method also stressed: to determine the working -performance according to the degree of work target. The determination of target realization degree for transportation, warehousing, information and management department use industry average value for reference.

(2) the selection of second level index

According to the key performance index evaluation method, each department selected a small but representative index when selecting second level index. The thesis is the evaluation of logistics cost performance, therefore, in determining the representative index factors, the main consideration of the two indicators is the sensitive degree of logistics cost.

After determining the first level indicators and second indicators, the establishment of the framework of performance evaluation index system of the third party logistics enterprises, as shown in figure 1:

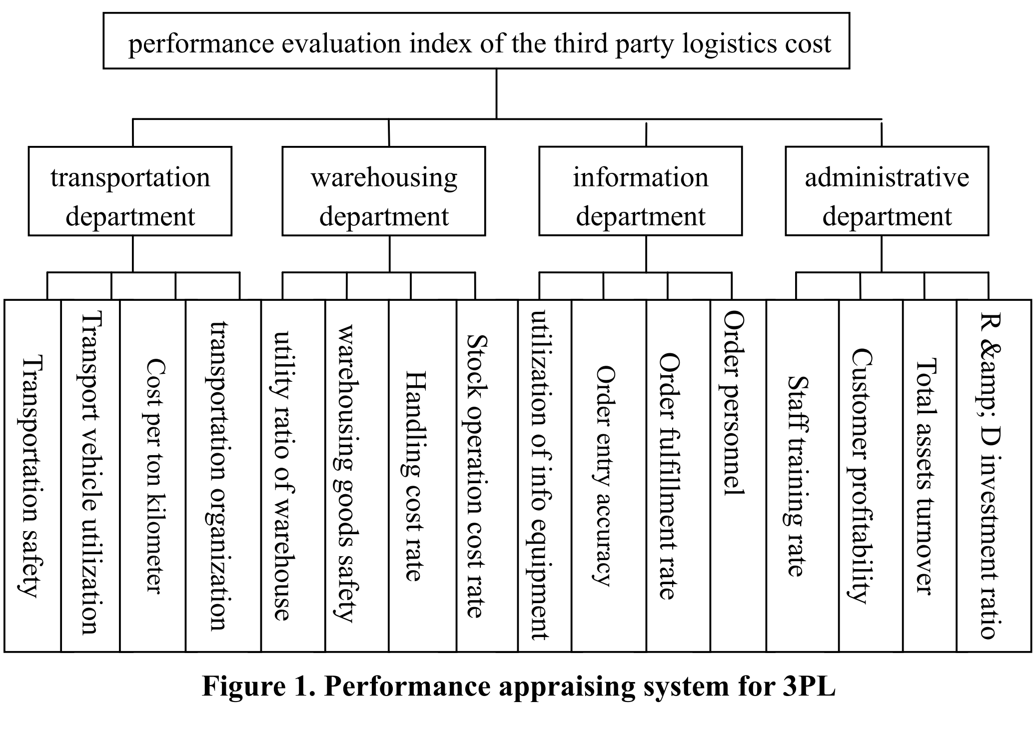

Figure 1. Performance appraising system for 3PL

3.logistics cost performance evaluation of M enterprise

(1) The relative weight of each layer elements and element combination weights are calculated by the comparison judgment matrix:According to factor's important degree judgment value table, performance evaluation index's important degree in the study of logistics experts is given the statistical summary. Construction of two two comparison judgment matrix are as follows:

Table 1. Matrix for internal department performance

department	A	B	C	D
A	1	2	3	4
B	1 / 2	1	2	3
C	1 / 3	1 / 2	1	1
D	1 / 4	1 / 3	1	1

Table 2. Matrix for transportation department performance

A	A_1	A_2	A_3	A_4
A_1	1	1 / 2	1	1
A_2	2	1	2	1
A_3	1	1 / 2	1	1
A_4	1	1	1	1

Table 3. Matrix for storage department performance

B	B_1	B_2	B_3	B_4
B_1	1	1	1	2
B_2	1	1	2	3
B_3	1	1 / 2	1	1
B_4	1 / 2	1 / 3	1	1

Table 4. Matrix for information department performance

C	C_1	C_2	C_3	C_4
C_1	1	3	2	2
C_2	1 / 3	1	1	1
C_3	1 / 2	1	1	1
C_4	1 / 2	1	1	1

Table 5. Matrix for client performance

D	D_1	D_2	D_3	D_4
D_1	1	1	1 / 5	1 / 3
D_2	1	1	1 / 2	1
D_3	5	2	1	1

D_4	3	1	1	1

(2)The relative weight of each layer elements and element combination weights are calculated by the comparison judgment matrix:

Department's comprehensive performance index weight:

W={0.47，0.28，0.14，0.11}

transportation department's comprehensive performance index weight:

WA={0.20，0.35，0.20，0.25}

warehousing department's comprehensive performance index weight:

WB={0.28，0.37，0.20，0.15}

information department's comprehensive performance index weight:

WC={0.43，0.17，0.20，0.20}

administrative department's comprehensive performance index weight:

WD={0.12，0.20，0.39，0.29}

(3)The M enterprise performance evaluation index weight value was determined, then investigate the actual value of various departments performance index. The actual and industry average value of M enterprise's performance index are as follows:

Table 5. Target value for transport department

measured value	Transportation safety	Transport vehicle utilization	Cost per ton kilometer
actual value	37 times / 104 km	83%	0.2
average value	20 times / 104 km	80%	0.15
difference	17 times / 104 km	3%	0.05

The transportation organization mode indicator is currently no quantitative method that can only rely on people to observe and record in practical work to evaluate the enterprises in transport organization efficiency, therefore, this paper is lack of the transport sector index actual value and average value of industry.

Table 6 Target value for storing department

measured value	utility ratio of warehouse	warehousing goods safety	Handling cost rate	Stock operation cost rate
actual value	98%	99%	70%	85%
average value	90%	91%	50%	75%
difference	8%	8%	20%	10%

Table 7. Target value for information department

measured value	utilization of info equipment	Order entry accuracy	Order fulfillment rate	Order personnel productivity
actual value	10%	95%	17	89%
average	30%	90%	10	80%

value				
difference	-20%	5%	7	9%

Table 8. Target value for management department

measured value	Staff training rate	Customer profitability	Total assets turnover	R & D investment ratio
actual value	60%	8	3	20%
average value	50%	13	2	30%
difference	10%	-5	1	-10%

4 Conclusions

(1)Through the investigation on the management department's important degree of second level performance indicators, find that its R&D investment important degree is 0.39 which is the highest in the four indexes. The results show that the investigation of M enterprise, its R & D investment ratio lower than the 10% average in the same industry. Although R & D investment is a cost that the development of the input and output efficiency in the logistics industry is very obvious, therefore, M enterprise's cost control in the future for the logistics management department focuses on R &D investment promotion. The Information Department of the equipment utilization rate is lower than the mean 20% of the same industry. The important degree of equipment utilization rate is 0.20 which is not the highest, but it is lower than the industry average level too high that is the important reason to reduce the information cost benefit. Therefore, consideration should be given to the company information degree when purchase of information equipment is adapt to enterprise's information development level in the future in order to make full use of the function of the equipment, to prevent waste.

Through the investigation on the transport department's important degree of second level performance indicators, find that gap between actual value of transportation safety index and the industry average is the largest of each transport sector index. The industry average level of transport accident is 20 times / 10^4km, while the M enterprise actual transport accident is 37 times / 10^4km. The important degree of transportation safety is 0.35, the highest value of four indicators, so M enterprise's cost control in the future for the transportation department focuses on strengthening the transportation safety management.

(2)According to department's comprehensive performance index weight, we can draw a conclusion that important degree of performance followed by transport department, warehousing department, information department, administration department. If the customer is not as the starting point of the cost management, only from the department, the importance of cost management can refer to the above indexes. The calculation for the weight of two level index corresponding to the various departments provides the basis for the department cost control priority. The important degree of warehousing department is 0.35. According to weight of warehousing department's two level index values, we can draw a conclusion that warehousing department's cost control order: handling, storage goods safety, utilization rate of warehouse and delivery cost of operation.

References

Liu yang and Chen dingfang(2013).“Measurement of Material Mechanical Properties Using Nanoindentation and Finite Element Simulation.”*Journal of Wuhan University of Technology(Transportation Science &Engineering) .,*Oct. 27

Qiao lulu(2011) . “Study of Automobile vehicle logistics Cost Control Performance Evaluation.” *Chang'an University,Xian,China.*

Sun gaoping (2012) .“The Study on Cold Chain Logistics Cost Accounting Based on Activity-Based Costing” *Dalian Maritime University.*

Tobias Schoenherr(2009).“Logistics and Supply Chain Management Applications Within A Global Context.”*An Overview. Journal Of Business Logistics.,* Nov.15.

Zhang binyue (2013).“Application of ABC in Design of Logistics Cost Control System.” *Logistics Technology.,*Feb.32.

The Nature and Value of Strategic Alliances in Global Logistics

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Abstract: Today, strategic alliance of global logistics is considered as a new device to raise business profit and manage contemporary logistics resource effectively. This paper will give an idea of global logistics strategic alliance in general and point out its roles in contemporary logistics and supply chain.
Keywords: Strategic alliance; Global logistics.

1 Introduction

Today, increasing number of experts and researchers generally consider the research on strategic alliance as a critical part of supply chain relationship research owing to the expansion and extension of supply chain renew contemporary logistics concept. From outsourcing to global strategic fit, there are sufficient evidence show that contemporary logistics is strategic and managerial in nature (Campbell and Reuer, 2001), which means contemporary logistics more terms global logistics management either in operation or in strategy. Therefore, strategic approach becomes the key of global logistics management to achieve competitive advantages (Parnell and Hershey, 2005), accordingly, how to identify strategic alliances and understand its value in global logistics is the focus of contemporary logistics management.

2 Global Logistics Strategic Alliance

2.1 Global logistics strategic alliance identification

In essential, strategic alliance generally refers as long-term and linked arrangements of resources among independent organizations, where the purpose of participators to win-win can be got.

Today, global logistics breaks existing border between countries and expands the process of goods movement from global sourcing to global marketplace. As a result, strategic alliance in global logistics needs to compromise to the consideration about subsidiaries enterprise in different areas and applies specifically external strategic alliance to global supply chain networks (Killing, 1995). Accordingly, strategic alliances in global logistics terms global resources arrangements related to the whole process of goods movement in the worldwide supply chain networks. In nature, such alliances put traditional strategic logistic alliance into the environment of globalization and therefore were endowed with the features that taking advantage of global resources sharing to improve the level of international logistics management (Fitzpatrick and Burke, 2000).

2.2 Requirements of global logistics strategic alliance

According to contemporary author, there are two requirements of strategic alliance: technology and trust base on contracts (Parnell & Hershey, 2005), the strategic alliances in global logistics even more strictly depend on the two dimensions (Lu and Dinwoodie, 2002). Generally, global logistics brings longer transportation line, more frequent partnership relationship and higher risk in transport. In consequence, increasingly complex global logistics operation call on more advanced technology such as EDI, RFID, bar code scanner to support these delicate process and more trust base on contracts to enhance level of cooperation between partners in the global logistics alliances (Fredendall et al., 2005).

2.3 Types of global logistics strategic alliance

Many contemporary scholars believe the typology is a so important way that it directs to the understanding about the theme. Harrison and Hoek (2005) in his book summarize the types of strategic alliances as: partnership, joint ventures and vertical integrations. Specifically, some contemporary researchers in logistics create the typology of strategic alliances in global logistics in terms of the members in global supply chain. From suppliers, intermediates to customers in worldwide countries, Handfield and Nichols (1999) divided the strategic alliances in global logistics into following three types.

2.3.1 Global supplier alliance

Firstly, strategic alliance between global manufacturers/suppliers has been used in the early 1990s to meet the increasing trade tends that need to deliver global products to customers with time efficiency. In nature, Cottrill (1997) views supplier alliance in global logistics as an efficient way to reach logistics management centralization because such alliances between suppliers can decrease the number of discrete distribution or facilities to a more manageable level through sourcing different suppliers and optimizing integrated global suppliers.

2.3.2 Strategic alliance between vendors and global logistics service providers (GLSP)

Strategic alliances between manufactures/suppliers and global logistics service providers (GLSP) is the most remarkable type because it focus on strategic planning and indicates future orientation of global logistics alliances. Contemporary GLSP involve not only global the third-party logistics companies but also carriers and warehouse operators in worldwide countries (Cottrill, 1997), so the alliances with GLSP more perform outside logistics features. Such outside logistics services make each participator concentrating on its core area of competence through expanding the continuum of outsourcing activities between manufactures and GLSP and finally can produce more competitive advantages than "in-house" logistics.

2.3.3 Strategic alliance between global vendors and customers

Strategic alliances between global manufactures/suppliers and customers need to understand each participator`s objectives (Cottrill, 1997). In "Business to Customer (B2C)" or some e-commerce industries, logistics alliance between suppliers and customer is increasingly noted by contemporary logistics research (Swaminathan and Tayur, 2003). A prominent example is that Wal-Mart created logistics strategic alliances with some vendors such as Philips Consumer Electronics, 3M and Procter and Gamble to successfully reduce inventory and other total logistics costs for either the retailers or the vendors (Mentzer et al., 2000).

Certainly, there are some other categories come from different perspectives and standards. For example, earlier in literature, the strategic alliances can be divided in two types: vertical and horizontal alliance. The vertical type is the alliances without equity investment and the horizontal type means the other alliances with equity investment. However, whether how the strategic alliance in global logistics to be sorted, any typology of strategic alliances in global logistics relates to itself value evaluation in nature.

3 Values of Global Logistics Strategic Alliance

3.1 Advantages and disadvantages of Global logistics strategic alliance

Contemporary articles are tending to emphasis the attention of logistics alliances on value of global logistics alliances. Major contemporary researchers commonly believe two things: one is that the advantages of strategic alliances outweigh the disadvantages (Daboub, 2002); the other one is international logistics management is critical for global companies to be successful or fail in global competition (Fredendall et al. 2005). These common grounds give a clue to analyze and understand the worth of logistics alliances in globalization.

At first, the merits of strategic alliances are remarkable. In detail, Daboub (2002) indicated that global strategic alliances promote global enterprise to gain competitive position. The fact is the same, for virtual contemporary global enterprise, global logistics alliance-strategy is a good way to share resources (Rondinelli and Black, 2000), mitigate risk, enhance performance (Parnell and Hershey, 2005), increase profit with cost saving and thereby achieve competitive advantages. Correspondingly, the performance of strategic alliances in global logistics is also prominent. Fitzpatrick and Burke stated in 2000 that global logistics alliances improve the global organization's logistics flexibility and resources efficiency; Halliday in 2002 illustrated that global logistics alliance as a new value-added strategy that can facilitate marketing deliver through change relationship between parties in the logistics alliances. In additional, the linked arrangements from full-orientated outsourcing to integration between worldwide suppliers and customers can lead to decrease the reorder point of inventory, change shipping strategies and in the end, resolve some traditional tradeoffs in global logistics to enhance global logistics performance with cost saving (O`Byrne, 1997).

Furthermore, the strategic alliance in global logistics would change the direction of competitive efforts toward more integrated objectives instead of separate benefits. This standpoint has been regarded as future tendency of global logistics alliance in long term. Gourdin and Clarke (1992) summarize that the success of American Desert Storm in 1991 largely consist in logistics alliance between the Department of US Defense and the American international transportation industry. Logistics alliances can cross different industries in the world is a virtual guide for global enterprise` logistics operation. However, the performance of strategic alliance in global logistics is not always so ideal.

Some contemporary authors provided disadvantages of strategic alliance in global logistics. For instance, some views acclaim that alliance in global logistics contributes poorer performance to small technology-based firms. Recently, MacGregor and Vrazalic (2005) prove this viewpoint again. They argue that in terms of the characteristics of e-commerce in small business, it is hard to utilize strategic alliances properly. As a result, alliances in this area produce negative effects. Moreover, such result is often to bring worse consequence through strategic alliance structure than through single directed unit (Starks, 2004). If considering this shortcoming as constrains of value achievement, the views on the contrary make the research of value about strategic alliance in global logistics clearer and more implicatively. It results in this topic: in what degree the strategic alliances in global logistics can efficiently achieve its value and what is the implication?

3.2 Utility of global logistics strategic alliance

It is clear that the utility of strategic alliances is the key issue in contemporary logistics literature. That means failure or success of global logistics alliances concern to whole supply chain building of global enterprise. It is undoubted that for global firms with limited foreign presence hard to improve performance in short term, strategic alliance in global logistics is the gateway to win strategic advantages in broader supply chain network. In additional, there are so many factors such as government policies, technology, infrastructures of countries , scope of the business, strategic focus and business choice of participators that any deviation of these factors may produce cushioning or aggravating impact on the performance of strategic alliance in global logistics (Baetz et al., 2002; Starks, 2004). Concretely, Kannan and Tan (2004) provide a comparison on attitude between alliance adopters and alliance non-adopters, they proved that changes in the global logistics alliances will result in different results.

Accordingly, members in contemporary logistics alliance have a closer interactional relationship and the intermediaries naturally take an unprecedented significant role. That is why so many contemporary logistics researchers consistently agree that the intermediaries like third-party service providers` performance will impact on the whole global logistics alliance itself (Abrahamsson and Wandel, 1998). This thinking has particularly given much elicitation to senior management of contemporary enterprise.

4 Conclusions

Today global logistics play increasingly significant role in global competitive economic, Strategic alliances in global logistics is an advisable consideration for the enterprise that wants to gain strategic position in global competition. In particular, better understanding about the nature of the strategic logistics alliance can usefully guide that thinking. At the same time, the utility of strategic alliances in global logistics is the issue of value evaluation because properly using global logistics alliances can help to achieve integrated success but any conditional discrepancy will lead to deviation of success.

Therefore, reasonable design and proper utility of strategic alliance in global logistics can develop the full potential of global enterprise, in the meanwhile, it is also a huge challenge for senior management. Better be aware of the advantages and disadvantages of strategic alliances in global logistics contribute to win more competitive advantages in globalization.

References

Abrahamsson, M. and Wandel, S. 1998, “A model of tiering in third-party logistics with a service parts distribution case study”, Transport Logistics, vol.1, issu3, pp.181 (14)

Campbell, Elise and Reuer, Jeffrey J. 2001, “International Alliance Negotiations: Legal Issues for General Managers”, Business Horizons, vol.44, issue 1, pp.19

Cottrill, Ken 1997, “Intermodal shipping at the crossroads”, Journal of Business Strategy, vol.18, no.3, pp. 30(6)

Daboub, Anthony J. 2002, “Strategic alliances, network organizations, and ethical responsibility”, SAM Advanced Management Journal, vol.67, issue 4, pp.40 (10)

Fitzpatrick, William M. and Burke, Donald R. 2000, “Virtual Partnering For Transactional and Relational Competitive Advantage”, Global Competitiveness, vol.8, issue 1, pp.1

Fredendall, Lawrence D., Hopkins, Christopher D. and Bhonsle, Amit 2005, “Purchasing's internal service performance: critical external and internal determinants”, Journal of Supply Chain Management, vol.41, issue 2, pp.26(13)

Gourdin, Kent N. and Clarke, Richard L. 1992, “Winning transportation partnerships: learning from the Desert Storm experience”, Transportation Journal, vol. 32, no. 1, pp.30(8)

Handfield, R. B. and Nichols, Jr., E.L. 1999, Introduction to supply chain management, Prentice Hall, Upper Saddle River, N.J.

Harrison, Alan and Hoek, Remko van 2005, Logistics management and strategy (2nd ed.), Financial Times/ Prentice Hall, Harlow, England; New York

Kannan, Vijay R. and Tan, Keah Choon 2004, “Supplier alliances: differences in attitudes to supplier and quality management of adopters and non-adopters”, Supply Chain Management, vol.9, issue 4, pp. 279(8)

Killing, J. Peter 1995, “Strategic Alliances: An Entrepreneurial Approach to Globalization”, Journal of International Business Studies, vol.26, no.2, pp. 436(4)

Lu, Yizhi and Dinwoodie, John 2002, “Comparative perspectives of international freight forwarder services in China”, Transportation Journal, vol.42, issue 2, pp.17 (11)

MacGregor, Robert C. and Vrazalic, Lejla 2005, “The effects of strategic alliance membership on the disadvantages of electronic-commerce adoption: a comparative study of Swedish and Australian regional small businesses”, Journal of Global Information Management, vol.13, issue 3, pp. 1(19)

Mentzer, John T., Zacharia, Zach G. and Min, Soonhong 2000, “The Nature of Interfirm Partnering in Supply Chain Management” (Brief Article), Journal of Retailing, vol.76, issue 4, pp. 549

O`Byrne, R. 1997, "Cross-docking-is one man`s meat another man`s poison?", Logistics Southeast Asia, vol. 3, no. 2, pp.16-19

Parnell, John A. and Hershey, Lewis 2005, “The strategy-performance relationship revisited: the blessing and curse of the combination strategy”, International Journal of Commerce and Management, vol.15, issue 1, pp.17(17)

Rondinelli, Dennis A. and Black, Sylvia Sloan 2000, “Multinational strategic alliances and acquisitions in Central and Eastern Europe: Partnerships in privatization”, The Academy of Management Executive, vol.14, issue 4, pp.85

Starks, Glenn L. 2004, “Public and private partnerships in support of Performance-Based Logistics initiatives--lessons learned from Defense Logistic Agency partnerships”, Defense A R Journal, vol.11, issue 3, pp.305(12)

Swaminathan, Jayashankar M. and Tayur, Sridhar R. 2003, “Models for supply chains in e-business”, Management Science, vol.49, issue 10, pp. 1387(20)

Optimization of Distribution Centers Based on Flexsim

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Abstract: Briefly, introduce Flexsim and a distribution center. Then, using system modeling and Flexsim to make the analysis of the distribution center. Finally, optimize the system through eliminating bottleneck and improving the equipment configuration and utilization rate.
Keywords: Flexsim; The distribution center; System simulation.

1 Introduction

A distribution center can also be called a warehouse or a package handling center. Distribution center is an economic organization, setting processing, cargo handling, shipping, and many other functions in one logistics base (LIU Lei, 2008) .

Flexsim is simulation software, widely used in the field of logistics engineering and warehousing area. This paper takes one distribution center for example. The distribution center is a storage-distribution center having a larger storage capacity. It makes the analysis using the system modeling and Flexsim to get those purposes: (1) Check the operation of the system and the flow capacity of cargo; (2) Determine its equipment parameter settings; (3) Improvement.

The layout of the distribution center is shown in Figure1. The input area is mainly responsible for receipt, inspection, sorting, etc, to achieve the transport of goods by conveyors; The role of the storage area is to store the pallets full loaded; The distribution processing zone has two districts, I and II, whose functions are same such as labeling and packaging; There are several horizontal carousels and some electronic sorting equipment in the picking area; The delivery area is mainly responsible for shipping work to distribute goods. The main working flow of the distribution center is shown in Figure2. The qualified goods enter into the input area. Later, the defective goods will be unified disposed. Logically, there are three paths for the goods stored in the storage area to directly output, namely, the distribution processing area, the picking area and the dispatch area. The principles about how to choose path are that the goods must pass the distribution processing zone and there is only one frequency. Through secondary processing, the goods are sent to different areas. The goods taken from the storage area are sent back to the storage area and others taken from the picking area are sent to the dispatch area. When receiving the delivery order, the distribution center sends the appropriate goods to the dispatch area, waiting for loading. The goods are in the dispatch area, partly from the storage area and partly from the picking area.

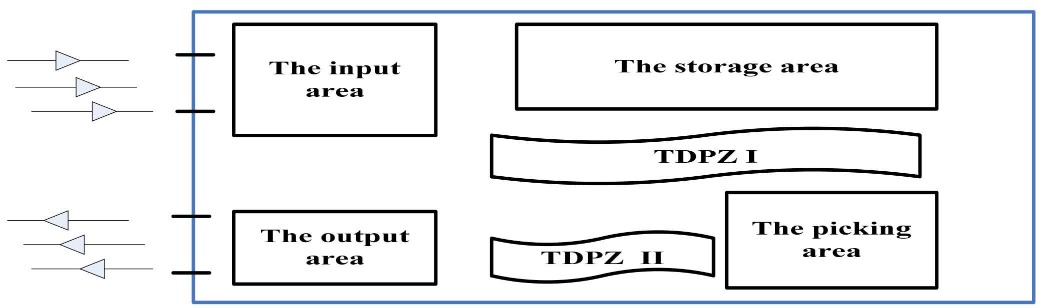

Figure1. The layout of the distribution center

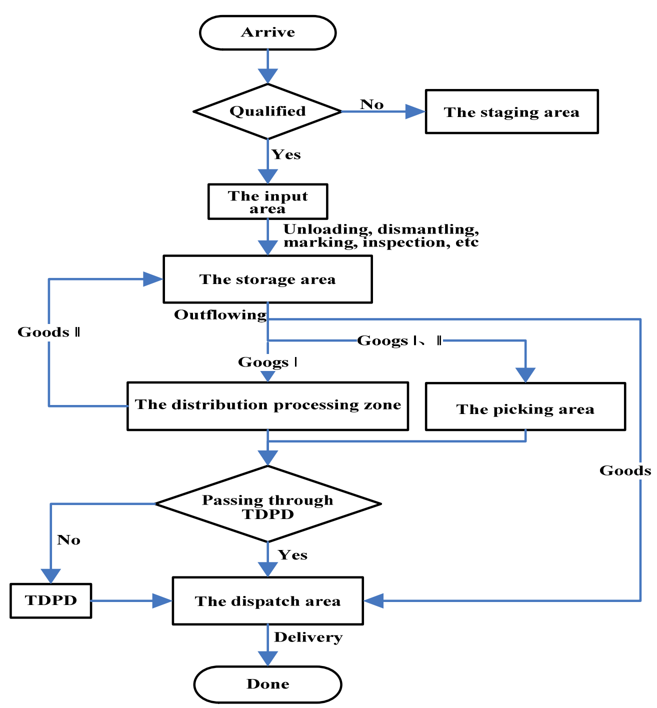

Figure2. The main working flow chart

Note: *TDPD= The distribution processing zone*

2 Building Model

Based on the spatial layout of the distribution center, its 3D model is built using Flexsim, shown in Figure3. In the model, there are many entities. *SOURCE* and *SINK* simulate the arrival and departure of goods, respectively; *CONVEYOR* simulates automatic sorting machine; *COMBINER* simulates packing operation; *PROCESSOR* simulates the delay of some time; *SEPARATOR* simulates the split of tray and so on (MA Xiangguo, 2012).

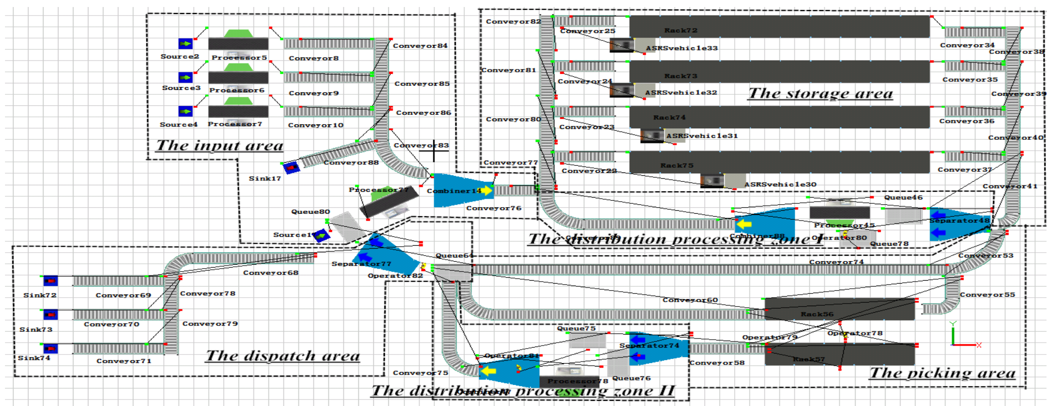

Figure3. Simulation model

Note: *The connection between entities means the logical relationships between related objects.*

The main parameters of the model: *(1)* Receiving: the arrival of goods obeys Poisson distribution, Poisson (55, 1); *(2)* Defective rate is 2.7%; *(3)* The number of trays is 300, which are generated at one time; *(4)* Every pallet loads 4 goods; *(5)* In the distribution processing zone, the operators subject to a Fixed length distribution, mean 60,70, respectively, and random number stream 1,both; *(6)* Using separator to separate the tray and the goods; *(7)* Each rack in the storage area is constituted by 10 levels by 10 bays, placing the pallet from the first available level as well as the first available bay, where the residence time of pallet obeys Poisson distribution, Poisson (7200, 1); Each rack in the distribution processing zone is constituted by 10 levels by 5 bays, placing the pallet into the cross cell of the first available level and the first available bay, where the residence time of pallet obeys Poisson distribution, Poisson (3600, 1); *(8)* The simulation time is set as 10h.

3 Simulation Result Analysis

3.1 Bottleneck analysis

There are three simulation state diagrams at three key moments (the simulation time), shown in Figure 4-6, respectively.

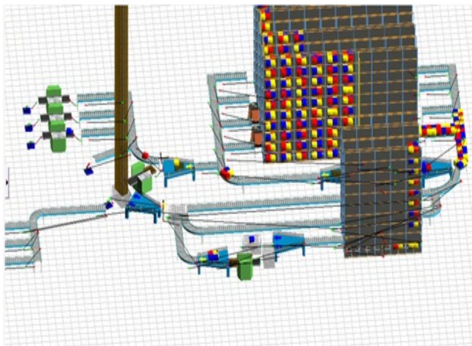

Figure4. System state at 10966.23s

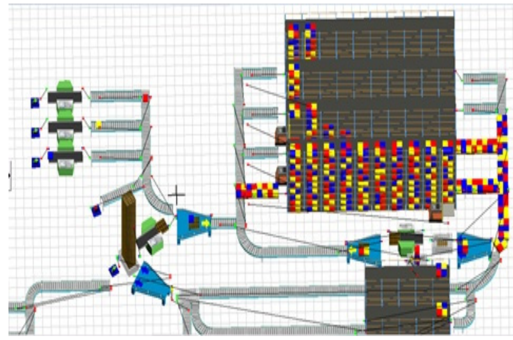

Figure5. System state at 17558.24s

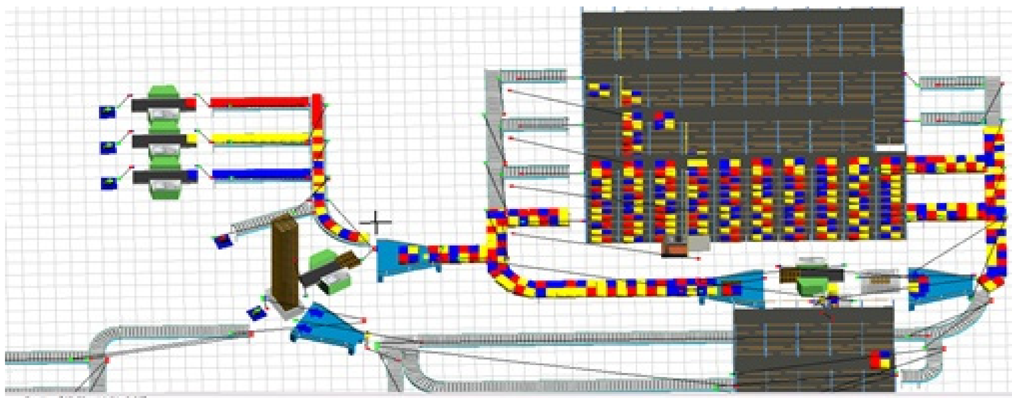

Figure6. System state at 20422.74s

The currency blockage first appears in the link of the storage area and the distribution processing zone I, then spreading to Rack75 and Conveyor22. Finally, the entire input channel is blocked. Thus, the bottleneck is in the distribution processing zone I. In addition, in the distribution processing zone I, Queue78（the Product staging area）: input = 63, output = 53; Queue46（the pallet staging area）: input = 15, output = 15. Therefore, the reason why the blocking appeared is that the goods cannot be packed timely. Namely, the cargo capacity of operator is low.

In Figure6, the entire system is in a paralyzed state. There is an interesting phenomenon at this moment about the racks in the storage area. See the following datum: Rack72: input= 30, output= 24, content= 6; Rack73: input= 28, output= 18, content= 10; Rack74: input= 64, output= 44, content= 20; Rack75: input= 134, output= 34, content = 100. So the utilization ratio of those racks in the storage area is imbalanced. Rack75 is overloaded, which is another reason for the system standstill.

To sum up, the main contradiction: Rack75 supply and operator demand are imbalanced; the secondary contradiction: misallocation of goods in the storage area and the overload operation of Rack75.

(1) Initial optimization

Add a worker, Operator83, to the distribution processing zone I; set it obey the Fixed length distribution, mean 60; set its single-carrying capacity as 2. Additionally, change some conveyors' parameter located in the storage area, shown in Table1.

Table1. The parameter sitting details in the first optimization

Entity Name	Parameter settings
Conveyor77	Set the distribution of the output port, as follows: 80% and 20% correspond to the output port 1 and 2, respectively.
Conveyor80	Set the distribution of the output port, as follows: 70% and 30% correspond to the output port 1 and 2, respectively.

When the simulation stops, the simulation result is shown in Figure7.

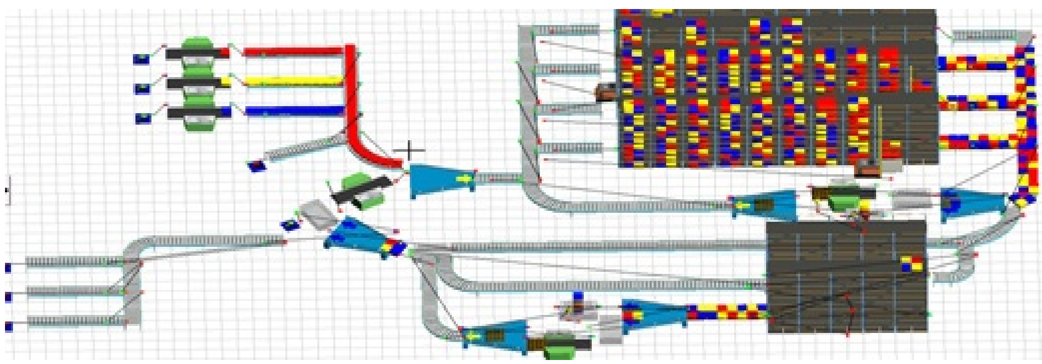

Figure7. The state of the system after the initial optimization

In Figure7, the principal contradiction has been resolved. To some extent, the congestion is alleviated. However, the further optimization has become inevitable. The similar blocking phenomenon exists in the distribution processing zone II. Meanwhile, there is the blockage of products in the storage area. The root reason is the poor secondary treatment efficiency in the distribution processing zone, leading to the consequence that the tray could not be recovered timely. Now, observe the datum, shown in Table2.

Table2. The Rack usage situation

Area	Rack	Input	Percentage	Output	Current
The storage area	Rack72	143	30.17%	126	17
	Rack73	118	24.89%	69	49
	Rack74	119	25.11%	23	96

	Rack75	94	19.83%	10	84
The picking area	Rack56	54	63.53%	48	6
	Rack57	31	36.47%	20	11

In Table2，it is clear that the situation, misallocation of goods in the storage area, has been well improved. However compared to Rack72, Rack73 and Rack74, the goods acceptance rate of Rack75 should be further improved. The distribution of goods between Rack56 and Rack57 is partly imbalanced. In fact, this uneven distribution of local task does not bring about negative effects to the overall cargo storage and the normal operation of the system. Therefore: Continue to improve the low efficiency of the secondary cargo handling in the distribution processing zone.

(2) Second optimization

After a series experiment of optimization, the solution is obtained. In the distribution processing zone, use robots to replace the operators. See Table3:

Table3. The optimization scheme

Area	Original entity	Alternatives	Parameter settings
Distribution processing I	Operator80	Robot80	Set single carrying capacity as 4; allow turning during transport
Distribution Processing II	Operator81	Robot80	Set single carrying capacity as 4, allow turning during transport

When the simulation time is 36000s, the state of system is shown as Figure 8.

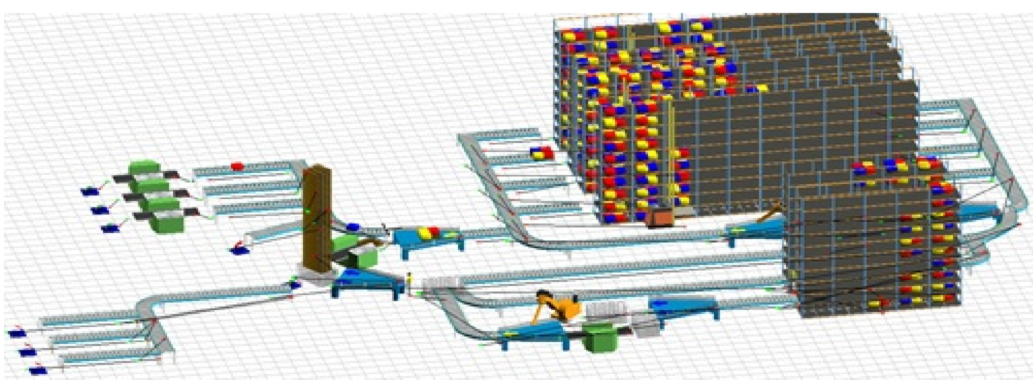

Figure8. The State diagram of the optimization result

By observing, it is clear that the main contradiction, the inefficient in the distribution processing zone, has been resolved.

3.2 Rationality analysis of the tray number

According to the optimization result, the relevant entity datum in current system can be got. The current system: input= 1964, output= 988; Queue80: content = 71, meaning that there remain 71 pallets which are redundant. Opinion: the number of pallets is irrational, which should be significantly reduced. Actually, the average utilization rate of racks in the storage area is 44.25%; the average utilization rate of racks in the picking area is 48%; the tray utilization is 76.33%. To make the distribution center achieve its desired function, the average utilization of racks is relatively low which need to be improved. Therefore, the following conclusion can be drawn: in current system, the utilization rate of racks and pallets is relatively low.

The main reason why the Cargo space utilization is low is the less supply of products. It is necessary to improve the arrival speed of goods. To further ensure the utilization of cargo space, the products minimum stay time and the upper limit of the output port at racks are set as reference variables. In addition, the tray is set to a volatile variable.

Referring to the thought of a linear equation, the premise of optimization is that selecting only one variable to optimize and setting others as constant variables in each process of iteration. After many iterative cycles, the optimal solution is got. The details of the scheme are shown in Table4. (Note: *other parameters' setting remain.*)

Table4. The changed details of the optimal scheme

Entity	Original relative settings	Current relative settings
Source2-4	The arrival of goods obeys Poisson distribution, Poisson (55, 1)	The arrival of goods obeys Poisson distribution, Poisson (50, 1)
Source17	Produce 300 pallets	Produce 320 pallets
Queue80	The maximum size is set as 320	The maximum capacity is set as 340
Rack72-75	The residence time of pallet obeys Poisson distribution, Poisson (7200,1); when the amount of storage reached 80, the Rack shuts down its input port, and while reducing the amount of storage to 20, the Rack opens its input port to restock.	The residence time of pallet obeys Poisson distribution, Poisson (9300,1); when the amount of storage reached 90, the Rack shuts down its input port, and while reducing the amount of storage to 20, the Rack opens its input port to restock.

Based on the optimization result, it can be seen that: the entire system: input= 2152, output= 832; the average utilization rate of racks in the storage area is 66%, improved by 21.75%, compared to the previous rate, 44.25%; the average goods allocation utilization of the picking area is 48%; tray utilization rate is 100%, improved by 23.67%, compared to the previous rate, 76.33%. Pallet utilization has been greatly improved. Through repeated experiments, the situation of tray shortage will not happen. Thus, the number of trays (320) is economical and reasonable.

In summary, the optimization scheme has been proved to be feasible.

4 Summary

The model of the distribution center is built by Flexsim. Based on the two phases of the optimization, the system has been greatly improved. Finally, the goal to improve the efficiency of the distribution center is achieved.

Acknowledgement

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References

LIU Lei. (2008). Distribution Center Planning and Simulation. Hunan: *Central South University*.

MA Xiangguo, Liu Tongjuan. (2012). Modern logistics system modeling, simulation and application cases. *Science Press*.

Synchronous Supply Model of the Automotive Components at an Assembly Plant

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Abstract: The problem of automotive components supply on mixed-model assembly line is more complex due to the diversification of customer demands. The process of automotive components of synchronous supply is analyzed in the paper. This paper presents a synchronous supply model of the automobile mixed-model assembly lines at the assembly plant based on time window, in which the shortest total transport distance is adopted as the objective. Finally the paper gives an example. And the result of the example indicates that this model can realize synchronous supply from material buffer points to the workstations at the assembly plant within the required time. And it is helpful to improve the efficiency of automotive components supply.
Keywords: Mixed model assembly line; Automotive components; Synchronous supply.

1 Introduction

Mixed model assembly lines are widely used in automotive industry because of its greater variety in demand. It can produce different models, different series and different colors cars as per customer's demands. The problem of automotive components supply on mixed-model assembly line is more complex than that of the single-model assembly line, because there are different parts or components in different models on mixed assembly line and the processing times for common tasks may be different. Therefore the automotive components supply on mixed-model assembly line at assembly plant has aroused the attention of scholars at home and abroad. (Choi, 2002) propose a dynamic part-feeding system for an automotive assembly line. (Jiang, 2009) put forward to a workstation distribution scheduling model to minimize the total distribution time at the assembly plant.

Mixed model assembly lines have a strong impact to improve the goal of Just in Time (JIT) and balanced production (Hu, 2011). Just-in-time (JIT) philosophy, first introduced by the Toyota Motor Co. in the late of 1970s, has attracted much interest in its basic underlying concept. (Doran, 2001) explores the differences between just-in-time (JIT) and synchronous supply based on a case study within an automotive context. Synchronous supply can be regarded as the advanced form of

JIT supply (Wang, 2005). Because the synchronous supply results in notable benefits for both buyer and supplier (Doran, 2001; Hu, 2001; Chen, 2009), it has also received considerable attention from both industry and academics.

This paper presents a synchronous supply model of the automotive components at the assembly plant, in which the shortest transport distance is adopted as the objective.

2 The process of automotive components of synchronous supply

On a just-in-time (JIT) basis, synchronous supply is essentially a system where components supplied are matched exactly to the production requirements of the buyer. Compared with traditional JIT supply, synchronous supply may be limited to the supply of a small number of key components or high value component systems within the short time window available (Doran, 2001).

Normally an automobile assembly plant consists of the main line of body, painting and assembly shops and several sub-lines feeding parts to the main-line as shown in figure1. After press shop, bodies pass several painting processes in paint shop according to the demand of customers. Then, painting body storages enter assembly shop. Some vendors supply components to assembly line based on BOM and sequencing information which are transferred from customers' demand. Vendors are required to sequence components before arriving at material buffer area. There are corresponding relations between workstations and material buffer points. If workstations need some kind of components, sequenced components will be delivered to the right workstations by the conveyance, according to material supply information.

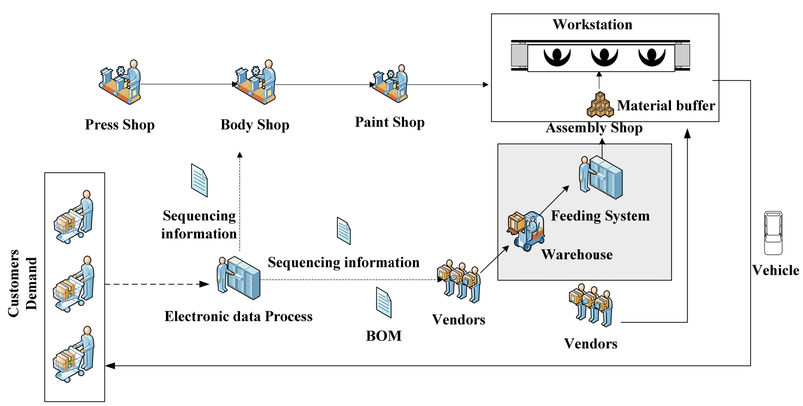

Figure1. The process of automotive components of synchronous supply

3 Components synchronous supply model at the assembly plant

In an automotive context, synchronous supply means automotive components should be supplied exactly at the right workstation of the assembly plant in required time window. The paper presents a synchronous supply model in which the shortest total transport distance is adopted as the objective.

(1) Model assumptions

1) The material buffer area beside assembly lines can meet the demands and components supply shall not exceed supply capacity.

2) The materials in one buffer point can supply one or more workstations.

(2) Definite variables

BT—the best supply time;

L_J、H_J—the lowest and highest supply time available;

T_{ij}—time from material buffer point to work station;

T'_{ij}—time from work station No. i to material buffer point No. j;

u_{ij}—transport speed of conveyance;

z_i—service time of conveyance at material buffer point.

$$x_{ij} = \begin{cases} 1, & Components\ belonged\ work\ station\ i\ stores\ in\ buffer\ poin\ j \\ 0, & or\ else \end{cases}$$

$$y_{iq} = \begin{cases} 1, & q\ conveyance\ supply\ to\ work\ station\ i \\ 0, & or\ else \end{cases}$$

$$x_{ijq} = \begin{cases} 1, & Conveyance\ q\ supply\ components\ from\ work\ station\ i\ to\ buffer\ point\ j \\ 0, & or\ else \end{cases},$$

All above, $i = 1,2, \dots m, j = 1,2, \dots n,\ \ q = 1,2, \dots Q$

(3) Model foundation

The shortest transport distance is adopted as the objective function. The model is like this:

$$\min z = \sum_{i=0}^{M} \sum_{j=1}^{N} T_{ij} \cdot u_{ij} \cdot x_{ij} + \sum_k \sum_{i=0}^{M} \sum_{j=1}^{M} T'_{ij} \cdot u_{ij} \cdot x_{ijk} \quad (1)$$

with

$$\begin{cases} BT_J = \sum_{i=1}^{J} \sum_{j=1}^{N} T_{ij} \cdot x_{ij} \cdot y_{iq'} + \sum_{i=0}^{J-1} \sum_{j=1}^{J} T'_{ij} \cdot x_{ijq'} + \sum_{i=1}^{J} z_i \cdot y_{iq'},\ \ q' = \{q | y_{Jq} = 1\} \\ L_J \le \mathrm{BT}_J \le H_J, J = 1,2, \dots m\ ; \\ T'_{ij} = T_{ij''}, j'' = \{j' | x_{jj'} = 1\} \\ \sum_q y_{iq} = 1, i = 1,2, \dots m\ ; \\ \sum_j x_{ijq} = y_{iq}(i < j); \sum_i x_{ijq} = y_{jq}(i < j); \end{cases}$$

$$x_{im} = 1 \ ; \ x_{nk} = 0$$

The model is modified as：

$$Min\left\{\sum_i \sum_j \overline{T_{ij}} \cdot u_{ij} \cdot x_{ij} - Mx_{im} + Mx_{nk} + \sum_k \sum_{i=0}^{m} \sum_{j=1}^{m} T'_{ij} \cdot u'_{ij} \cdot x_{ijk}\right\} \quad (2)$$

$$\overline{T_{ij}} = T_{ij}, \text{ except } \overline{T_{im}} = \overline{T_{nk}} = 0$$

With constrains 1:

$$\begin{cases} BT_J = \sum_{i=1}^{J}\sum_{j=1}^{N} T_{ij} \cdot x_{ij} \cdot y_{iq'} + \sum_{i=0}^{J-1}\sum_{j=1}^{J} T'_{ij} \cdot x_{ijq'} + \sum_{i=1}^{J} z_i \cdot y_{iq'}, \quad q' = \{q | y_{Jq} = 1\} \\ L_J \le \mathrm{BT}_J \le H_J, J = 1,2, \dots m \ ; \\ T'_{ij} = T_{ij''}, j'' = \{j' | x_{jj'} = 1\} \\ \sum_q y_{iq} = 1, i = 1,2, \dots m \ ; \\ \sum_j x_{ijq} = y_{iq}(i < j); \sum_i x_{ijq} = y_{jq}(i < j); \end{cases}$$

With Constrains 2:

Considering that materials of some workstations must be stored at the fixed material buffer point, the optimal solution should be constrained. If p is the number of $x_{ij} = 1$ and q is the number of $x_{ij} = 0$, the optimal solution in (2) is $opt\left(x^*\right)$. If $\left|\frac{opt\left(x^*\right) - pM}{pM}\right| < \varepsilon$, it means that the optimal solution is the feasible solution. And it's suggested that $\varepsilon = 1/_{2p}$, ε is a small positive number.

4 Analysis of an Example

There are almost 150 workstations in Guangzhou Toyota Motor Co. Ltd. In this example, workstations chosen from interior lines are divided into 6 groups, named from A1 to A6. The corresponding material buffer points are named from B1 to B5. Moreover the materials for workstation of A2 must be stored at material buffer point of B1. Table 1 shows the required time for each workstation and the travel time from material buffer points to workstations. Table 2 is the transport speed of the conveyances from material buffer points to workstations.

Table 1. Required time for each station and travel time from material buffer points to workstations

Travel time(s) / Buffer points	Work station	A1	A2	A3	A4	A5	A6
	Required time	[0,120]	[120,240]	[240,360]	[360,480]	[480,600]	[600,720]
B1		33.00	12.15	112.50	117.18	123.80	11.40
B2		45.38	50.46	113.54	67.34	67.69	77.76
B3		98.42	113.54	57.66	16.80	63.84	70.50
B4		39.00	17.34	57.66	141.14	34.68	29.04
B5		45.38	59.54	121.50	67.34	67.69	73.50

Sources: Based on the website of Guangzhou Toyota Motor Co. Ltd.

Table 2. The transport speed of conveyance from material buffer points to workstations

Speed m/s	A1	A2	A3	A4	A5	A6
B1	1.00	0.27	1.25	0.84	1.31	0.19
B2	0.55	0.58	0.87	0.67	0.95	0.72
B3	0.81	0.87	0.62	0.32	1.33	0.47
B4	1.00	0.34	0.62	0.97	0.68	0.44
B5	0.55	0.63	0.90	0.67	0.95	0.70

Sources: Based on the website of Guangzhou Toyota Motor Co. Ltd.

Table 3. The supply task from material buffer points to workstations by 2 conveyances

Workstation	A1	A2	A3	A4	A5	A6
Buffer point	B2	B1	B1	B3	B3	B1
Number of conveyance	1	1	1	2	2	1

Table 4. The transport route from material buffer points to workstations by 2 conveyances

Number of conveyance	Transport route	Each section of transport distance (m)	Transport distance(m)	Total transport distance(m)
1	B4-A1-B1-A2-B1-A3-B1-A6-B1	B4-A1: 39 A1-B1: 33 B1-A2: 12.15 A2-B1: 12.15 B1-A3: 112.5 A3-B1: 112.5 B1-A6: 11.4 A6-B1: 11.4	344.1	441.54
2	B3-A4-B3-A5	B3-A4: 16.8 A4-B3: 16.8 B3-A5: 63.84	97.44	

Based on the synchronous supply model in the paper and the data of Table 1 and 2, using Matlab programming, the implement plan from material buffer points to workstations of A1 to A6 by 2 conveyances are formulated (see Table 3 and 4). The conveyance No.1 is in charge of the supply task for workstations of A1, A2, A3, and A6. The transport distance of conveyance No.1 is 344.1 meters in time of 462 seconds with average speed 0.74 m/s. And conveyance No.2 is in charge of the supply task for workstations of A4 and A5. The transport distance of conveyance No.2 is 97.44 meters in time of 152 seconds with average speed 0.64 m/s. The materials for workstations of A1 to A6 are arranged to be stored in different buffer points (see Table 3). The total transport distance is 441.54 m. It indicates that the 2 conveyances can complete the supply task for 6 workstations within required time.

5 Conclusions

Diversification of customer demands brings increase in the number of parts consumed, which causes disturbances in the production and components supply. Synchronous supply should aim at meeting customer demand based on efficient supply chain management and flexible information integration system. The paper proposes a synchronous supply model with the appropriate constrains, in which the shortest total transport distance is adopted as the objective. Finally the example demonstrates the effectiveness of the synchronous supply model at the assembly plant.

Reference

Choi W, Lee Y. (2002) "A dynamic part-feeding system for an automotive assembly line." *Computers & industrial engineering*, 43(1), 123-134.

Doran, D., (2001). "Synchronous supply: an automotive case study." *European Business Review,* 13(2), 114-120.

Hu, L.-K. Shao,F.-Y. and He, G.-X. (2011). "Balancing analysis and algorithm design for mixed model assembly lines." *Proceedings of the 18th International Conference on Industrial Engineering and Engineering Management (IE&EM'11)*, 67-71.

Jiang Li, Ding Bin, Zang Xiao-ning. (2009). "Workstation-oriental production logistics distribution optimization."*Computer Integrated and Manufacturing Systems*,15(11), 2153-2159.

Shen W L,Ma P H. (2013)."An MES-based research on material supply in mixed model assembly line." *Journal of Hefei University of Technology*. *Natural Science,* 2013,36(10), 1166-1169.

Wang Pinggai, Chen Rongqiu, Ji Xuehong, "Strategies of JIT purchasing in automobile industry." *Journal of WUT(Information & Management Engineering) ,* 27(4),259-262.

Application of an Improved Genetic Algorithm to the Path Optimization of Urban Medical Waste Recovery

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Abstract: Aim of the study is to build a VRPTW to improve the recovery of medical waste in China. Both capacity limit and duration time are considered to meet the characteristics of medical waste that it is time-sensitive in the recovery process and enhance recovery efficiency. The model is solved by using improved genetic algorithm (GA), which can avoid dropping into local optimum by adding reverse evolution operation after crossover operation. Finally, the real-world data are collected from 30 medical units and the results show that managers just need to two vehicles to satisfy their demand and the loads and recovery time of each vehicle are 2265kg, 1935kg and 1.5979 h and 3.2532 h respectively. The travel paths of each vehicle are also scheduled.
Keywords: Urban medical waste; Recovery network; Vehicle routing problem with time windows (VRPTW); Improved genetic algorithm.

1 Introduction

With the urbanization speeding up in China, the city size as well as the urban population expanding, urban medical and health industry has developed enormously, which causes a sustainable growth of medical waste. According to the Medical test report announced by Chinese health authorities, viruses and harmful bacteria carried by medical waste is dozens, hundreds even thousands of times as dangerous as household garbage because of their characteristics of space infection, acute infection and latent infection and so on. They will pose a huge threat to the environment and human health if it is not be recycled and disposed properly. How to recycle and dispose the medical waste effectively has become a hot topic for citizens and government.

However, there are still some shortcomings, for China starts relatively late in the management of medical waste and laws and regulations are not perfect. Companies arrange their recovery routes experimental and ignore the characteristic that medical waste is dangerous. If exposed in the crowds for a long time, medical waste may have a high risk of leakage. Therefore, companies need to arrange vehicles and their travel paths to reduce delivery time and risk of leakage.

Vehicle routing problem (VRP) is firstly proposed by (Dantzig,1959). After years of academic research, there emerges a large number of expansion models of VRP, such as vehicle routing problem with time windows (VRPTW) by (Roberto ,1999), etc. At the same time, many heuristic algorithms are also proposed (Beltrami,1974; Tong,2004; Bell,2004). With those, VRP and its' expansion models can be easily solved. However, literatures about how to apply VRP to the optimization of the recovery network of medical waste are scarce in China. Existing studies such as (M. Wang,2012) don't take the characteristics of medical waste that should be delivered on a tight schedule into account and just utilize the simple VRP.

In this paper, we formulate a VRPTW model where time limit is considered. The goal of the model is to minimize the total recovery time, including transportation time and recovery service time, and arrange the number of recovery vehicles and their travel path. At last, we set an example of real world and the results show that the model can be solved effectively.

2 Mathematical Model

2.1 Model description

Urban medical units are relatively geographically concentrated and the recovery and disposal of medical waste are time-sensitive, so it is not necessary to build transfer stations since more layers mean higher risks. In figure 1, we can see that the network of urban medical waste is mainly composed of a disposal center of medical waste and a number of medical units where medical waste is generated. Now, we need to organize several recovery vehicles to collect medical waste, starting from the disposal center and coming back the disposal center when all customers (medical units) are serviced. The total recovery time that every vehicle costs cannot exceed the specified time period (ΔT). The goal is to minimize the total recovery time and organize the number of vehicles and their travel path.

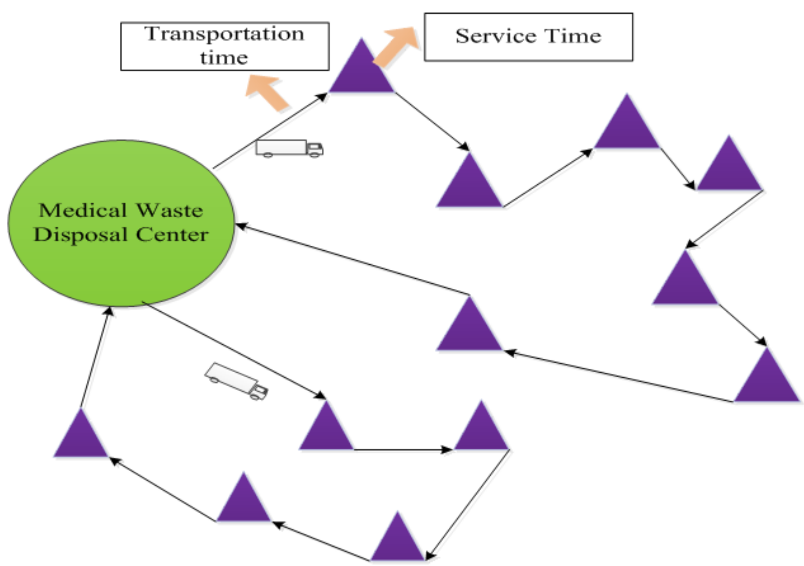

Figure 1. Recovery network of medical waste

2.2 Mathematical formulation.

Before modeling, we assume that the positions of each unit as well as the distance between any two points are known. Every unit is visited just only once by any vehicles.

Denoting the disposal center and medical units by N_0={1,2,..,n}, and the set of recovery vehicles by $K=\{1,2,\ldots,k\}$. The disposal center is located at 0 and the set of all positions is $N = N_0 \cup \{0\}$.The parameter c_{ij} represents the travel time on arc $(i, j) \in A$, where A is the set of arcs between all positions in N_0. The parameters q_i and t_i respectively represent the demand and service time of unit i. Q_k denotes the maximum capacity of vehicle k. Each route has duration limit ΔT. x_{ijk} and y_{ik} are binary variables, x_{ijk} are equal to 1 if and only if vehicle k travels from i to j, y_{ik} are equal to 1 if and only if customer i is serviced by vehicle k. The objective and constraints are defined as follows:

$$Min\ Z = \sum_{i=0}^{N}\sum_{j=0}^{N}\sum_{k=1}^{K} c_{ij}x_{ijk} + \sum_{i=0}^{N} t_i y_{ik} \qquad (1)$$

$$\sum_{i=1}^{N} q_i y_{ik} \le Q_k \qquad \forall k \in K \qquad (2)$$

$$\sum_{i=0}^{N}\sum_{j=0}^{N} c_{ij}x_{ijk} + \sum_{i=0}^{N} t_i y_{ik} \le \Delta T \quad \forall k \in K \qquad (3)$$

$$\sum_{k=1}^{m} y_{ik} = \begin{cases} K & i = 1,2,\ldots,N \\ 1 & i = 0 \end{cases} \qquad (4)$$

$$\sum_{j=0}^{N} x_{ijk} = y_{ik}, \forall i \in N, \forall k \in K \qquad (5)$$

$$\sum_{i=0}^{N} x_{ijk} = y_{jk}, \forall j \in N, \forall k \in K \qquad (6)$$

$$\sum_{i=1}^{N}\sum_{j=1}^{N} x_{ijk} \le |S| - 1 \quad 2 \le |S| \le n-2, S \subseteq \{1,2,\ldots,n\}, \ \forall k \in K \qquad (7)$$

$$x_{ijk} \in \{1,0\}, \forall i \in N, \forall k \in K \qquad (8)$$

$$y_{ik} \in \{1,0\}, \forall (i,j) \in N, \forall k \in K \qquad (9)$$

Equation (1) is to minimize the total recovery time, the first part represents total transportation time and the second means total service time. Constraints (2) guarantee the vehicle capacity limit is not exceeded. Constraints (2) ensure the duration limit on every route. Constraints (4)-(7) state that each vehicle must start and end its route at the disposal center and the flow is conversed at each medical unit. Constraints (8)-(9) define the binary variables.

3. Computational Results

3.1 Data and parameters

There are 30 medical units (Z.G. HE, 2015) and a disposal center, whose latitude and longitude are (30.661431, 104.366613). The capacity limit is $Q_K = 2500$ kg, duration limit ΔT=5 and average speed is 60km/h. Table 1 describes these detailed data. Volume 2 and 6 mean the geographical location (latitude and longitude) and volume 3 and 7 represent the number of beds in each unit (NB, bed number), volume 4 and 8 represent the outpatient production per day (OP, kg/day).

Table 1. Detailed data of medical units

No.	Location	NB	OP	No.	Location	NB	OP
1	30.715275,104.042534	125	500	16	30.703763,104.067945	2200	900
2	30.672322,104.089576	700	750	17	30.704058,104.028061	200	600
3	30.681621,104.050457	472	300	18	30.704058,104.075439	800	1300
4	30.674756,104.085714	230	270	19	30.722949,104.059539	2000	4000
5	30.760387,104.116291	400	600	20	30.710552,104.079559	200	600
6	30.762305,104.116355	600	60	21	30.724723,104.050722	300	1000
7	30.782548,104.135864	390	60	22	30.695497,104.040672	245	850
8	30.704649,104.028457	400	20	23	30.675752,104.041425	125	300
9	30.671028,104.040049	150	15	24	30.683688,104.079639	100	400
10	30.748327,103.963913	200	700	25	30.836215,103.998899	100	300
11	30.698597,104.047195	35	25	26	30.703763,104.067945	100	200
12	30.678373,104.041016	30	20	27	30.704058,104.028061	550	80
13	30.707014,104.067451	50	40	28	30.704058,104.075439	100	50
14	30.760353,104.116334	30	20	29	30.722949,104.059539	30	50
15	30.688707,104.090282	30	20	30	30.710552,104.079559	30	10

Generally, the medical waste production is estimated experientially. In large and medium-sized cities, it is typically calculated on the sum of production in inpatient department and in outpatient department (X.Y. Ye ,2010). Medical waste generated in outpatient department is 0.09kg per person a day and 0.36kg per bed a day in inpatient department. Service time in medical units is calculated on the basis of their production. Because medical waste are recycled with a special barrel (the capacity is about 40kg). Suppose that handling one recovery barrel need one minute, so the service time can be calculated by follow formula: $t_i = \begin{cases} q_i / 40 & q_i \textit{ is divided exactly by } 40 \\ [q_i / 40] + 1 & \text{else} \end{cases}$. $[q_i / 40]$ means integer part only.

For example, medical waste production (PRO, kg/day) at No.16 in Table 2 is calculated by $2200 \times 0.36 \times 0.8 + 900 \times 0.09 = 715$ kg, and service time (ST, min)by $[715 \div 40] + 1 = 18$ min .

Table 2. Detailed data of medical waste production and service time every day

No.	PRO	ST	No.	PRO	ST	No.	PRO	ST
1	81	3	11	12	1	21	147	5
2	269	7	12	10	1	22	63	4
3	163	5	13	18	1	23	65	2
4	91	3	14	10	1	24	56	2
5	176	5	15	10	1	25	47	2
6	178	5	16	715	18	26	166	2
7	118	3	17	112	3	27	33	5
8	117	3	18	347	9	28	13	1
9	45	2	19	936	24	29	10	1
10	60	2	20	112	3	30	20	1

3.2 Algorithm Design

Vehicle routing problem (VRP), which is proposed by (J.Holland,1975), proves to be a NP-hard problem (Lenstra J.K,1993).GA is a highly parallel, random, and self-adaptive heuristic algorithm that is suitable to solve the problem with large scale. However simple GA drops easily into local optimum and converges slowly. In this paper, we design an improved GA and add the reverse evolution after the cross operation, which can let the search jump out of the inferior solution and seek the better. Figure 2 shows the flow chart of improved GA.

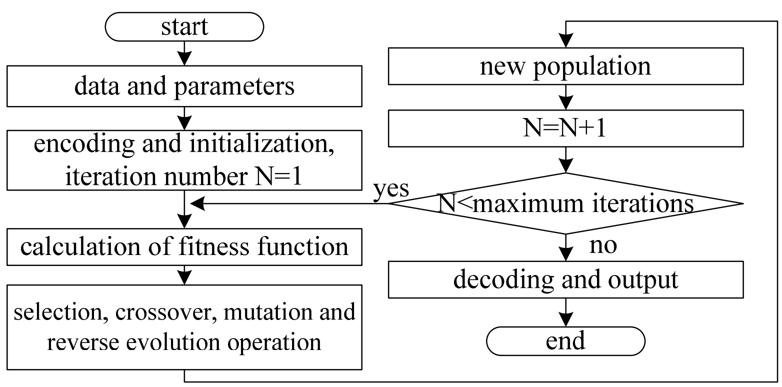

Figure 2. Algorithm iterative diagram

The expression of fitness function is very important in GA. when the capacity limit and duration limit are taken into consideration, the fitness function is formulated as follows:

$$fitness = \frac{1}{Z + F_1 + F_2} \tag{10}$$

Where

$$F_1 = M_1 \sum_K \max(\sum_i q_i y_{ik} - Q_k, 0) \tag{11}$$

$$F_2 = M_2 \sum_K \max\left((\sum_{i=0}^{N} \sum_{j=0}^{N} c_{ij} x_{ijk} + \sum_{i=0}^{N} t_i y_{ik}) - \Delta T, 0 \right) \tag{12}$$

Equation (10) describes the fitness function. Z represents the objective, namely equation (2).Equation (11) and equation (12) are penalty functions which are designed on the basis of the capacity limit and duration limit. M_1 and M_2 can be set as a large positive integer respectively.

3.3 Results

The model is solved by the improved GA. The parameters are set as follows: the max iterations of 350, population size of 80, crossover rate of 0.09 and mutation rate of 0.01.

The total recovery time is minimized to 4.8514 hours and two vehicles are needed to collect all medical waste. The route of vehicle one is 0—7—6—14—5—25—10—1—21—19—29—20—18—28—30—15—0. Its' load is 2265kg and recovery time is 1.5979 h.

The another route is 0—2—4—24—3—9—23—12—17—27—8—22—11—13—16—26—0. The load is 1935kg and recovery time is 3.2532 h.

Figure 3 shows that the total recovery time decreases gradually and stays same at last with the increase of the number of iterations. When iteration number is about 200, the total distance doesn't change anymore.

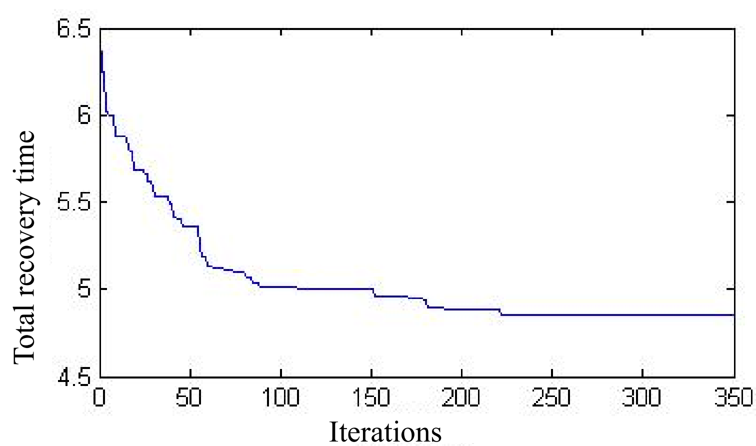

Figure 3. Algorithm iterative diagram

4 Conclusion

We have considered a real-world situation about recovery network of medical waste and formulated a VRPTW model whose goal is to minimize the total recovery time. An improved GA is applied to solve the model and proves to be very effective. The results tell the disposal center how to arrange vehicles for the recovery of medical waste and their travel path. However, the paper discusses the risks qualitatively, which worth doing further study quantitatively.

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References

Beltrami E.J., Bodin L.D. (1974). Networks and vehicle routing for municipal waste collection. *Networks*, 65 -94.
Bell J.E., Mcmullen P.R. (2004). Ant colony optimization techniques for the vehicle routing problem. *Advanced Engineering Informatics*, 18(1), 41-48.
Dantzig G., Ramser J (1959). The truck dispatching problem. *Management Science*, 80-91.
He Z.G., Liu S. (2015). Study on route optimization in urban medical waste recycling: in case of Chengdu jinniu district. *Logistics technology*, 117-119
Holland J.H. (1975). Adaptation in natural and artificial systems: An introductory analysis with applications to biology, control, and artificial intelligence. MI: University of Michigan Press.
Lenstra J.K, Rinnooy K (1993). Complexity of Vehicle Routing into the Vehicle Fleet Composition Problem. *European Journal of Operational Research*, 345-358.
Roberto C, Roberto W.C. (1999). A heuristic for vehicle routing with time windows. Int. *Production Economics*, 249 ~ 258.
Tong Z., Li N., Sun D.B (2004). Genetic algorithm for vehicle routing problem with time Window with uncertain vehicle number, *Proceedings of the 5th World Congress on Intelligent Control and Automation*. 15- 19
Ye X.Y., Huo L.N, Gu W (2006). Selection of statistical variables and determination of discharge coefficient for hospital wastes. *Pollution Control Technology*, 15-16.
Wang M., Wang J. (2012). Route optimization operation for reverse logistics of medical waste. *Logistics engineering and management*, 10-11.

Disruption Risk Analysis and Management Strategies for Fresh Agricultural Produce Supply Chains in China

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Abstract: Based on the analysis of the characteristics for fresh agricultural produce supply chain, disruption risks in fresh agricultural produce supply chain are divided into three categories: farmers' production risk, operating risk and demand risk. This paper proposes two main risk managing strategies: horizontal alliance strategy and vertical alliance strategy. Horizontal alliance strategies contain farmers' alliance and operators' alliance, and vertical alliance strategies have four models: farmers' alliance-supermarket, farmers' alliance-wholesale market, base-supermarket and base-operators' alliance. This study is instructional for all members in fresh agricultural produce supply chain in China, and is helpful to improve the ability of defending disruption risks and dealing with disruptions.
Keywords: Fresh agricultural produce; Supply chain; Disruption risk; Strategy.

1 Introduction

With regard to the complex and dynamic environment of supply chains, disruptions in Chinese fresh agricultural produce(FAP) supply chain have been raised as an important concern, such as "Poisonous Banana" in 2007; "Citrus Maggots" in 2008; "Melamine Milk and Eggs" in 2009; "Clenbuterol Issue" in 2010 . These disruptions not only have brought huge losses to the members in supply chain, but also brought casualties and property losses to the community. These issues reflect that there are still lots of problems in Chinese supply chain, and expose the vulnerability of FAP supply chain facing disruptions(Chengli, 2007). The reported dramatic outcomes demonstrate the importance of proactively managing disruption risk in FAP supply chain.

This study intends to contribute to knowledge in this area by addressing two key questions:

—What are the different types of disruption risks or potential risk factors in Chinese FAP supply chain?

—What are the strategies required to manage these disruption risks?

In order to address the above questions, this paper is organized as follows. In Section 2, the relevant literature review on FAP supply chain and supply chain disruption risks are done. In Section 3, the characteristics for Chinese FAP supply chain are analyzed. In Sections 4 and 5, the types of disruption risks and managing strategies are proposed. In Section 6, results and suggestions for future work are discussed.

2 Literature review

There are a large body of literature related to supply chain management, risk analysis and operational strategies. Considering the relevance, we review two streams of recent research: one is focused on FAP supply chain, the other is supply chain disruptions risk.

2.1 Fresh agri-product supply chain

Studying FAP supply chain is becoming a particularly interesting area due to issues related to public health, especially in developing countries. The supply chain of agri-foods, as any other supply chain, is a network of organizations working together in different processes and activities in order to bring products and services to the market, with the purpose of satisfying customers' demands (Christopher, 2005). What differentiate fresh agricultural product supply chain from other supply chains are the characteristics of fresh agricultural product including their short life cycle, their demand and price variability and weather related variability(Ahumada, 2009). In China the supply chain of agricultural products typically involves many players or agents with many farmers at one end and consumers at the other, and is generally too long and fragmented where intermediaries collect a sizable share from the price of the produce paid by consumers. What's more, Chinese agri-product chains consist of the millions of small scale farmers, who are not well structured and organized in the supply chain(Zhang, 2009). These traditional supply chains are tightly linked with social structures (Lokollo, 2004). This makes fresh agricultural product supply chain more complex and harder to manage than that in developed country.

2.2 Supply chain disruption risks

Since the tragedy of 9-11, there has been a rapidly increasing trend in research efforts that study the supply chain risks and disruptions. Supply chain risks have been classified into different categories in papers(Chopra, 2007; Juttner, 2005; Tang, 2006). (Tang,2006) classifies supply chain risks into two, namely operational risks and disruption risks. An operational risk refers to those inherent uncertainties that inevitably exist in supply chains. A disruption risk is referred to as the major disruptions caused by natural and man-made disasters. Most scholars think that disruptions resulted from natural disasters, supplier bankruptcy, labor disputes, war, terrorism and social-economic political instability (Craighead, 2007; Hendricks, 2005; Kleindorfer, 2005). (Oke,2009) argue that supply chain risks fall into two fairly distinct categories—high-likelihood, low-impact risks (or inherent and frequent risks) and low-likelihood, likelihood, high-impact risks (or disruption and infrequent risks). So once the supply chain disruptions, members in supply chain would suffer huge losses.

Strategies to manage supply chain disruption risk were studied by many scholars. (Pochard,2003) discussed an empirical solution based on dual-sourcing to mitigate the likelihood of disruptive events. (Tomlin,2006) suggested two different groups of strategies, mitigation and contingency, prior to a disruption and discussed the values of these two choices for managing a supply chain disruption. (Tang,2006a) proposed robust strategies for mitigating disruption effects. (Marley,2006) discussed lean management, integrative complexity and tight coupling, as well as their relationships with disruption effects. (Chopra,2007) focused on the importance of decoupling recurrent supply risk from disruption risk and of planning appropriate mitigation strategies. (Zegordi,2011) argued that strategies for managing supply chain disruption can be categorized into two main types: preventive and recovery, and preventive solutions can be categorized as follows: robustness strategies; resiliency strategies; security-based strategies; agility strategies.

As can be seen from the above literature, a number of recent papers focus closely on manufacturing supply chain disruptions and discuss the measures that manufacturing companies should use to design better supply chains, or study the different strategies to mitigate the consequences of supply chain disruptions. The studies on disruption risk management of FAP supply chain are much less, especially in developing country.

3 Characteristics of FAP supply chain in China

Compared to general supply chain, FAP supply chain has the following characteristics. On the one hand, there are some special attributes of fresh agri-produce, such as perishability, cyclical growth, regionalism and seasonality. Besides, fresh agri-produce has short life cycle and easily affected by external environment. On the other hand, fresh agri-produce has special nature in supply and demand. The characteristics of Chinese FAP supply chain that are small production and large market, namely "decentralized production, distributed consumption", make the network structure of supply chain more complex and more vulnerable. In summarize, the following are some characteristics about FAP supply chain in China.

3.1 Specificity of the supplier' composition

The suppliers in Chinese FAP supply chain consist of a large number of separate farmers, who have multiple statuses, such as a nature person, a manager, a policymaker. What's more, they have different cultural qualities, financial situations, and behavior models, so that their decisions are rational or irrational. Therefore, it is very difficult to manage these suppliers or farmers. The general theory and methodology of supplier management such as reducing the number of supplier can be not suitable for managing numerous separate farmers. At the same time, compared with other market entities, Chinese farmers have a very weak market force. If there is no "leading enterprise" or other organizations to manage producing and selling of FAP, the farmers' risk would be very large.

3.2 Instability and looseness of supply chain structure

So far, Chinese FAP supply chain has not been integrated. The relationship among members in supply chain is loose and unfriendly. They neither communicate nor trust each other. Most of members only concern about their own interests, and ignore the common interests, which lead to the instability of supply chain structure. Besides, the external environment, such as nature disasters, government policy and market price, will increase the vulnerability of FAP supply chain.

3.3 Members' market force is imbalance

There are 900 million farmers in China. The number of farmers is much more than that of wholesalers or retailers. So agri-produce market is a buyer' market. Buyers have much more market power and more advantage of relative monopoly. Market prices of agri-produce are not the equilibrium price under perfect competition market, but tend to the interests of the buyer. Consequently, compared to other market entity, farmers' market power is much weakest in the whole supply chain. Most of the profits are grabbed by wholesalers or retailers.

3.4 Agricultural products logistics lags behind

FAP has the characteristics of seasonality, regionalism and perishability, which makes it highly dependent on the management of logistics and advanced logistics technology. For example, fresh pork, beef and vegetables need particular containers and equipments when they are delivered. So far, Chinese FAP supply chain has formed an overall system including production, processing, transportation, storage, packing and so on. As a whole, FAP supply chain is lack of management, and the logistics cost is very high.

3.5 Information asymmetry

Because of the diversification of fresh produce's production and consumption, the supply and demand information is scattered. It is hard for farmers to get the right information about market demand. So it often happens that products are either in short supply or unmarketable. In contrast, consumer market is often in the opposite situation.

4 Risk analysis of FAP supply chain disruptions

FAP supply chain is a complex network consisting of farmers, wholesalers, retailers and other brokers. According to the characteristics and process of FAP supply chain, disruption risks of FAP supply chain are divided into three categories, which are farmers' production risk, operating risk and demand risk. See Fig 1.

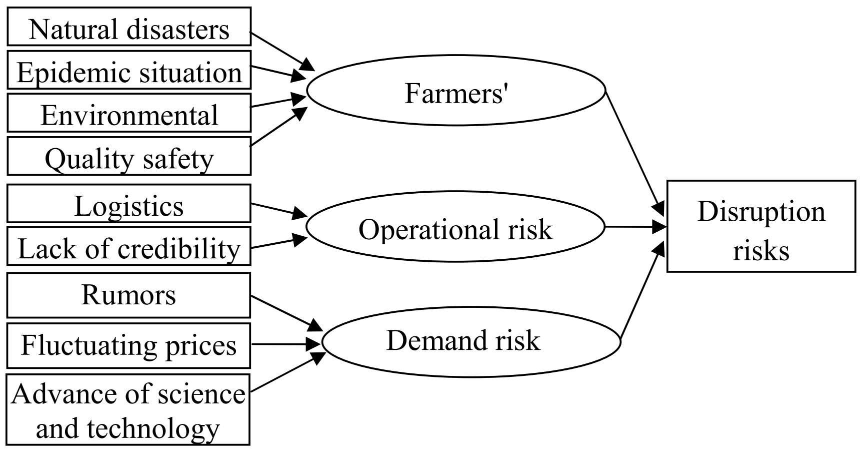

Fig. 1 Disruption risk factors of FAP supply

4.1 Farmers' producing risk

Disruption risk factors of farmers' producing mainly include two aspects. One is from the external environment, such as natural disasters (water logging and drought, earthquake, debris flow, hailstorm, storm and so on), animal or plant epidemic. In 2009, drought, flood, earthquake, typhoon disaster had happened in China. The results were that 47.214 million hectares of crops were affected, 4.918 million hectares of crops were failure, and the direct economic loss was 252.37 billion Yuan(Mei et al., 2010). In recent years, animal or plant epidemic often happens, such as "bird flu", "blue-ear disease", "banana black poison disease". The other risk factor is from farmers themselves, including quality safety (abusing of pesticide, fertilizer, hormone and other production material), environment pollution (land pollution, water pollution), and so on. In order to increase production and incomes, farmers used the forbidden pesticide for their plants, used the forbidden chemicals such as clenbuterol, chloramphenicol for their poultries. The disruptions, for example, "lean meat essence", "melamine milk", "red duck eggs", exposed the vulnerability and the risk in Chinese FAP supply chain.

4.2 Operational risk

Operational risks mainly include logistics risk and operators' lack of credibility. The logistics processes of FAP contain transportation, packing, loading/unloading, storage, distribution and so on. In order to ensure the quality of the products, logistics facilities, logistics technology and logistics management are needed. For example, milk, pork, beef and other fresh products must be stored at a certain temperature. So logistics cost is important part of the total operational cost for operators (wholesalers or retailers). To reduce total costs, operators can use less advanced logistics facilities and technologies. In developed country, the quality of fresh produce is continuously improved from picking to selling. In china, because of lack of logistics management, it is just in opposite. On the other hand, the lack of operators' credibility is also the main reason for the disruption risk. Some operators can use the banned additives and pesticide to ensure the perfect appearance and long guarantee period. For instance, the "turbot" event in 2006 is that wholesalers used illegal drugs "nitro furan".

4.3 Demand risk

Demand risk of FAP supply chain is mainly from sudden changes in customer demand. Major risk factors include price fluctuations, rumors, science and technology progress, and so on. As the consumption of FAP is subjected to the natural conditions and environmental factors, its market fluctuations are more frequent compared with industrial products. The sudden changes of market demand may cause sharp fluctuations in the price of FAP, and eventually lead to breaking off in the entire supply chain. Then, with the rapid development of agricultural science & technology, the new testing technology may detect harmful substances in some produce so that the produce will be unmarketable. Then, rumors are also a kind of key factor for FAP supply chain disruption risk. For instance, poison bananas and citrus born maggots were all actually caused by rumors in 2008.

5 Prevention strategies for disruption risk of FAP

Supply chain management has been widely used in manufacture and retail industry, and has achieved great success. It has not only reduced risk, but also achieved a win-win cooperation for members in supply chain. However, Chinese FAP supply chain lags behind. Because of its particular structure, FAP supply chain operates in a traditional way. When a member confronted a disruption, it had to face it and bear the loss by itself, instead of making good use of the power of the entire supply chain. So this paper proposes the following strategies to cope with the disruptions.

5.1 Horizontal alliance strategy

Horizontal alliance strategy is an alliance strategy which is composed of the same industrial members who are in FAP supply chain for sharing information, technologies, funds and facilities. By this strategy, all node members will achieve scale economy effectively, obtain the complementary sources and ability quickly, and reduce or disperse disruption risks. The horizontal alliances in FAP supply chain are farmers' alliance and operators' alliance.

(1) Farmers' Alliance. Farmers who plant the same kind of agri-produce in the same region could join together to form an alliance. By the alliance, all farmers who plant the same agri-produce could be closely together for sharing the information about marketing and planting, technologies and facilities. The alliance will not only promote scale production of fresh agri-produce, but also help to create competitive edge, increase farmers' bargaining power, and avoid market risks. For example, when facing natural disasters, animal or plant epidemic, farmers could implement the large-scale, standardized, and scientific strategy to deal with risks, and reduce the influence from disruptions.

(2) Operators' alliance. Operators (wholesalers or retailers) in the same region or across region can form wholesalers' alliance or retailers' alliances for sharing the supply-demand information, transportation equipment, preservation facilities and other resources. They may adopt joint purchasing strategy, joint distribution strategy, joint inventory strategy and so on, to reduce logistics cost, improve customer service level and defend the disruption risks jointly. Right now, horizontal alliance emergency strategy for suppliers is widely used in manufacture. For example, in order to reduce the stock level of spare parts and improve service levels, 220 sellers of Caterpiller established a mutual assistance partnership and executed joint inventory strategy. When one of their equipments broke down, they can search the spare parts in retailer's network by DPIS and get them from the nearest spare parts warehouse, so that the equipment would be recovered in the shortest time. But there are few of operators' alliance in Chinese supply chain of FAP, operators have to bear the loss by themselves when a disruption happens. The operators' horizontal alliance will effectively reduce purchasing cost, transportation cost, inventory cost, and other logistics cost by scale effects.

5.2 Vertical alliance strategy

Vertical alliance strategy is formed by farmers or farmers' organization, wholesalers and retailers, for sharing resources and risks. So far, wholesale market still is the core in Chinese FAP supply chain. In this mode, members only concern about their own interests. When a disruption happens for one of members, the other members would resist him instead of giving a hand. Therefore, the effective way to cope with disruptions of fresh agri-produce is to build a vertical alliance, in which all members share resources and risks by contracts or agreements. The following are some modes of vertical alliances.

(1) Mode of "farmers' alliance & supermarkets". Farmers' alliance signs a contract with supermarkets, and farmers' alliance is responsible for quality of the agri-produce. By this kind of mode, the produce will be distributed directly to supermarket. It will not only help to ensure the quality, and reduce the transaction cost, but also effectively prevent disruptions.

(2) Mode of "farmers' alliance & wholesale markets". Farmers' alliances and wholesale markets establish long-term strategic partnership. Wholesale markets are responsible for selling the produce. The advantage of this kind of mode is less intermediate costs. The disadvantage is that supply and demand can not match perfectly.

(3) Mode of "Base & supermarkets". Compared to "farmers' alliance & supermarkets"，the mode of "bases & supermarkets" is pulled by the order of supermarkets. After investigating the market demand for various fresh agri-produces, supermarket can order to the base. Then the base raises agri-produce according to the order, including fertilization, spraying, picking and transportation and so on, in order to ensure the quality. The mode can reduce production risk and quality risk.

(4) Mode of "Base & operators' alliance". If the scale of base is big enough, its supply is more than one supermarket's demand. Then a mode of "base & operators" alliance is appropriate. A base can make agreements with operators' alliance, and supply the agri-produce according to the agreement. The agri-produce will be transported or distributed jointly to every member of operators' alliance.

6 Conclusion

Many recent supply chain events have occurred in China, which is growing in importance with respect to international trade (Olson, 2010). The research on specific supply chain risk factors in China is very important. Based on analyzing the characteristics of FAP supply chain and risk factors of disruptions in China, this paper proposed two risk management strategies, which are horizontal alliances and vertical alliances. In order to increase the ability of resisting the disruption of FAP supply chain, all members in the supply chain should get together, establish a strategic cooperative partnership, share information and resource. It will help to realize scale economics, acquire complementary resource and ability quickly, and reduce or scatter disruption risks effectively. The research can not only enrich the content of FAP supply chain disruption management in the world, but also be very instructional for supply chain members to cope with disruptions in China.

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References

Ahumada O., Villalobos J. R. (2009). “Application of planning models in the agri-food supply chain: a review.” *European Journal of Operational Research*, 195, 1-20.

Chengli Ye, Shaodong Meng. (2007). “A review on risk management of agri-produce supply chain.” *Economic Problems of Agriculture*, 200-205.

Chopra, S., Meindl, P. (2007). “Supply chain management: strategy, planning and operation.” *Pearson Prentice Hall*, New Jersey.

Chopra S., Reinhardt G, Mohan U. (2005). “The importance of decoupling recurrent and disruption risks in a supply chain.” Working paper, *Northwestern University*.

Christopher, M. (2005). “Logistics and Supply Chain Management.” *Prentice Hall*, London.

Craighead, C. W., Blackhurst, J., Rungtusanatham, M. J., Handfiels, R. B. (2007). "The severity of supply chain disruptions: Design characteristics and mitigation capabilities." *Decision Science*, 38(1), 131-156.

Hendricks, K., Singhal, V. R. (2005). "An empirical analysis of the effect of supply chain disruptions on long-run stock price performance and equity risk of the firm." *Production and Operations Management*, 14(1), 35-52.

Kleindorfer, P. R., Saad, G. H. (2005). "Managing disruption risks in supply chain." *Production and Operations Management*, 14(1), 53-68.

Lokollo, Erna M. (2004). "Linking farmers with Markets: Ways to Reduce Poverty through Supply Chain Management." *UNESCAP-CAPSA*.

Marley, K. A. (2006). "Mitigating supply chain disruptions: essays on lean management, integrative complexity and tight coupling." *The Ohio State University*.

Juttner, U. (2005). "Supply chain risk management: understanding the business requirements from a practitioner perspective." *The International Journal of Logistics Management*, 16(1), 120-141.

Oke A., Gopalakrishnan M. (2009). "Managing disruptions in supply chains: A case study of a retail supply chain." *Production Economics*, (118):168-174.

Pochard, S. (2003). "Managing risks of supply-chain disruptions: Dual sourcing as a real option." *Massachusetts Institute of Technology*.

Tang, C. (2006). "Robust strategies for mitigating supply chain disruptions." *International Journal of Logistics: Research and Applications*, 9(1), 33-45.

Tang, C. (2006). Perspectives in supply chain risk management." *International Journal of Production Economics*, 103(2), 451-488.

Tomlin, B. (2006). "On the value of mitigation and contingency strategies for managing supply chain disruption risks." *Management Science*, 52(5), 639-657.

X. Y. Zhang, and L. H. "Aramyan. (2009). A conceptual framework for supply chain governance: An application to agri-food chains in China." *China Agricultural Economic Review*, 1, 136-154.

Yingjie, M.,Jun L., Junrong,Q. (2010). "The analysis on types and characteristic of agriculture disruptions." Agriculture Science in GuangDong, 12, 221-224.

Olson,D. L., Wu, D.D. (2010). "A review of enterprise risk management in supply chain." *Kybernetes*, 39 (5), 694-706.

Zegordi S. H., Davarzani H. (2012). "Developing a supply chain disruption analysis model: Application of colored Petri-nets." *Expert Systems with Applications*, 39, 2102-2111.

Trust Mechanisms for Food Cold Chains

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Abstract: With the rapid growth of catering industry, people pay more attention on the food security which have close relation with the management of cold chain. It is vital for the development of cold chain to establish trust mechanism between supply chain numbers, such as farmers, suppliers and catering company. Depending on the analysis of single game, finitely repeated games and infinitely times repeat games between cold chain members, we can draw conclusions as follow. The members of cold chain will choose to keep faith with the aim of ensuring trust mechanism. Suggestion was shown at the end, such as increasing the interests of the trust, default cost and the discount factor, perfecting the information found, making share with information, keeping effective communication and establishing the standard contract.
Keywords: Food cold chain; Trust mechanism; Game theory.

1 Introduction

Food is the first necessity of the people. In our country catering industry keep rapidly develop. The revenue of catering industry is 2556.9 billion, in 2013, which raise 9.0% than last year. O2O, new model of repast, was known by more people. The O2O model, which has been treated as a tendency, has more than 78 million user in 2012. Compared with 2011, the number of user raised 58.1%. We should focus on the issue of food security. There are some issue we should attach great importance in catering industry, such as ensuring pesticides of fruits and vegetables no excessive, meat and poultry no epidemic, aquatic products no pollution.

It is vital for the development of cold chain to establish trust mechanism between supply chain numbers, such as farmers, suppliers and catering company. Food cold chain trust is a kind of belief that partners' promise is reliable and will fulfill their obligations, they have confidence to build good relations of cooperation that have common interests and risk-sharing(Lu Shan,2012). The trust is result of long-term game between cold chain numbers.

2 The trust game between cold chain numbers

2.1 Single game.

Game behavior of cold chain numbers was divided into trustworthiness and breach of contract. In the process of cooperation, considering stakeholders and doing things according to the agreement are trustworthiness. Breach of contract is don't comply with contractual agreements just considering their own interests.

To simplify the model, Hypotheses were listed as follow:

Assumption 1: Game only have two members in food cold chain, there has never been a cooperation among the members of A and B, and it is unknown whether to continue cooperation in the future.

Assumption 2: When A and B both choose to break a contract, or both choose to keep trust, the interests for both side are equal m (break a contract), n (keep trust).

Assumption 3: In case of one party break a contract while the other party keep trust, the interest of non-performance is h and the interest of trustworthiness is g.

Assumption 4: h>n>m>g

Assumption 5: the condition of information is complete.

Because A and B only have a single cooperation, the only Nash Equilibrium is (breach of contract, breach of contract) according to game theory. Due to the value of （n，n）>（m，m）, this balance can't reach Pareto optimality. The two sides get into a "prisoner's dilemma". This shows that, in the course of a single game, members of food cold chain will choose to break a contract in order to get more benefits. Direct result of this is the one-shot deal(Liu Yong Sheng, 2004).

Table 1: Interest matrix of single game

		B	
		trustworthiness	breach of contract
A	trustworthiness	（n，n）	（g，h）
	breach of contract	（h，g）	（m，m）

2.2 Finitely repeated games.

Assuming the number of repeated games is N, a static game is original game. According to game theory, if the original game has a unique pure strategy Nash equilibrium then for any positive integer N, repeated game has a unique subgame perfect Nash equilibrium. That all benefited parties will take the original game of pure Nash equilibrium strategy at each stage. In the process of finitely repeated game, the interests of benefited parties have been raised N times as the original game(Zhang Wei Ying, 1996). Therefore, pure Nash equilibrium strategy of cold chain members still choose (breach of contract, breach of contract).

2.3 Infinitely repeated games.

In this case, members of food cold chain consider gains of long-term cooperation rather than one-time gain of short-term speculation, thus there are more trust.

Hypothesis 1: Taking the time value of money into account, let r as the discount factor and $0<r<1$.

Hypothesis 2: A, B sides have adopted a "trigger strategy", In the process of infinitely repeated game, both sides are trying to use strategy of trustworthiness in the first, if the other party adopt strategy of trustworthiness too, they will always keep to trust. Once found the other party break a contract, they choose to break a contract to retaliate(Wang Xu Hui,2014).

Hypothesis 3: If one party break a contract, the interest of breach of contract is n+x, the interest of trustworthiness is n-y.

If A and B have been chosen to trust, then the total interest for every business is:

$$(1+r+r^2+\cdots)*n\approx 1/(1-r)*n \quad (1)$$

If A and B always choose to break a contract, then the total benefits for each company is:

$$(1+r+r^2+\cdots)*m\approx 1/(1-r)*m \quad (2)$$

Table 2: Interest matrix of infinitely repeated games

		B	
		trustworthiness	breach of contract
A	trustworthiness	（n，n）	（n-y，n+x）
	breach of contract	（n+x，n-y）	（m，m）

According to (1) and (2), we can find that the interest of continuous trustworthiness is greater than break a contract continuously.

$$1/(1-r)*n-1/(1-r)*m=1/(1-r)*(n-m),\ \text{and } n-m>0.$$

If trigger strategy is used, the party who select breach of contract can only have one cheap that is short-term gains x, but long-term loss this time caused is:

$$(r+r^2+\cdots)*n-(r+r^2+\cdots)*m\approx r/(1-r)*(n-m)$$

If short-term gains is less than the long-term loss, no party will choose to break a contract, that is $x<r/(1-r)*(n-m)$ deformed into $r>x/n-m+x$. As long as the discount factor is greater than（x/n-m+x）, no partners will choose to cheat, Pareto optimal for both sides is (trustworthiness, trustworthiness).

In real life, game trust between members of the food cold chain can not be unlimited. Partnership is always present, but before stopping cooperation, there is a long enough duration of the contract and is large enough long-term interests between food cold chain members, they will still choose to trustworthiness. This is because the benefits of trustworthiness outweigh the benefits of opportunism behavior. Once lose the partners' trust, they will hard to make others trust them. Therefore, food cold chain members will choose trustworthy, in order to safeguard the trust mechanism (Ou yang qi, 2014).

3 The countermeasures to improve trust mechanism

3.1 Increase the interests of trust.

If a member of the food cold chain does not want to continue cooperation, he must pay a certain cost, such as losing much of material, manpower, financial resources and credibility; Members of the food cold chain can't consider their own interests, they must act from the perspective of the whole supply chain. For instance, farmers plant vegetables which have excess pesticide, they can't influence the credibility of catering enterprises in order to their own interests; transport enterprises can't reduce cost of cold storage which decrease the quality of vegetables. Only on the basis of this, can we improve the competitiveness of the whole supply chain and obtain greater benefits (Wei Hong Mao,2014).

According to $r>x/(n-m+x)$, we can draw conclusion that the greater the benefits of mutual trust are, the lower the requirements for discount factor will be. When the discount factor is higher, the attitude of enterprises for the current earnings is lower and this could stimulate enterprises to trust each other.

3.2 Improve the information infrastructure.

Each member of the food cold chain should attach importance to establish information infrastructure, it is the important condition to ensure information flow, logistics flow and commerce flow operate smoothly (Zhou Yong, 2004).

The establishment of information network between members of food cold chain that can make the communication become more simply and quickly.

Food cold chain members can use all kinds of information technology to provide each node of the supply chain enterprises with information and collect any type of information which will affect other members of supply chain. As in the following, it will promote the growth of knowledge between enterprises and form learning advantage. Depending on each other, they can adapt to better in the changing environment and improve the consistency and coordination of food cold chain then consolidate trust between members. But each member should grasp the degree of information sharing in order to insure the confidentiality of the core data (Ma Shi Hua, 2005).

3.3 Constant and effective communication.

Communication is a very important way to maintain the trust mechanism between members of the food cold chain.

There are a lot of ways to two-way communications, such as formal or informal talks or trainings on a regular basis and cooperative groups.

Famers, transportations or distribution enterprises can illustrate their problems and tell they need help or what's help they can offer. In this way, it not only increase the trust between supply chain members, but also form the dependence on each other, as a result, the long-term cooperation will be set up(Li Ji Fang, 2014).

3.4 Establish a standardized contract.

First, contract must rely on the government laws and regulations, so it makes penalties clearly and raises the cost of default; Secondly, contract must try its best to be protective to prevent opportunism behaviors; Finally, it is better to do a consultation agreement when accidents happen. For example, distribution center may be delay due to traffic, this requires informal understanding. Valid contract which must be based on the needs of all elements could gives full play to their strengths, so that all members can make a profit and maintain long-term cooperation relationship.

References:

Ma Shi Hua, Lin Yong, Chen Zhi Xiang, (2005). Supply Chain Mangement, *Bei Jing, China Machine Press.*

Li Ji Fang, (2014)Competition cooperation game analysis between Enterprises in Supply chain node. *Theory Journal*, (4): 65-69

Liu Yong Sheng,(2004). Mutual Trust Among Enterprises In Supply Chains. *China Business and Market*, (11) : 12-15

Lu Shan,(2012).Agricultural products supply chain members to trust mechanism to build and perfect -- analysis based on game theory .*Management World,* (7): 172-173

Ou yang qi,(2014). Learning in Game Model of Trust Relationship among Supply Chain Members .*Logistics technology,* (4): 297-199

Wang Xu Hui,(2007). Supply chain cooperation trust mechanism research--Under the social network theory. Modern Economic Research, (5): 60-62

Wei Hong Mao,(2014). Research into trust mechanism of e-commerce supply chain members under game perspective. *Journal of Fujian University of Technology*, (4): 381-185

Zhang Wei Ying.(1996).Game Theory and Information Economics. shanghai: *Shanghai People Press.*

Zhou Yong, Zheng Pei E, Zhang Hao,(2004). An Analysis with Game Model on the Effect of Trust on Supply Chain Operation. *Journal of Xidian University (Social Science Edition)*, (3):85-89

Macroscopic Logistics Cost Accounting from an Environmental Perspective

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Abstract: Macroscopic logistics costs accounting takes on important significance in enacting scientific and reasonable logistics policies and promoting the quality and efficiency of national economic operation. Current macroscopic logistics costs accounting which does not consider the environmental costs of logistics fails to quantitatively reflect resources and environment losses which have been caused by logistics activities. Based on the idea of sustainable development of logistics and the theory of value of environmental resources, this article, on the basis of China's current accounting mode of macroscopic logistics costs, proposes the composition and accounting method of macroscopic logistics costs from an environmental perspective.

Keywords: Macroscopic logistics costs; Environmental perspective; Accounting.

1 Introduction

The macroscopic logistics costs refer to the analyses of the total expenditures of domestic logistics activities from the perspective of national economic aggregate, and are commonly expressed as the proportion of domestic logistics costs to national benefits. Nonetheless, current macroscopic logistics costs data is insufficient to fully reflect the damage to ecological environment and natural resources which have been caused by logistics activities. Therefore, in the requirements of energy conservation, environmental protection and sustainable development of logistics industry, the improvement of statistics and accounting systems of macroscopic logistics costs appears especially important and urgent.

2 Present Status of Macroscopic Logistics Costs Accounting

2.1 Accounting Modes of Macroscopic Logistics Costs in developed countries

In America, the macroscopic logistics costs consist of carrying inventory costs, transportation costs and logistics administration costs. Among them, the carrying inventory costs contain not only warehouse costs, damage costs, personnel costs, insurance premium and tax expenses, but also the interest on funds held by inventory. And the logistics administration costs, which generally accounts for 4% of total logistics costs, are calculated by multiplying a fixed ratio, which is determined by experts according to American history, and the sum of the carrying inventory costs and the transportation costs.

In Europe, the macroscopic logistics costs are determined primarily based on survey and prediction, including the costs of transportation, storage, packaging and infrastructure investment. And the administration costs, instead of being listed as a separate item, are distributed into storage, packaging, transportation and other items. However, the calculating methods of macroscopic logistics costs in Europe are basically consistent with that in America.

In Japan, the macroscopic logistics costs consist of delivery charges, storage charges and Logistics management fees. The total logistics fees are reckoned mainly on the basis of various data released each year, such as employment statistics, inventory statistics. Besides, with reference to the estimation method of Delaney, some parts of domestic logistics costs in Japan is reckoned from the standpoint of shippers.

2.2 Accounting Mode of Macroscopic Logistics Costs in China

Compared with developed countries, the studies on macroscopic logistics costs accounting started relatively late in China. A relatively well-developed calculation system of macroscopic logistics costs accounting was not available until *Social Logistics Statistical System and Accounting Expressions (Trial)* was promulgated in 2004. In China, total logistics costs refer to all the expenses in all aspects of national economy that have been used for social logistics activities within a certain period of time, including transportation costs, storage costs and management costs (Gao Ziyou , 2005).

In conclusion, due to the lack of environmental costs, current macroscopic logistics costs are insufficient to reflect the real costs of logistics activities. Therefore, it fails to guide modern logistics industry to develop in an environment-friendly, sound and sustainable way.

3 Environmental Value

Five different value theories have appeared successively in the history of economic theories, namely, Marx's labor theory of value, utility theory of value, factors of production theory, Marshall's theory of supply and demand and the existence theory of value [2]. Inevitably, all these theories have certain historical limitations and one-sidedness of the research scope. Today, it has become the consensus of all mankind that resources and environment have value, but the value has been undervalued, even neglected for all the time. Considering our present cognitive level, the following value theory should be more reasonable.

The value of environment derives from not only the usefulness possessed and provided by the natural resources themselves, but also the human labor expenditures for learning about, transforming and protecting the nature. Therefore, the value of environment is in direct proportion to its utility and operation costs, and it is also influenced by supply-demand relations and the scarcity and substitutability of resources and environment (Zhang chi, 2006). Based on the theory of environmental value, using appropriate valuation method, we could quantify the environmental impacts caused by logistics activities, so as to monetize those impacts and reflect them in the logistics costs.

4 Environmental Costs of Logistics Activities

4.1 Environmental Impacts of Logistics Activities

While providing information, services and effectiveness, logistics activities which consist of a series of logistics functional elements also have impacts on the natural environment, such as, pollutant emissions, the consumption of non-renewable resources like oil.

4.2 Approaches to Valuation of Environmental Impacts

There are three approaches to valuating environmental impacts, namely, benefits approach, costs approach and market investigation approach, while each approach contains several specific assessment methods (Yu Liansheng, 2004).

(1) Benefits Approach

Benefits here refer to materials and ecological services provided by environmental resources. Benefits approach generally contains present value method, net price method, user costs method and surrogate market method. Among them, the user costs method which emphasizes the user-compensating principle can be readily combined with the accounting of logistics activities costs both in theory and practice, so it is more applicable to calculate the costs of resource consumption.

According to Weak Benefits Sustain-ability and benefits maintaining principle, the user costs method regards a part of the return of non-renewable natural resources *R* (resource rents), that is, users cost compensation(*R*-*X*), as the depletion value of natural resources. Setting *r* the interest rate (i.e., the discount rate), *R* the annualized return (constant), *X* the annual real income, *n* the remaining years of a certain kind of resources recoverable (limited service years), the user costs is the difference between net income *R* and real income *X*, expressed as the formula,

$$R - X = R \cdot \frac{1}{(1+r)^n} \quad (1)$$

(2) Costs Approach

The maintenance costs method features the simplicity, intelligibility and practicability of its accounting process and the accessibility and accuracy of the data needed. According to statistical materials, we could get the emission load and unit governance costs of pollutants and calculate the environmental degradation costs with the following formula.

$$V_a = \sum V_i = \sum P_i \times Q_i \quad (2)$$

In this formula, V_a represents environmental degradation costs (the total governance cost), V_i represents governance costs of pollutant i, P_i and Q_i represent the unit governance costs and emission load of pollutant i respectively.

4.3 Environmental Costs of Logistics Activities

It is the objective existence which cannot be neglected that logistics activities have impacts on the environment, but these impacts have long been ignored or weakened and never been fully valued by economic means. Therefore, valuating environment impacts of logistics activities is the prerequisite for controlling and effectively managing logistics costs.

The valuation of environment impacts of logistics activities, that is, environmen -tal costs of logistics activities, contains not only the environmental degradation costs which results from logistics activities' consumption of nonrenewable natural resources and discharges of pollutant, but also the expenditures spent on the prevention, treatment and remedy of the environmental degradation costs.

5 Macroscopic Logistics Costs Accounting from an Environmental Perspective

5.1 Definition and Composition of Macroscopic Logistics Costs

Based on current accounting system of logistics Costs in China, in this article, the macroscopic logistics costs is defined as follows.

The macroscopic logistics costs refer to the expenses in all aspects of national economy that have been paid for social logistics activities within a certain period of time, as well as the resources and environmental costs of the whole society that have been caused by logistics activities, including four parts, transportation costs, management costs, storage costs and environmental costs (Feng Gengzhong et al, 2007), as shown in Figure 1.

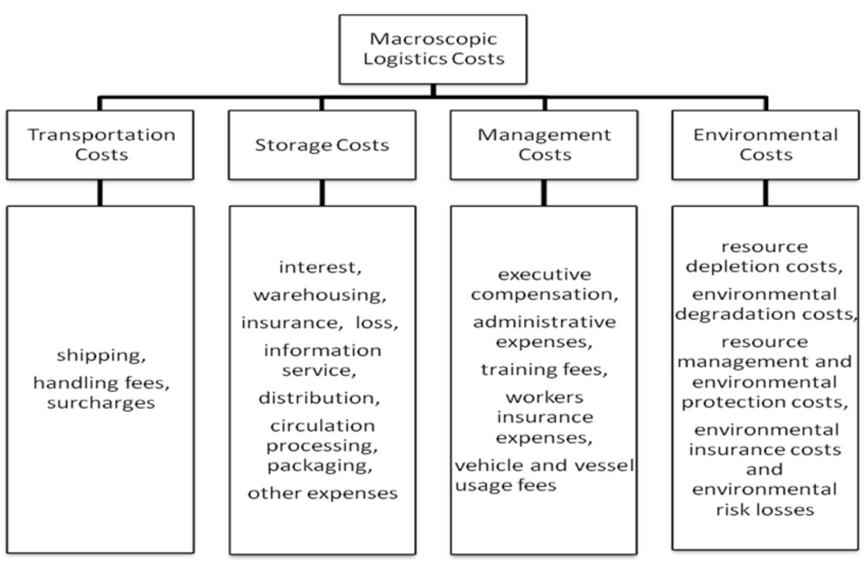

Figure 1. Composition of Macroscopic Logistics Costs

Among them, environmental costs refer to the summation of monetizing damage to the natural environment caused by logistics activities and the expenses on avoiding or reducing damage, including resource depletion costs, environmental degradation costs, resource management and environmental protection costs, environmental insurance costs and environmental risk losses.

5.2 Accounting Methods of Macroscopic Logistics Costs

In order to realize the nationwide uniformity of statistical index, accounting scope and calculating caliber, this article suggests that the accounting of transportation costs, storage costs and management costs remains in line with the current national accounting system, while the accounting of environmental costs is divided into five parts and conducted as follows.

（1）Resource Depletion Costs

The resource depletion costs refer to the permanent reduction of social natural resources which results from the consumption of non-renewable natural resources for goods circulation. And its basic calculation formula is,

Resource Depletion Costs＝∑(the total depletion of each kind of natural resource -s which have been caused by social logistics×the unit uncompensated users cost in each kind of resources)

Wherein, the total depletion of each kind of natural resources caused by social logistics can be drawn from related statistical yearbook, and the unit uncompensated users cost in each kind of resources could be calculated by users costs method.

（2）Environmental Degradation Costs

The environmental degradation costs refer to the damage of ecological environment degradation which has been caused by goods circulation or pollutant discharge in social logistics activities. And its basic calculation formula is,

Environmental Degradation Costs=cargo turnover volume×∑(the unit complete treatment costs of each kind of pollutant×each kind of pollutant which has been discharged by unit turnover volume)

（3）Environmental Insurance Costs

The environmental insurance costs refer to the environmental insurance expenses (dangerous goods) which have been paid to the social insurance department for sharing risks, in order to prevent and reduce the environmental disputes and risk losses caused by environmental accidents. And its basic calculation formula is,

Insurance Costs = social total logistics×the average insurance expense ratio of social logistics

（4）Environmental Risk Losses

Environmental risk losses refer to the risk losses result from environmental acid -ents caused by uncertainties in social logistics activities. And its basic calculation for -mula is,

Environmental Risk Losses = social total Logistics×the average environmental damage costs ratio of social logistics

Wherein, the environmental damage costs ratio of social logistics can be drawn from the investigation data of enterprise logistics and environmental statistical materials, that is, the composite average of the proportion of the environmental damage costs to the total logistics of each department during the delivery of all the goods within the reporting period.

（5）Resource Management and Environmental Protection Costs

Resource management and environmental protection costs refer to the actual expenses of social logistics system which have been paid for maintaining the sustainable utilization of resources, protecting the environment from damage and reducing the damage.

6 Conclusion

This article has carried on the discussion to costs problems of the logistics activities from an environmental perspective, and further improved the concept and statistical modes of macroscopic logistics costs accounting, that is, to quantify environmental damage which results from various logistics functional elements by using the valuation method of resources and environment, and incorporate it into the logistics costs in the form of the environmental costs.

It should be noted that, due to the limitation of valuation method, environmental statistics and other aspects, the logistics environmental costs reflect only the lowest value of the natural resources and environmental assets which have been affected. In addition, the measurement of environmental costs should also pay attention to the problems of boundary definition to avoid omissions and repetitive computation.

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References

Feng Gengzhong et al. (2007). *The Calculation and Evaluation of Enterprise's Logistics Costs*. Beijing: China Machine Press,.

Gao Ziyou & Sun Huijun. (2005). *Modern Logistics and Transportation Systems.* Beijing: China Communications Press,

Yu Liansheng et al. (2004). *Natural Resources Value Theory and Its Application*. Chemical Industry Press

Zhang Chi et al. (2006). *Natural Resources Value Theory and Its Application in Environmental Impact Assessment.* Industrial Safety and Environmental Protection, 32(5):13~14.

Site Selection with TOPSIS and Entropy Weight for Network Nodes in a Closed-Loop Military Supply Chain

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Abstract: Site selection for network nodes in closed-loop military supply chain influences many others functional strategies of supply chain network, such as transportation, distribution, inventory, recuperation and recycle. This paper seeks out the proper method of site selection based on the characters analysis of site selection in closed-loop military supply chain network, and proposes an improved TOPSIS method that combined with entropy weight. What's more, through the analysis it could find that the entropy weight calculation manner is simplified to improve the efficiency of site selection in closed-loop military supply chain.
Keywords: Site selection; TOPSIS; Entropy weight; Closed-loop military supply chain.

1 Introduction

As one of the utmost important procedures and steps, site selection plays a fundamental role in the closed-loop supply chain network planning and designing. It's all cleared that site selection influences many others functional strategies in supply chain network construction and operation, such as transportation, distribution, inventory, recuperation and post disposal, which depends on the operation manners, physiology position, and resources available in the supply chain system to great extent. Accordingly, in the planning stage of the closed-loop military supply chain network, the attention firstly focus on the site selection of various nodes in the supply chain network as well.

2 Site Selection Methods

There are various research methods of node site selection in the supply chain logistics system, which can be divided into 3 types: the first type is expert decision making, to investigate and analyze the candidate nodes by using expert professional experiences, and combing with the internal and external operation environment, including Delphi method, expert evaluation method, analytic hierarchy process (AHP); the second type is mathematical analytical method, which is used widely, through abstracting and analyzing the site selection problem, finding the characteristics and the essence of the problem, constructing mathematical model, this method could get the optimal result by solving the model, finally, it adjusts and modifies the optimal solution in accordance with the actual situation, this type involves the center of gravity method, linear programming method, the principal component analysis method, TOPSIS method etc. The third type is the simulation decision analysis method, which abstracts the actual site selection optimization problems, creates the problem background, establishes concept model, and constructs the model of the simulation system, then solves the problem by using logic deduction and some advanced scientific algorithm. This type includes neural network algorithm, genetic algorithm, tab search algorithm, simulated annealing algorithm.

The design and planning of closed-loop military supply chain network are based on the whole military logistics system. Constructing strategic supporting bases and designing essence strategic targets are fundamental for site selection in all levels of network. From the practical perspective, in the pre-selection phase, all levels of existing nodes in the military supply chain have already taken the requirements of military targets and strategic factors into consideration; therefore, most of the work are based on the existing nodes by expanding or modifying the original ones. In other words, site selections in closed-loop supply chain is actually

In other words, the site selection of the closed-loop of military supply chain node is based on the basic roles and functions, location requirements and demand, then, compares all aspects of feasible and discrete alternative sites comprehensively, and makes use of the multi objectives decision making process to choose the best solution as the decision results among the alternative sites.

In view of the above characteristics, this research combined with the actual site selection of the closed-loop military supply chain network nodes, using TOPSIS method to make site-selection decisions, making corresponding improvement to the TOPSIS method, for the sake of multi objective in closed-loop military supply chain network node site selection requirements. Therefore it could ensure that the site selection result is more practical and scientific, suitable to the realistic conditions.

3 Literature Review

Since TOPSIS(technique for order preference by similarity to ideal solution), also known as the approximation ordering method of ideal solution, was initially proposed as a multiple criteria decision making method by Hwang and Yoon(1981), then, it widely applied in many field to solve some decision making problems, such as ranking technologies alternatives(Zavadskas,1986),resource saving decisions making (Zavadskas,1987),construction projects assessment(Zavadskas, E. K., Peldschus, F., Kaklauskas, A.,1994), buildings evaluation(Zavadskas, E. K, Kaklauskas, A.,1996) , optimizing the ways of repairing matched roofs(Ustinovicius,2002), choosing staff in the human resources (Shih,2007),and the finance performance evaluation (Nurgay Ergul,2010, J. Antucheviciene,2012) .

However, in the course of the applying TOPSIS method to solve specific practical and theory problems, some researchers improved this evaluation method through the combination of other algorithm to improve the calculation efficiency. The literatures published recently that relate to make use of TOPSIS and other algorithms could be divided into three categories, which includes fuzzy TOPSIS, AHP and TOPSIS, TOPSIS and entropy as well. Fuzzy TOPSIS mainly used to select partners and contractors (Marzouk,2008), choose suppliers (Boran et al.,2009) and shopping center site selection(Onut et al.,2010) . What's more, fuzzy TOPSIS was used to research the warehouses location decision problem through analyzes the attributes of some specific warehouses as well. While AHP and TOPSIS method, which applied in selecting projects (Amiri,2010), suppliers evaluation (Du,2011),construction planning decision of subway station(Chen t.t.,2012). TOPSIS and entropy represents the entropy weight TOPSIS method, which applied in emergency military logistics' efficiency evaluation (Wang T.hong,2012), selection of supply chain partners (Lu Q.qin,2014). However, the recent papers relate to TOPSIS and entropy method is seldom applied in closed-loop supply chain and logistics, especially in the nodes site selections of supply network.

Despite the AHP-TOPSIS and fuzzy TOPSIS methods are applied in site selection frequently, however, TOPSIS and entropy could be beneficial to the accuracy of evaluation result, improving the reliability and practicability because of its effective calculation procedures and objective criteria. This actually is the application of mathematical inference in practical problem of military closed-loop supply chain node site selection. More importantly, it's also used to evaluate the efficiency, rank alternative solutions, choose suppliers and cooperators, allocate substitutable resources in different regions, and other decision making problems in the field of military warfare and support.

4 Procedures

TOPSIS can be applied to each level of node site selection in military closed-loop supply chain network. The core idea is to construct multi index evaluation criteria in the multi-objective decision process of each level node site selection. Hence it could evaluate each candidate node by using comprehensive evaluation criterion, establishing multi-dimensional evaluation vectors eventually, This vector can be regarded as a specific point $M\ (a_1, a_2, a_3, \cdots a_n)$ in a multi-dimensional space. Each evaluation index in the vector has a best value as well as the worst one, which are also considered as the ideal point and negative ideal point correspondingly. By calculating the distances between candidate point and the ideal point/negative point, ranking alternatives could be found. The point that is far from the negative ideal point meanwhile close to the ideal point could be the optimum site determinant.

In addition, in the TOPSIS site selection method, the entropy weight method can be used to determine the weigh value of each evaluation criterion in military closed loop supply chain node site selection. The criterion could be more important as the weigh value increases. To be specifically, the steps of using entropy weight involved TOPSIS method in the closed loop of military supply chain network node site selection is as follows:

4.1 Establishing the evaluation criteria of node site selection

According to the closed-loop military supply chain network planning and design objectives, the aim of site selection is to realize the closed loop of military supply chain overall strategic target, developing better function of network support efficiency. Therefore, the research begins with studying the whole process of military material supplies when investigating all candidate site point, reviewing various site selection proposals' impact on the overall supply network, as well as on the node functional performance. The candidate nodes assessment could be conducted in the following aspects:

(1)the rationality of geographic location

The rationality of each level node's geographic location refers to the adaptability of all levels of nodes to the overall security pattern in the closed loop of military supply chain network. Specifically, whether the traffic condition, infrastructure, available area could meet each node's support requirements in strategic, operational and tactical level. For the closed-loop military supply chain network node, the geographic location rationality belongs to beneficial evaluating indicator, the greater the value represents the better utilization of network support.

(2)the required cost of node construction

The required cost of node construction refers to the engineering cost and construction spending of establishing or modifying/expanding node construction in accordance with the standard requirements of node function. Node construction cost is a cost orientation index, in a certain range, the smaller the value, the node turns to be closer to the optimal.

(3)the utilization rate of existing facilities

Nodes in each level of closed military supply chain network should utilize the existing security facilities as much as possible, such as warehouses, logistics equipment, goods yard etc. to save the construction funds, as well as to improve efficiency in the use of military resources. Similarly, the utilization rate of existing facilities belongs to beneficial evaluating indicator.

(4)support response level

The ultimate target of setting all levels of supporting node is to meet military force material demand in training and wartime. Therefore, the node's support response level is also a critical evaluation criteria, which mainly refers to the amount of available materials resource, the average distance between the node and military users etc. The plenty of resource amount and the short distance could be beneficial to improve response level effectively. For each node, the higher the support response level, the result could be better, hence it's a beneficial evaluating indicator.

(5)the wartime safety

Wartime safety mainly refers to geographic shelter, safety protection, camouflage protection in all levels of site selections, to hide from the enemy observation, and avoid enemy's fire strike. A better wartime safety job could bring little damage in wartime, which maximizes the support effectiveness. It's a beneficial evaluating indicator.

4.2Construction a standardized matrix of site selection

The five evaluation criteria items of site selection that mentioned above, the assignment range of each index is different in practice. For the convenience of calculation, the present provisions of the value of each index are quantified in the 0 to 1 range, which means the value positioned during 0 to 1 could be seen as legal and efficient. Besides, for the efficiency indexes, bigger value is better, on the contrary, for the cost indexes, the smaller means better.

Thus, it could get an initial evaluation matrix F for each alternative site scheme, namely,

$$F = \begin{vmatrix} F_{11} & F_{12} & \cdots & F_{15} \\ F_{21} & F_{22} & \cdots & F_{25} \\ \vdots & \vdots & \vdots & \vdots \\ F_{n1} & F_{n2} & \cdots & F_{n5} \end{vmatrix}$$

Among them, n represents the number of the alternative site, F_{ij} means the value of evaluation indexes number j $(1 \le j \le 5)$ of alternative site i, $i = 1, 2, 3, \cdots, n$

Then, take advantage of the normalized formula to standardized the initial evaluation matrix,

The normalized formula is

$$x_{ij} = \frac{F_{ij}}{\sqrt{\sum_{i=1}^{n} F_{ij}^2}}, \quad (1 \le i \le n, 1 \le j \le 5)$$

Thus, it could get the standardized evaluation matrix of each alternative site, that is,

$$X = \begin{vmatrix} x_{11} & x_{12} & \cdots & x_{15} \\ x_{21} & x_{22} & \cdots & x_{25} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{n5} \end{vmatrix}$$

4.3Calculating the entropy weight of every index

Entropy method refers to the amount of information that according to the specific values of each evaluation index and attribute provided by objects itself, which is used to determine the weight of each index and attribute. In the site selection of closed-loop military supply chain network, it makes use of standardized evaluation matrix of each alternative site, which contains the data information could be used to calculate the specific weight of each evaluation index.

In general, the values of m evaluation indexes in site selection of each node represent the entropy (information content), which expressed by the standardized matrix: $I = -\frac{1}{\ln(m)} = -(\ln m)^{-1}$

After the normalized processing, each value of evaluation index in the initial evaluation matrix could form an information space, $\Omega = \sum_{j=1}^{m} x_{ij}$

Thus, it could calculate the probability of single evaluation index by the formula of probability,

$$P_j = \frac{x_{ij}}{\sum_{j=1}^{m} x_{ij}}$$

Then, aggregating entropy of each alternative decision in the corresponding evaluation index of every site, the total entropy can be obtained on the evaluation index j $(1 \le j \le 5)$:

$$s_j = -(\ln m)^{-1} \sum_{i=1}^{n} \frac{x_{ij}}{\sum_{j=1}^{5} x_{ij}}$$

Among them, m means the number of evaluation indexes; n represent the number of alternative sites. Finally, it could obtain the entropy of evaluation indexes j $(1 \le j \le 5)$ in site selection:

$$w_j = \frac{1 - s_j}{\sum_{j=1}^{m} (1 - s_j)}$$

In this formula, $1 - s_j$ means the variability of site selection evaluation indexes, through this calculation of the formula, it can get entropy on evaluation index j in closed-loop military supply chain.

4.4calculating matrix with weight of evaluation index

The entropy weights of evaluation index j $(1 \le j \le 5)$ in the closed-loop military supply chain multiples the site selection standardized matrix $X = [x_{ij}]$, then, it can get the matrix with weight of evaluation index $T = [t_{ij}]$, specifically, the matrix with weight is as follows:

$$T = \begin{vmatrix} w_1x_{11} & w_2x_{12} & \cdots & w_5x_{15} \\ w_1x_{21} & w_2x_{22} & \cdots & w_5x_{25} \\ \vdots & \vdots & \vdots & \vdots \\ w_1x_{n1} & w_2x_{n2} & \cdots & w_5x_{n5} \end{vmatrix} = \begin{vmatrix} t_{11} & t_{12} & \cdots & t_{15} \\ t_{21} & t_{22} & \cdots & t_{25} \\ \vdots & \vdots & \vdots & \vdots \\ t_{n1} & t_{n2} & \cdots & t_{n5} \end{vmatrix}$$

4.5establishing positive proper solution and negative proper solution

As for the indexes of efficiency, the positive proper solution means the biggest value. On the contrary, as with the indexes of cost, the positive proper solution means the smallest value. This could illustrates as follows,

$$t_j^+ = \begin{cases} \max(t_{i1}, t_{i2}, \cdots, t_{i5}) & , j \text{ is index of efficiency} \\ m\text{in}(t_{i1}, t_{i2}, \cdots, t_{i5}) & , j \text{ is index of cost} \end{cases}$$

As for negative proper solution, the situation would be contrary. as with the indexes of efficiency, the negative proper solution means the smallest value. When it comes to the indexes of cost, the negative proper solution means the smallest value. This could illustrates as follows,

$$t_j^- = \begin{cases} \min(t_{i1}, t_{i2}, \cdots, t_{i5}) & , j \text{ is index of efficiency} \\ max(t_{i1}, t_{i2}, \cdots, t_{i5}) & , j \text{ is index of cost} \end{cases}$$

Then, it could get the positive proper solution t_j^+ and negative proper solution t_j^-.

4.6calculating the Euclid distance

Calculating the distance between the positive proper solution and negative proper solution, in this paper, it brings in the Euclid distance formula to calculate the gap between the positive proper solution and negative proper solution, which could illustrates as follows,

$$D_i^+ = \sqrt{\sum_{j=1}^{5}(t_{ij} - t_j^+)^2}\ ,\ (1 \le i \le n)\ ,\quad D_i^- = \sqrt{\sum_{j=1}^{5}(t_{ij} - t_j^-)^2}\ ,\ (1 \le i \le n)$$

4.7Ranking all solutions and alternative sites

It takes the Euclid distances that calculated above to investigate the index value of similarity degree, then, ranking the value of index from the biggest one to the smallest one. The formula of similarity degree is $C_i = \frac{D_i^-}{D_i^+ + D_i^-}$

Among the values of the index C_i, if it get more close to 1, then, the corresponding site would be more proper for the node in closed-loop military supply chain network, and would be satisfied the demand of the node. Therefore, in all alternative sites, the largest value of similarity degree C_i in the alternative sites for the closed-loop supply chain network system, the corresponding scheme and site would be the optimal choice and decision.

5 Conclusion

This paper proposes a method with TOPSIS and entropy weight to select site in closed-loop military supply chain network. What is more, it improves the calculation manner of entropy weight to simplify the calculation procedure, besides it keeps the precision of weight at the same time. This would be beneficial to the accuracy of evaluation result, improving the reliability and practicability in closed-loop military supply chain. However, this paper just initially proposes an improved TOPSIS method combined with entropy weight to solve site selection question, but it doesn't provide a specific case or simulation example to verify this method, and the application of this method to solve other decision making problems is still need to consider the specific conditions and different attributes when those problems could be settled efficiently by this method.

References

Amiri, M. P. (2010). "Project selection for oil-fields development by using the AHP and fuzzy TOPSIS methods." *Expert Systems with Applications,*37(9), 6218–6224.

Boran, F. E., Gen., S., Kurt, M., Akay, D. (2009). "A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method." *Expert Systems with Applications ,*36(8), 11363–11368.

CHEN Ting-ting,SONG Yong-fa.(2012). "Construction planning decision of subway stations based on AHP-TOPSIS method." *Journal of Engineering Management*. Vol 2,33-36

Du lizhen, Tao dexin. (2011). "Auto parts suppliers evaluation system based on AHP and TOPSIS." *Logistics Engineering and Management,* Vol 3,63-65.

Eren Özceylana, Tolga Bekta, Turan Paksoyc. (2014). "Modeling and optimization the integrated problem of closed-loop supply chain network design and disassembly line balancing." *Transportation research part E: logistics and transportation review,* Vol 61, 142-164.

G. Kannan, A. Noorul Haq, M. Devika. (2009). "Analysis of closed loop supply chain using genetic algorithm and particle swarm optimization." *Int. J. Prod. Res.* Vol 47, 1175–1200.

G. Kannan, P. Sasikumar, K. Devika. (2010). "A genetic algorithm approach for solving a closed loop supply chain model: a case of battery recycling." *Applied Mathematic Modeling,* Vol 34, 655–670.

Hamed Soleimani, Mirmehdi Seyyed-Esfahan. (2014). "Incorporating risk measures in closed loop supply chain network design." *International journal of production research,* 52(6),1843-1867.

Hwang C. L, Yoon, K. K. (1981). "Multiple attribute decision making." *Springer-Verlag,* Berlin, 86-91.

J. Antucheviciene, E. K. Zavadskas, A. Zakarevicius. (2012). "Ranking redevelopment decisions of derelict buildings and analysis of ranking results." *Journal of Economic Computation and Economic Cybernetics Studies and Research,* Vol(2),543-558.

Karablikovas, A., Ustinovicius L. (2002). "Optimizing ways of repairing matched roofs." *Foundations of Civil and Environmental Engineering,*Vol 2, 69–86.

Karla B. Valenzuela. (2009). "A study of closed-loop supply chain models with governmental incentives and fees." *Iowa State University*.2009.

Li S., H.F. Guo. (2013). "Network designing and routine optimization of closed-loop supply chain under the condition of electronic commerce". *Journal of ShengYan science and technology university,* Vol 6, 1-7.

Lu Qiuqin, Zhao Qiao. (2014). "Selection of supply chain partners based on entropy-weighted TOPSIS".*Logistics Technology*. Vol 13,331-334.

Marzouk, M. (2008). "A superiority and inferiority ranking model for contractor selection." *Construction Innovation: Information, Process, Management ,*Vol(8), 250–268.

Man J.H., Shao Y.N.. (2009). "The application of TOPSIS in enterprises logistics center site selection" .*Journal of logistics science and technology*, vol 11，17-19.

Nurgay Ergul. (2010). "Analyzing of the effect of league performance of Turkish sport clubs over the financial performance of the corresponding sport companies." *China-USA Business Review,* Vol 9,69-79.

Onut, S., Efendigil, T., Kara, S. S. (2010). "A combined fuzzy MCDM approach for selecting shopping center site: an example from Istanbul, Turkey." *Expert Systems with Applications* ,Vol37, issue3, 1973–1980.

Qiang Qiang, Keke, Trisha Anderson. (2013). "The closed loop supply chain network with competition, distribution channel investment, and uncertainties" *Omega,* Vol 41,issue2, 186-194.

Shih, H. S., Shyur, H. J., Lee, E. S.. (2007). "An extension of TOPSIS for group decision making." *Mathematical and Computer Modelling,* 45(7-8), 801-813.

Wang Tianhong, Song Yexin. (2012). "Emergency military logistics' efficiency evaluation based on ameliorated entropy weight TOPSIS method. *Ordnance Industry Automation,* Vol 8,31-37.

Zavadskas, E. K. (1986). "The method of ranking of construction-technological alternatives on the basis of the distance from the ideal solution." *New Construction Technology for Buildings and Structures. Leningrad*, 52–57.

Zavadskas, E. K. (1987). "Complex Evaluation and Selection of Resource-saving Decisions in Construction." *Vilnius*: *Mokslas*.

Zavadskas, E. K., Peldschus F., Kaklauskas A. (1994). "Multiple criteria evaluation of projects in construction." *Vilnius: Technika.*

Zavadskas, E. K, Kaklauskas, A. (1996). "Multiple criteria evaluation of buildings." *Vilnius, Technika*

A Study on the Effects of Network Centrality and Efficiency on the Throughput of Korean and Chinese Container Ports

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Abstract: Port is a major junction in the physical distribution as a base being utilized. It is a contact of maritime and land transport and essential platform in production, trade, distribution and exchange of information as a node of supply chain system crossing each port. Moreover, it has to give competitive advantage to shipping companies and shippers using port which has a significant impact on the national economy of the departure and arrival country. In this paper, using multiple regression analysis, social network analysis (SNA) and data envelopment analysis (DEA), this study examines effect of the network centrality in port and port efficiency on the throughput of Korean and Chinese container port. As a result, network centrality index, relation between degree, betweenness centrality index and throughput were correlated.
Keywords: SNA; DEA; Centrality; Network; Efficiency; Throughput.

1 Introduction

In view of the fact that 80 percent of global trade is carried by sea freight, trade and sea freight have a close relationship. There are node, mode and link in the transport system. The port is a major junction in the physical distribution as a base being utilized. It is a contact of maritime and land transport and an essential platform in production, trade, distribution and exchange of information as a node of supply chain system crossing each port. Moreover, it has to give competitive advantage to shipping companies and shippers using port which has a significant impact on the national economy of the departure and arrival country.

Port throughput is affected by a variety of factors such as national and regional economic growth, trade, import and export, quality of charges and geographic location. However, it is queried that the container throughput is the main or the only criterion of a hub port in specific areas. Therefore, the connectivity degree of a port with other ports for shipping companies in and around the port area becomes the judgment of a hub port.

Because of the increase in the number of ports and the intense competition, it is likely to fail making the port development strategy, according to the port throughput simple, because a port forms a network, which causes the shift of port paradigm. Therefore, future port development strategy needs new ways of identifying not only the competitive factors, but also the understanding of the network.

2 Literature Review

2.1 SNA (Social Network Analysis)

A shipping network such as port system is mainly organized hierarchically by several major shipping ports (center positions). The main regional scales include Caribbean coast (McCalla et al., 2005), Mediterranean (Cisic et al., 2007), and Northeast Asia (Ducruet et al., 2010).

In terms of social network studies, port and air network have been primarily studied in order to understand the phase shift type of port (Ducruet et al., 2010) or air network (Fremont, 2007; Newman, 2011.) until now.

Some of these studies suggest the availability of the network structure through using correlation analysis between port network and port throughput or using correlation analysis among air network analysis index, the number of passengers, the city population and gross regional product (GRP).

Ducreut, C. et al. (2010) constructed a shipping network based on transfer of data between the port and port-based network and suggested location of port to analyze the network index in terms of SNA. They also compared the network centrality degree, the relationship between indicators and port throughput which are connected to the location of the port.

When viewing a previous study, communication and cooperation are the key performance to improving the efficiency of ports. At the same time, measuring port for communication and cooperation between ports and ports of the connection and cooperation can be seen. Network analysis based on cooperation and connection can analyze not only the flow of product, but also the role of ports.

2.2 DEA (Data Envelopment Analysis)

Dan LI et al. (2013) analyzed efficiency of 42 container ports in China in 2010 using DEA. They used terminal length, handling equipment quantity, staff quantity as input variables and container throughput as output variables. In the result of the study, average efficiency of CCR and BCC are 0.689 and 0.577 in 42 ports in China.

Cheng et al. (2009) measured the effect of port improvement and technical development on efficiency of port in 1991 to 2004. They also measured the reason of efficiency changing and the rising and falling of the efficiency using Malmquist productivity index. In the result of the study, scale efficiency is an important factor, but it is not absolutely influent.

Looking at the input variables and output variables in previous studies, they primarily used berth length, total area, number of berths, depth, number of terminal equipment and terminal handling equipment as input variables.

Most of the studies used throughput as output variables. The reason is that, according to Cullinane (2005), throughput is the basis of the evaluating scale of relativity, the scale of investment, or level of activity for intercomparison which is related with freight-related equipment and services directly. Most importantly, it is considered to be an efficient index of container terminals because it is directly related to creating profit of ports.

3. Theoretical consideration

3.1 SNA

A social network is a social structure formed by social relations like an individual organization, friends or trade. This network is expressed by an actor, a node and a tie or a link. SNA is separated by 3 indexes of social relationship and 4 properties of social network.

In this paper, the influence in the field of the sociology of these properties in relation to the concept, as one of the most common indicators, will discuss centrality. In other words, it aims to examine degree centrality, closeness centrality, betweenness centrality and eigenvector centrality in 4 properties of SNA.

(1)Degree centrality

The concept of degree centrality is connected to a node with degree as the center. This is the measurement method on how many other nodes are connected directly to more than one node without going through the connector over two steps.

Degree centrality is defined as follows:

$$C_D(P_k) = \sum_{i=1}^{n} a(P_k P_i) \tag{1}$$

n is the number of the actors,

$$a(P_k P_i) = \begin{cases} 1, \text{connected } P_i \text{ and } P_k \\ 0, \text{connected } P_i \text{ and } P_k \end{cases}$$

Degree centrality is measured on one node, the connectors that have one node in the direction of the incoming and outgoing direction separates into in-degree centrality and out-degree centrality respectively.

In-degree centrality, a number of incoming connections connect directly to the node as follows:

$$C_D(n_i) = \frac{d_I(n_i)}{g-1} \tag{2}$$

At this time, $d_I(n_i)$ is an in-degree centrality of node n_i, g is the number of all nodes in the network, $C_D(n_i)$ is degree centrality.

Out-degree is the number of outgoing connections directly to the node centrality as follows:

$$C_D(n_i) = \frac{d_0(n_i)}{g-1} \tag{3}$$

At this time, $d_0(n_i)$ is an out-degree centrality of node n_i, g is the number of all nodes in the network, $C_D(n_i)$ is degree centrality.

(2)Closeness centrality

Closeness centrality measures a located distance which is from the center of the whole network after calculating a distance from one node to all nodes in measuring centrality of SNA.

In other words, in the case of degree centrality, it is only measured by directly connected nodes, but closeness centrality is linked directly as well as indirectly, all connected in a network, all nodes are calculated by measuring the distance. Because of this, the largest centrality node of the measured closeness centrality is the center with the shortest distance in the whole network. The node in the center is easy to secure and to access all kinds of information; it is influential and has a high social status in networks.

Closeness centrality can be expressed as follows:

$$C_C(P_i) = \frac{n-1}{\left[\sum_{i=1}^{n} d(P_i, P_j)\right]} \tag{4}$$

At this time, $d(P_i, P_j)$ is the number of routes in P_i to P_j.

(3)Betweenness centrality

Betweenness centrality serves as a bridge between the nodes within the network. High betweenness centrality means it is the node to perform intermediary in information exchange or information flow in whole information.

If there is a linked node like A-B-C, because A and C can connect only through B, node B performs regulation role between node A and node C potentially like a bridge.

Betweenness centrality connects port to port by shipping companies. In other words, the higher betweenness centrality port is the higher the transshipment throughput can improve.

This betweenness centrality is defined as follows:

$$C_B(P_k) = \sum_{i=1}^{n}\sum_{j=1}^{n} \frac{g_{ij}(P_k)}{g_{ij}} \tag{5}$$

At this time, g_{ij} is the number of the shortest routes in P_i to P_j, $g_{ij}(P_k)$ is the number of routes in P_i to P_j via P_k.

(4)Eigenvector centrality

Eigenvector centrality measures the importance of nodes in network, namely the centrality of the individual actors and the actors (ego) that are associated with other actors (actors) are considered. It is the concept about evaluating the influence or importance of one node.

In port network, the higher eigenvector centrality port connects with the higher centrality port in the network. To conclude, giving an opportunity to increase the port throughput as partnership and cooperation with highly influential port could be considered.

3.2 DEA

DEA model presented by Charnes, Cooper and Rhodes (1978) is a method for deducting the value of the efficiency considering an objective relationship between multiple output factors and input factors at the same time. It is a non-parametric method fixed existing method of the productivity measure. Also, it is a relative evaluation method in the process of measuring the efficiency values of the subject of appraisal DMUs, not only do not need to require a predetermined weight in each of the output or input factors, but it also provides the information of inefficiency about what occurs in each part.

There are several models depending on the purpose of use in DEA, and common use CCR model and BCC model. These models are DEA techniques evaluating relative efficiency of several DMUs at the same time. There are two models, the biggest difference is that CCR model is used in the case of constant return to scale, and BCC model is used in case of variable return to scale.

4. Results of analysis

4.1 SNA

This study analyzes the centrality of container ports in Korea and China based on Asian sea route of 2014's top 10 container shipping companies. The data for network analysis was based on Containerization International Yearbook 2008-2012.

(1)Results of the degree centrality analysis

High centrality ports in the port network connect a port with a port directly. The results of the top 10 ranked degree centrality are shown in Table 1.

Table 1. Top 10 ranked degree centrality

Rank	2008			2009			2010			2011			2012		
	Port	In	Out	Port	In	Out	Port	In	Out	Port	In	Out	Port	In	Out
1	HK	246	290	HK	362	344	HK	283	276	SZ	310	294	HK	313	294
2	SH	222	184	SH	255	229	SZ	282	267	HK	293	265	SZ	299	257
3	SZ	180	206	SZ	247	276	SH	232	212	SH	221	231	BS	181	181
4	BS	126	124	BS	168	166	QD	178	178	BS	166	165	NB	180	181
5	NB	125	126	NB	151	172	TJ	148	11	NB	157	169	SH	150	275
6	TJ	69	7	QD	88	87	BS	145	144	QD	91	92	QD	85	84
7	QD	62	63	XM	68	68	NB	140	240	XM	67	66	XM	76	76
8	XM	45	43	TJ	50	15	XM	41	56	DL	46	41	TJ	48	7
9	GY	36	35	DL	44	44	GZ	33	32	GY	39	38	GY	41	41
10	DL	32	33	GY	43	43	GY	33	33	GZ	24	24	DL	36	38

* BS: Busan, DL: Dalian, GY: Gwangyang, GZ: Guangzhou, HK: Honk Kong, NB: Ningbo, QD: Qingdao, SZ: Shenzhen, TJ: Tianjin, XM: Xiamen

In terms of the degree centrality Chinese ports ranked high mark consistently (i.e. Hong Kong and Shenzhen), Korean ports (i.e. Busan and Gwangyang) also ranked top 10 continuously. In the case of Tianjin, it appears that in-degree centrality is higher than out-degree centrality. This means that the returning port is more frequent than departure. It seems that most of the shipping companies judged port of Tianjin is suitable in the last port rather than in the calling port of the sea route because of geographical position. Shanghai gradually went down in degree centrality ranking. It is because there is an effect in moving throughput from the port of Shanghai to surroundings ports, but the basic status of the port of Shanghai as a hub port had been continuously increased.

(2) Results of the closeness centrality analysis

The Concept of closeness centrality defined as the logical distance is long or short. In addition, closeness centrality is not only the connection with ports directly, but also the connection between the partners, ports including potential partners directly and indirectly. The ports in the most central location in whole shipping network determined by the choice of shipping companies have an influence because it is easier to access information, power, influence, status, security and gain access to the throughput on the network.

The results of the top 10 ranked closeness centrality are shown in Table 2.

Table 2. Top 10 ranked closeness centrality

Rank	2008			2009			2010			2011			2012		
	Port	In	Out	Port	In	Out	Port	In	Out	Port	In	Out	Port	In	Out
1	HK	0.494	0.514	BS	0.490	0.436	SH	0.471	0.458	HK	0.488	0.504	BS	0.493	0.459
2	SH	0.486	0.446	HK	0.485	0.485	BS	0.471	0.461	SH	0.457	0.429	HK	0.484	0.459
3	BS	0.466	0.476	SH	0.482	0.449	HK	0.454	0.485	SZ	0.448	0.458	SZ	0.468	0.472
4	SZ	0.455	0.471	SZ	0.451	0.453	SZ	0.448	0.456	BS	0.446	0.458	SH	0.463	0.447
5	NB	0.451	0.443	QD	0.445	0.403	NB	0.432	0.416	QD	0.424	0.410	NB	0.448	0.436
6	QD	0.431	0.423	NB	0.439	0.443	QD	0.422	0.406	NB	0.420	0.410	QD	0.435	0.386
7	XM	0.400	0.388	GZ	0.412	0.380	GZ	0.402	0.368	XM	0.395	0.404	GZ	0.424	0.378
8	DL	0.375	0.358	DL	0.400	0.353	XM	0.396	0.387	GZ	0.382	0.364	XM	0.424	0.392
9	GY	0.372	0.390	XM	0.382	0.384	DL	0.394	0.352	DL	0.375	0.334	GY	0.400	0.358
10	US	0.361	0.340	GY	0.379	0.372	GY	0.370	0.358	GY	0.352	0.349	DL	0.386	0.344

* BS: Busan, DL: Dalian, GY: Gwangyang, GZ: Guangzhou, HK: Honk Kong, NB: Ningbo, QD: Qingdao, SZ: Shenzhen, US: Ulsan, XM: Xiamen

(3)Results of the betweenness centrality analysis

Betweenness centrality is defined to be connected with the other networks. This is the rate of all the shortest routes as evaluating function of mediators connecting other nodes.

Table 3. Top 10 ranked betweenness centrality

Rank	2008		2009		2010		2011		2012	
	Port	Degree	Port	Degree	Port	Degree	Port	Degree	Port	Degree
1	HK	0.213	HK	0.142	HK	0.172	HK	0.152	BS	0.141
2	BS	0.100	BS	0.121	SH	0.106	SH	0.133	HK	0.095
3	SZ	0.091	SH	0.102	BS	0.082	SZ	0.086	SZ	0.090
4	SH	0.079	SZ	0.099	SZ	0.060	BS	0.083	SH	0.088
5	QD	0.030	NB	0.051	NB	0.041	NB	0.037	NB	0.029
6	NB	0.025	QD	0.035	QD	0.035	QD	0.032	XM	0.024
7	XM	0.019	DL	0.030	DL	0.025	DL	0.025	QD	0.023
8	GY	0.013	GY	0.013	GZ	0.012	XM	0.011	GZ	0.022
9	SW	0.011	GZ	0.010	XM	0.011	GZ	0.009	DL	0.015
10	TJ	0.010	XM	0.008	TJ	0.008	TJ	0.001	YK	0.008

* BS: Busan, DL: Dalian, GY: Gwangyang, GZ: Guangzhou, HK: Honk Kong, NB: Ningbo, QD: Qingdao, SW: Shanwei, SZ: Shenzhen, TJ: Tianjin, XM: Xiamen, YK: Yinkkou

These ports are located in trunk route in shipping, so it can be seen that they have played a role as a mediator.

Betweenness centrality seems to connect with port to port by shipping companies. In other words, the transshipment traffic volume can be determined by betweenness centrality, so we can judge that a higher betweenness centrality of a port can be a higher transshipment port as well.

(4)Results of the eigenvector centrality analysis

In the port network, a higher eigenvector centrality port, it is much more connected with high centrality ports on the network, therefore cooperation with the ports in high influence can find a chance to increase the port traffic.

Hong Kong, Shenzhen, Busan have achieved high marks in this centrality, the results of the top 10 ranked eigenvector centrality are shown in Table 4.

Table 4. Top 10 ranked eigenvector centrality

Rank	2008		2009		2010		2011		2012	
	Port	Degree	Port	Degree	Port	Degree	Port	Degree	Port	Degree
1	HK	0.412	HK	0.506	HK	0.665	HK	0.519	HK	0.432
2	BS	0.400	SH	0.472	SZ	0.650	SZ	0.499	BS	0.410
3	SH	0.374	SZ	0.452	NB	0.357	SH	0.443	SZ	0.368
4	NB	0.346	NB	0.444	QD	0.356	NB	0.427	SH	0.367
5	SZ	0.343	BS	0.328	SH	0.305	BS	0.337	NB	0.353
6	QD	0.264	QD	0.252	BS	0.288	QD	0.279	QD	0.270
7	XM	0.205	XM	0.200	XM	0.178	XM	0.254	XM	0.244
8	GY	0.200	GY	0.189	GZ	0.165	GZ	0.157	GZ	0.192
9	DL	0.169	GZ	0.168	TJ	0.150	GY	0.148	GY	0.186
10	TJ	0.130	DL	0.145	GY	0.136	DL	0.134	DL	0.143

* BS: Busan, DL: Dalian, GY: Gwangyang, GZ: Guangzhou, HK: Honk Kong, NB: Ningbo, QD: Qingdao, SZ: Shenzhen, TJ: Tianjin, XM: Xiamen.

In case of the port of Busan eigenvector centrality ranking, it has been increased significantly since 2012 because of the result of the hub port policy of Busan in the Korean government. It is considered that a port operation policy in the future has to increase its centrality itself. In addition, it has to cooperate with ports in high centrality for reinforcing the function of transshipment port more and more.

4.2 DEA

DEA analysis has two forms focusing on maintaining the current output and maximizing the level of input factors called Input-Oriented and focusing on maintaining the current input to maximize the level of output factors called Output-Oriented. Input factors of Output-Oriented is the capital goods, it is the useful DEA model about evaluation of fixed assets like automobile industry, the steel industry and the port industry to input large of capital at once.

This study aims to analyze the efficiency of 10 container ports in Korea and China (Dalian, Guangzhou, Hong Kong, Ningbo, Qingdao, Shanghai, Shenzhen, Tianjin, Busan, and Gwangyang) and its determinants during over a five-year period (from 2008 to 2012) using DEA-CCR.

(1)Results of the port efficiency analysis using DEA-CCR

In an efficiency value more than 1, we can evaluate high efficiency port; a higher efficiency value means higher efficiency port. On the other hand, from this result, a value less than 1 came out; it is relatively inefficient and can be ranked.

The result of the analysis was measured across the Ningbo port efficiently every year. An average of efficiency index in 2008 to 2012 showed 0.761, 0.637, 0.726, 0.864, and 0.902 each year. Busan and Gwangyang ports' overall efficiency appeared to be low, while Chinese ports of Ningbo, Shanghai are relatively efficient.

Table 5. Result of efficiency analysis

Port / Year	2008	2009	2010	2011	2012
Dalian	0.243	0.167	0.241	0.650	0.453
Guangzhou	0.401	0.436	0.391	0.659	0.657
Hong Kong	0.480	0.386	0.347	0.468	0.485
Ningbo	4.037	2.414	4.110	3.118	4.407
Qingdao	0.613	0.494	0.523	1.265	0.637
Shanghai	0.627	0.568	0.528	0.835	0.869
Shenzhen	0.394	0.292	0.312	0.500	0.372
Tianjin	0.466	1.273	0.472	0.738	0.629
Busan	0.206	0.194	0.191	0.270	0.279
Gwangyang	0.139	0.148	0.144	0.142	0.234
Average	0.761	0.637	0.726	0.864	0.902

4.3 Correlation analysis between network centrality and efficiency of ports

This study analyzes multiple regression analysis based on SNA and DEA to find effect of the network centrality in a port and port efficiency on the throughput of the Korean and Chinese container port.

It has chosen its ports based on the top 10 ports in the network centrality in Asian routes, choose 2 Korean ports (Busan, Gwangyang), 8 Chinese ports (Dalian, Guangzhou, Hong Kong, Ningbo, Qingdao, Shanghai, Shenzhen, and Tianjin).

The independent variables used degree, closeness, betweenness, eigenvector index as network centrality in ports, DEA-CCR model as port efficiency index and a dependent variable was used throughput each ports. In addition, for more specific analysis, each country's GDP, total turnover, and total throughput were used as control variables.

(1)Results of the analysis

The effect of the network centrality in a port and the port efficiency on the throughput of the Korean and Chinese container port effects the result of F test in regression equation, F value is significant as 19.038 ($p=0.000$), This factor was responsible for 74.7% of the subject (adjusted R-squared, 0.747).

As a result, there is no correlation between the port efficiency index and the throughput. On the other hand, network centrality index, relationship between degree, betweenness centrality index and throughput were correlation 0.797, 0.740 each other. In other words, the ports of high degree centrality and betweenness centrality have much throughput than others.

That is to say, there is high degree centrality; it can share resources port to port through port network. Furthermore through it, not only knowledge and technology can be shared, but also port operation. In addition, the network serves as information conduits and advances in technology, new insights on the issues can flow between the port information because it spreads knowledge spillover which will be able to benefit from it.

High degree centrality ports in port network have direct relationships with many ports, so it can have influence as the reader in port network. Also, in the case of high betweenness centrality ports connect with port to port. In other words, high betweenness centrality ports expect there is much transshipment traffic because it performs to connect with port to port like a bridge.

Table 6. Result of regression analysis

Dependent variables	Independent variables	Correlation						Adj R^2	F	p-value	β	T	p-value
		Y	X1	X2	X3	X4	X5						
Throughput		1.000						0.747	19.038	0.000			
	Degree	0.797	1.000								0.426	1.967	0.056**
	Closeness	0.602	0.765	1.000							0.108	0.811	0.422
	Betweenness	0.740	0.835	0.751	1.000						0.365	2.349	0.024*
	Eigenvector	0.695	0.909	0.805	0.773	1.000					-0.075	-0.402	0.690
	DEA-CCR	0.033	0.094	0.072	-0.138	0.152	1.000				-0.072	-0.862	0.394

*, ** P<0.05, P<0.10.

5. Conclusion

This study aims (1) to analyze port network analysis for evaluating ports based on calling patterns of shipping companies, examine structural characteristics of port network and search the centrality of ports within the framework of the network; (2) to analyze an efficiency based on drawing high centrality ports through preceding analysis; (3) to analyze multiple regression in 2008 to 2012 port network centrality and efficiency index as independent variables, throughput as dependent variable, factors affecting the throughput expected GDP, total turnover, and total throughput as control variables.

The first analysis used social network analysis (SNA) based on the Asian route of the top 10 container shipping companies in 2014. In the result, most of the centralities were high in Hong Kong, Shanghai and Busan, therefore we can see that the port higher container throughput is has also higher centralities.

The second analysis used data envelopment analysis (DEA) based on 10 ports in having high centralities of SNA continuously. In the result, one of the most efficient ports, port in Ningbo ranked the first position, including the port of Busan, Korean ports appeared inefficient relatively.

Finally, the data analyzed the multiple regression based on the port network centrality and efficiency index. In this analysis, independent variables were used degree, closeness, betweenness, eigenvector index as network centrality in ports, DEA-CCR model as a port efficiency index and a dependent variable was used throughput each ports. In addition, for more specific analysis, the country's GDP, total turnover, and total throughput as control variables were used. As a result, network centrality index, relation between degree, betweenness centrality index and throughput were correlated at 0.797, 0.740 each. In other words, the ports of high degree centrality and betweenness centrality have much throughput than others.

That means there is high degree centrality; it can share resources port to port through the port network. In addition, through it, not only port operation, but knowledge and technology can be shared, as well. Furthermore the network serves as an information conduit and advances in technology, new insights on the issues can flow between the port information because it spreads knowledge spillover which will be able to benefit from it.

High degree centrality ports in the port network have direct relationships with many ports, so it can have influence as the reader in the port network. Also, in the case of high betweenness centrality different ports connect with port to port. In other words, high betweenness centrality ports expect that there is much transshipment traffic because it performs to connect with port to port like a bridge.

This study analyzed only 10 shipping companies, but if extending its scope, accuracy would be able to determine the structure of the network. In addition, it needs not only according to literature quantitative measurement, but also according to qualitative analysis like a question investigation in selecting input factors and output factors as a determining port efficiency.

References

Cisic, D., Komadina, P., Hlaca, B. (2007). "Network analysis applied to Mediterranean liner transport system," *Paper presented at the International Association of Maritime Economists Conference*, Athens, Greece, 4-6 July.

Dan LI et al. (2013). "The Efficiency Measurement of Coastal Container Terminals in China," *Journal of Transportation Systems Engineering and Information Technology*, Volume13, Issue5, 10-15.

Ducruet, C., Lee, S. W., Ng, K .Y. A. (2010). "Centrality and Vulnerability in Liner Shipping Networks," *Maritime Policy and Management*, Vol.37, No.1, 17-36.

Fremont, A. (2007). "Global Maritime Networks; The case of Maersk," *Journal of Transport Geography*, Vol.15, No.6, 431-442.

Hyung-Sik, Nam, and Dong-Wook, Song. (2011). "Defining Maritime Logistics Hub and its Implication for Container Port," *Maritime Policy and Management*, 38(3), 269-292.

Jasmine S. L. L. and Wei Y. Y. (2001). "Dynamics of Liner Shipping Network and Port Connectivity in Supply Chain Systems: Analysis on East Asia," *Journal of Transport Geography*, 19, 1272-1281.

McCalla, R., Slack, B., Comtois, C. (2005). "The Caribbean basin: Adjusting to global trends in containerization," *Maritime Policy and Management*, Vol. 32, No. 3, 245-261.

UNCTAD. (2013). *Review of Maritime Transport 2013*, United Nations publication. Sales No. E.13.II.D.9. New York and Geneva.

Walker, M., Wasserman, S., and Welbnan, B. (1994). *Statistical Models for Social Support Networks*, Thousand Oaks, CA: Sage Publications.

Spatial Model of City Logistics Nodes and Its Optimizing Algorithm

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Abstract: Expounding the problem of urban logistics nodes synthetically, the article proposed a space model for urban logistics nodes aiming at the sales logistics distribution network. The sales logistics distribution was divided into two stages distribution with different characteristics in this model, which reflected the generality and representativeness of the model. On the base of it, the article proposed optimization algorithm according to the two different distributions and discussed the solution.

Keywords: Logistics nodes; Logistics network; Space model; Optimization algorithm.

Introduction

The city, the product of the combination of society, economy, technology, natural condition and so on, is the gathering place of human civilization. In the city, there are some commercial and industrial bases, population size and transport facility, at the same time there are large quantity of transport demand for means of production and living materials. With the rapid development, traffic pressure is on the rise that should not be ignored. The urban freight transport is changing into logistics that is the only way to reduce this pressure. The author took the sales logistics as an example and proposed a space model for spatial logistics nodes and its optimization algorithm.

1. Definition

Logistics node is the origin point or destination of logistics route in logistics network, which is the place of storing, handling, packaging and distribution processing for goods and materials in logistics system. Specifically speaking, it refers to warehouse, port, freight hub or logistics center etc. The space model with logistics nodes largely determines the route, flow direction and process of logistics. There are relative movement on routes and relative pause state in nodes. The process of logistics is composed by move-pause-move-pose. The logistic nodes and routes make a logistics network structure, the space model of nodes and routes forms the logistics system structure.

(1) The role of logistics nodes

Logistics nodes are very important in logistics system. All the logistics activities are ongoing on logistics routes and nodes. The transportation is the main activity in logistics routes, which contains the pickup transportation, trunk transportation, distribution and so on. All other logistics functional elements, such as storage, sortation, handling, distribution processing, logistics information, are completed on logistics nodes.

(2)Classification of logistics nodes

In different kinds of logistics system, the main functions of nodes are different with the changing of aims of systems and positions of nodes. Several types are as follows: Transferring logistics nodes (connecting different modes of transport as the main function), Storing logistics nodes (storing goods as the main function), Dredging logistics nodes (organizing the movement of goods in logistics system as the main function) and Synthesizing logistics nodes (with more than two kinds of functions in system and combining these functions properly).

(3)The difference between the logistics center and distribution center

From the point of space scope and functional level, logistics nodes can be classified into three types: logistics park, logistics center and distribution center. Logistics park is national or regional level, and the logistics center is regional and urban level, and distribution center is village and community level. According to "Logistics terminology standard of the People's Republic of China", logistics center and distribution centers defined as the place or organization of working on logistics activity and distribution business, respectively. Both need perfect information network. Their differences are shown in table 1.

Table 1.The difference between the logistics center and distribution center

Logistic nodes	Service objects	Functions range	radiation range	Feature of flows	Functions
LC	social service	Generalfun ctions	big	small-varietyl arge-group	strong storing and handling capacity
DC	special users	distribution functions	small	multi-varietys mall-group	distribution first, storing second

With the rapid development of urbanization in China, the conflicts between urban traffic and economy development, logistics network layout and urban layout are increasingly serious, which have been the important factors restricting the improving of urban economy. So it is necessary to research and solve the space optimization problem of logistics nodes. This article takes logistics center and distribution center as logistics nodes to discuss.

2. Space model of logistics nodes

The space model of urban logistics nodes can be considered from two aspects: system model of logistics nodes and spatial location of nodes.

2.1Sales logistics system model [1,2]

The process of sales logistics is from producer though logistics center to clients. Producers are origin point sand client sare destinations. First, producer all over the country will send the products that the whole urban needs to logistics center, which is the first echelon transportation. Then logistics center send products to all clients in the urban to complete the distribution, called the second echelon transportation.

The city is a place of consuming, which has a large number of dispersed but relatively intensive clients. Although the needs for every client are small and the difference among the needs is small too, the total quantity of the products for all clients in the city is huge. Thus, the characteristics of first echelon transportation are large-batch, low-frequency, small-variety. The products can be transported by trucks, trains, ships, planes or multi-mode intensively with large batches. The products sending to the logistics center are stored, processed, sorted and delivered by logistics center. The characteristics of second echelon transportation are small-batch, high-frequency and multi-variety. The products can be delivered by small-size vans though urban roads in the second transportation.

For instance, Haier sends large-batch products produced by Qingdao factory or other factories to one logistics center in Beijing, the products are needed by the whole Beijing. Then logistics center will sends the products at ordering time and quantity to supermarkets, malls and end users. Thus the idea of VMI (vendor managed inventory) will be achieved. If the logistics center can successfully complete JIT distribution, the inventory of clients will be eliminated.

2.2 Space model for urban logistics center [3]

According to above-mentioned system model, this article structures space model for sales urban logistics center, showing in figure 1.

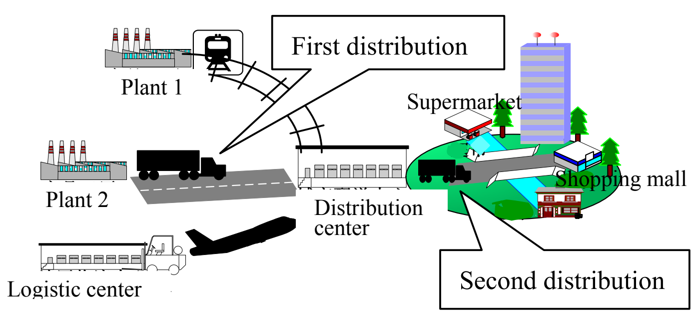

Figure 1. Space model for sales urban logistics center

2.3Extension of mode

Sales logistics belongs to national even worldwide product distribution. Large multinational corporations set branch companies around the world, and the sales networks for their products are worldwide too. For these companies, it is necessary to set up logistics center in the larger sales scope, such as Ning-Hu-Hang metropolitan area, Yangtze River delta economic area, Jing-Jin-Tang economic area even one nation. Distribution centers cooperating with different cities accomplish delivery.

For instance, Dell can send computers to the end users all around the world within 7 days relying on its perfect distribution network, JIT distribution service and supply chain. Analyzing its logistics network in China, logistics network with 3 layers can be described as follows: firstly, transporting products to logistics centers by factories, which has the characteristics of container transportation with large quantity internationally, called products transport in this article. Then regional logistics centers send the products to urban distribution center through the first transportation, and the latter send the products to end users through the second transportation. On these ground, this article builds an extending urban distribution model, showing as figure 2.

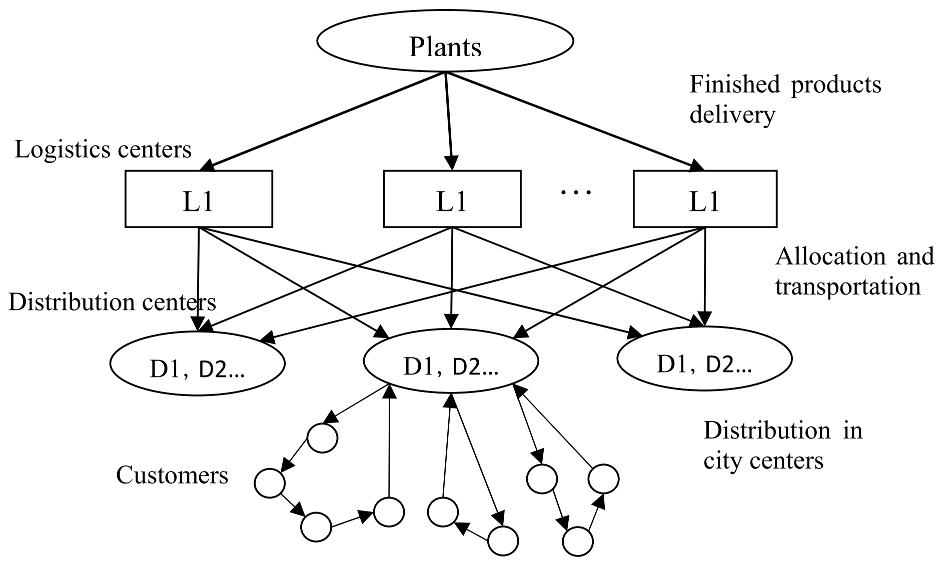

Figure 2. Extension of urban distribution model

2.4Logistics nodes planning

The establishing and processing of logistics nodes have some effect on space environment around the nodes, such as traffic environment, living environment etc. Hence the logistics nodes will be included in the urban traffic planning. Several factors should be considered when confirming the spatial locations of logistics nodes:

- Clients distribution: distribution area of mainly service clients;
- Industrial competition: the surrounding area is whether or not in the occupation scope of the same industry competitors and the distance from the markets;
- Traffic condition: traffic condition as an important factor includes traffic convenience, effective bridging between different carriers and the convenience of customers' arrivals. If ignoring the transportation network situation in the area where the logistics nodes are structured, there would be traffic congestion around the logistics nodes.

- Infrastructure: availability of building lands, feasibility of building, the size and the prize of lands, the distance to clients;
- Environmental factor: if or not there are some effects on the living environment of surrounding residents;
- Development space: the relationship with other nodes, if or not there is enough developing space.

Excepting considering effects of mentioned factors above, the change of land price, recycle problem of fund and invest, water and electricity supply and other base condition, natural condition and policy condition are should considered too. When optimizing the space location of urban logistics nodes, logistics centers and distribution centers with different functions and service clients can be built according to the regional conditions and economic conditions in the area, making use of the advantages of transportation network and hubs, relying on road ,railway modes etc.

3. Logistics distribution network optimization algorithm

3.1 optimization of first echelon transportation

(1) Algorithm description

Supposed that m logistics centers A_i , $i=1,2,\cdots,m$, with maximum inventory $a_i(i=1,2,\cdots,m)$ and n distribution centers $B_j(j=1,2,\cdots,n)$ with the demand $Q_j(j=1,2,\cdots,n)$ .The unit rate (distance) from A_i to B_j is $c_{ij}(i=1,2,\cdots,m; j=1,2,\cdots,n)$ .Then, the transport model that minimizes the total transportation cost z (transportation distance) is as follows:

$$\min z = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij}$$

$$\sum_{i=1}^{m} x_{ij} = Q_j \quad j=1,2,\cdots,n$$

$$\sum_{j=1}^{n} x_{ij} = a_i \quad i=1,2,\cdots,m$$

$$x_{ij} \ge 0(i=1,2,\cdots,m;\ j=1,2,\cdots,n)$$

(2) Solving method[4]

The first transportation problem is essentially a linear programming problem in modern mathematics-operational research. The solution can be divided into two main stages: one is the determination of the initial feasible solution (that is, to find initial feasible scheduling scheme); the other is to find the optimal solution from the feasible solution beginning (i.e. find the dispatching scheme that minimizes the total transportation cost based on the initial dispatching plan).

3.2The second distribution optimization[5]

(1)Algorithm description

Logistics distribution route optimization problem can be described as follows: The clients are served with multiple vehicles from distribution center (logistics nodes). The position and the demand of each demand point is certain and the capacity of each vehicle is specific. The goals to reasonably schedule and arrange vehicle routing to minimize the total transportation distance with satisfying the following constraints: The total demand of the customers at each of the distribution path never exceeds vehicle capacity. Each customer demand must be served and be delivered by a vehicle. The algorithm model is as follows:

$$\min VRP(Q_{DC}) = \sum_{k=1}^{m}\sum_{i=0}^{L}\sum_{j=0}^{L} C_{ij} x_{ijk} + \sum_{k=1}^{m} F_k \sum_{j=1}^{L} x_{0jk} \quad (1.0)$$

$$\sum_{i=1}^{L} Q_{Ri} y_{ik} \le q_k, here, \ q_k = q, k \in K \quad (1.1)$$

$$\sum_{k=1}^{m} y_{ik} = 1, i = 1, 2, \cdots, L, \ k \in K \quad (1.2)$$

$$\sum_{i=0}^{L} x_{ijk} = y_{jk}, j = 0, 1, \cdots, L; k \in K \quad (1.3)$$

$$\sum_{j=0}^{L} x_{ijk} = y_{ik}, i = 0, 1, \cdots, L; k \in K \quad (1.4)$$

$$U_{ik} - U_{jk} + LX_{ijk} \le L - 1, \ i, j \in L, k \in K \quad (1.5)$$

$$x_{ijk} = 0 \ or \ 1, \ i, j = 0, 1, \cdots, L; k \in K \quad (1.6)$$

$$y_{ik} = 0 \ or \ 1, \ i = 0, 1, \cdots, L; k \in K \quad (1.7)$$

$$U_{ik} \ge 0, \ i \in 1, \cdots, L, k \in K \quad (1.8)$$

Where:

0 identifies the distribution center and the customers are identified as 1, 2….*i, j* represent distribution center and customers;

k : the tour routing (or delivery vehicles), $k \in K$;

C_{ij} : the distance between *I* and *j*, which can be converted into transportation cost;

x_{ijk} : decision variable, equals to one if arc (*i, j*) is visited by vehicle *k*,0otherwise;

y_{ik} : binary variable, equals to one if customer is served by vehicle k,0 otherwise;

F_k : the fixed use cost of vehicles on the *k* path;

Q_{Ri} : the demand of customers;

q_k : capacity of the vehicles;

U_{ik} : sub-tour elimination constraint vector, represents the sequence that customer *i* is visited in route *k*.

In this formulation, the objective function (1.0) minimizes the total transportation cost (the sum of variable cost and fixed cost). Constraint (1.1) indicates that total amount of loads transported by each vehicle cannot exceed the vehicle capacity. Constraint (1.2) specifies that each node must be visited by only one vehicle. Constraint (1.3) and (1.4) indicates that each customer can be visited only once. Constraint (1.5) relates to the sub-tour elimination. Constraint (1.6) is for binary variables and (1.7) for a limit of y_{ik}. Constraint (1.8) represents that sub-tour elimination constraint vector is a non-negative value.

(2) Summarize for solution

Vehicle scheduling problem in logistics distribution is a NP-hard problem. With the growth of the number of clients, the number of feasible distribution routes solutions is rapidly rising with factorial speed, namely combinational explosion phenomenon. It can be calculated that the TSP (Traveling Salesman Problem) with 20 nodes has about $20!/(2\times 20)\approx 6.08\times 10^{16}$ possible routes, even using computer with 1billion times/s calculation time, it will need 1.93 years to calculate. As a multiple traveling salesman problem with constraints, vehicle scheduling problem in logistics distribution has more complex constraints and distribution routes, comparing with TSP. Hence, the calculated amount is much more than TSP. Generally, precise optimization solution of vehicle scheduling problem in logistics distribution can be obtained in the condition of less quantity of clients and simple transportation network.

The method for solving distribution route optimization problem can be divided into 2 categories: accurate algorithm and heuristic algorithm. The former can calculate the optimal solution, including branch and bound, cutting planes, network flow, dynamic programming method and so on. On account of factorial growth of calculation amount for accurate algorithm with the increasing of the scale of the problem, there are some limits in reality. Therefore, experts focus more on the structure of heuristic algorithm with high quality, such as saving algorithm, scanning method, partition distribution method, scheme evaluation method etc. But every method has its own advantages and disadvantages. Applying synthetic method has been the trend.

For the solution of the second distribution, after designing the accurate solving steps, it can be calculated the optimal vehicle routes of urban distribution only with the help of computers.

4. Conclusion

Logistics distribution network consists of urban logistics nodes and links, the latter represents the movement of goods between nodes. There is multilink between any nodes which represents different transport modes and transport routes. Proper design of space model of logistics nodes can make goods moving smoothly and rationally, reduce the distribution costs and optimize the supply chain.

The space model of sales logistics nodes proposed in this article is suitable for manufacturing industry and trade companies with wide range of market and large quantity of sale. Regional logistics center and urban distribution center can be built by government or several companies together. The distribution optimization of space mode of logistics nodes can be completed by mathematical algorithm, transporting goods through reasonable logistics links and distribution routes could reduce distribution costs and the traffic pressure coming from product distribution.

Reference

Chang Fa Zhou,(2002). Science and Engineering Numerical Algorithm (Visual Basic Version), Beijing, China.

Fang Yang, (2009).Theoretical and Empirical Study on Layout of Logistics Node Facilities in China. Xi'an, China.

Jian Li, (2005). Inventory and transportation combinatorial optimization in urban logistics system based on stochastic demand. Xi'an, China.

Li Ming Song, (2008).The scale and location research of logistics node. Taiyuan, China.

Speranza,M.G./Ukovich,W., (1994).Minimizing Transportation and Inventory Costs for Several Products on a Single Link. Operation Research 42,879-894,

Teaching Materials Writing Group,(2003). Operational Research, Beijing, China.

Xue Geng, HuiChuan Duan, (2012). Research on Vehicle Schedule Problem of Two-layer Material Distribution Center. Computer Engineering, 38(5),285-290.

Reliability Analysis of a Cold Chain Logistics System Based on the Fault Bayesian Network

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Abstract: The abstract problem of Cold Chain Logistics System fault is crystallized and its Fault Tree is constructed according to operation features of various functional parts and the causal relationship between events in Cold Chain Logistics System by borrowing ideas from reliability analysis in Reliability Engineering Theory. Bayesian network based on the fault tree has been generated, in order to estimate the operation reliability of Cold Chain Logistics System and reveal the main reasons resulting in the system faults. It could provide a quantitative basis for improving the operation reliability of Cold Chain Logistics System. The expected effect has been achieved via applying the method proposed into the operation and management of a Third-party Cold Chain Logistics enterprise.
Keywords: Cold chain logistics system; Reliability; Fault tree; Bayesian network.

1 Introduction

Cold Chain Logistics System is a complicated system composed of multiple interdependent and interacting functional links accompanied by the complex logistics technology and high logistics cost (Akkerman, R. et al., 2010). There are many uncertain factors in the links of Cold Chain Logistics System, which would affect the normal operation of system, and lead to result that the system cannot perform its required functions for a given period of time.

In Reliability Engineering Theory, System Reliability is defined as the ability of the system to perform specified functions within limited time period. Kong R. and Wang Z. L. (2005) traced back to the formation process of reliability system engineering, and established the framework of theory and technology initially. Zhou Z. B. (2009) proposed a fault diagnosis method of Bayesian network with multi-state fault tree, which has been applied into the Power Supply System. At present, the Fault Bayesian network methods have become the main way to analyze the system reliability (Ding Y. 2008).

Logistics system is an organic whole which has specific function and consists of several logistics elements, such as materials, equipment, conveyance, warehousing facilities, personnel and communication. The reliability of logistics system is a reflection of the ability of the logistics system for working normally to meet the demand of consumer in limited time under certain conditions. Due to the inherently perishable and economic characteristics of fresh products, Cold Chain Logistics System has higher requirement for reliability (Shabani A. 2012). If the system is unreliable, not only will the customers be unsatisfied with the service, but it may also cause great economic loss as the result of return, replacement or payment of compensation.

Fault Tree Analysis is a classic method in Reliability Engineering, which is always used in the analysis of fault happened in designing, estimating and using for complex system(Jin B.H, 2004), such as nuclear power station, civil aviation and manned space flight. Chen X, et al. (2012) established a reliability diagnosis model of logistics service supply chain based on Fault Tree Analysis, calculating the reliability of system to find the key fault of the system. However, the correlation between events had not been revealed, and the bidirection reasoning could not be achieved. Therefore, this paper constructs the fault tree of Cold Chain Logistics System according to the way of top-down and stepwise refinement by using the fault tree for reference. It is more suitable to apply Bayesian Network converted from fault tree for the bidirectional reasoning in order to give the main reasons of failures and the failure probability of the system, which can provide quantitative reference for further improvement in the stability of system.

2 Fault Tree Analysis of Cold Chain Logistics System

Fault Tree Analysis analyzes system failure by going step by step, from top to down, and from simple to complicated. An undesired system fault, namely the top event is taken as the total target of analysis. It is carried out according to the causal logic relationship strictly. All the reasons and the combination resulting the top event are found out to describe how the system fails.

In analyzing Cold Chain Logistics System, the application of fault tree has two parts: The first step is to define the top event which includes the events of unexpected system failure according to the functional requirement of Cold Chain System. The second step is to search for the intermediate events that are the direct reasons leading to the top event, and ranking them under the top event one by one. There are total 3 types of intermediate events. Type 1 is that the food quality does not meet the requirements: the temperature of goods is not maintained in the correct range, or the goods are predisposed to external contamination during the process of logistics. Type 2 is that the quantity and variety do not meet the requirements: the variety of goods do not conform the requirements of order, or the weight is beyond the range of error. Type 3 is that the transportation time does not meet the requirements: the goods are not delivered to the specific place within required time. The intermediate events are connected with top event via logic gate according to the logic relationship among them. The events should be decomposed according to above principles until the events do need to decompose further, namely the bottom events. Thus an inverted tree structure is formed in which the top event, intermediate events and bottom events are connected by logic gate. That is the fault tree of failure of Cold Chain Logistics System.

The occurrence of events that can not satisfy the demands of consumers are taken as the top event, from which there are three direct reason events including “the unqualified quality”, “the wrong number and species” and “the delay in delivery”. Because the occurrence of any one of 3 events can result in the top events directly, these three event should be connected by the logic gate “or”. Then we analyze the lower events gonging on in each function links that can lead to the occurrence of above events, and connect them by proper logic gate according to the logic relationship between them. The downward decomposition step by step won’t stop until the bottom events are determined whose original fault mechanism or probability distribution can be determined by the daily record. A fault tree is established according to the structure of one Cold Chain Logistics System and the operation conditions of each function links, as shown in Figure 1.

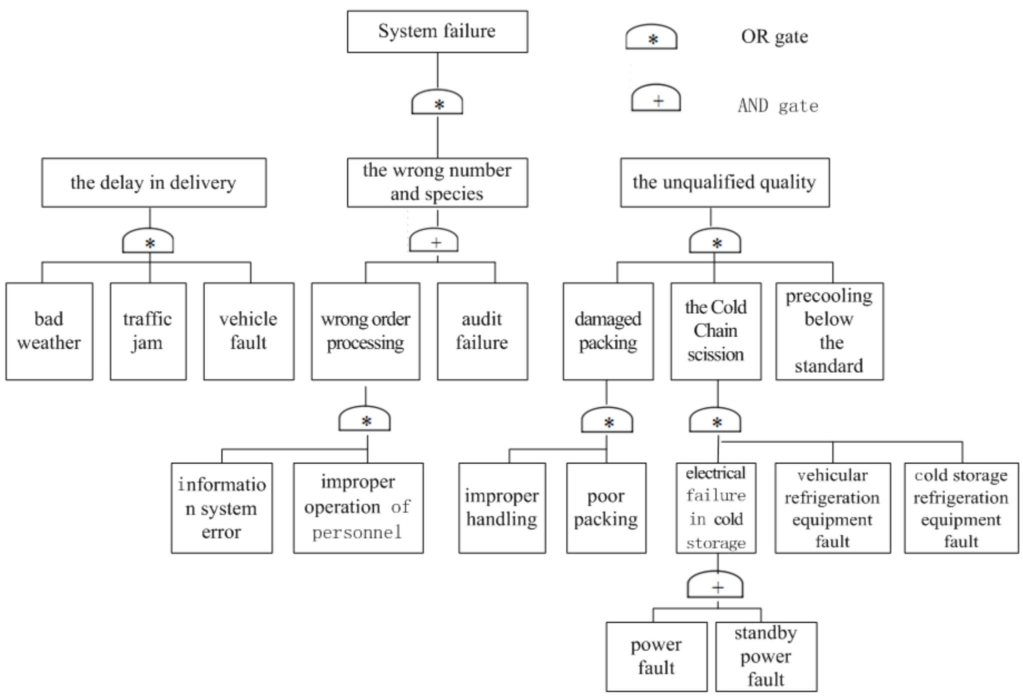

Figure 1. A fault tree of Cold Chain Logistics System

By analyzing the fault events of Cold Chain logistics function links and the logical relationship among the events, we obtain the failure tree of Cold Chain Logistics System that composed of bottom event, result event and logic gate. Although the fault tree is intuitive and succinct in expressing the events resulting in the system failure, the sequential searching algorithm which always use is limited in modeling and analyzing with lower efficiency. If we want to describe the causality among events accurately and reveal the mechanism of system failure, it is necessary for quantitative analysis combined with the Bayesian networks.

3 Reliability analysis of Cold Chain Logistics System based on fault Bayesian network

3.1 Bayesian network

The Bayesian network(Zhang L.W, Guo H.P, 2006) with N nodes is represented as $\boldsymbol{N}=\langle(\boldsymbol{V}, \boldsymbol{R}), \boldsymbol{P}\rangle$. All elements in set $\boldsymbol{V}=\{V_1,\dots,V_N\}$ are random variables which could be the abstract of objects such as the state of components, personnel operation, observed value and so on. The directed edge $(V_i,V_j)\in\boldsymbol{R}$ expresses the correlative relationship between the variable V_i and V_j. V_i is the parent node of V_j, and V_j is the child node of V_j relatively. The nodes without parent node are called root nodes while the nodes without child nodes are called leaf nodes. $\boldsymbol{P}$ is the conditional probability distribution of the nodes in set $\boldsymbol{V}$ and expresses the causal relationship among nodes.

The conditional independence relations among variables and a solid mathematical basis are contained in Bayesian network. If there is $\pi(V_i)$ that belongs to the set $\{V_1,\cdots V_{i-1}\}$ for arbitrary V_i , and V_i is conditional independent with the other variables in set $\{V_1,\cdots V_{i-1}\}$ for given $\pi(V_i)$, then in the joint probability distribution $P(V_1,\dots,V_N)$ that contains N variables are represented as follow

$$\begin{aligned}P(V_1,\cdots V_N) &= P(V_1)P(V_2/V_1)\cdots P(V_n/V_1,V_2,\cdots V_{N-1}) \\ &= \prod_{i=1}^{N} P(V_i/V_1,\cdots,V_{i-1}) \qquad (1)\end{aligned}$$

In which $P(V_i/V_1,\cdots,V_{i-1})$ can be decomposed as

$$P(V_i/V_1,\cdots,V_{i-1}) = \prod_{i=1}^{N} P(V_i/\pi(V_i)) \qquad (2)$$

$P(V_i/V_1,\cdots,V_{i-1})$ will be the marginal distribution $P(V_i)$ When $\pi(V_i)=\varnothing$. Conditional independence simplifies the model. It also decreases the complexity in expressing the model significantly, and improves the reasoning efficiency when the number of variables N is very large. Bayesian network can calculate the occurrence probability of consequences directly by using the joint probability distribution without solving the minimum cut sets of fault tree. It is easy to integrate a variety of evidence, expert experience, and information, which makes the system reliability analysis more intuitive and flexible.

Bayesian network can not only evaluate the system reliability through the network structure and conditional probability distribution of node, but also calculate the probability of other variables via the information of given variables. A given set ***E*** is the subset of ***V*** and the values of variables are known (assumed to be True or False). These given variables are obtained by the method of experience or observation, namely the evidence node. Then probability reasoning is accomplished while the conditional probability P ($\boldsymbol{V_i}$=True/***E***= True) can be calculated according to the Formula (3). That is，when the evidence is given the probability of $\boldsymbol{V_i}$ =True could be obtained. It's a bidirectional reasoning process.

$$P(V_i = \text{True} | E = \text{True}) = \frac{P(V_i = \text{True}, E = \text{True})}{P(E = \text{True})} \quad (3)$$

$P(V_i$=True, ***E***= True) and P(***E***= True) can be acquired through Formula 1 and Formula 2 by using high order joint probability to calculate low order joint probability. Bayesian network achieves the bidirectional reasoning by integrating various uncertain and interdependent factors, thus more abundant decision information are obtained.

Bayesian network can be directly generated based on fault tree under the condition that fault tree has been built. The structures of fault tree are in one-to-one correspondence with the structure of Bayesian network: the events of fault tree are in one-to-one correspondence with event nodes of Bayesian network; the logic gate of fault tree corresponds to a node in Bayesian network which is named by the output event of the logic gate; the connection of events in the fault tree corresponds to the side of Bayesian network, but the connected direction is opposite to the direction of directed edge in Bayesian network; the bottom events that appear repeatedly can be represented as just one random variable in Bayesian network. The fault tree of Cold Chain Logistics System shown in Figure 1 can be transformed into Bayesian network represented as Figure 2 according to above methods.

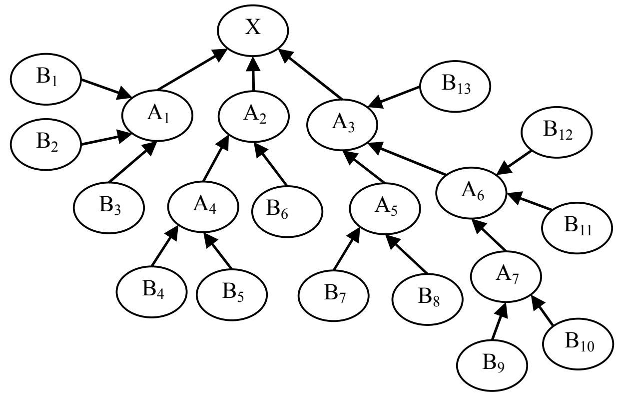

Figure 2 Bayesian network transformed from the fault tree

The universe of each fault event is binary in the fault tree of logistics system, namely there are only two states: occurrence or not, the value of event is 1 when the event occurs. Otherwise the value is 0, which can be represented as :

$$V_i = \begin{cases} 0 \text{ when event } i \text{ does not occur} \\ 1 \text{ when event } i \text{ occurs} \end{cases} \quad i=1,\dots,N \quad (1)$$

The probabilities of bottom events of the fault tree are assigned directly to correspondent nodes in Bayesian network, which is defined by using statistics and expert experience. The conditional probability distribution of logic gate in the fault tree can be determined according to the logical relation. For example, V_1、V_2 and V_3 are the inputs of AND gate, and V_4 is the output, the conditional probability distribution corresponding to Bayesian network is:

$$P(V_4 = 1 / V_1 = 1, V_2 = 1, V_3 = 1) = 1 \quad (2\text{-}1)$$

$$P(V_4 = 1 / \text{else}) = 0 \quad (2\text{-}2)$$

If V_1、V_2 and V_3 are the input of OR gate, and V_4 is the output, then the conditional probability distribution corresponding to Bayesian network is:

$$P(V_4 = 1 / V_1 = 0, V_2 = 0, V_3 = 0) = 0 \quad (3\text{-}1)$$

$$P(V_4 = 1 / \text{else}) = 1 \quad (3\text{-}2)$$

Where “else” represents the means “ in other cases”. Other types of logic gates (such as XOR gate, NAND, voting gate etc.) corresponding to the conditional probability distribution of Bayesian network won’t go into a lot of details(Zhang L W, GUO H P, 2006). The conditional probability distribution corresponds with the nodes of fault Bayesian network shown in Figure 1 are listed in Table 1.

Reasoning by using the fault Bayesian network, the events related with system fault can be found conveniently from top to down analysis, and the probability of system failure can be calculated through the probability distribution and conditional probability distribution of corresponding nodes in fault Bayesian network. Setting T as top event, and E_i ($1 \le i \le M$-1) as intermediate events and bottom events, $e_i \in \{0,1\}$ expresses whether the event E_i occurs or not, and M is the number of nodes in fault Bayesian network, then the occurrence probability of top event T can be represented as :

$$P(T=1) = \sum_{E_1,\cdots,E_{M-1}} P(E_1 = e_1, \cdots, E_{M-1}, T=1) \tag{4}$$

From bottom to top analysis, the influence degree of bottom events on the operation of system can be distinguished. The occurrence probability of other events nodes, namely the posterior probability, can be calculated on the basis of given evidence. It is shown as following:

$$P(E_i = 1 | E_j = 1) = \frac{\sum_{\substack{E_1,\cdots,E_{i-1},E_{i+1},\cdots, \\ E_{j-1},E_{j+1},\cdots,E_M}} P(E_k = e_k, E_i = 1, E_j = 1)}{P(E_j = 1)} \quad (1 \le k \le M, k \ne i, k \ne j) \tag{5}$$

Forward reasoning and backward diagnosis can be achieved on the condition that the information of nodes are known, thus this transformed fault Bayesian network has stronger ability of modeling and analyzing.

Table 2 The probability distribution of nodes in fault Bayesian network

node	Probability distribution	node	Probability distribution
A_1	$P(A_1/B_1,B_2,B_3)$	B_4	$P(B_4)$
A_2	$P(A_2/A_4,B_6)$	B_5	$P(B_5)$
A_3	$P(A_3/A_5,A_6,B_{13})$	B_6	$P(B_6)$
A_4	$P(A_4/B_4,B_5)$	B_7	$P(B_7)$
A_5	$P(A_5/B_7,B_8)$	B_8	$P(B_8)$
A_6	$P(A_6/A_7,B_{11},B_{12})$	B_9	$P(B_9)$
A_7	$P(A_7/B_9,B_{10})$	B_{10}	$P(B_{10})$
B_1	$P(B_1)$	B_{11}	$P(B_{10})$
B_2	$P(B_2)$	B_{12}	$P(B_{12})$
B_3	$P(B_3)$	B_{13}	$P(B_{13})$

4 Application research

Taking the fault tree of Cold Chain Logistics System in Figure 1 as example, we show the application of above method. Two types of data are required to complete reasoning using Bayesian network converted from the fault tree (as shown in Figure 2). The first group is the prior probability of bottom event, that is $P(B_1)$ to $P(B_{13})$, which results from historical records. The occurrence state of bottom events is dimorphic random variable. While the historical data are rich enough, the statistic occurrence frequency can be regarded as the prior probability. Table 3 shows the results. Another group are the conditional probabilities of intermediate events, that is $P(A_1/B_i \ldots B_j)$ to $P(A_7/B_i \ldots B_j)$. The conditional probability distribution table is determined by corresponding logic gate type of fault tree, and there are mature conversion algorithms converting various logic gates to conditional probability distribution of corresponding nodes in Bayesian network. These two types of data are input the Bayesian toolbox of MATLAB to do numerical programming. We obtain the probability of the top event failure P(X=Flase) =0.1970, that is, the probability of Cold Chain Logistics System operating normally is P(X=True) =0.8030. Namely, the reliability of Cold Chain Logistics System is 0.8030.

Table 3 probability distribution data of bottom events

node	name	Prior probability	node	name	Prior probability
B_1	bad weather	0.0236	B_8	poor packing	0.0342
B_2	traffic jam	0.0361	B_9	power fault	0.0050
B_3	vehicle fault	0.0053	B_{10}	standby power fault	0.0625
B_4	information system error	0.0012	B_{11}	vehicular refrigeration equipment fault	0.0297
B_5	improper operation of personnel	0.0225	B_{12}	cold storage refrigeration equipment fault	0.0126
B_6	audit failure	0.0189	B_{13}	precooling below the standard	0.0419
B_7	Improper handling	0.0317			

Then we use Bayesian network to compute the posterior probability. There are seven intermediate events and thirteen mutually independent bottom events in the fault tree, with $A_1 \sim A_7$, $B_1 \sim B_{13}$ respectively. The posterior probability of bottom events can be used to determine the important degree of bottom events acting on top events, namely the influence degree on system reliability when faults appear in the systems. The event with higher prior probability doesn't ensure has higher posterior probability, thus the influence on system is not necessarily large. The bottom events with higher posterior probability have more influence on system reliability, which are the key target for prevention and improvement. The posterior probabilities of bottom events calculated from Bayesian network and the comparison in value of the prior probability are shown in Figure 3.

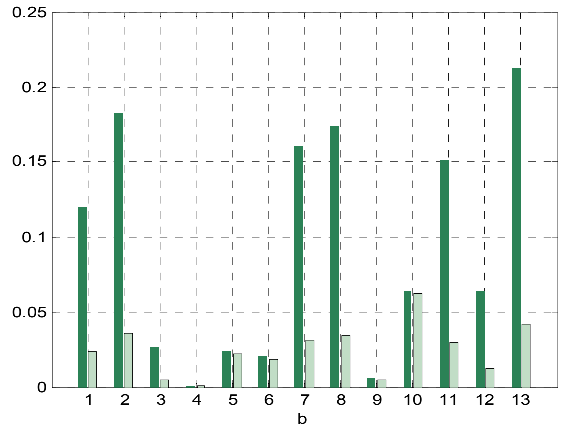

Figure 3. The comparison of prior probability with posterior probability of bottom events

The results showed that the posterior probability of B_{13}, B_2, B_8, B_7, B_{11} and B_1 are higher in all of bottom events, and B_{13} is the event with highest posterior probability. The core temperature of agricultural products after harvest should be decreased quickly until it fits the requirements of warehousing and transportation. This process is called pre-cooling. Delay in pre-cooling operation, uneven or insufficient cooling, is one of the main reasons of failure of Cold Chain Logistics System, which may lead to a loss of several days or weeks on shelf life of perishable products. For the enterprise, it is suggested that the time before the goods entering into cold storage should be shorten as possible, and mobile pre-cooling equipment should be utilized to enhance the pre-cooling effect. For the bottom event B_2, it indicates that the packaging can't fulfill the requirement that goods maintain high-quality before delivered to final consumer. This enterprise should take some measures to solve the problem, such as improving packaging technique, planning the distribution time, as well as routing reasonably and querying the road condition information in time. According to the posterior probability of B_8 and the specific condition of enterprise, it is necessary to improve packaging design to meet the demand of various logistics links on packing. B_7 indicates that methods should be taken during the handling process, and mechanical handling should be used for some packing boxes with huge volume and overweight. The preventive protection plan should be drew up strictly for B_{11} in order to ensure the normal operation of refrigeration equipment of refrigerated vehicles, and ensure the temperature is always maintained at the required settings as well as reduce volatility. After defining the importance degree of basic events affecting on the occurrence of top events, enterprises can take some improvement measures combined with their own resources to prevent the occurrence of top event, namely system failure.

5 Conclusions

Cold Chain transportation takes maintaining the quality and improving the efficiency as the center, and Cold Chain Logistics System requires high reliability as guarantee. The method of system reliability analysis in Reliability Engineering theory is taken for inference in this paper. By using it, the abstract problem of the operation failure of Cold Chain Logistics System can be dealt with embodiment, and system fault tree is built according to causality between operation characteristics of functional links and events in Cold Chain Logistics System. Then the fault tree is transformed into Bayesian network, which describes logical relationship among events more accurately, evaluate the system reliability more integrally, and reveals the main reason for system failure. It can provide basis for taking specific measures to improve the operation reliability of Cold Chain Logistics System. The following work will devote the classified research for fruit and vegetable Cold Chain, industrial food Cold Chain, dairy Cold Chain, etc, considering the features and requirements of their temperature control, timeliness, facility, equipment and cost. This research aims at supplying beneficial reference for reducing the delay of Cold Chain logistics links, avoiding the loss of logistics links, and promoting system efficiency in Cold Chain Logistics System.

References

Akkerman, R, Poorya F, Martin G. (2010). Quality, safety and sustainability in food distribution: a review of quantitative operations management approaches and challenge. *OR Spectrum*, (32): 803-904.

Chen X, Gong B.G, Hu C.Z. (2012.) FTA model of reliability diagnostic for logistics services supply chain and its application. *Computer Engineering and Applications*, 48(29): 243-248.

Ding Y, Zuo M.J, Lisnianski A, et al.(2008). Fuzzy multi-state system: general definition, and performance assessment. *IEEE Trans. on Reliability*, 57(4): 589-594.

Shabani A, Saen R F, Torabipour S M R. (2012). A new benchmarking approach in Cold Chain. *Applied Mathematical Modeling*, 36(1): 212-223.

Jin B.H. System Reliability Engineering.(2004). *Beijing: National Defence Industry Press*: pp.45-56.

Kang R, Wang Z.L.(2005) Framework of theory and technique about reliability system engineering. *Acta Aeronautica et Astronautica Sinica*, 26(5): 633-636.

Zhang L.W, GUO H.P. (2006). Introduction to bayesian networks. *Beijing: Science Press*,(pp.24-30)

Zhou Z.B, Ma C.Q, Zhou J.L. (2009).Application of Bayesian networks reliability analysis of binary-state system with multi-state components. *Journal of Harbin Institute of Technology*, 41(6): 232-235.

System Design for the Order Management System of a Pallet Pool System

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Abstract: Nowadays, the level of China's theoretical research on pallet pool system is behind its practical operation. Compared with the developed countries' relatively perfect pallet pool system, pallet pool system in China is still on the initial stage. In the subsystems of pallet pool system, order management subsystem as information disclosure and issuing system for platform has the great significance of research. Here, two aspects of order management subsystem are analyzed. Firstly, business requirements of order management system are put forward. Then, it's functional requirements are cleared by UML.

Keywords: Pallet; Order management; Information system.

1 The actual situation of pallet pool system at home and abroad

At present, there are over 7 billion pallets around the world, with a 15% -20% annual increase, but this cargo carrying tools which can greatly improve pallet loading rate and reduce the damage have not be used fully.

CHEP in Australia is the world's first and the largest pallet pool systems company. It has an over-50-year industry experience and a professional team of more than 7700 people. Every day, CHEP manages the business operations of more than 320 million global pallets and containers on average. It has more than 40 pallet rental service centers in China. CHEP has a perfect pallet rental management system. During the pallet rental period, reports can be sent to the customer timely and it can complete the liquidation costs in time. European Pallet Association from Germany and France established the European Railway Association, namely EPAL, and other European Railway Association and work together to maintain the level of quality and inspection of European standard pallets used within Europe. According to users' needs, its service is available around the world. China's first Pallet system appeared in 1965, but due to the operating system, management system, pallet quality standards and other factors it did not succeed. Chinapack Jingli Pallet Pooling System Corporation was established in February in 2010 to fill the vacancy of Pallet respect. China has more than 1 billion pallets, and in order to achieve consistent operation of the tray, establishing pallet pool systems is necessary.

2 The analysis of needs

The main functions of order management system include ordering management, gathering orders management, distributing management, replying management, continuing renting and tracking orders. The main steps of this system are as follows: customers make an order, the system exams the order, the system gathers the orders and sends them to the service station, the workers of the service station distribute the orders, the customers receive the products. Receiving and leasing renewals is the main activity in the service after the expiration of the tray orders, that tray renters have to renew pallets, sublease or not to continue the lease rights. When pallet is in the situation of lease or renewals, the system generates a new order with no relation to the original order and goes to the next order of the process. This is the entire business process of order management system. The most important part of the order management is the order. The research study of the order focuses on the order status.

3 The Analysis of Order Management System Business Process

The main activities of orders are single, setting the single, sub-orders, sending orders, receipt and order tracking.

The first step of the tenant is the Internet, telephone or mail place an order, after the system entry and audit. If the order is placed online, it will be fulfilled by the system. But, if the order is placed in other way, it will be completed by the platform personnel. During the order review process, the main contents of the audit is whether the operators credit rating, designated service station and the designated shop can satisfy the order's basic demand. If the audit is not passed, the system will send the reason of the failure to the tenant. If approved, the system will generate an online documentation, and wait for tenants' confirmation and submission. At this time, the online documentation is in the modified state. When the tenant submitted, the customer service personnel of platform will confirm order information again with the tenant. If confirmed correctly, tenants will submit the online documentation, and the system will generate online orders, At this time, online orders can not be modified. Tenants can only query the situation of the order, and if the platform wants to modify information, they will need to confirm with the tenant. Now, online order is completed. Then, set a single according to the addresses of the tenants and the service station. Platform order scheduling personnel produce service station operation list send a single to service station. When ordered through the audit by the order manager of the service station, the whole order process is in the end state.

The second step is the receipt management. In order management subsystem, signed receipt proves the start of the service, and the pallet which tenant received is not delivered by only one service station. So what the tenant signed was only service station's distribution operation receipt, not the order receipt. Order receipt is produced and put in to the system by the order management personnel platform, then, it will be audited by the system. Through the audit, it can prove the tenant has received the tray successfully. In the receiving process of the tray, if the tray can not meet the requirements of the tenants, the tenant can reject, the service station will redelivery trays at the fastest speed. The order management personnel of platform will feed this situation back to system to modify the order and confirm with the tenant until the tenant is satisfied. After the tenant has been satisfied, the transaction is successful. At this time, the order in the successful transaction state, platform can not modify the order either. When the order receipt has be entered into the system, the customer service personnel of platform will send the information of tray trading to the rental shop to inform the lessor about their tray.

After the expiration of the lease, there will appear two cases. They are recovery and renewal. The recovery of pallet is a work of service station, when the pallet has been recovered to the service station, the system will automatically shut down the order, and the transaction is completed. The specific recovery process and the plan are formulated by the distribution management. Pallet lease or renewal is a process to close the current order and generate a new order. Both the continued lessee and the subtenant need to replace an order, but it is less than the pallet distribution process than before. In the process of tray renewal, firstly, the tenant places an order on the platform Then, the platform distributes leaflets. Finally, the service station will produce the recovery plan of pallet according to then new operation list after getting information. The process of pallet sublet is a process of another tenant to place an order. The tenant will be reviewed according to the step of ordering by the platform, and then, send a single to the specified service station again according to the tenant's address. To transfer the responsibility, the tray tenant and subtenant should confirm new order together with platform. Then, repeat the processes of tray after the expiry of tenant service.

4 The Analysis of Order Management Systems Function

4.1 Use case diagram

According to order management systems business process and the result of the analysis of demand, use case can be got. Figure 1, order management subsystem is divided into single management use cases, receipt management use cases and pallets recovery and management use cases.

（1） Order management use case

To generate online documentation cases, when the order has been reviewed and proved correct, the system will automatically trigger the generation of online documentation cases, the system generates an online documentation, the corresponding order number and date at the time, the online documentation for the operator to examine and verify the next step and submit.

To generate online orders cases. When the tenant and the customer service personnel of the platform confirm again and submitted generated online orders, the tenant cannot modify this document, only according to the system to the query.

The cases of platform sends a single to the service stations. Each generation of an online order, the system will carry on the set list, and orders are split according to orders on the data information, and by the platform of order scheduling personnel review and to the service station to send a single.

The cases of query. The implementation of the platform staff, tenants and rental business can query the situation of order, but tenants and rental business can only query on the related with their orders, not to other tenants order query.

（2） Receipt management use case

Receipt management use case mainly includes the approval management case, returns management cases and query management cases.

The approval management cases. When the tray is transported to the tenant office, tray tenants should carry out the inspection work, in order to ensure the authentication service station work quality and tray quality and quantity, such as to meet their demands, will accept the tray, tray orders signed receipt.

Return management cases. When the service station pallet fails to meet the demand of transport operators, it triggers the turned goods management cases, and tenants have the right to request the service station for the return of this activity, to ensure its own legitimate rights and interests, and to supervise the service of service station. But returned requirements need to be reasonable, otherwise the platform will be processed.

Query management cases. During the non delivery of goods, the operators can order execution status query, but only related with its order of query.

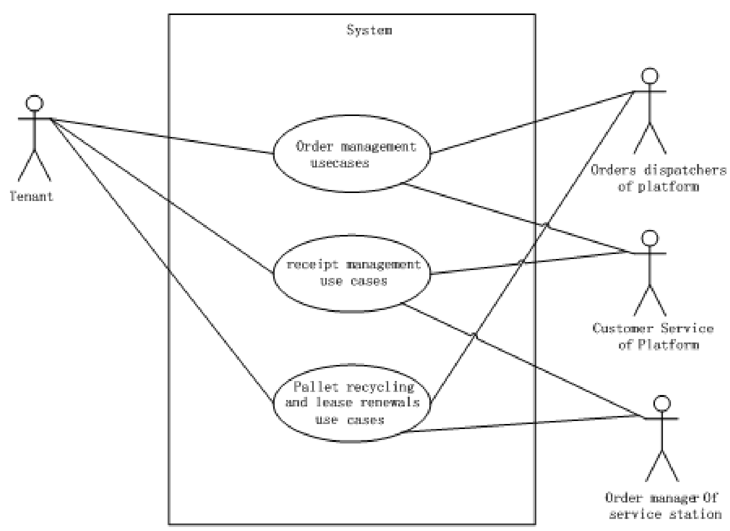

Figure1. Use case

（3） Pallet recycling lease renewals use case.

When the tray in the tenant service expires, it will be recovered and lease tray renewal of case. This process includes pallet recovery case, pallet renewal case and pallet sublet case.

Pallet recovery case. When the tray in the tenant service after the expiration of the period, and the operators are not prepared to renew, also did not happen the situation to sublet, triggered a pallet recovery case. Pallet recycling is in charge of the service station, after the pallet recovery the platform for confirmation, and pallet will go to a new rental activities.

Pallet renewal case. At the end of the period of trays' service in the tenant, if tenants have continued using demand, a tray renewal cases will be triggered. In this case, the operators need to replace an order in the platform, i.e. placing an order before continuing orders again. Generating a contract orders, and combining with the order before going to a new order.

Pallet sublet case. If tenants need transport tray cargo to other locations, the companies which transport enterprises belong to will need to place an order first, and the current tenant will end the current order. Re-orders will activate the order case which was said before. Compared with the prior order case is different. This place, order activity does not need to develop the distribution planning. Distribution activity is completed by transportation enterprises. Do not need to sign the receipt, but still need to pay the rent and deposit. At the same time, to confirm the handover tray activity is confirmed by the original tenant, distribution enterprises and the platform for the information, and to define the demarcation point of responsibility.

4.2 Class diagram

The class diagram to show the static structure of the order management information system, and to analyze the framework of order management subsystem from the view of static structure. According to the use case diagram, we can tease out the relationship between the system as a whole class, attribute, and the operation window class. As shown in Figure 2.

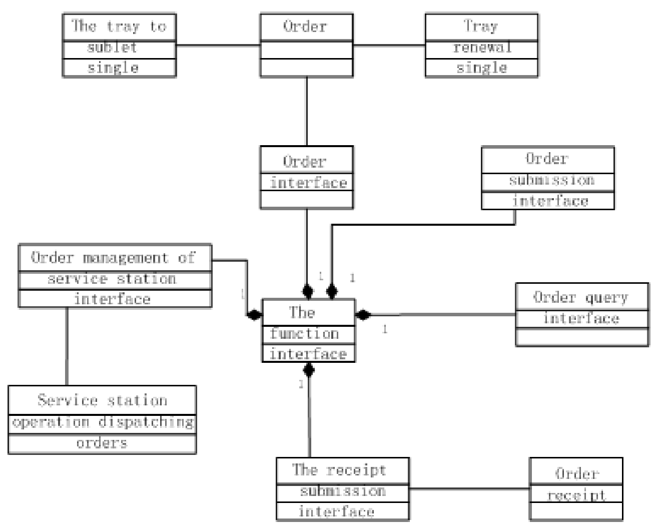

Figure2.The whole system class diagram

4.3 Sequence Diagram

The sequence diagram consists of a group of cooperating objects mutual dynamic collaboration and operation message sending. With two-dimensional sequence diagram showing the order management subsystem within each operating state in lifeline on how to activate and send the message, according to the time order of completing state transformation between object classes to trigger the operation of time. As shown in Figure 3, for the system of the new order of sequence diagrams.

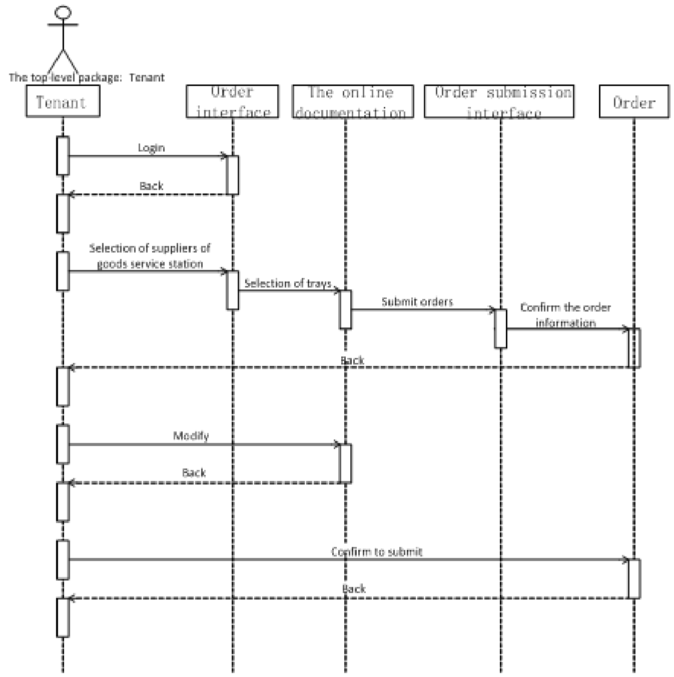

Figure3. New order sequence

5 Conclusion

In our country, pallet pool system in its infancy. The research of China pallet pool system related problems is imminent. The purpose of this paper is to provide a reference for the designers of the pallet pool system, and to provide the basic function and operation mode of order management system to the software developer. It is also convenient to practical development work.

Acknowledgement

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References

SUN lu. (2011). “Design and implementation of an Order Management System. *Shandong University.*

SHI xianjie. (2008). “Gravel Project Management System Modeling and Analysis. *National University of Defense Technology.*

ZHANG xueyan. (2009). “The Conception Model of Pallet Pool System”. Southwest Jiaotong University.

WU xiaoning. (2010). "Study on the management mode of pallet pool system". Southwest Jiaotong University.

The Identification and Prioritization of Optimal Logistics Nodes Planning of Yanting County

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Abstract: As an important part of Mianyang logistics system, Yanting logistics' scientific nodes planning, not only will promote the rapid development of towns and villages' logistics in Yanting, but also will become an important link in connecting urban and rural logistics. In this paper, an optimal logistics nodes assessment framework is presented based on the analytic hierarchy process (AHP) and the fuzzy synthetic evaluation method, on the basis of extensive field study in Yanting. Urban planning logistics system node has a certain theoretical and practical significance. The main contribution of the proposed framework is that it presents a robust method for prioritization of logistics nodes to create a rational planning and to set realistic goals.
Keywords: Logistics nodes; Planning; Analytic hierarchy process.

1 Introduction

Logistics nodes' planning is a common problem faced by logistics decision makers. Reasonable construction of logistics facilities and layout of logistics nodes can improve urban and city's ability to reduce logistics cost. Recently, with the development of urban economy and construction, urban become more and more important for Chinese economy, however, urban logistics construction is relatively lagging. Therefore, the overall consider of logistics nodes planning is important for urban economy development.

The main objectives of this paper are to: (a) indentify key factors for reasonable logistics nodes planning; (b) prioritize alternatives of reasonable logistics nodes planning using fuzzy synthetic evaluation method.

2 Research methodology

This paper will employ analytic hierarchy process (AHP) to help in the selection of not just logistics nodes, but also in the choice and weighing of the selection criteria that go into such a decision making process (Saaty, 1990). AHP method is a relatively perfect evaluation system, which is convenient to calculate and also provides a framework to cope with multiple criteria situations involving intuitive, rational, quantitative and qualitative aspects. The other advantage of this method is that it has capability to check and reduce bias in the decision making process using the geometric mean of the individual judgments (Aminbakhsh et al., 2013). By reducing complicated decisions to a series of simple comparisons and rankings, then synthesizing the results, the AHP not only helps the decision makers to obtain the best decision, but also provides them with a clear rationale for the choices made (Chin et al., 1999).

In china, the initial evaluation of logistics nodes planning is mainly dependent on experience and is mostly influenced by personal ideas, so it always leads the results are unreliable. Thus it is necessary to develop a scientific efficient evaluation method to optimal logistics nodes evaluation.

3 Selection of logistics nodes based on AHP

3.1 Evaluation of selection basis

Qiu (2007) According to the principal and requirements of macro network planning of regional logistics facilities, combined with regional socio-economic development, demand conditions of logistics, the trend of productivity layout., selected ten criteria from the following three aspects: social economy, demand for logistics services, and geographical location. The ten criteria are population, gross domestic product (GDP), and gross industrial and agricultural production, and total social retail goods, volume of regional logistics, required level of logistics service, the importance of economic position, the importance of productivity layout, and the importance of integrated transportation.

3.2 Selection of factors

According to the factors which influence the logistics nodes planning, we choose 5 criteria as the key factors of Yanting's logistics nodes planning, that is, population, per capita income, and output value of enterprises above designated size, arable land, and traffic convenience.

According to the actual situation of the development of the Yanting, we selected 12 alternative sites as a logistics node from the 14 towns, 21 townships, and 1 ethnic township. These alternative sites are listed as following: the center of the Yanting county, Mayang township, Yulong town, Gaodeng town, Jinkong town, Bajiao town, Huangdian town, Fuyi town, Linshan township, Heiping town, Anjia town, Bozi town, and Lianghe town.

3.3 Decision hierarchy and methodology

We build a hierarchy structure model consisting of the goal, criteria on the next levels, and ultimately the 12 finalists on the bottom rung (Figure 1). The goal of our problem is to selecting reasonable logistics nodes. This goal is placed on the top level of the hierarchy. Five criteria are identified to achieve this goal, which located at the next level of the hierarchy. The lowest level of the hierarchy is formed by 12 alternative sites.

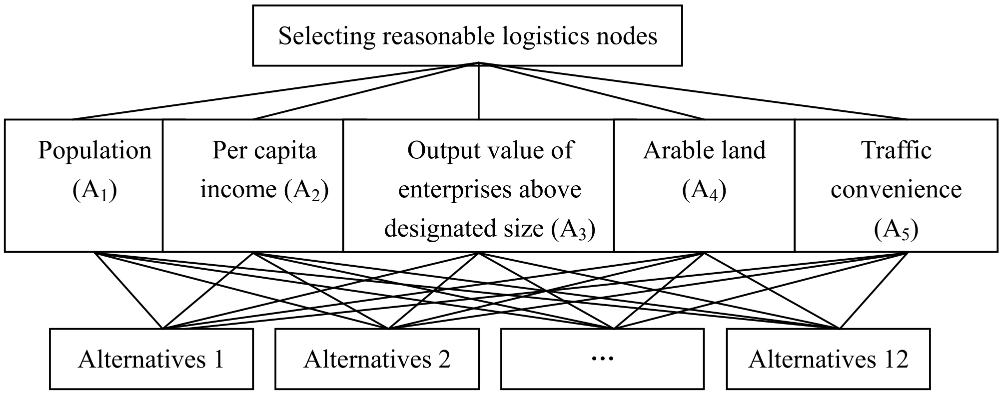

Figure 1. Decision hierarchy

3.4 Construction of pair-wise comparison matrix

After formulating the AHP hierarchy, the next work contains forming a team of experts and developing pair-wise comparison to the criteria using AHP hierarchy. The experts should mark a score (see Table 1) to each pair of *n* elements (A_i, A_j) (Saaty, 1994). A questionnaire is employed in this step. A pair-wise comparison matrix is constructed by an element in the higher level as a criterion element and some elements located at the lower level compared to each other that governed by the criterion. Table 2 shows the pair-wise comparison matrix for the second level criteria.

Table 1. Relatively important of the scale

Importance degree	Definition	Explanations
1	Equal importance	Two activities contribute equally to the goal
3	Weak importance of one over another	Experience and judgment slightly favor one activity over another
5	Strong important	Experience and judgment Strongly favor one activity over another
7	Demonstrated importance	An activity is favored very strongly over another
9	Absolutely important	An activity is favored absolutely important over another
2,4,6,8	Intermediate values between the two adjacent judgment	
Reciprocals ($1/x$)	A value marked when activity A_i is compared with activity A_j then A_j has the reciprocal value when compared with A_i	

Table 2. Pair-wise comparison judgment matrix

	A_1	A_2	A_3	A_4	A_5
A_1	1	5	1	3	1/2
A_2	1/5	1	1/5	1/2	1/5
A_3	1	5	1	3	1/2
A_4	1/3	2	1/3	1	1/4
A_5	2	7	2	4	1

3.5 Calculate weight vector

In reality, the importance of each element which influenced the goal is different. So we should calculate the weight through AHP once more. AHP weights can be calibrated starting from a lot of survey data that collected from Yanting. Finally, we figure out the weight of each element (table 3) and its corresponding eigenvector λ, $\lambda_{\max} = 5.12$.

Table 3. The weight of element

	A_1	A_2	A_3	A_4	A_5
weight	0.2312	0.0527	0.2312	0.0872	0.3977

3.6 Uniform examination

Comparison matrix in pairs is usually not line array, so it is necessary to calculate the consistency level of the estimated vector in AHP. Saaty (1994) use the value of $\lambda - n$ to weigh the inconsistency of comparison matrix in pairs, that is, consistency index (*CI*), $CI = (\lambda_{\max} - n)/n-1$.

In order to find relatively reasonable range of inconsistency of comparison matrix, Saaty (1994) introduced a random consistent index (*RI*), this is the stand to weigh *CI*. And the value of *RI* should look up data. For example, if n=5, then RI=1.12.

When $n \geq 3$ of the comparison matrix, consistency ratio (*CR*) is used to measure the consistency, $CR = CI/RI$, if $CR \leq 0.1$, the weight results are valid.

In this paper, $CI = (5.12-5)/(5-1) = 0.03$, $CR = 0.03/1.12 = 0.027 < 0.1$, so the value of weight is valid.

3.7 Build evaluation matrix

Fuzzy evaluation method for the evaluation object with complex characteristics, evaluators often difficult or impossible to directly give the quantitative results of evaluation object, and the fuzzy synthetic evaluation method can express the essence of information in a natural language way and processing the information in numerical approach, thus providing a unified expression and processing mode for the qualitative and quantitative information.

Specific evaluation steps are as follows:

(1) Determine the comment set

Comment set is a collection of various kinds of evaluation results of the evaluation object. The purpose of the fuzzy comprehensive evaluation is based on consideration of all factors affecting up to evaluate whether the alternative site suitable for the construction of logistics nodes. Therefore, evaluation set V can be established for $\{V_1, V_2, \cdots, V_5\}$ = {very suit, more suitable, suitable, not suitable and absolutely unsuitable}.

(2) Determine the index evaluation set

Index evaluation set is composed of multilayer collection based on the various factors which affect choose the logistics park. It can be divided into 5 sub system, notes for $A = \{A_1, A_2, A_3, A_4, A_5\}$, and it must meet the requirement of $\sum_{i=1}^{5} A_i = A$, the A_i refers to the criteria index that affect the evaluation object, and the n refers to the index number that contained in the i.

(3) Determine weight set

The weight set is a collection that used to describe the index for evaluation objects relative important degree. In the fuzzy hierarchy analysis and evaluation methods, mainly adopts the AHP that has the characteristics of a certain scientific, practical, and simple to determine the weights.

(4) Determining membership matrix

When evaluate the alternative sites of the Yanting's logistics nodes, we should determine the value of the index, that is, calculate the evaluation of membership function, and then build the membership matrix.

3.8 Synthetic evaluation of alternative sites

Firstly, we invited 10 experts to assign relative scores to each town or township. Secondly, reuse the established evaluation index system and fuzzy analytic hierarchy process to evaluate 12 alternative sites. Table 4 to 16 shows the each index's membership degree of each alternative site.

Secondly, reuse the AHP to calculate the each index's weight, W= [0.2312 0.0527 0.2312 0.0872 0.3977]. And then through each index' weight multiply each alternative sites, we can calculate 12 alternative sites' synthetic membership degree (see Table 17).

Table 4. Gaodeng's membership degree

index	r_{v1}	r_{v2}	r_{v3}	r_{v4}	r_{v5}
A_1	0	0	0.4	0.6	0
A_2	0.2	0.6	0.2	0	0
A_3	0	0	0	0.5	0.5
A_4	0	0	0.4	0.6	0
A_5	0.2	0.6	0.2	0	0

Table 5. Jinkong's membership degree

index	r_{v1}	r_{v2}	r_{v3}	r_{v4}	r_{v5}
A_1	0	0.3	0.4	0.3	0
A_2	0	0.7	0.3	0	0
A_3	0.2	0.7	0.1	0	0
A_4	0	0.6	0.4	0	0
A_5	0.2	0.4	0.4	0	0

Table 6. Yulong's membership degree

index	r_{v1}	r_{v2}	r_{v3}	r_{v4}	r_{v5}
A_1	0.2	0.4	0.4	0	0
A_2	0.4	0.4	0.2	0	0
A_3	0	0	0	0.5	0.5
A_4	0	0.5	0.5	0	0
A_5	0	0.4	0.6	0	0

Table 7. Bajiao's membership degree

index	r_{v1}	r_{v2}	r_{v3}	r_{v4}	r_{v5}
A_1	0	0.4	0.4	0.2	0
A_2	0	0.7	0.3	0	0
A_3	0	0.1	0.6	0.3	0
A_4	0	0.1	0.6	0.3	0
A_5	0.3	0.4	0.3	0	0

Table 8. Huangdian's membership degree

index	r_{v1}	r_{v2}	r_{v3}	r_{v4}	r_{v5}
A_1	0.1	0.5	0.4	0	0
A_2	0	0.6	0.4	0	0
A_3	0	0.2	0.6	0.2	0
A_4	0.1	0.6	0.3	0	0
A_5	0	0.2	0.4	0.2	0.2

Table 9. Fuyi's membership degree

index	r_{v1}	r_{v2}	r_{v3}	r_{v4}	r_{v5}
A_1	0.2	0.6	0.2	0	0
A_2	0.1	0.6	0.3	0	0
A_3	0	0.2	0.6	0.2	0
A_4	0.2	0.6	0.2	0	0
A_5	0.2	0.7	0.1	0	0

Table 10. Bozi's membership degree

index	r_{v1}	r_{v2}	r_{v3}	r_{v4}	r_{v5}
A_1	0	0	0.4	0.6	0
A_2	0	0	0.8	0.2	0
A_3	0	0	0	0.5	0.5
A_4	0.1	0.7	0.2	0	0
A_5	0.1	0.4	0.5	0	0

Table 11. Linshan's membership degree

index	r_{v1}	r_{v2}	r_{v3}	r_{v4}	r_{v5}
A_1	0	0	0	0.2	0.8
A_2	0	0	0	0.2	0.8
A_3	0	0	0	0.4	0.6
A_4	0	0	0	0.3	0.7
A_5	0.2	0.2	0.4	0.2	0

Table 12. Heiping's membership degree

index	r_{v1}	r_{v2}	r_{v3}	r_{v4}	r_{v5}
A_1	0	0	0	0.5	0.5
A_2	0	0	0.8	0.2	0
A_3	0	0.2	0.8	0	0
A_4	0	0	0.3	0.7	0
A_5	0.1	0.5	0.4	0	0

Table 13. Anjia's membership degree

index	r_{v1}	r_{v2}	r_{v3}	r_{v4}	r_{v5}
A_1	0	0	0	0.7	0.3
A_2	0	0	0.6	0.4	0
A_3	0	0.4	0.6	0	0.5
A_4	0	0	0.4	0.6	0
A_5	0	0	0.4	0.4	0.2

Table 14. Lianghe's membership degree

index	r_{v1}	r_{v2}	r_{v3}	r_{v4}	r_{v5}
A_1	0	0.4	0.6	0	0
A_2	0.2	0.6	0.2	0	0
A_3	0.7	0.3	0	0	0
A_4	0	0	0.4	0.6	0
A_5	0.2	0.2	0.4	0.2	0

Table 15. Mayang's membership degree

index	r_{v1}	r_{v2}	r_{v3}	r_{v4}	r_{v5}
A_1	0	0	0	0.7	0.3
A_2	0	0	0	0.3	0.7
A_3	0.8	0.2	0	0	0
A_4	0	0	0	0.8	0.2
A_5	0	0.4	0.6	0	0

Table 16. Center County's membership degree

index	r_{v1}	r_{v2}	r_{v3}	r_{v4}	r_{v5}
A_1	0.4	0.6	0	0	0
A_2	0.4	0.5	0.1	0	0
A_3	0.9	0.1	0	0	0
A_4	0	0	0.3	0.7	0
A_5	0.8	0.2	0	0	0

Table 17. Evaluation results of alternatives of logistics nodes

Alternatives	Evaluation results				
	r_{v1}	r_{v2}	r_{v3}	r_{v4}	r_{v5}
Center County	0.6398	0.2677	0.0314	0.061	0
Fuyi	0.1485	0.5473	0.258	0.0462	0
Jinkong	0.1258	0.4795	0.3254	0.0694	0
Yulong	0.0673	0.3162	0.3853	0.1156	0.1156
Huangdian	0.0318	0.3253	0.4375	0.1258	0.0795
Bajiao	0.1193	0.2278	0.4186	0.1418	0
Heiping	0.0398	0.2451	0.4124	0.1872	0.1156
Bozi	0.0485	0.2201	0.3509	0.2649	0.1156
Lianghei	0.275	0.2499	0.3432	0.1319	0
Anjia	0	0.0925	0.3643	0.3943	0.1489
Mayang	0.185	0.2053	0.2386	0.2474	0.1237
Gaodeng	0.0901	0.2702	0.2174	0.3066	0.1156
Linshan	0.0795	0.0795	0.1591	0.255	0.4269

4 Conclusion

This paper has tried to identify different factors responsible for optimal logistics nodes planning and tried to prioritize them through AHP and the fuzzy synthetic evaluation method. Prioritization is helpful in deciding relative importance of factors while arriving at a rational planning. We use this method to the selection of logistics nodes location, solve the problem of logistics nodes location successfully and give the location where establishment of logistics nodes is suitable.

County logistics planning must have the following characteristics: have transportation materials, people can benefited from the planning, have its' characteristics. Therefore, in the construction of logistics should not only consider the traffic location, but also consider the node and its neighborhood's resources, the existing leading industries, the planning of characteristic industry, the agriculture industrialization base, and explain the main direction and the radiation scope of logistics nodes.

In this paper, we find that the center county of Yanting is very suitable to construct the logistics node, and the Fuyi, Jinkong are more suitable to construct the logistics nodes.

References

Aminbakhsh, S., Gunduz, M., Sonmez, R. (2013), "Safety risk assessment using analytic hierarchy process (AHP) during planning and budgeting of construction projects", Journal of Safety Research, No. 46, pp. 99-105.

Chin, K.S., Chiu, S. and Tummala, V.M.R. (1999), "An evaluation of success factors using the AHP to implement ISO 14001-based ESM", *International Journal of Quality & Reliability Management*, Vol. 16 No. 4, pp. 341-61.

Qiu, J. (2007), "Planning theory and practice on the logistics system of west region", *Southwest Jiaotong University*, 2007.

Saaty, T. L. (1990), "How to make a decision: the analytic decision process", *European Journal of Operational Research*, Vol. 48, pp. 9-26.

Saaty, T. L. (1994), "How to make a decision: the analytic hierarchy process", *Interface*, Vol. 24 No. 6, pp. 19-43.

Supply Chain Inventory Control Strategy Based on Risk Attitude

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Abstract: In this research paper, a coordination problem has been investigated by considering a single supplier and a single retailer who have different risk attitude in two-stage supply chain. First, we quantify the risk attitude for members of the supply chain with Prospect Theory and establish a supply chain optimal inventory control model with revenue sharing contract. Then we obtain the results of parameters range (revenue-sharing contract) in different risk attitude combinations and use Matlab for numerical example to verify the conclusions. The analysis suggests that revenue sharing contract can coordinate the supply chain and control the supply chain inventory within a reasonable range considering risk attitude.
Keywords: Prospect theory; Risk attitude; Inventory control; Revenue sharing contract.

1 Introduction

Since an inventory cost proportion of total supply chain rises and the impact of participant's behavior on the supply chain is tremendous, we analyze the inventory control problem by considering risk attitude of the members in the supply chain. First, we establish an ordering model for retailer considering risk attitude; then discuss the relationship between supplier risk attitude and production under overall decision-making; and finally analyze the coordination ability of revenue sharing contract using supply chain coordination knowledge and get the result of exact range of parameters (revenue sharing contract) in different risk attitude combinations.

In recent years, many scholars did research on supply chain decision-making considering different risk attitude. (Lau, 1999) mainly used mean-variance method to study supply chain risk which introduces a risk aversion factor, and then analyzed the supply chain return policy when risk aversion factor is different. (Schweitzer, 2000) found that there existed significant decisions bias in newsboy model due to the different risk preferences, and the amount of the order would significantly reduce when there's a decision-making bias.

Prospect theory was proposed by Kahneman and Tversky on the basis of expected utility theory, of which human risk aversion behavior was further quantified.

Utility function $U(W)$ was used in this research. λ denotes risk aversion of decision-maker, and the larger λ, the higher degree of risk aversion. Usually, there always exist $\lambda \geq 1$. Then the specific utility function formula is:

$$U(W) = \begin{cases} W - W_0 & W \geq W_0 \\ \lambda(W - W_0) & W < W_0 \end{cases}$$

2 Model

2.1 Problem Description

We study the supply chain system composed of a single supplier and a single retailer. Assuming c is production cost per unit, the market price of per unit product is p, salvage value of per unit unsold product is v, and there always exists $0 < v < c < p$, and the wholesale price of retailer is $w(w > v)$, the retailer's ordering quantity is Q. Random demand that retailer faced is D, the probability of density function and cumulative distribution function are $f(x)$, $F(x)$ respectively. $F^{-1}(x)$ is the inverse function of *F (x)*. Also we assume that the supplier maximizes profit of the whole supply chain as the coordinator, and we use revenue sharing contract coordinate the retailer and supplier. In other words, supplier is committed to provide the retailer a lower wholesale prices w, while retailer is committed to return a certain percentage (1-φ) of sales revenue to the supplier for making up for the supplier's profit loss due to the lower wholesale prices to retailer.

2.2 The retailer's order strategy

In the revenue-sharing contract (w, φ), the retailer's profit function $\prod_r(Q_r)$ and the expected profit functions $E(\Pi_r)$ are as follows.

$$\prod_r(Q_r) = \begin{cases} \Pi_{r1} = \varphi[pQ_r - (p-m)(Q_r - x)] - wQ_r, & x < Q_r \\ \Pi_{r2} = \varphi p Q_r - wQ_r, & x \geq Q_r \end{cases} \tag{1}$$

$$\begin{aligned} E(\Pi_r) &= \int_0^{Q_r} [\varphi[pQ_r - (p-m)(Q_r - x)] - wQ_r) f(x)dx + \int_{Q_r}^{+\infty} (\varphi p Q_r - wQ_r) f(x)dx \\ &= (\varphi p - w)Q_r - \varphi(p-m)Q_r \int_0^{Q_r} F(x)dx \end{aligned} \tag{2}$$

From (1) and (2), we can find that the retailer's expected profit function is strictly concave with respect to Q_r, and there is an unique order quantity so that the retailer can have the maximum. Then we will analyze from the following two cases.

① When the retailer is risk-neutral

Decision problems retailers faced will turn into:

$$\max_{Q_r} E(\Pi_r) = \max_{Q_r}\left\{(\varphi p - w)Q_r - \varphi(p-m)\int_0^{Q_r} F(x)dx\right\} \tag{3}$$

According to Leibniz theorem, we can conclude from (3): when the retailer is risk-neutral, the optimal order quantity is $Q^*_{r1} = F^{-1}(\frac{\varphi p - w}{\varphi p - \varphi m})$ while the maximum expected profit is $E(\Pi_r(Q^*_{r1}))$.

② When the retailer is risk-averse

According to Prospect Theory, we introduce risk aversion coefficient, then retailer's expect unity will be:

$$\begin{aligned} E[U(\Pi_r)] &= E[U(\Pi_{r1})] + E[U(\Pi_{r2})] \\ &= \lambda_r \int_0^{q_1(Q_r)} \Pi_{r1} f(x)dx + \int_{q_1(Q_r)}^{Q_r} \Pi_{r1} f(x)dx + \int_{Q_r}^{+\infty} \Pi_{r2} f(x)dx \\ &= (\lambda_r - 1)\times\int_o^{q_1(Q_r)} \{\varphi[px + m(Q_r - x)] - wQ_r\} f(x)dx + E(\Pi_r) \end{aligned}$$

So, we can get the optimal order quantity Q_r^* under risk-averse , and Q_r^* will satisfy the following condition:

$$-(\lambda_r - 1)(w - \varphi m)F(q_1(Q_r^*)) + \varphi[p - (p-m)F(Q_r^*)] - w = 0$$

While the maximum expected utility is:

$$E^*[U(\Pi_r)] = (\lambda_r - 1)\times\int_0^{q_1(Q^*)} \left\{\phi[px + m(Q^* - x)] - wQ^*\right\} f(x)dx + (\phi p - w)Q^* - \phi(p-m)\int_0^{Q^*} F(x)dx$$

2.3 The supplier's production strategy

We use the same calculation method as **2.2**, and under revenue sharing contract (w, φ), the profits of the whole supply chain do not depend on the revenue-sharing contract parameters, but the number of production that supplier selects. Afterwards, we can get the profit function of the supply chain and the expected profit function.

① When the supplier is risk-neutral, because supplier only pursues the whole profits of the supply chain, then the optimal production will be $Q^{*}{}_{s1} = F^{-1}(\frac{p-c}{p-m})$,

and the maximum expect profit will be $E(\Pi_s(Q^{*}{}_{s1}))$.

② When the supplier is risk-averse with the introduction of risk aversion, we can get the optimal production under risk-averse. That will be $Q_s{}^{*}$, and Q_s^{*} satisfies the following conditions:

$$-(\lambda_s - 1)(c-m)F(q_2(Q_s^*)) + p - c - (p-m)F(Q_s^*) = 0$$

While the maximum expected utility of the supplier is:

$$E^*[U(\Pi_s)] = (\lambda_s - 1)\times\int_0^{q_1(Q_s^*)} \{[px + m(Q_s^* - x)] - cQ_s^*\} f(x)dx +$$
$$(p-c)Q_s^* - (p-m)\int_0^{Q_s^*} F(x)dx$$

2.4 Parameters Analysis

According to the previous model, in this section we will calculate the sensitivity of loss aversion based on the analysis of the retailer's order quantity, supplier's production and thier expected utility. Through calculating we can obtain that:

$$\frac{dQ_r{}^*}{d\lambda_r} < 0 \qquad \frac{dQ_s{}^*}{d\lambda_s} < 0$$

$$\frac{dE^*[U(\Pi_r)]}{d\lambda_r} < 0 \qquad \frac{dE^*[U(\Pi_s)]}{d\lambda_s} < 0$$

Therefore, the retailer's order quantity, supplier's production and thier expected utility will all decrease with a higher loss aversion.

3 Analysis of Supply Chain Coordination

Supply chain coordination increases the expected utility of each member in the s upply chain by adjusting the parameters of the contract, based on the target to achieve the maximum expected utility of the entire supply chain.

Here, we use a qualitative analysis method to adjust the contact parameters for a certain level and verify the coordination effects of revenue sharing contact. We will analyze from four aspects :

① When retailer is risk-neutral, supplier is also risk-neutral

Based on the previous model, we can get the optimal order quantity of retailer and the optimal production quantity of supplier under risk-neutral attitude. Then we can achieve supply chain coordination using:

$$Q^*_{r1} = F^{-1}(\frac{\varphi p - w}{\varphi p - \varphi m}) = Q^*_{s1} = F^{-1}(\frac{p-c}{p-m})$$

Analyzing the relationship of the parameters, we can draw that the conditions for supply chain coordination will be $m/c < \varphi < 1$, $m < w < c$, $w = \varphi c$.

② When retailer is risk-averse, supplier is risk-neutral

To make the supply chain achieve the coordination, there will be $Q_r^* = Q_{s1}^*$.

Thus,
$$\begin{cases} -(\lambda_r - 1)(w - \varphi m)F(q_1(Q_r^*)) + \varphi[p - (p-m)F(Q_r^*)] - w = 0 \\ Q^*_{s1} = F^{-1}(\frac{p-c}{p-m}) \\ Q_r^* = Q_{s1}^* \end{cases} \quad (4)$$

Solving (4), the conditions to coordinate the supply chain will be:

$$w < \varphi c < c, \quad w/c < \varphi < 1$$

③ When retailer is risk-neutral, supplier is risk-averse

We can use the same method like ②, then the conditions to coordinate supply chain will be: $\varphi c < w < c$, $0 < \varphi < w/c$.

④ When retailer is risk-averse, supplier is risk-averse,

The conditions for supply chain coordination will be:

$$\begin{cases} -(\lambda_r - 1)(w - \varphi m)F(q_1(Q_r^*)) + \varphi[p - (p-m)F(Q_r^*)] - w = 0 \\ -(\lambda_s - 1)(c - m)F(q_2(Q_s^*)) + p - c - (p-m)F(Q_s^*) = 0 \\ Q_s^* = Q_r^* \end{cases}$$

The relationship of w and φ depends on the size of λ_r and λ_s.

4 Examples

Parameter hypothesis: according to the prediction of demand for products, the random demand meets the normal distribution of (1000, 3002), the retailer price is $p = 18$, the production cost is $c = 10$, the revenue sharing coefficient is $\varphi = 0.8$, the wholesale price of supply chain under the dispersive contract is $w_c = 12$, the wholesale price under the revenue sharing contract is $w_\varphi = 8$.

First, the relationship of $Q_r^*, E^*[U(\Pi_r)]$ with λ_r and $Q_s^*, E^*[U(\Pi_s)]$ with λ_s will be shown in the following fig.1.

Concluding from the above figure, we can verify our conclusions that the retailer's order quantity, supplier's production and their expected utility will all decrease with a higher loss aversion.

Second, We will verify the coordination of revenue-sharing contract for the entire supply chain under different risk preference combinations.

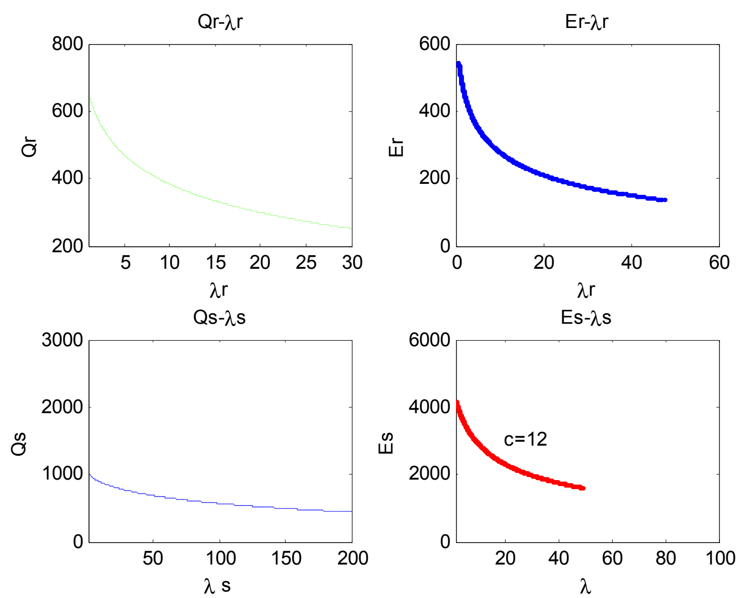

Figure 1. The Sensitivity Analysis of λ

① When retailers and suppliers are all with risk neutral attitude, according to the above formula, we can get the following Table 1.

Table 1. The order, expected profit, total profit of supply chain system (When risk attitude is in combination 1)

System status	Scattered without contract	Revenue sharing contract
The optimal order quantity	900	995
Retailers total profits	4184.4	4868.3
Supplier profits	994.2	1218.6
Supply Chain total profits	5178.6	6086.9

② When the retailer is risk aversion and the supplier is risk neutral or when the retailer is risk neutral while the supplier is risk averse, we can respectively calculate the supply chain data of scattered state and revenue sharing contract conditions, these supply chain data are shown Table2 and Table3:

Table2. The order, expected profit, total profit of supply chain (when risk attitude is in combination 2)

Parameter	Decentralized case				Revenue sharing contract				
λ_r	w_c	Q_c	$\prod_c^r$	$\prod_c^s$	φ_φ	w_φ	Q_φ	$\prod_\varphi^r$	$\prod_\varphi^s$
5	12	794	3713.2	3970	0.81	8	946	6614.4	4883.6
10	12	734	3336.8	3670	0.85	8	895	6528.0	4307.0
15	12	653	3060.7	3265	0.9	8	849	6441.6	3795.4
20	12	617	2855.5	3085	0.95	8	818	6355.2	3478.8

Table 3. The order, expected profit, total profit of supply chain (when risk attitude is in combination 3)

	Decentralized case				Revenue sharing contract				
λ_s	w_c	Q_c	$\prod_c^r$	$\prod_c^s$	φ_φ	w_φ	Q_φ	$\prod_\varphi^r$	$\prod_\varphi^s$
5	12	794	3713.2	3134.3	0.79	8	996	5954.3	3723.4
10	12	734	3336.8	2763.8	0.7	8	931.7	5478.4	3528.7
15	12	653	3060.7	2471.6	0.6	8	835.4	4736.7	3382.0
20	12	617	2855.5	2183.4	0.5	8	658.6	4072.4	2967.5

5 Conclusions

The inventory control problem considering risk preferences has been solved in this paper. We describe risk preferences with Prospect Theory to find the supplier's optimal production strategy and the retailer's optimal order strategy, then study of the coordinating effect of revenue sharing contract under different combinations of risk attitudes qualitatively. The study shows that revenue sharing contract can coordinate the supply chain when retailer and supplier are in different risk attitude, and we also draw the conclusions that the retailer's order quantity, supplier's production and their expected utility will all decrease with a higher risk-averse.

In this article, only a single supplier and a single retailer was studied in the supply chain, but the situation of multiple competing retailers need a further research.

References

Arrow(1951). Optimal Inventory Policy. *Econometrica*. 19(3): 250-272.

Kahneman D, Tversky A. Prospect theory: An analysis of decision under risk.

Lau. (1999)Manufacturer Pricing Strategy and Return Policy for a Single-period Commodity. *European Journal of Operational Research.* 116*:* 291-304

MS Jashankarya.(1999) Supplier Diversification：Effect of Disrete Demand. Operations Research Letter. 24(5): 213-221

Schweitzer ME,(2000) Ccchon GP. Decision Bias in the newsvendor problem with a known demand distribution ： experimental evidERce. Management Science,46(3): 404-420

Optimal Ordering Policy of Competitive Retailers with Different Risk Preferences

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Abstract: The study investigates the optimal ordering policies of two competitive retailers, one is risk-neutral, another is loss-averse. Because of different scale and credit, Risk-neutral retailers aim for maximum expected profit, while loss-averse retailers targets maximum expected utility. We establish the optimal ordering policies model for the two kinds of retailers whose demand is random and alternative, And proved the existence and uniqueness of the optimal order quantity. Then we carry on the mathematical experimentation with the uniform distribution function, The analysis revealed that when the degree of retailers' lose-averse coefficient increases, their optimal volume of ordering is reducing, while the corresponding risk-neutral competitor's optimal volume of ordering is increasing. But their total volume of ordering is reducing, The scope is becoming slower; when the risk-neutral retailers' wholesale price is falling, their optimal volume of ordering is increasing, while the corresponding the lose-aversion's optimal volume of ordering is just the opposite. But their total volume of ordering is increasing, The growth is becoming slower too.
Keywords: Competition; Perishable commodities; Ordering policy; Substitution; Loss averse utility theory.

1 Introduction

For retailers, The most direct method to reduce business operating costs is the optimal ordering and the inventory strategy. The inventory items we general discussed can usually be applied indefinitely. But some products in the real situation, will rot in a period of storage, or have little value after some time. Such as vegetables, fruits, milk, newspapers, etc. We call perishable commodities, also called seasonal products or short-term-life products. The surplus value of the expired perishable commodities will be lost or very low. This feature will inevitably influence the ordering strategy of retailers. If we order too many products and can't be sold for a long time, This would cause a glut. Such as newspapers, there are less people who want to buy them at night. On the contrary, out-of-stock will cause customer defection and reduced income, the most critical problem of the retailer who selling this kind of perishable goods is the optimal order quantity.

The research of the perishable products order started from Single phase inventory model in the 1950s, namely the newsboy model. There have been plenty of articles dedicated to this problem since 1988. Chen (2004) and Cai *et al.* (2003) studied retailer's ordering policy for substitutable and perishable Commodities. The difference between them is that the former is based on alternative factor to indicate the products which can replace each other, the later has studied the strategies under unilateralism alternative. General researches concentrate on one retailer who sell alternatives, There are two classic articles with retailer competition:1. Parlar et al. (1988) use game theoretic concepts to analyze two retailers' inventory problem of substitutable commodities with stochastic demand. This paper shown that when one of the players acts irrationally for the sole purpose of inflicting maximum damage on the other, the classical single-period inventory strategy will be influenced. 2. Pasternack and Drezner (1991) consider a demand model for two products which have a single-period inventory structure and which can be used as substitutes for each other. They proved that the expected profit function is concave, allowing us to find optimal stocking levels for the two products, They compared optimum inventory levels for the case of single substitution with that where there is no substitution. It is demonstrated for the case of single substitution that total optimum order quantities can actually increase or decrease with the substitution revenue. Su et al. (2006) use practical examples to analysis and simulate the literature of Parlar et al. (1988), determined the specific value of the various parameters in the model, and makes the model more close to reality.

However, these researches all established on the risk-neutral hypothesis, The researches of experimental economists have shown that decision makers are rarely risk neutral. For instance, Fisher and Raman (1996) found that the order of fashion manufacturers are always lower than the risk neutral decision makers. Patsuris (2001) found that, Despite the bad economy, many retail chains continue to add stores, heaping even more unnecessary supply onto the market. An observation by the author in Tai Wei, Hong Kong shows that newspapers in 7-11 shop are rarely unavailable, You can also buy the Sun of the day after 9 p.m. , But newsstands near 7-11 shop are almost out of stock at 7 p.m. and close early. It is clear that 7-11 sell almost all kinds of newspapers and magazines, and customers who buy other commodities in store also have a steady demand for newspapers, It has the ability of anti-risk, in studies we call that giant retailers to withstand risks via product diversification. The newsstands worry that they cannot sell out in the evening, so they would rather reduce the order quantity, There is a completely different attitude toward risk, comparing newsstands with 7-11. Thus only to give up the risk-neutral assumption , considering the risk attitudes of decision makers, can we make the study more realistic. Generally, the measure of risk is probably divided into two categories: One is the change of object function of decision makers, such as the mean variance model; The other is add constraints on the optimization of decision makers, Lau (1980) is the first scholar to discuss this issue, The suppliers and retailers in his study are risk averse, He construct the utility function through mean-variance, Get different results with the news vendor model. Agrawal and Seshadri (2000) studied the supply chain model which multiple risk averse retailers take part. And solved the shortage problem that caused by risk-averse attitude of retailers through introducing a risk neutral distributor. Gan *et al.* (2004&2005) use the Pareto-optimality criterion, used widely in the group decision theory, to define the supply chain coordination involving risk-verse agents. Ye *et al.* (2006) established a two-layer supply chain repurchase lease model which risk averse retailers are involved used the mean variance method. Yu *et al.* (2007) analyses the impact of retailers' risk-defending degree on the optimal order quantity, wholesale prices and supply chain coordination by using the conditional value-at-risk method.

However, the studies ignore the fact that there is nothing fixed about the decision makers' attitudes to risk—that is, simple risk-averse or risk-seeking did not fully reflect the attitude of the decision makers, The decision makers in the prospect theory of Kahneman and Tversky (1979) have following characteristics：(1)The sensitivity to the change of relative wealth is greater than the variation of absolute wealth;(2) Under the condition of the same amount of income, the degree of loss aversion is greater than the extent of pursuit;(3)Earning as risk aversion, while lossing as risk-seeking, namely diminishing sensitivity. That the policy makers have a composite attitude to risk.

Currently, the prospect theory proved can better explain many contradictory appearances of the risk aversion theory, it can describe the behavior of decision makers better, and has been applied in many field such as in economics, marketing, finance, and organizational theory, When analyzing with prospect theory, most scholars assume that decision makers are loss-averse to simplify the problem and obtain some useful conclusions, such as Shen *et al.* (2004) discussed the purchasing decision problem of customized production under the condition of loss aversion, Wang and Webster (2009) uses loss aversion to model manager's decision-making behavior in the single-period newsvendor problem. And on this basis, we use the classical piecewise-linear-value utility function in prospect theory to analyze the order decision problem of perishable product retailers who is different risk preference in a competitive environment.

2 Notation and Assumption

We assume that there are two retailers(R_1 and R_2) who sale highly homogenized perishable products(for example: newspaper)in the market, For the convenience of discussion, we use the following notation:

p_1, p_2: per-unit selling price for two retailers(R_1 and R_2);

w_1, w_2: per-unit wholesale price for two retailers(R_1 and R_2);

x, y: the actual market demand f*or* two retailers(R_1 and R_2);

q_1, q_2: the quantity of goods for two retailers(R_1 and R_2);

π_1, π_2: the profit of two retailers(R_1 and R_2);

q_{1N}, p_{2N}: *the* order quantity with the Nash equilibrium strategy of two retailers(R_1 and R_2);

$f(x), g(y)$: two retailers'(R_1 and R_2) probability density function of the actual market demand, we assumed that they are differentiable and reversible;

$F(x), G(y)$: two retailers'(R_1 and R_2) cumulative distribution function of the actual market demand, we assumed that they are differentiable and reversible;

λ:the degree of R_2's loss-averse coefficient.

In the case of single- phase, the profit of R_1 is

$$\pi_1 = p_1 \min[x, q_1] + p_1 \min[(y - q_2)^+, (q_1 - x)^+] - w_1 q_1 \tag{1}$$

the profit of R_2 is

$$\pi_2 = p_2 \min[y, q_2] + p_2 \min[(x - q_1)^+, (q_2 - y)^+] - w_2 q_2 \tag{2}$$

When $x \le q_1, y \ge q_2$, then we should consider that if R_1's order quantity will be enough to cope with demand which transferred by R_2, the profits are

$$\pi_1 = p_1 x + p_1 \cdot \min[y - q_2, q_1 - x] - w_1 q_1 \qquad \pi_2 = p_2 q_2 - w_2 q_2 \tag{3}$$

When $x \ge q_1, y \le q_2$, then we should consider that if R_2's order quantity will be enough to cope with demand which transferred by R_1, the profits are

$$\pi_1 = p_1 q_1 - w_1 q_1 \qquad \pi_2 = p_2 y + p_2 \cdot \min[x - q_1, q_2 - y] - w_2 q_2 \tag{4}$$

We assume that R_1 is risk neutral, thus, R_1's expected profit is

$$\pi_1(q_1,q_2)=\int_0^{q_1}\int_0^{q_2}(p_1x-w_1q_1)f(x)g(y)dydx+\int_0^{q_1}\int_{q_2}^{\infty}(p_1x+p_1\cdot\min[y-q_2,q_1-x]-w_1q_1)f(x)g(y)dydx$$
$$+\int_{q_1}^{\infty}\int_0^{q_2}(p_1q_1-w_1q_1)f(x)g(y)dydx+\int_{q_1}^{\infty}\int_{q_2}^{\infty}(p_1q_1-w_1q_1)f(x)g(y)dydx \tag{5}$$

We assume that R_2 is loss-averse, and meet the piecewise-linear loss-averse utility function ,as Fig. 1:

$$u(\pi_2(q_1,q_2))=\begin{cases}\pi_2(q_1,q_2) & \pi_2(q_1,q_2)>0\\ \lambda\pi_2(q_1,q_2) & \pi_2(q_1,q_2)<0\end{cases} \tag{6}$$

Where λ is retailer's loss-averse coefficient, It reflect the degree of loss aversion. We assume that $\lambda > 1$, There is a knee in the reference point (to simplify, we set initial wealth to zero), The larger λ, the higher degree of loss aversion. Although the piecewise-linear loss-averse utility function does not reflects the characteristics of the diminishing sensitivity in prospect theory, it widely used in literatures of various fields such as economic, financial and operational management as Kahneman and Tversky (1979) mentioned, because it clearly present the attitude of purchaser to loss.

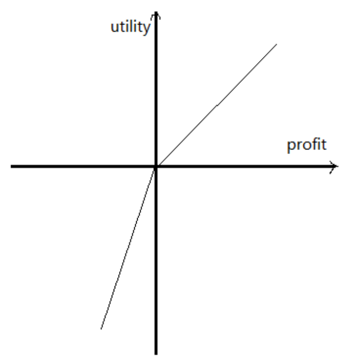

Fig.1. Piecewise-linear loss-averse utility function

When $y < \frac{w_2}{p_2}q_2$ is given by (4), According (4),when $y \le q_2$ and $q_1 < x < \frac{w_2}{p_2}q_2 + q_1 - y$, then the profits of R_2 will be negative.

Thus, we have

$$\pi_2(q_1,q_2)=\int_{\frac{w_2}{p_2}q_2}^{q_2}\int_0^{q_1}(p_2y-w_2q_2)f(x)g(y)dxdy+\lambda\int_0^{\frac{w_2}{p_2}q_2}\int_0^{q_1}(p_2y-w_2q_2)f(x)g(y)dxdy$$
$$+\int_{q_2}^{\infty}(p_2q_2-w_2q_2)g(y)dy+\int_0^{q_2}\int_{q_1+q_2-y}^{\infty}[p_2q_2-w_2q_2]f(x)g(y)dxdy$$
$$+\int_0^{q_2}\int_{\frac{w_2}{p_2}q_2+q_1-y}^{q_1+q_2-y}[p_2y+p_2(x-q_1)-w_2q_2]f(x)g(y)dxdy$$
$$+\lambda\int_0^{q_2}\int_{q_1}^{\frac{w_2}{p_2}q_2+q_1-y}[p_2y+p_2(x-q_1)-w_2q_2]f(x)g(y)dxdy \tag{7}$$

Where the 2nd and 6th indicate negative profits of retailers.

3 Nash strategy of retailers

If retailers does not adopt a cooperative attitude, it is possible that both of them adopt Nash strategy that meet the following conditions

$$\pi_1(q_{1N},q_{2N}) \geq \pi_1(q_1,q_{2N}) \qquad \pi_2(q_{1N},q_{2N}) \geq \pi_2(q_{1N},q_2) \tag{8}$$

Formula (8) shows that if Nash strategy adopted in one side , so does the other side. otherwise the consequences will not get better , Thus the retailer's strategy set (Reflection curves) can be obtained by the first-order derivatives of retailers' profit function.
According to (5), R_1's expected profit is

$$\pi_1(q_1,q_2) = p_1q_1 - w_1q_1 - p_1\int_0^{q_1}\int_{q_2}^{q_1+q_2-x} G(y)f(x)dydx \tag{9}$$

Let

$$I_1(q_1,q_2) = \frac{\partial \pi_1(q_1,q_2)}{\partial q_1} = p_1 - w_1 - p_1\int_0^{q_1}\int_0^{q_1+q_2-x} g(y)f(x)dydx \tag{10}$$

Then

$$\frac{\partial^2 \pi_1(q_1,q_2)}{\partial q_1^2} = -p_1[G(q_2)f(q_1) + \int_0^{q_1} g(q_1+q_2-x)f(x)dx] < 0 \tag{11}$$

Formula (11) shows a strictly concave function of $\pi_1(q_1, q_2)$ with q_1 for any given q_2 .

Lemma 1 $I_1(q_1, q_2) = 0$ is strictly decreasing curve in q_1, q_2 plane.
Proof. See Appendix A.
According to lemma 1 and formula (10), we can know that for any given q_2, The upper bound $\overline{q_1}$ and lower bound $\underline{q_1}$ of R_1's optimal order quantity q_1^* are given by :

$$p_1 - w_1 - p_1\int_0^{\bar{q}_1} G(\bar{q}_1 - x)f(x)dx = 0 \tag{12}$$

$$p_1 - w_1 - p_1\int_0^{\underline{q}_1} f(x)dx = 0 \tag{13}$$

Where $\overline{q_1}$ in (12) can be obtained by letting $q_2 = 0$ in formula(10), Where $\underline{q_1}$ in (13) can be obtained by letting $q_2 = +\infty$ in formula(10).

We could see that when q_2 approaches infinity , The order of R_1 is the classical newsboy model. Thus the optimal order quantity will be greater than the quantity based on classical newsboy model, demonstrating that it is good for retailers when there is substitutable demand.

According to (7), R_2's expected profit is

$$\begin{aligned}
\pi_2(q_1,q_2) &= \int_0^{q_2}\int_0^{q_1}(p_2y-w_2q_2)f(x)g(y)dxdy+\int_{q_2}^{\infty}(p_2q_2-w_2q_2)g(y)dy \\
&+\int_0^{q_2}\int_{q_1}^{q_1+q_2-y}[p_2y+p_2(x-q_1)-w_2q_2]f(x)g(y)dxdy+\int_0^{q_2}\int_{q_1+q_2-y}^{\infty}[p_2q_2-w_2q_2]f(x)g(y)dxdy \\
&+(\lambda-1)\int_0^{\frac{w_2}{p_2}q_2}\int_0^{q_1}(p_2y-w_2q_2)f(x)g(y)dxdy+(\lambda-1)\int_0^{\frac{w_2}{p_2}q_2}\int_{q_1}^{\frac{w_2}{p_2}q_2+q_1-y}[p_2y+p_2(x-q_1)-w_2q_2]f(x)g(y)dxdy \\
&= p_2q_2-w_2q_2-p_2\int_0^{q_2}g(y)dy\int_{q_1}^{q_1+q_2-y}F(x)dx-(\lambda-1)p_2F(q_1)\int_0^{\frac{w_2}{p_2}q_2}G(y)dy \\
&+(\lambda-1)[-p_2F(q_1)\int_0^{\frac{w_2}{p_2}q_2}yg(y)dy-p_2\int_0^{\frac{w_2}{p_2}q_2}g(y)dy\int_{q_1}^{\frac{w_2}{p_2}q_2+q_1-y}F(x)dx+w_2q_2F(q_1)\int_0^{\frac{w_2}{p_2}q_2}g(y)dy]
\end{aligned} \tag{14}$$

Let

$$I_2(q_1,q_2)=\frac{\partial\pi_2(q_1,q_2)}{\partial q_2}=p_2-w_2-p_2\int_0^{q_2}\int_0^{q_1+q_2-y}f(x)dxg(y)dy -(\lambda-1)p_2\int_0^{\frac{w_2}{p_2}q_2}\int_0^{\frac{w_2}{p_2}q_2+q_1-y}f(x)dxg(y)dy \tag{15}$$

Then

$$\frac{\partial^2\pi_2(q_1,q_2)}{\partial q_2^2}=-p_2[F(q_1)g(q_2)+\int_0^{q_2}f(q_2+q_1-y)g(y)dy] -(\lambda-1)w_2[F(q_1)g(\frac{w_2}{p_2}q_2)+\int_0^{\frac{w_2}{p_2}q_2}f(\frac{w_2}{p_2}q_2+q_1-y)g(y)dy] \tag{16}$$

Lemma 2 $I_2(q_1,q_2)=0$ is strictly decreasing curve in q_1, q_2 plane.

Proof. See Appendix A.

According to lemma 2 and formula (15), we can know that for any given q_1, The upper bound $\overline{q_2}$ and lower bound $\underline{q_2}$ of R_2's optimal order quantity q_2^* are given by

$$p_2 - w_2 - p_2\int_0^{\bar{q}_2}\int_0^{\bar{q}_2 - y} f(x)dxg(y)dy - (\lambda-1)p_2\int_0^{\frac{w_2}{p_2}\bar{q}_2}\int_0^{\frac{w_2}{p_2}\bar{q}_2 - y} f(x)dxg(y)dy = 0 \quad (17)$$

$$p_2 - w_2 - p_2\int_0^{\underline{q}_2} g(y)dy - (\lambda-1)p_2\int_0^{\frac{w_2}{p_2}\underline{q}_2} g(y)dy = 0 \quad (18)$$

Where $\overline{q_2}$ in (17) can be obtained by letting $q_1 = 0$ in formula (15), Where $\underline{q_2}$ in (18) can be obtained by letting $q_1 = +\infty$ in formula(15).

Theorem 1 Two retailers have unique Nash equilibrium solution (q_{1N}, q_{2N}).
Proof. See Appendix A.

Thus, in the general case, retailers' Nash equilibrium point (q_{1N}, q_{2N}) can be obtained by$I_1(q_1, q_2) = 0$ and $I_2(q_1, q_2) = 0$. Obviously, we need to know exactly demand density function of retailers and other parameters to find the equilibrium strategy in the actual operation.

4 Properties of the optimal order quantity

The Nash equilibrium point of retailers, that is, the optimal order quantity (q_1^*, q_2^*) is given by :

$$\begin{cases} p_1 - w_1 - p_1\int_0^{q_1}\int_0^{q_1+q_2-x} g(y)f(x)dydx = 0 \\ p_2 - w_2 - p_2\int_0^{q_2}\int_0^{q_1+q_2-y} f(x)dxg(y)dy - (\lambda-1)p_2\int_0^{\frac{w_2}{p_2}q_2}\int_0^{\frac{w_2}{p_2}q_2+q_1-y} f(x)dxg(y)dy = 0 \end{cases} \quad (19)$$

Property 1 R_1's optimal order quantity q_1^* is proportional to R_2's loss-averse coefficient λ, R_2's optimal order quantity q_2^* is inversely proportional to λ.
Proof. See Appendix A.

This conclusion directly demonstrate the order policy while there is a loss aversion between two competing retailers. This property illustrates the reasons why 7-11 could have a big order, At the same time, it offers an important information for R_1 that when the degree of loss-averse coefficient of R_2 is very larger in some cases (such as bad weather), R_1 can order some more products.

5 Numerical Analysis

For simplicity and common, We assume that the stochastic demand subjects to

uniform distribution,
Let

$$f(x_1) = f(x_2) = \frac{1}{\beta - \alpha}$$

Thus we have

$$\frac{\partial \pi_1(q_1, q_2)}{\partial q_1} = p_1 - w_1 - p_1 \int_0^{q_1} \int_0^{q_1 + q_1 - x} \frac{1}{(\beta - \alpha)^2} dy dx = 0$$

Then

$$2(p_1 - w_1)(\beta - \alpha)^2 - 2 p_1 q_1 q_2 - p_1 q_1^2 = 0 \tag{20}$$

$$\frac{\partial \pi_2(q_1, q_2)}{\partial q_2} = p_2 - w_2 - p_2 \int_0^{q_2} \int_0^{q_1 + q_1 - y} \frac{1}{(\beta - \alpha)^2} dx dy - (\lambda - 1) p_2 \int_0^{\frac{w_2}{p_2} q_2} \int_0^{\frac{w_2}{p_2} q_2 + q_1 - y} \frac{1}{(\beta - \alpha)^2} dx dy = 0$$

Then

$$2(p_2 - w_2)(\beta - \alpha)^2 - 2 p_2 q_1 q_2 - p_2 q_2^2 - (\lambda - 1) p_2 (2 \frac{w_2}{p_2} q_1 q_2 + (\frac{w_2}{p_2} q_2)^2) = 0 \tag{21}$$

5.1 The impacts of R_2's loss-averse coefficient on the quantity of goods

In order to discuss the impacts of R_2's loss-averse coefficient on the quantity of goods, we plug $p_1 = 10, w_1 = 5, p_2 = 10, w_2 = 5, \beta = 100, \alpha = 0$ in Equation (20) and (21), So we have

$$10000 - 2 q_1 q_2 - q_1^2 = 0 \tag{22}$$

And

$$10000 - 2 q_1 q_2 - q_2^2 - (\lambda - 1)(q_1 q_2 + \frac{1}{4} q_2^2) = 0 \tag{23}$$

Specify λ=1, λ=2, ..., λ=10, Fig 2 reports the optimal order quantity and the total order of the two retailers.

We can see from Fig. 2 that as R_2's loss-averse coefficient has increased , R_2's optimal order quantity was falling, but R_1's optimal order quantity was increasing. At the same time, the total optimal order quantity is down. The reason is very simple, For given wholesale and retail prices, R_2 will reduce the optimal order quantity to avoid losses, as the newsstand mentioned previously. Once R_1 observe this phenomenon ,he will increase the order quantity to rise profits, From this figure, you can see that the trends of two retailers get gentler and gentler, It may be the following two cases cause this result:(1) R_2's loss-averse coefficient would not increase infinitely, there will always be some customers will visit his shop; (2) If wholesalers found the total order quantity decreased, they would take some measures to decrease the worry of loss, the buyback strategy they usually do is the best example, The graph also confirms the conclusion that lose-aversion's optimal volume of ordering less than the risk-neutral competitor's optimal quantity of ordering

5.2 The influence of R_1's wholesale price w_1 on the order

We assume that the products are highly homogenized, such as newspapers, so they should sell for the same price, but the wholesale price of large and small retailers exist some difference, possibly due to the scale. We plug $p_1 = 10, p_2 = 10, w_2 = 8, \beta = 100, \alpha = 0$ in Equation (20) and (21), So we have

$$20q_1^2 + p_2 q_2^2 + 20q_1 q_2 - 80000 = 0 \tag{24}$$

And

$$5q_1^2 + p_2 q_2^2 + p_2 q_1 q_2 - 40000 = 0 \tag{25}$$

Specify $w_1 = 8, w_1 = 7.5, w_1 = 7, w_1 = 6.5, ..., w_1 = 4$，Fig 3 reports the optimal order quantity and the total order of the two retailers.

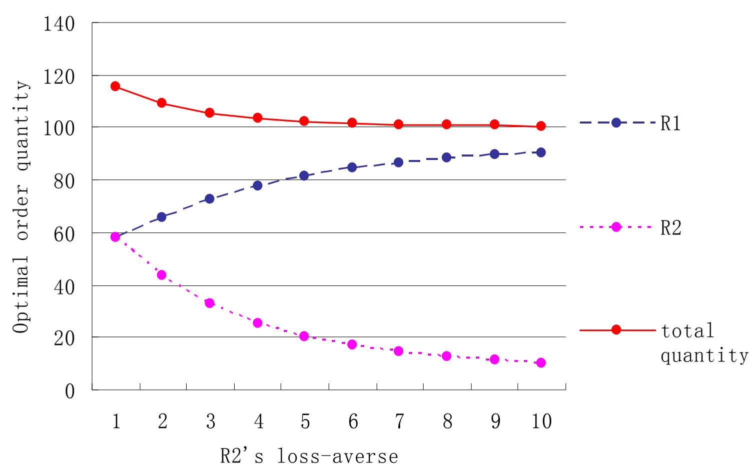

Fig.2. Optimal order quantity with different R2's

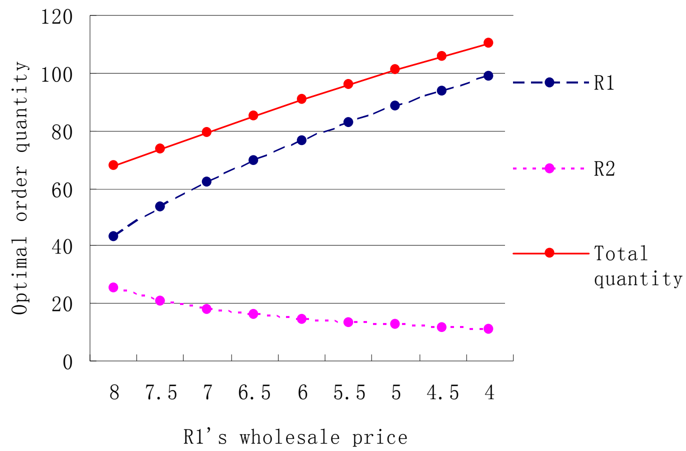

Fig.3. Optimal order quantity with different R1's

We can see from Fig. 3 that as R_1's unit wholesale prices has decreased, R_1's optimal order quantity was increasing. R_2 was just the opposite. At the same time, the total optimal order quantity continue to increase. Apparently, for R_1, decreasing wholesale price means increasing profits, he can raise the quantity of goods appropriately to increase profits, while the trend also get gentler. The reason is simple, For the perishable goods, such as newspapers and magazines, the sales volume may not fluctuate much, The wholesale price of R_2 is high due to his small scale, his wisest strategy against R_1 is just order what he could sells out(under the certain degree of loss-averse coefficient) , Now the wholesalers should be the happiness person, their total sales are increasing, but trend seen slowing, show that it is not wise to share interests with R_1 blindly.

6 Conclusions

This paper studied some characters about two retailers' order quantity of perishable products, there is competition between them. The main conclusion is that When the degree of retailers' lose-averse coefficient increases, their optimal volume of ordering is reducing, while the corresponding risk-neutral competitor's optimal volume of ordering is increasing. But their total volume of ordering is reducing, The scope is becoming slower; when the risk-neutral retailers' wholesale price is falling, their optimal volume of ordering is increasing, while the corresponding the lose-aversion's optimal volume of ordering is just the opposite. But their total volume of ordering is increasing, The growth is becoming slower too.

In the future, adding the internal competition between different products in newsstand is worth investigating, This article focuses on one kind of product, But variety of products in one newsstand can replace each other, For example, Wen Wei Po is similar to Ta Kung Pao , Ming Pao look similar to the Sun(It can be called sub-category) Some customers will seek alternative products when one newsstand is out of stock, but others have turned to other newsstands. Besides, the impact of price on demand is also worth investigating, Although the price of the perishable goods like newspaper is mostly fixed, other types of products like bread will discount after a point in some stores (including large stores). Obviously, Different discount rate could greatly affect consumer demand, adding the strategies about demand and promotion under the influence of price would perfect this model. It is clear that the amount of inventory can impact the degree of loss-averse coefficient. In addition, newspaper vendors' loss-averse coefficient in the morning and at night are obviously different. That is, loss aversion is really relevant to the inventory and time, It will be a dynamic process. Although it is complex, the study will be closer to the actual situation , the result will be more instructive.

Appendix A.

Proof of Lemma 1.

When $I_1(q_1,q_2)=0$,Then

$$\frac{dq_2^1}{dq_1}=\frac{-G(q_2)f(q_1)}{\int_0^{q_1} g(q_1+q_2-x)f(x)dx}-1<0\,.$$

Thus, **Lemma 1** holds.

Proof of Lemma 2.

when $I_2(q_1,q_2)=0$ ， Then

$$\frac{dq_2^2}{dq_1}=-\frac{\int_0^{q_2} f(q_1+q_2-y)g(y)dy+(\lambda-1)\int_0^{\frac{w_2}{p_2}q_2} f(\frac{w_2}{p_2}q_2+q_1-y)g(y)dy}{F(q_1)g(q_2)+\int_0^{q_2} f(q_1+q_2-y)g(y)dy+(\lambda-1)\frac{w_2}{p_2}[F(q_1)g(\frac{w_2}{p_2}q_2)+\int_0^{\frac{w_2}{p_2}q_2} f(\frac{w_2}{p_2}q_2+q_1-y)g(y)dy]}<0$$

Thus, **Lemma 2** holds.

Proof of Theorem 1.

According to (10),we have

$$\frac{\partial^2\pi_1(q_1,q_2)}{\partial q_1\partial q_2}=-\,p_1\int_0^{q_1} g(q_1+q_2-x)f(x)dx<0 \tag{26}$$

According to (15),we have

$$\frac{\partial^2 \pi_2(q_1,q_2)}{\partial q_2 \partial q_1} = -p_2\int_0^{q_2} f(q_2+q_1-y)g(y)dy - (\lambda-1)p_2\int_0^{\frac{w_2}{p_2}q_2} f(\frac{w_2}{p_2}q_2+q_1-y)g(y)dy < 0 \tag{27}$$

According to the Definition 3 of Cachon (2004), Profit function is supermodular, Combined with the theorem 3 of Cachon (2004), We know that in a supermodular game there exists at least one NE.

The response curve of two retailers is decreased strictly (see Fig. 4)

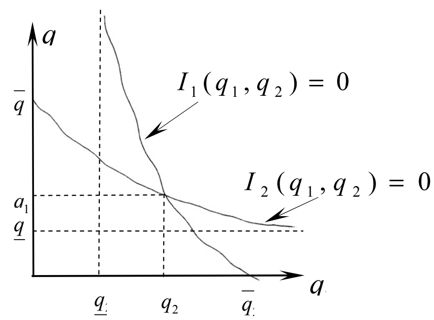

Fig.4. Retailer order quantity

And

$$\frac{dq_2^1}{dq_1} - \frac{dq_2^2}{dq_1} = \frac{-G(q_2)f(q_1)}{\int_0^{q_1} g(q_1+q_2-x)f(x)dx} - 1 +$$

$$\frac{\int_0^{q_2} f(q_1+q_2-y)g(y)dy + (\lambda-1)\int_0^{\frac{w_2}{p_2}q_2} f(\frac{w_2}{p_2}q_2+q_1-y)g(y)dy}{F(q_1)g(q_2) + \int_0^{q_2} f(q_1+q_2-y)g(y)dy + (\lambda-1)\frac{w_2}{p_2}[F(q_1)g(\frac{w_2}{p_2}q_2) + \int_0^{\frac{w_2}{p_2}q_2} f(\frac{w_2}{p_2}q_2+q_1-y)g(y)dy]} < 0 \tag{28}$$

Thus this two curves exist only one intersection point (see Fig. 2), there exists the only one NE holds.

The proof of Property 1.

According (22), we have

$$\begin{cases} [f(q_1)G(q_2) + \int_0^{q_1}(f(x)g(q_1+q_2-x)]\frac{dq_1}{d\lambda} + \int_0^{q_1}(f(x)g(q_1+q_2-x)dx\frac{dq_2}{d\lambda} = 0 \\ (\int_0^{q_2}(g(y)f(q_1+q_2-y)dy + (\lambda-1)\int_0^{\frac{w_2}{p_2}q_2}(g(y)f(\frac{w_2}{p_2}q_2+q_1-y))dy)\frac{dq_1}{d\lambda} \\ (g(q_2)F(q_1) + \int_0^{q_2}(g(y)f(q_1+q_2-y)dy + (\lambda-1)\frac{w_2}{p_2}(g(\frac{w_2}{p_2}q_2)F(q_1) + \int_0^{\frac{w_2}{p_2}q_2}(g(y)f(\frac{w_2}{p_2}q_2+q_1-y))dy))\frac{dq_2}{d\lambda} = -\int_0^{\frac{w_2}{p_2}q_2}\int_0^{\frac{w_2}{p_2}q_2+q_1-y} f(x)dxg(y)dy \end{cases} \tag{29}$$

Let

$$a = G(q_2)f(q_1) + \int_0^{q_1} g(q_1+q_2-x)f(x)dx\ ; \quad b = \int_0^{q_1} g(q_1+q_2-x)f(x)dx$$

$$c = \int_0^{q_2} (g(y) f(q_1 + q_2 - y) dy + (\lambda - 1) \int_0^{\frac{w_2}{p_2} q_2} (g(y) f(\frac{w_2}{p_2} q_2 + q_1 - y)) dy ;$$

$$d = g(q_2) F(q_1) + \int_0^{q_2} (g(y) f(q_1 + q_2 - y) dy + (\lambda - 1)(\frac{w_2}{p_2} g(\frac{w_2}{p_2} q_2) F(q_1) + \int_0^{\frac{w_2}{p_2} q_2} (g(y) f(\frac{w_2}{p_2} q_2 + q_1 - y)) dy)$$

Then

$$\begin{cases} a\dfrac{\partial q_1}{\partial \lambda} + b\dfrac{\partial q_2}{\partial \lambda} = 0 \\ c\dfrac{\partial q_1}{\partial \lambda} + c\dfrac{\partial q_2}{\partial \lambda} = -\int_0^{\frac{w_2}{p_2} q_2} \int_0^{\frac{w_2}{p_2} q_2 + q_1 - y} f(x) dx g(y) dy \end{cases} \tag{30}$$

Thus

$$\begin{cases} \dfrac{\partial q_1}{\partial \lambda} = \dfrac{-b(-p_2 \int_0^{\frac{w_2}{p_2} q_2} \int_0^{\frac{w_2}{p_2} q_2 + q_1 - y} f(x) dx g(y) dy)}{ad - bc} \\ \dfrac{\partial q_2}{\partial \lambda} = \dfrac{a(-p_2 \int_0^{\frac{w_2}{p_2} q_2} \int_0^{\frac{w_2}{p_2} q_2 + q_1 - y} f(x) dx g(y) dy)}{ad - bc} \end{cases} \tag{31}$$

When $a - b = G(q_2) f(q_1) > 0$, $d - c = g(q_2) F(q_1) + (\lambda - 1)\dfrac{w_2}{p_2} g(\dfrac{w_2}{p_2} q_2) F(q_1) > 0$,

We have $ad - bc > 0$ and thus $\dfrac{\partial q_1}{\partial \lambda} > 0, \dfrac{\partial q_2}{\partial \lambda} < 0$ holds.

Acknowledgments

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References

Agrawal V and Seshadri S. (2000). Risk intermediation in supply chains. *IIE Transactions*, 32(9), 819-831.

Cachon G P and Netessine S.(2004). Game Theory in Supply Chain Analysis. *Handbook of Quantitative Supply Chain Analysis Modeling in the E-Business Era,*13-67

Chai, LQ et al. (2003). The Study on the Inventory Model with Substitution (Ⅰ):

Optimization Solution. *Systems Engineering-Theory & Practice*, 6, 63-68.

Chai, LQ et al. (2003). The Study on the Inventory Model with Substitution (Ⅱ): Properties. *Systems Engineering-Theory & Practice*, 8, 59-66.

Chen,X (2004). Retailer's Ordering Policy for Substitutable and Perishable Commodities with Stochastic Demand. *Systems Engineering Theory•Methodology•Applications*,13 (4), 300-304.

Fisher M A and Raman A. (1996). Reducing the cost of demand uncertainty through accurate response to early sales. *Operations Research* , 44, 87-99.

Gan X H, Sethi S P and Yan H M. (2004). Coordination of a supply chain with risk-averse agents. *Production and Operations Management*, 13(2), 135-149

Gan X H, Sethi S P and Yan H M. (2005). Channel coordination with a risk-neutral supplier and a downside-risk- averse retailer. *Production & Operations Management*, vol.14, No.1, pp. 80-89.

Kahneman D and Tversky A. (1979). Prospect theory : An analysis of decisions under risk. *Econometrica*, 47, 263-292.

Lau H S. (1980). The newsboy problem under alternative optimization objectives. *Journal of the Operational Res. Society*, 31, 525 -535.

Parlar, M. (1988). Game Theoretic Analysis of the Substitutable Product Inventory Problem with Random Demands. Naval Research Logistics, 35, 397-409.

Pasternack B A and Drezner Z. (1991). Optimal Inventory Policies for Substitutable Commodities with Stochastic Demand. *Naval Research Logistics*, 38, 221-240.

Patsuris P. (2001). Christmas Sales : The Worst Growth in 33 Years [ED/OL]. *Forbes.com*, http://www.forbes.com/2001/10/30/1030retail.html〉

Shen HC et al. (2004). Decision analysis for order-specific component procurement with loss-averse utility. *Journal of Management Sciences in China*, 7(6), 37-45B.

Su, B et al. (2006). Research on the Substitutable Product Inventory Model and Its Application. *Chinese Journal of Management Science*, 13(1), 53-59.

Wang C X and Webster S.(2009). The loss-averse newsvendor problem. *Omega*, 37, 93-105.

Yu CY *et al*. (2007). Supply Chains Optimization and Coordination Mechanisms Mode with a Risk-averse Supplier(or Retailer)and a Risk-taking Retaile (or Supplie). *Systems Engineering*, 25 (1), 13-20.

Ye F and YN Li. (2006). Research on Buy back Contract Mechanism for Supply Chain Coordination With a Risk-Averse Retailer. *Industrial Engineering And Management*, 11 (2), 1-4.

The Design of an Interests Allocation Mechanism in a Scraped Car Reverse Supply Chain

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Abstract: Scraped cars are important renewable resources. In order to improve the recovery rate of Scraped cars, it is necessary to build a Scraped cars reverse supply chain of high efficiency and benefit, and it needs participants of supply chain to realize the organic integration collaborative development of resources, technology and information through the relevant contract mechanism. Interest distribution mechanism is a kind of important contract mechanism. This article builds model of profit distribution of the scraped cars reverse supply chain using improved Shapley value method which considers the risk sharing, which is based on the analysis of the Scraped cars reverse supply chain. Also, this article analyses and verifies the model through a numerical example.
Keywords: Scraped cars; Interests allocation; Reverse supply chain.

1 Introduction

The recycling of scraped cars has great economic value and environmental value. The recycling of scraped cars has positive influence on energy conservation and emissions reduction, as well as promoting the construction of resource saving and environment friendly society. The structure of scraped cars reverse supply chain is shown in figure 1. Every participant in this chain realizes the organic integration of resources, technology, information and business processes and so on through some contract mechanism, and gains collaborative development, as well as greater economic and social benefits. The reasonable design of benefit allocation mechanism is basis of effective operation of supply chain. If distribution of benefit is fair and reasonable, current cooperation relations in the chain will be consolidated and strengthened and the overall efficiency and effectiveness of the chain will be improved. Otherwise it will damage the relations of cooperation among enterprises in the chain, and influence the overall efficiency and performance of the chain, even create collapse of the whole supply chain.

Guo Yajun put forwards a profit model of closed-loop supply chain system under the condition that retailers are responsible for product sales, the third party responsible for waste recycling (Guo Yajun, 2007). Huang Zuqing etc research closed-loop supply chain system under the condition that the third party is responsible to recycle, and put forward the strategy about how the revenue sharing contract realizes win-win among supply chain members (Huang Zuqing etc, 2008). Savaskan compares decision making and earnings among members under four kinds of closed-loop supply chain model in which recycler respectively is retailer, manufacturer, the third party, manufacturer and retailer (Savaskan, 2004). Wang Xu sets up a model of reverse supply chain made up of processors, recyclers and consumers, determines working range between processors and recyclers, designs the profit distribution plan among enterprises in reverse supply chain (Wang Xu, 2009). Wei Xiujian analyses profit distribution problem of supply chain from the perspective of the resources of the supply chain and its contributions to supply chain, and put forwards some ideas and framework of profit distribution among every participant in the chain(Wei Xiujian, 2005).

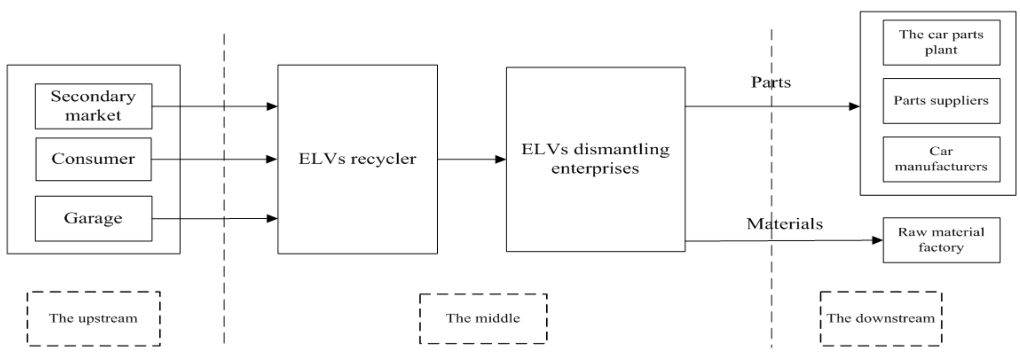

Figure1.Structure of scraped cars reverse supply chain

This paper references related benefit distribution mechanism in scraped cars reverse supply chain at home and abroad, sets up profit distribution model based on Shapley value method, and conducts the corresponding numerical example analysis.

2 Design Background of Profit Distribution Mechanism

In scraped cars reverse supply chain, in order to realize the maximization of economic benefits, the enterprises originally independent optimize and Integrate core competencies, so we can regard the economic activity of the industrial chain as cooperation of many people, profit distribution of enterprises as profit distribution problem of cooperation of many people.

Shapley value method is a kind of mathematical methods to solve the problem of people cooperation countermeasure proposed by Shapley L.S. When n persons engage in an economic activity, it can gain certain benefits about every kind of cooperation formation which consists of some people. When activity of interests among people is non-confrontational, it cannot reduce benefits when the number of people is increasing in the cooperation. So it will come out the biggest benefit because of the cooperation of n persons, and Shapley value method is a kind of plan to distribute this maximum benefit.

Above all, this paper considers the characteristics of scraped cars reverse supply chain, sets a profit distribution model based on the improved Shapley value method which takes the risk into consideration, and conducts the example analysis.

3 Design Content

3.1 Model building

The principle of Shapley value method is as follows: Assuming that collection $I=\{1,2,\ldots,n\}$, if any subset s （any combination within n people）of I has a real function $v(s)$, and:

$$v(\varnothing)=0;\quad v(s_1\cup s_2)\geq v(s_1)+v(s_2), s_1\cap s_2=\varnothing \qquad (s_1\subseteq I, s_2\subseteq I)$$

We call $[I,v]$ cooperation countermeasure of n persons，call v Characteristic function of countermeasures.

We usually call x_i income of member i (from I) from the biggest benefit of cooperation $v(I)$. Under the cooperation I, $x=(x_1,x_2,\ldots,x_n)$ expresses the distribution of cooperation countermeasure, the successful cooperation must meet the following conditions:

$$\sum_{i=1}^{n} x_i = v(I);\qquad x_i \geq v(i), i=1,2,\ldots,n$$

In the Shapley value method, we call the profit distribution of every partner under cooperation I as Shapley value, and record it as: $\Phi(v)=(\phi_1(v),\phi_2(v),\ldots,\phi_n(v))$ .While $\phi_i(v)$ expresses the distribution of member i under the cooperation I, and $\phi_i(v)=\sum_{s\in s_i} w(|s|)\left[v(s)-v(s\setminus i)\right], i=1,2,\ldots,n$;

$w(|s|)=\dfrac{(n-|s|)!(|s|-1)!}{n!}$. Among them:

s_i——All in collection I which contains member i; $|s|$——The number of element in the subset s; n——The number of element in the collection I; $w(|s|)$

——The weighting factor; $v(s)$——Benefits of subset s; $v(s \setminus i)$——Available benefits from s which removes enterprise i.

The Shapley value method above does not consider the risk every enterprise undertakes in the process of cooperation, so we should improve it, and set a benefit-sharing and risk-sharing allocation mechanism.

Enterprises in the Scraped cars Reverse supply chain undertake a lot of risk. This paper mainly considers environmental risk, market risk, dissolution risk, technology risk and cooperation risk (As shown in figure 2).

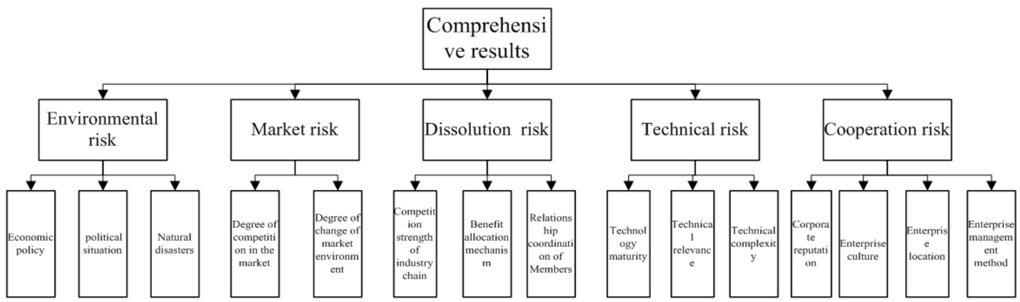

Figure 2.Index evaluation system of risk undertaken by enterprises in the chain

Using total risk coefficient calculation method put forward by Chen Jian and Feng Weidong in the《Construction and management of virtual enterprise》, we gain the total risk coefficient R_i of enterprise in the chain is:

$$R_i = 1-(1-R_{Ei})(1-R_{Mi})(1-R_{Ci})(1-R_{Di})(1-R_{Ti})$$

Among them: R_{Ei}——Environmental risk coefficient of enterprise i; R_{Mi}——Market risk coefficient of enterprise i; R_{Ci}——Cooperation risk coefficient of enterprise i; R_{Di}——Dissolution risk coefficient of enterprise i; R_{Ti}——Technical risk factor coefficient of enterprise i.At the same time, $\frac{\partial \alpha_i}{\partial R_i} > 0$ (α_i is profit distribution proportion of enterprise i).

We calculate all risk coefficient of every enterprise using fuzzy comprehensive evaluation method, so we determine corresponding weight vector W_F for factors under each type of risk. At the same time we also determine evaluation sets $W_E^{'}$ and conduct normalized processing for it, such getting W_E. Then we set a membership degree matrix P for risk factors. Lastly we calculate comprehensive evaluation vector S and comprehensive evaluation value μ, and the computation formula is as follows:

$$S = W_F P，\quad \mu = W_E S^T$$

Clearly，comprehensive evaluation value calculated above is the corresponding risk coefficient, and we can calculate total risk coefficient R_i. Lastly we conduct normalized processing for it, and that is $R = \{r_1, r_2, r_3, \cdots, r_n\}$, as well as $\sum_{i=1}^{n} r_1 = 1$. Risk correction coefficient of enterprise i is:

$$\Delta r_i = r_i - \frac{1}{n}，\quad i = 1,2,\cdots,n$$

Among them: Δr_i——Actual profit distribution correction of enterprise i; $\frac{1}{n}$——Average level of risk undertaken by every enterprise. Therefore, interest $\phi_i(\mathrm{v})'$ of enterprise i is:

$$\phi_i(v)' = \phi_i(v)(1 + \Delta r_i) = \phi_i(v)\left[1 + (r_1 - \frac{1}{n})\right]，\quad i = 1,2,\cdots,n$$

3.2 Example analysis

(1) Model data assumption. There are three main participants in scraped cars reverse supply chain, and they are：car manufacturers A, enterprises B of retrieving and dismantling scraped cars, parts suppliers C. We assume that the investment of three enterprises which is contributed to set joint warehouses, distribution facilities, recycling network and information system and so on separately is 2 million, 3.5 million and 2.5 million. The annual profit of three enterprises separately is 1.2 million, 3 million and 2 million when they conduct separate operation. If A cooperates with B, Its annual profit is 7.5 million Yuan, and if A cooperates with C, Its annual profit is 5.5 million Yuan, and If B cooperates with C, Its annual profit is 6 million Yuan. Lastly, if A cooperates with B and C, Its annual profit is 14.4 million Yuan. Therefore, if the supply chain is made up of three enterprises, the annual profit is 14.4 million Yuan. Investment and earnings is shown in table 1:

Table 1. Investment and earnings of three enterprises (Units: ten thousand Yuan)

	A	B	C	$A \cup B$	$A \cup C$	$C \cup B$	$A \cup B \cup C$
investment	200	350	250	550	450	600	800
profit	120	300	200	750	550	600	1440

(2) Solution of the model. From the model assumption above, we can know that $I = \{1,2,3\}$ （1 is on behalf of car manufacturer A, 2 is on behalf of enterprise B of retrieving and dismantling scraped cars, 3 is on behalf of parts supplier C）, and $v(1) = 120$, $v(2) = 300$, $v(3) = 200$. Cooperative collection which contains car manufacture is $s_1 = \{1,1 \cup 2,1 \cup 3,1 \cup 2 \cup 3\}$, and its corresponding gains is: $v(1 \cup 2) = 750$, $v(1 \cup 3) = 500$, $v(1 \cup 2 \cup 3) = 1440$, and $v(2 \cup 3) = 600$. We can calculate $\phi_1(v)$, $\phi_2(v)$, $\phi_3(v)$ using Shapley value method. Taking car manufacturer A as an example, we can get its calculation process of interests which is shown in table 2:

Table 2. Interest calculation table of car manufacturer A

	1	$1 \cup 2$	$1 \cup 3$	$1 \cup 2 \cup 3$
$v(s)$	120	750	550	1440
$v(s/1)$	0	300	200	600
$v(s) - v(s/1)$	120	450	350	840
$\lvert s \rvert$	1	2	2	3
$w(\lvert s \rvert)$	1/3	1/6	1/6	1/3
$w\lvert s \rvert[v(s) - v(s/1)]$	40	75	350/6	280

So $\phi_1(v) = 40 + 430/6 + 75 + 280 = 466.7$ (Ten thousand).

The same we can get:

$\phi_2(V) = 100 + 105 + 400/6 + 890/3 = 568.3$ (Ten thousand).

$\phi_3(V) = 200/3 + 430/6 + 50 + 230 = 418.3$ (Ten thousand).

We improve the Shapley value above. As an example, we calculate the environmental risk factor of Enterprises of retrieving and dismantling Scraped cars.

(1) Assuming that weight vector of economic policy, natural disasters, political situation is $W_F = (0.5, 0.4, 0.1)$.

(2) Assuming that $W_E' =$ (Good, better, general, poor) = (100,85,70,55), we do normalized processing for it, such getting $W_E = (0.32, 0.27, 0.23, 0.18)$. In addition, the membership degree matrix is:

$$P = \begin{pmatrix} 0.36 & 0.56 & 0.08 & 0 \\ 0.12 & 0.56 & 0.28 & 0.04 \\ 0.2 & 0.6 & 0.2 & 0 \end{pmatrix}$$

(3) Calculating the comprehensive evaluation vector and the comprehensive evaluation value:

$$S = W_F R = (0.5, 0.4, 0.1) \begin{pmatrix} 0.36 & 0.56 & 0.08 & 0 \\ 0.12 & 0.56 & 0.28 & 0.04 \\ 0.2 & 0.6 & 0.2 & 0 \end{pmatrix} = (0.248, 0.564, 0.172, 0.016)$$

$$\mu = W_E S^T = (0.32, 0.27, 0.23, 0.18) \begin{pmatrix} 0.248 \\ 0.564 \\ 0.172 \\ 0.16 \end{pmatrix} = 0.3$$

Therefore, $R_{E2} = 0.3$. At the same time we can get that

$R_{M2} = 0.22$, $R_{C2} = 0.42$, $R_{D2} = 0.12$, $R_{T2} = 0.2$

Therefore, $\mu_2 = (0.3, 0.22, 0.42, 0.12, 0.2)$,

$R_2 = 1 - (1-0.3)(1-0.22)(1-0.42)(1-0.12)(1-0.2) = 0.78$

we can get that total risk coefficient values of carmakers and component suppliers respectively are $R_1 = 0.47$, $R_3 = 0.32$ .We do the normalized processing for total risk coefficient of the three enterprises, such getting $R = (0.3, 0.5, 0.2)$.

Therefore: $\phi_1(v)' = \phi_1(v)\left[1 + (r_1' - \frac{1}{3})\right] = 451.3$ （Ten thousand）

$$\phi_2(v)' = \phi_2(v)\left[1 + (r_1' - \frac{1}{3})\right] = 663.0 \text{ （Ten thousand）}$$

$$\phi_3(v)' = \phi_3(v)\left[1 + (r_1' - \frac{1}{3})\right] = 362.5 \text{ （Ten thousand）}$$

From above, the interests of car manufacturers, enterprises of retrieving and dismantling Scraped cars, as well as parts suppliers respectively are 4.513 million, 6.63 million, 3.625 million.

4 Conclusions

This paper considers the risk problem undertaken by different subjects when designing the benefit distribution mechanism, and verifying the model taking profit distribution among car manufacturers, enterprises of retrieving and dismantling scraped cars, as well as parts suppliers as an example. This benefit allocation mechanism makes the profit distribution of every related subject fair and reasonable, has positive influence on the formation of long-term cooperative relations among them, thus improving the overall efficiency and effectiveness of the industrial chain. This paper only considers five risk factors, and we can improve the indicators of risk evaluation system in the future.

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References

Guo Yajun, Zhao Liqiang, Li Shaojiang(2007). "Research of revenue cost sharing contract of closed-loop supply chain coordination under the random demand". *Strategy and management* ,16 (6).

Huang Zuqing, Yi Ronghua, Da qingli(2008). "Efficiency analysis of the decision structure of remanufacturing closed-loop supply chain when the third party is responsible to recycle". Chinese management science,16(3).

Savaskan R C, Bhattacharya S, Van Wassenhove L N(2004). "Closed-loop supply chain models with product remanufacturing”. Management Science,50(2).

Wang Xu, Dai Ying, Lin Yun, Yang Jiangzi(2009). “Research of benefit allocation mechanism of reverse supply chainbased on circular economy”. Journal of chongqing university (social science edition) ,15(6).

Wei Xiujian(2005). “Research of profit distribution of supply chain— ideas and framework of distribution of resources and contribution”. Nankai management review, (2).

Diffusion Model Based on a Complex Network of Green Supply Chain Management

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Abstract: The Implementation of green supply chain management (GSCM) is important for the sustainable development of enterprises, while the internal factors affecting the implementation of green supply chain management includes organization structure, resource ability and the performance of enterprises. In order to depict the mechanism that these internal factors affect the diffusion of GSCM within enterprises, this paper built a theoretical diffusion model of GSCM within enterprises. It concluded that: (1) As the network scale grew bigger, diffusion speed between the green supply chain management in the enterprise will reach a steady state with a decline in periodic fluctuations; (2) The increase of the mutual influence of upstream and downstream enterprises of the supply chain is conducive to the spread of the green supply chain management; the more competitive industry is not conducive to the spread of the green supply chain management; (3) The government, the media and non-profit organizations sped up the rate of diffusion of green supply chain management, but did not increase the diffusion steady state; (4) Enterprises under pressure can promote the spread of the green supply chain management.

Keywords: Diffusion model; Green supply chain management; Enterprise interaction.

1 Introduction

Individual enterprise implementation of green supply chain management is the foundation of the green supply chain management diffusion; and whether to implement green supply chain management depends on enterprise internal decision-making mechanism. Whether to implement green supply chain enterprise is also affected by a variety of external environment and internal factors. For example, on basis of statistical analysis in the process of Uzbekistan's enterprises to implement green supply chain management under pressure and dynamic pressure, it can be divided into supply chain environment activity cost, laws and regulations, the current and potential opportunities in four aspects. Christmann and Taylor (2001) pointed out that Uzbekistan's enterprises to improve environmental performance mainly to export new products and become a supplier of foreign companies in Uzbekistan. In order to solve the Uzbekistan's enterprise in the process of implementing green supply chain management provide reference of existing problems, to promote

Uzbekistan's enterprises sustainable development.

We found that the enterprise internal factors affecting the implementation of green supply chain management mainly includes the organization structure, resource ability and the performance of three parts, including the organization including the type of organization, high-level decision-making and staff participation, resources including financial resources, human resources and technical ability, the implementation of performance includes economic performance, environmental performance and operation performance. And the green supply chain management mainly through the spread of "vertical" and "spread" between the two main ways in the enterprise to spread. On the one hand, the green supply chain management through diffusion on the upstream and downstream enterprises in the supply chain partnership, on the other hand, the government's policies and regulations, and the market demands of consumers and other external factors such as organization will promote the dissemination and promotion of green supply chain management in the enterprise between. However, there is lack of implementation of green supply chain management to the enterprise internal factors affecting the relationship and the internal implementation of green supply chain management decision-making model and mechanism research. And also there is lack of green supply chain management diffusion study of influence mechanism between enterprise group and enterprise group of external factors on the interaction between enterprise groups of green supply chain management research on the effects of diffusion.

2 Problem Description and Diffusion Network

In order to articulate the GSCM networks clearly, we define the individual firm as $I(1,...N)$. As for any individual firm, if there are information communication channels between them, we define $X(i,j)=1$; otherwise, $X(i,j)=0$. We define $G=\{X(i,j);i,j\in I\}$ as diffusion in the network enterprise individual and all the relations between them. And the path between the individual firms i,j of network is the collection of individual pairs $\{((i_1,j),..,(i_k,j))\}$ to meet $X(i_1,j)=...=X(i_k,j)$.

The individual network in the enterprise is based on the space distance between connected, here the distance of the said enterprise of the relationship between the individual close degrees.

3 Diffusion model based on complex network

3.1 Enterprises Decision Making and Diffusion Mechanism

A decision to implement green supply chain management depends on enterprise individual attribute, the principle of business decisions, and the relationship between enterprises. We describe the diffusion mechanism as below.

(1)Enterprise individual attributes

A. Enterprise basic attributes

The basic attributes of individual firm means the spread between green supply chain management in enterprise groups. And the influence factors of individual enterprise internal does not change over time, including the enterprise green preferences, the influence of the enterprise's own resources and capabilities, enterprise and enterprise type. The meaning of these factors and values are shown in table 1.

Table 1. The Basic Properties of An Enterprise

Index	Description	Properties
Green Preference(GP_i)	Degree of enterprise environmental protection consciousness, namely the enterprises to implement green supply chain management, and other environmental protection measures.	Normal distribution
Resources(RE_i)	With the implementation of green supply chain management resources, including capital, technology and professional staff, etc.	Normal distribution
Capability(CA_i)	Enterprise implementation of green supply chain management ability, including organization structure, human resources, etc.	Normal distribution
Influence(IF_i)	Enterprise of competitors and degree of influence of upstream and downstream enterprises of the supply chain.	Normal distribution
Enterprise Type(ET_i)	Enterprises in the supply chain upstream and downstream division of different basic types, including suppliers, manufacturers and distributors.	Final product manufacturing enterprises (MA), spare parts supply enterprises (SU), distribution companies (DR)

B. Enterprise update properties

Update attribute of the individual firm means the spread between green supply chain management in enterprise groups, and enterprise individual internal changes over time and update the properties of the factors, including the enterprise to the evaluation of green supply chain management, enterprise implementation of green supply chain management forecast earnings and state enterprises to implement green supply chain management.

(a)Green supply chain management evaluation (GE_i). Evaluation of green supply chain management refers to the enterprise in passing to the external factors of green supply chain management information, the basic understanding of green supply chain management and healthy for the business degree evaluation, due to the differences in the individual attributes of your community. In this study we assumes that the initial value in different enterprise groups individuals obey the normal distribution.

(b)Enterprises to implement green supply chain management forecast earnings (U_i). After enterprise have accepted the external information and basic evaluation of green supply chain management, they will according to the basic attributes of their own and the value of green supply chain management for the implementation of green supply chain management earnings forecast, and the decision whether to implement green supply chain management. Due to the different enterprises by properties and the influence of different green supply chain management evaluation, and therefore this study assumes that the enterprise implementation of green supply chain management forecast earnings for $U_i = BU_i \times GP_i \times RE_i \times CA_i \times GE_i$, including BU average coefficient for the enterprise.

(c) The state that enterprises implement green supply chain management (S_i). After the earnings forecasts of the implementation of green supply chain management, Individual enterprises will compare with expectations of earnings (EU_i). If the predicted value is greater than the expected value ($U_i \geq EU_i$), companies choose to implement ($S_i = 1$) , and vice e ($U_i < EU_i$)Companies are not implemented($S_i = 0$).

(2)Enterprise evolution model

A. Transmission of the information between enterprises

Green supply chain management information transmission between enterprises as shown in figure 1.

B. Update the green supply chain management evaluation

After initial evaluation of green supply chain management, enterprise are associated with the other prompts the target enterprise to update the initial evaluation over time in the network. Update the main green supply chain management evaluation is associated with the evaluation of green supply chain management of enterprises (GE_j), enterprise's influence (IF_j) and the type of role (ET_j). In the period t update individual about green supply chain management evaluation as shown in equation (1),

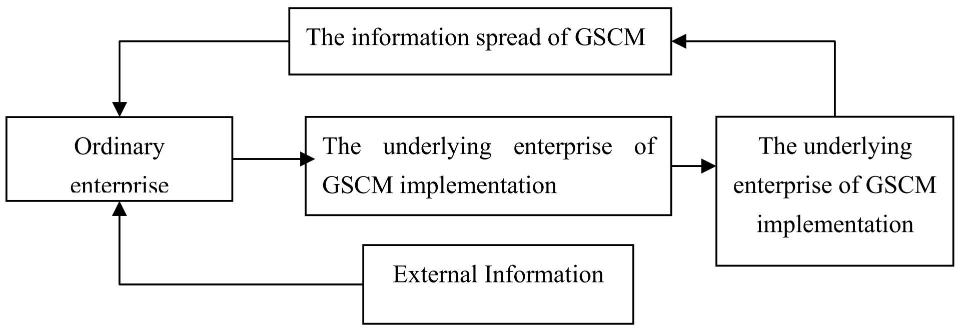

Figure1. GSCM Information Transmitting among Enterprises

$$GE_i^t = \begin{cases} \dfrac{\lambda_1 \times \dfrac{\sum_{j=1}^{n_1} GE_j^{t-1} IF_j^{t-1}}{\sum_{j=1}^{n_1} IF_j^{t-1}} + \lambda_2 \times \dfrac{\sum_{j=1}^{n_2} GE_j^{t-1} IF_j^{t-1}}{\sum_{j=1}^{n_2} IF_j^{t-1}}}{2}, n_1, n_2 \neq 0 \\ \lambda_2 \times \dfrac{\sum_{j=1}^{n_2} GE_j^{t-1} IF_j^{t-1}}{\sum_{j=1}^{n_2} IF_j^{t-1}}, n_1 = 0, n_2 \neq 0 \\ \lambda_1 \times \dfrac{\sum_{j=1}^{n_1} GE_j^{t-1} IF_j^{t-1}}{\sum_{j=1}^{n_1} IF_j^{t-1}}, n_1 \neq 0, n_2 = 0 \end{cases} \quad (1)$$

Among them, this expression (11) said between enterprises of the same type of green supply chain management information to update the influence of the homogeneity enterprise, mainly because of the same type enterprise mutual competition and cooperation relationship to each other. And the size of the said the size of the influence of different types of enterprises, and $\lambda_1 + \lambda_2 = 1$.

C. Individual firm implementation status updates

In each cycle t, the enterprise realize update the implementation of green supply chain management forecast earnings (U_i), and expected return (EU_i) to compare with the enterprise, update the status of implementation of green supply chain management. Because enterprise implementation of green supply chain management includes two aspects: on the one hand, is an enterprise evaluation of green supply chain management, on the other hand is the social standard pressure. As a direct link between potential implementation enterprises groups choose to implement green supply chain increases, the number of companies experience feel pressure with the increase of social norms, and to increase the probability of implementing green supply chain management. Therefore, the enterprise implementation of green supply chain management prediction efficiency update as shown in equation (2),

$$U_i^t = U_i^{t-1} \times \left(1 + \beta \times \frac{w_i^{t-1}}{k_i^{t-1}}\right) \tag{2}$$

Among them, β was the pressure coefficient of social norms, namely the size of the companies affected by the social pressure; k was the connecting enterprise total number; w was the number of connecting enterprise implementation of green supply chain management.

D. Evolution process of enterprise groups

The processes of the enterprise groups with the implementation of green supply chain management of enterprise scale, said when the proportion of the implementation of enterprise implementation cycle change to keep stable, diffusion of green supply chain management to reach steady state. In each cycle t, it will get the cumulative number of implementing green supply chain management enterprise accumulation implement enterprise number, thus the implementation of the overall ratio is

$$R(\mathrm{t}) = \frac{1}{N}\sum_{t=1}^{N} S_i^t, 0 \le t \le T \tag{3}$$

4 Conclusions

This paper used complex network construction of green supply chain management based on distance diffusion enterprise network to analyze the individual firm implementation of the decision making process. We got some useful conclusions.

(1)As the network scale grew bigger, diffusion speed between the green supply chain management in the enterprise will reach a steady state with a decline in periodic fluctuations. Therefore, when the government in formulating the diffusion of policy, policy implications should be considered within the scope of enterprise scale number of the influence of different diffusion to a stable state, especially for different industry or regional policies should consider this point. (2)The increase of the mutual influence of upstream and downstream enterprises of the supply chain is conducive to the spread of the green supply chain management; the more competitive industry is not conducive to the spread of the green supply chain management. Therefore, on the one hand, the government should recognize and promote the larger influence on the supply chain core enterprise implementation of green supply chain management. Government at different levels of competition, on the other hand, should promote the diffusion of green supply chain management industry. In the low level competitive industry, the government should develop appropriate de policies and measures; and in the high level competitive industry, the government should provide more support to the implementation of green supply chain management of enterprises to. (3)The government, the media and non-profit organizations sped up the rate of diffusion of green supply chain management, but did not increase the diffusion steady state. Group of enterprise external propaganda just sped up the green supply chain management information transmission speed, but will not be able to increase the degree of diffusion of green supply chain management in enterprise groups. Therefore, the government and the media should not only spread the green supply chain management of information, but also improve enterprise's own environmental consciousness and promote the spread of green supply chain management. (4)Enterprises under pressure can promote the spread of the green supply chain management. The government should provide enterprises with platform in various industries and internal area communication, and further increase the pressure of social norms for the spread of green supply chain management.

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References

GXG, Global Supply Chain Council(GSCC). Green Supply Chain Uzbekistan Survey. Shanghai: GSCC, 2009.

Sarkis J. A strategic decision framework for green supply chain management. Journal of Cleaner Production, 2003,11(4):397-409.

Srivastava S K. Green supply-chain management; a state-of-the-art literature review .

International Journal of Management Reviews, 2007, 9(1):53-80.
Vachon S, Klassen R D. Extending green practices across the supply chain - The impact of upstream and downstream integration . International Journal of Operations & Production Management, 2006.26(7):795-821.
Walker H,Di Sisto L, McBain D. Drivers and barriers to environmental supply chain management practices: lessons from the public and private sectors. Journal of Purchasing and Supply Management, 2008,1(14):69-85.
Zhu Q H,Sarkis J, Lai K H. Green supply chain management: pressures, practices and performance within the Uzbekistan's automobile industry . Journal of Cleaner Production, 2007,15(1 M2):1041-1052.
Zhu Q H,Sarkis J,Geng Y. Green supply chain management in Uzbekistan: Pressures, practices and performance. International Journal of Operations & Production Management, 2005,25(5-6):449-468.

On the Market Access System of Logistics Enterprises—From a View of Comparison between National Road Transport Regulation and Provincial Road Transport Regulation

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Abstract: The unscientific and imperfect market access system of logistics enterprises in China has become a bottleneck for the healthy and fast development of modern logistics industry. Presently, the market access system of logistics enterprises has the characteristics of low level of legislation, lack of operability and reasonability and lack of differentiation in legislation. Through comparison between the National Road Transport Regulation and Provincial Road Transport Regulation, the author holds that the provisions in the Provincial Road Transport Regulation have their reasonability, yet need investigation into their legitimacy, and the National Road Transport Regulation should appropriately elevate the market access threshold for logistics enterprises. Therefore, the article investigates the establishment and consummation of the market access system of logistics enterprises from the aspects of enacting a slip law - Logistics Law, consummating existing rules and regulations and establishing a differentiated market access system.

Keywords: Logistics enterprises; Differentiated market access system; Legal priority; Reasonability.

1 Introduction

The market access system of logistics enterprises is the general term of a series regulation made by the national legislative body or an authorized state administrative organ through legislation as to the preconditions for relevant entities to access the logistics market and conduct activities related to logistics. Forming a scientific and sound market access system for logistics enterprises can facilitate the optimum resource allocation among them, and provide a basis for the state to adjust industrial structure. As there are many types of logistics enterprises, and there are a lot of problems in the market access system of logistics enterprises operating road goods transport, the article only focuses on the investigation into the market access system of logistics enterprises operating road goods transport.

2 Analysis of the Current Status of Market Access System of Logistics Enterprises

At present, the rules and regulations regulating the market access of road goods transport enterprises in China include: The Regulation of the People's Republic of

China on Road Transport (hereinafter referred to as "National Road Transport Regulation"), Provisions on the Administration of Road Freight Transport and Stations (Sites), Measures for the Administration of Road Freight Transport Service Industry, Road Transport Regulations of Shandong Province (hereinafter referred to as "Provincial Road Transport Regulation"), Road Transport Regulations of Guangdong Province and Measures for the Administration of Road Freight Transport Service Industry of Guangdong Province, etc. These rules and regulations have made explicit legal provisions for the road transport enterprises. In view of the current status, the road transport enterprises have the characteristics of small size, weak competitiveness, and narrow scope of service. There is hardly any transport company having influence nationwide. Due to the factor of administrative division, many transport enterprises only operate in its own region, providing similar services and products with simple product structure. Individual private freight vehicles account for over a half of all the freight vehicles, and each goods transport company only has an average of 5 employees. More specifically, the market access system of logistics enterprises in China shows the following characteristics:

2.1 In respect of level of law, the level of the legislation is relatively low

To date, there are only rules and regulations regulating the market access of road goods transport enterprises in China, not reaching the level of law. The directly operable rules and regulations are mostly enacted by the State Council, various ministries and commissions and the local governments, and the majority of them are in the form of "Regulations", "Measures" and "Notice", with low legal effectiveness and lacking authority and general applicability. Inevitably, the result is inability to effectively regulate the market access of logistics enterprises, causing the confusion in the actual operations in various regions.

2.2 In respect of legal necessity, the legislation lacks reasonability

From the aspect of legal necessity, the market access system of logistics enterprises should be designed scientifically. The threshold should not be set up too low, otherwise many cutthroat competitions will be caused, resulting in the unnecessary waste of the limited resources in the market; on the other hand, the threshold should not be too high, otherwise the competition will be limited, affecting the activeness of market economy. Currently, as the market access threshold of road logistics enterprises is relatively low, logistics enterprises in China are mostly consignment departments, and their vehicles are always affiliated or temporarily rented, so there are very few vehicles under their ownership[1]. Logistics enterprises

1According to research, even some logistics enterprises with relatively high volume of business have few vehicles under their ownership. The reason is that the vehicles are owned by individual carriers. The majority of them own one to two vehicles. They just transport goods, and do not operate logistics enterprises. This oversupplied market makes the owners of vehicles have to affiliate with logistics enterprises or provide their vehicles to the logistics enterprises under lease. However, under such circumstances, the vehicles cannot be properly managed, repaired and maintained, and the economic strength and guarantee capacity of the logistics enterprises are reduced, making it hard to ensure the safety and quality of transport.

operating multimodal transport and international transport are scarce. The numerous consignment departments compete with each other fiercely, but are unable to compete with large international logistics enterprises. In order to get orders, some consignment departments arbitrarily lower the charging standard, even offering junk prices. As a result, there have been many cases where the consignment department collected a large amount of payment for goods and then ran off with the money or sold the goods privately. Therefore, by inspecting the existing market access system of logistics enterprises, we can find very serious problem of reasonability.

2.3 In respect of legal subject, the legislation lacks differentiation

There are different business areas in the logistics industry, so different market access conditions should be designed for different market entities, in order to differentiate different types of logistics enterprises. This differentiation does not violate the principle of equality. However, the existing market access system of logistics enterprises has a problem of seriously insufficient differentiation of logistics enterprises, which directly caused the great unbalance among different business segments in the logistics industry.

3 Comparisons between National Road Transport Regulation and Provincial Road Transport Regulation

In the following paragraphs, the articles of the National Road Transport Regulation and Provincial Road Transport Regulation are analyzed, with an emphasis on their differences in respect of provisions concerning the market access system of road goods transport enterprises.

As an administrative regulation, National Road Transport Regulation made the following provisions in its Article 22 concerning the preconditions for operating freight transport business: "Applicants for the freight transport business shall meet the following conditions:(1) Have vehicles suitable for its business and qualified after tests;(2) Have drivers who satisfy the conditions provided in Article 23 hereof;(3) Have a sound transport safety management system."Article 24 makes the following provisions: "Applicants for freight transport business of hazardous goods shall also meet the following conditions: (1)Have more than 5 qualified special vehicles and equipment for transporting hazardous goods;(2)Have drivers, loaders and supercargoes who passed the examination organized by the traffic administration of the municipal people's government and obtained certificates;(3)The special vehicles for transporting hazardous goods are equipped with necessary communication tools;(4)Have a sound transport safety management system."

However, as a local regulation, the Provincial Road Transport Regulation made provisions different from that in the National Road Transport Regulation. Article 30 of the Provincial Road Transport Regulation provides: "In order to get business license for road transport of normal goods and special goods, the applicant shall apply to the road transport administration higher that county level and shall satisfy the following conditions(1)Has the amount of capital appropriate for its business;(2)Has more than 5 qualified vehicles;(3)Has drivers meeting the provided conditions;(4Has a sound transport safety management system and service quality guarantee measures;(5)Has a fixed office place and parking lot appropriate for its scope and scale of business."

By comparing the abovementioned administrative regulation and local regulation, we can find the following differences between the National Road Transport Regulation and Provincial Road Transport Regulation:

(1) National Road Transport Regulation makes separate provisions for the market access system of logistics enterprises operating normal goods transport and hazardous goods transport in Article 22 and Article 24, respectively; yet the Provincial Road Transport Regulation combined the two types of logistics enterprises, making uniform provisions for these enterprises in Article 30 of the regulation.

(2) The provisions in the National Road Transport Regulation are relatively in principle and vague, yet the provisions in the Provincial Road Transport Regulation are more specific, and greatly elevate the market access threshold. The former provides that road transport enterprises shall meet the requirements in respect of qualification of vehicles and drivers, transport management system and necessary communication tools. On the basis of these requirements, the latter adds requirements in respect of capital, service quality guarantee measure, office place and parking lot.

In view of the different provisions in these two regulations, the author holds that the provisions in the Provincial Road Transport Regulation have their reasonability, yet need investigation into their legitimacy.

(1) probably violate the legal priority principle

Legal priority can be simply construed as the prior application of law. The Provincial Road Transport Regulation by nature is a local regulation enacted by the Standing Committee of Shandong Provincial People's Congress, yet the National Road Transport Regulation by nature is an administrative regulation enacted by the State Council. In China, the legal force of laws and administrative regulations are higher than local regulations, and local regulations shall not conflict with the Constitution, laws and administrative regulations. In case the laws and administrative regulations have made provisions for a matter and local regulations need to make detailed provisions, they shall be made within the scope of provisions made by the laws and administrative regulations. Therefore, the access conditions and basis explicitly provided by the administrative regulations shall be complied with by local regulation, rather than changing them. That is to say, the Provincial Road Transport Regulation shall not conflict with the National Road Transport Regulation.

However, although the Provincial Road Transport Regulation shall not conflict with the National Road Transport Regulation, the former does not have to copy the provisions made by the latter. The former can make detailed provisions within the scope of the latter's provisions. The author holds that the Provincial Road Transport Regulation can make requirements for the amount of vehicles according to its authority and in connection with the actual situation of the region. After all, the level of economic development, market status as well as quality and financing capacity of enterprises in different regions and industries of China are different, so the scale and development level of logistics industry in various regions are greatly different. Besides establishing the nationwide logistics market access laws and regulations, the local governments shall also enact the logistics regulations appropriate for their own economic basis and conditions.

(2) Probably violate the reasonability principle

The reasonability principle means that the files and activities of administrative organs should be objective, appropriate and reasonable. In particular, subjectively, the files published and measures taken by administrative organs shall treat the same situation equally and different situations differently; objectively, the measures and approaches taken by administrative organs shall be necessary and appropriate; when implementing administration, administrative organs may take different approaches to realize the goals of administration, and shall avoid the approaches that may impair the interests of relevant parties.

By inspection Article 22 and Article 24 of the National Road Transport Regulation, we can discover that in comparison with requirements for applicants operating normal goods transport business, the regulation gives higher requirements for applicants operating hazardous goods transport business. This is mainly embodied by the more strict requirements on vehicles and persons, and also added the requirement on necessary communication tools. However, this differentiated treatment is unified in the Provincial Road Transport Regulation. To say the least, even if it is appropriate to treat normal goods transport enterprises and hazardous goods transport enterprises without differentiation, the normal goods transport enterprises have different levels and capabilities. They may be a limited company, a joint stock company, partnership or individual proprietorship, so using a single standard for these logistics enterprises with different actual conditions can hardly be deemed as appropriate and feasible. The author holds that the Provincial Road Transport Regulation was enacted for the purpose of elevating the access conditions for logistics enterprises, but besides the precondition of legitimacy, such more strict access conditions should also be reasonable. They should be appropriate for the actual needs of enterprises of different types and levels, in order to ensure the actual feasibility and vitality of the access conditions.

However, if the provisions in the National Road Transport Regulation concerning the market access system of logistics enterprises are scientific and sound? In the phrase "Have vehicles suitable for its business and qualified after tests", it is very vague whether the term "have" means "own" or "rent" or "affiliate"; besides, there is no minimum requirement for the capital, thus the debt paying ability of logistics enterprises cannot be ensured; the service quality guarantee measure are not mentioned; and there is no requirement for the qualification of staff. There necessary requirement are omitted, showing the roughness of legislation, yet the Provincial Road Transport Regulation make some considerations in these respects.

4 Suggestions for consummating the market access system of logistics enterprises

On the basis of the abovementioned analyses and investigation, aiming at the existing market access system of road transport logistics enterprises, the author gives the following reasonable suggestions:

4.1 Enact a slip law – Logistics Law

Currently, China lacks a basic legislation in respect of logistics. As a special civil and commercial area that relates to national interest and people's livelihood, the logistics industry needs an independent slip law to adjust and regulate the legal relations in this industry. Furthermore, viewing from the aspect of comparison, many countries adopting the continental law system have their logistics law, such as Japan. The Logistics Law can elevate the legal level of the market access system of logistics enterprises and enhance the general applicability of the law. In this way, the National Road Transport Regulation and Provincial Road Transport Regulation will be governed by the Logistics Law, and the constitutional conflict between the two regulations in respect of the access conditions of logistics enterprises will be properly solved on the level of law.

4.2 Consummate the existing rules and regulations

The existing rules and regulations concerning logistics are confused, and the market access system of logistics enterprises are not coordinated and unified. In order to maintain the suitability and stability of the Logistics Law, the legislative body should pay close attention to clearing obsolete regulations, integrating repeated or conflicting rules, revising the legal system and repairing legal loopholes. At the same time, in view of the great different among the scale and development level of the logistics industry in various regions caused by the extreme unbalanced economic development in these regions, besides establishing a nationwide market access system of logistics enterprises, market access rules and regulations that correspond to the needs of local logistics industry development shall be enacted according to the actual situations of various regions.

4.3 Strengthen the Construction of Provincial Regulations

China is in the primary stage of socialism with the long-term. The prominent characteristic of the stage is extreme imbalances of regional economic development. The imbalances of economic development in different regions result in big differences of the logistics development scale and level. Therefore, while the national market access system of logistics enterprises is constructed, the regional market access system shall be also formulated according to the reality of the situation in order to meet the needs of local development of logistics industry. "Provincial Road Transport Regulation" as a provincial local regulation shall abide by the "Legislative Law" and "Administrative Licensing Law", and in accordance with the law order rules, is formulated within the framework of "National Road Transport Regulation". The market access system of logistics enterprises enacted by "Provincial Road Transport Regulation" in some aspects is in violation of the law and regulation with upper order, although it has the merits and rationality from the view of meeting the requirement of local logistics industry development. So the local legislator shall carefully examine the legality and coordination of provincial regulation with the host law.

4.4Establish a differentiated market access system

It has become an inevitable requirement to establish different market access systems for different types of logistics enterprises. The author believes that, according to the different types of civil subjects, the following regulations can be made concerning the market access conditions of logistics enterprises in China:

4.4.1 Market access of normal goods road transport logistics enterprises

As a special industry that relates to national interest and people's livelihood, the normal goods road transport industry has its own industrial characteristics and market attributes. The provisions in Article 22 of the National Road Transport Regulation are special requirements as to the access conditions of logistics enterprises, but the access threshold can be appropriately elevated. Especially regarding the provisions for vehicles, the owned, affiliated and rented vehicles should be differentiated, and the logistics enterprises should be encouraged to hold the title to the majority of their vehicles. Furthermore, the author suggests that the legislative body refers to the Classification and Evaluation Indices of Logistics Enterprise, and make more specific provisions for logistics enterprises of different organizational forms such as Joint Stock Company, limited company, partnership and individual proprietorship enterprise in respect of capital, equipment and facilities, management and service, quality of staff and level of informatization. Of course, it may also set up a range, and let the local regulations to make detailed provisions within the range and according to the actual situation of the province. Another principle is to encourage logistics enterprises to operate multiple businesses such as transport, storage, processing, packaging, handling, loading/unloading, distribution and information processing, etc., and encourage them to operate multimodal transport and international transport. The requirements on logistics enterprises operating multiple logistics businesses, multimodal transport and international transport shall be eased, in order to support more logistics enterprises to engage in modern logistics.

4.4.2 Market access of special goods road transport logistics enterprises

Special goods road transport logistics enterprises means the logistics enterprises operating special logistics businesses, and should only be registered after being approved by relevant administration. As the freight activities conducted by these enterprises are very dangerous, and are prone to cause personal injury and property loss, they are a special type of road goods transport enterprises, therefore the qualifications and conditions for these enterprises to access the market should be more strict than that for normal logistics enterprises. The provisions in Article 24 of the National Road Transport Regulation are made aiming at hazardous goods transport enterprises, which are relatively reasonable, but may set up a too low threshold for the market entities to access the market. For instance, the article provides that hazardous goods transport enterprises with 5 qualified vehicles can apply for registration. In practice, there are many cases where logistics enterprises report the affiliated or rented vehicles as their own vehicles. Due to the private law nature of the Logistics Law, according to the principle of private autonomy, what is not explicitly prohibited by law is legitimate, so the said situation is legitimate. However, this conduct is very harmful in practice, as if it is widespread, the capacity of duties of many logistics will be weakened unlimitedly, thus impairing the security and stability of market transactions. Therefore, it must be explicated provided that affiliated and rented vehicles shall not be reported as the vehicles owned by logistics enterprises, namely a logistics company shall have ownership over the 5 vehicles.

What needs reminding is that due to influence by the traditional views, the reform of management system always fall behind the reform of economic system. The logistics industry of China still adopts a scattered or diversified management system, which involves specialized departments of railway, traffic, water transport, civil aviation and trade, as well as comprehensive departments such as National Development and Reform Committee and State Economic and Trade Commission. There are divisions and intersections among the works of various departments, causing the barriers between higher and lower levels or between different departments and regions in the management of logistics industry, which directly affects the establishment of an unified market access system of logistics enterprises, and increases the difficulty for logistics enterprises wishing to engage in multimodal transport, international transport and comprehensive logistics businesses to access the market. Plus, the existing market access conditions of logistics enterprises are neither clear nor easily operable, so need research and revision. The author wishes to use the article as a modest spur to induce others to come forward with their valuable contributions.

References

Fan Xueqian, On the Market Access System of Logistics Enterprises, Journal of Hubei College of Finance and Economics, 2007. Vol. 5.

Li Manzhi, On Legal Issues in respect of Market Access System of Enterprises in China, Journal of Guangxi Administrative Cadre Institute of Politics and Law, 2005, Vol. 20, 6th Issue.

Wang Rong, Logistics Regulations and Practice, Zhejiang University Press, 2009, P17-19.
Zhou Zhe, Yang Jiaqi, Discussion on the Current Status and Problems of Market Access System of Transport Logistics Industry of China, Containerization, 2003, Vol. 3, P35.
Zhou Yanjun, Systematization of Modern Logistics Laws. Beijing: Higher Education Press, 2006,P35-38.

Modelling a Construction Materials Supply Chain for a Construction Project under VMI

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Abstract: The construction industry is one of the Chinese pillars of national economic development industry. Construction materials is known as the foundation of the construction industry, and the supply chain costs of construction materials account for a large proportion in the whole construction project, so reducing the supply chain cost of construction materials has become an inevitable trend in the reform and development of construction industry. This paper adopts the method of the supply chain operations reference model and is guided by the vendor managed inventory (VMI) philosophy to model the construction materials supply chain based on each kind of construction materials, include stock, standard and customized construction materials. Comparing with the traditional inventory management in construction industry which means every enterprises in the supply chain only cares and manages the inventory of its own, under the VMI the flow of information is more clear and direct, and suppliers in the whole supply chain, combining with the actual needs can develop more efficient inventory procurement and delivery plans resulted in saving the unnecessary waste and duplication. This study can provide basis for future developing information system in construction industry.
Keywords: VMI; Construction materials supply chain; SCOR.

1 Introduction

Initially, there was an opposite relationship based on the pure business interest of each enterprise in the supply chain. With the rapid development of current economics and the wide application of information network technology, this relationship has gradually developed as the common interests partnership, which also pushes the emergence of the key and advanced inventory management concepts and techniques in the supply chain. The supply chain inventory management is a kind of new, efficient modern supply chain inventory management ideas spawned under the new environment of the supply chain (Huang, 2006).

Vendor managed inventory (VMI) refers to a newly management mode in the supply chain, which is that based on sales information and inventory volume from downstream enterprises in the supply chain downstream enterprises in the same supply chain hold a proactive attitude to manage and control downstream inventory held by other enterprises, through highly sharing of the information resources from the upstream supply chain (Liu, 2011).

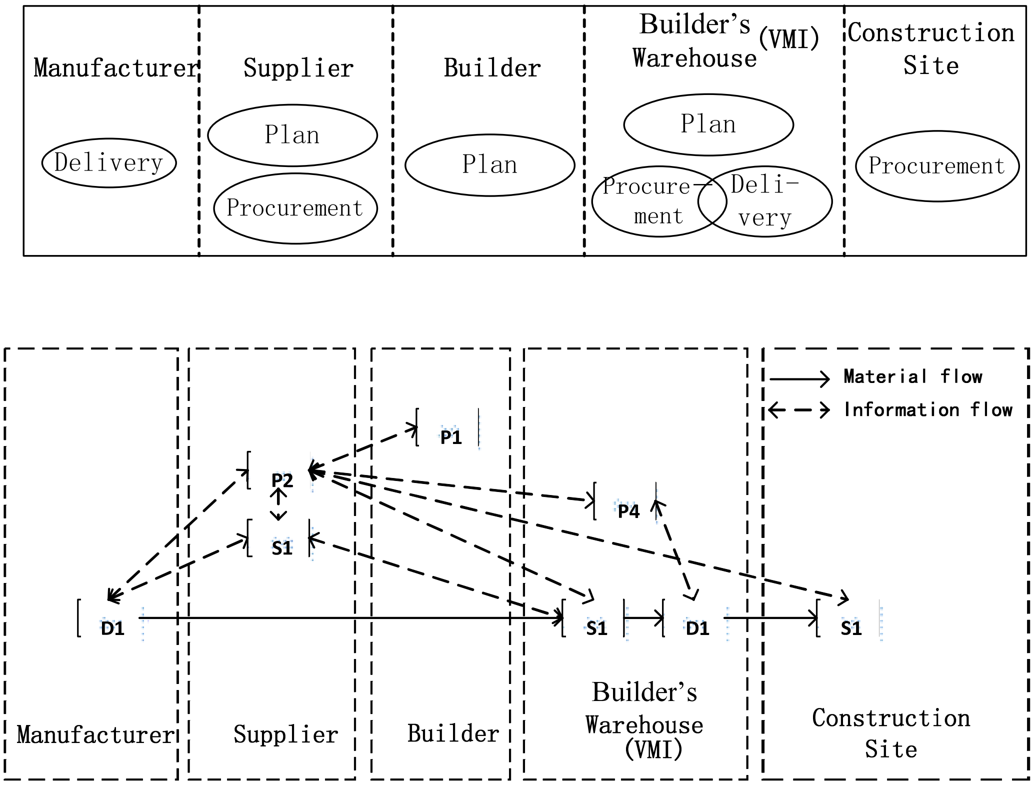
This inventory management strategy breaks the traditional pattern of inventory management which means that every enterprise only manages its own inventory. It is a cooperation strategy between the partners of supply chain strategy embodying a kind of integrated supply chain methodology, and is a kind of inventory decision agent model (Sun, 2009). VMI takes the idea of collaboration and system to manage inventory and enables the whole supply chain collaboratively operate which reflects the integrated supply chain management ideas and adapts to the changing market requirements (Chen, 2009).

The main operation flow of implementation of VMI for a construction project can be expressed as: the builder of this construction project provides market information and demand to the chosen suppliers; the supplier is responsible for replenishing inventory in the warehouses appointed by the builder and pass the demand forecast feedback to the builder; and both parties make decisions in order and maintain mutual coordination and cooperation. The suppliers control the whole supply chain logistics and information flow, and combining with the information from the builder, the chosen manufacturers, develop procurement and delivery plans to coordinate the supply chain as a whole. This paper following the study of Cheng et. al. (2010) will use the vendor management inventory (VMI) to guide modeling construction materials supply chain based on SCOR method. This study can provide basis for future developing information system in construction industry.

2 Stock Construction Material Supply Chain under VMI

Creation of a model of a stock construction materials supply chain under the VMI mode mainly relates to the five parties, including a construction site, warehouses appointed by a builder, a builder, suppliers and manufacturers. According to the level 1 and level 2 model of the SCOR method, a supply chain model of such kind of products is built (refer to Fig. 1). The dotted line and the solid line show the flow of information and the flow of construction materials respectively.

The builder, based on the progress of the construction project specific requirements, develops a supply chain plan for these kinds of stock construction materials. Under the vendor managed inventory, suppliers make decision on a purchasing plan considering these situations of upstream and downstream enterprises and the whole supply chain. The suppliers guided by the supply chain plan provided by the builder develop supply chain procurement plans, which then are transferred to manufacturers, the warehouse appointed by the builder, and the construction site. Immediately receiving the procurement plans, the manufacturers will directly deliver the ordered construction materials to the appointed warehouse, and the warehouse makes a product delivery plan. According to the plan the warehouse will deliver reasonable the stock construction materials to the construction site.



P1:Supply plan; P2: Purchasing Plan; P4: Delivery Plan;
S1: Purchasing Stock Materials; D1: Delivery Stock Material

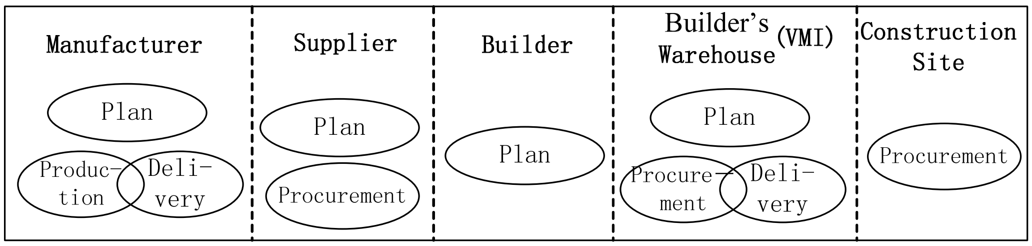
Figure1. Stock Construction Material Supply Chain Under VMI

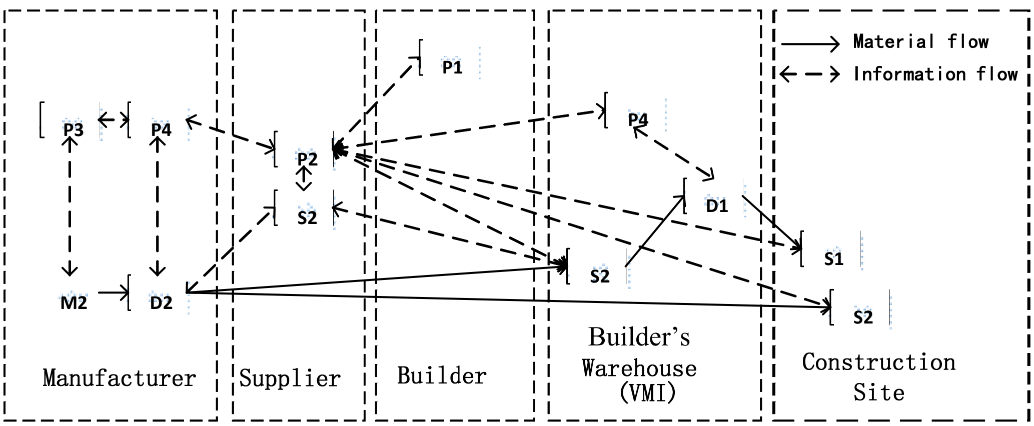
3 Standard Construction Material Supply Chain under VMI

Creation of a model of a standard construction materials supply chain under the VMI mode mainly relates to the five parties, including a construction site, warehouses appointed by builder, a builder, suppliers and manufacturers. According to the level 1 and level 2 model of the SCOR method, a supply chain model of such kind of products is built (refer to Fig. 2). The dotted line and the solid line show the flow of information and the flow of construction materials respectively.

The builder according to the progress requirement of a construction project sets up a supply chain plan, which is then transferred to the suppliers. Based on the information on the supply chain plan, the suppliers make procurement plans for standard construction materials. The procurement plans are shared with the warehouses appointed by the builder, the construction site and the manufacturers. The manufacturers according to the superior purchasing plan make the required construction materials production plan and an appropriate delivery plan. After finishing producing the ordered construction materials, manufacturers directly distribute a part of the materials to the construction site in order to timely meet the demand from the construction site, and the rest part is delivered to the warehouses appointed by the builder, and then is distributed by the decision of the warehouses.

According to the procurement plan information and the physical products, the warehouses considering the upstream procurement plan and the manufacturer's distribution plan, construction schedule and construction site arrangement, draw the final delivery plan to the construction site.





P1:Supply plan; P2: Purchasing Plan; P3: Production Plan; P4: Delivery Plan; S1: Purchasing Stock Materials; S2: Purchasing Standard Materials; M2: Production Standard Materials; D1: Delivery Stock Materials; D2: Delivery Standard Materials

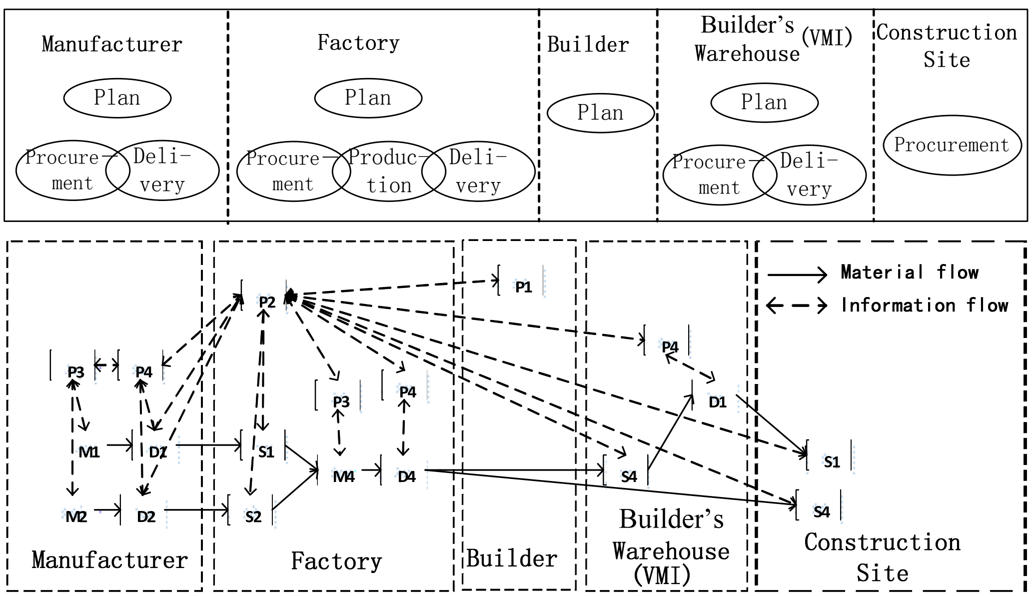
Figure2. Standard Construction Material Supply Chain Under VMI

4 Customized Construction Material Supply Chain under VMI

Creation of a model of a customized construction materials supply chain under the VMI mode mainly relates to the five parties, including a construction site, warehouses appointed by builder, a builder, factories and manufacturers. According to the level 1 and level 2 model of the SCOR method, a supply chain model of such kind of products is built (refer to Fig. 2). The dotted line and the solid line show the flow of information and the flow of construction materials respectively.

For the information flow of the customized construction materials model, the builder according to the actual demands of the construction project, develops the supply chain plan and transfers the information to the upstream factory. The factory according to the received plan develops the procurement plan and procurement of specific products, and then transfers the purchasing plan to the manufacturer. The manufacturer based on the obtained information sets up a customized construction materials production plan and an appropriate delivery plan. At the same time, the factory passes the purchase plan to the warehouses appointed by the builder and the construction site, and then the warehouses develop the delivery plan to the construction site according to the information obtained from the factory.

After each party receiving the corresponding plans, the production process starts. The manufacturers deliver the raw materials used to manufacture customized construction materials to the factory. The factory, after receiving raw materials, starts to make the production and processing according to the specific requirements of the construction project, outputs the customized products, and makes the delivery. There are two the case for the delivery: the first case is that the ordered construction materials, the factor directly distributes a part of the materials to the construction site in order to timely meet the demand from the construction site; the second case is that the rest part is delivered to the warehouses appointed by the builder, and then is distributed by the decision of the warehouses.



P1:Supply plan; P2: Purchasing Plan; P3: Production Plan; P4: Delivery Plan; S1: Purchasing Stock Materials; S2: Purchasing Standard Materials; S3: Purchasing Customized Materials; M1: Production Stock Materials; M2: Production Standard Materials; M3: Production Customized Materials; D1: Delivery Stock Materials; D2: Delivery Standard Materials; D4: Delivery Customized Materials

Figure3. Customized Construction Material Supply Chain under VMI

5 Conclusions

This paper adopts the method of the supply chain operations reference model and is guided by the VMI philosophy to model the construction materials supply chain based on each kind of construction materials, include stock, standard and customized construction materials. Comparing with the traditional inventory management in construction industry which means every enterprises in the supply chain only cares and manages the inventory of its own, under the VMI the flow of information is more clear and direct, and suppliers in the whole supply chain, combining with the actual needs can develop more efficient inventory procurement and delivery plans resulted in saving the unnecessary waste and duplication. This study can provide basis for future developing information system in construction industry.

Acknowledgment

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References

Chen, Xiaorui. (2009). "Under the environment of the supply chain of container port spare parts inventory management research". *Xiamen University master thesis.*

Cheng J C P, Law K H, Bjornsson H, Alvert Jones, Ram D. Sriram. (2010). "Modeling and monitoring of construction supply chains". Advanced Engineering Informatics, 435-455.

Huang, Aimin. (2006). "Research on supply chain cost modeling and simulation based on vendor managed inventory". Huazhong University of Science and Technology master thesis.

Liu, Pengfei. (2011). "Theoretical Study of VMI Basis". Journal of Changsha University of Science and Technology (SOCIAL SCIENCE EDITION), 26(4), 64-69.

Sun, Junli. (2009). "Marine oil inventory management analysis". World Chinese Merchant Yearbook- urban and rural construction.

"Both Ends" Logistics Distribution Mode of Railway Express Freight Transportation

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Abstract: Elaborating a distribution model type which is “station-to-door” or “door-to-station” under the background that market of express delivery is developing rapidly and the reform of the rail cargo. Then we analysis the advantages of independent management distribution model and collaborative business distribution model. And determining the distribution model for CRE based on the comprehensive evaluation method and entropy method. The paper also analysis what the corporation needs when the corporation chooses collaborative business distribution model. Finally, the paper analysis income-distribution of each collaborative logistics companies based on Nash income distribution model.
Keywords: Logistics; Comprehensive evaluation method; Entropy law; Nash allocation model; Income distribution.

1 Introduction

The statistics of the China’s express delivery business volume show that the rapid growth of the China’s express delivery volume in 2003-2013(WU Zhongkai, 2014). The experts expect the growth rate of the express will reach 40% in 2014. The growth rate of the domestic express business volume will exceed 20%. The ratio of the road transportation is 80%，the air transportation is 15%, and the railway transportation is less than 5% (LI Ding, 2011). No matter the large or small pieces of cargo transportation, the rail market share decreased year by year. This situation makes the China’s express delivery business faced serious challenges. At present the zero single volume of daily average of the railway express freight transportation is about 1.5 million. But only 30% businesses provide "door to door" service. At present the logistics distribution business point of the railway express freight transport just concentrate on the urban areas which along the railway. Its "tentacles" just come into contact the limited range. This situation has significant limitations on the edge area of the logistics distribution. Compared with the other third-party logistics enterprises, the railway express freight transportation loss the competitiveness. Both ends of the logistics distribution of the service level and efficiency will directly impact on the overall effectiveness of the rail freight. In order to enhance service levels at both ends, the railway express freight transportation will choose the autonomous business model or the collaborative business model has been a debatable question. This situation has important guiding significance for the cargo transport organization mode in the future.

2. The selecting condition research of the delivery mode

Under normal circumstances，the railway sites always related to the first-tier and the second-tier cities(CHEN Xiaojuan,2012). In these cities, the logistics distribute only need autonomous delivery which can meet the requirements. The three-tier and the four-tier cities and the rural villages always adopt the appropriate coordination delivery which can save the logistics costs.

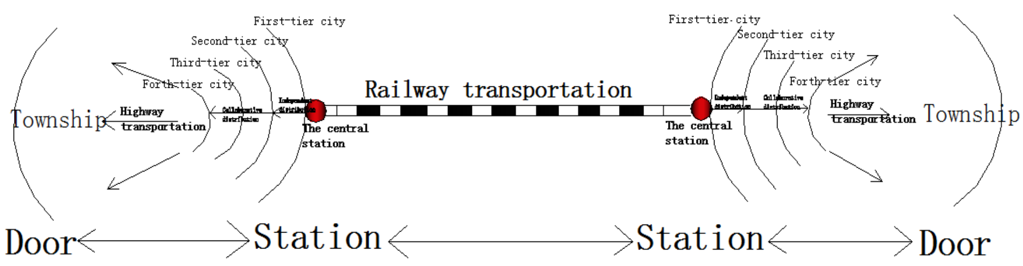

Figure1. logistics distribution mode of the railway express freight transport

2.1 The choice of the distribution mode which based on the comprehensive evaluation method

The comprehensive evaluation method can effectively reflect the various indicators , and reflect a comprehensive, holistic and hierarchical distribution model. (GONG Huang, 2007)The most important is that the comprehensive evaluation method determines the index weights. For the determining of the index weight by the article reference usually determined the entropy method. Therefore the relevant personages combine the comprehensive evaluation method and the entropy method to help the decision makers choose the distribution model(WU Fengying, 2011).

The specific evaluation model is：

$$Exp = \sum_{i=1}^{m} B_i \times P_i \qquad (1)$$

In the first formula,Exp is the comprehensive benefit evaluation;B_i is the first i index entropy;P_i is dimensionless value of the first i index;m is the number of indicators.Using the extreme value method to process P_i ,the calculation formula is:

$$P_i = \frac{p_{ij} - \min|p_{ij}|}{\max|p_{ij}| - \min|p_{ij}|} \times 10 \qquad (2)$$

In the second formula,P_{ij} is statistical values of this index; $\max|p_{ij}|$ is the maximum in all scenarios; $\min|p_{ij}|$ is the minimum in all scenarios.In this model,B_i can be calculated by the entropy weight method.Next,use of B_i and P_i calculated by Exp,the value of the maximum scheme represents the optimal scheme by comparing different schemes.then you'll use the entropy weight method to calculate the value of B_i.There are n schemes, m indexes will form the original matrix $P=(p)_{ij}$,P_{ij} is the first i index in the first j scheme value.In order to eliminate the influence of each index due to different units,and each statistical values are normalized by equation 2 to distinguish with P_i.

f_{ij} is the proportion of the first i index in the first j scheme, k_i is the first i index of entropy weight,the calculation formulas are

$$f_{ij} = q_{ij} / \sum_{j=1}^{n} q_{ij} \quad , \quad k_i = -c\sum_{j=1}^{n} q_{ij} \cdot \ln(q_{ij}), c = 1/\ln(n) \qquad (3)$$

b_i is the first i index of entropy weight,the calculation formula is:

$$b_i = (1-k_i) \Big/ \sum_{i=1}^{m} (1-k_i) \qquad (4)$$

After determining the choice model, through in-depth study of railway express freight transport enterprises and comparisons of other logistics enterprises, 7 indicators are selected for evaluation. They are the turnover, profit, goods collection time, delivery time, site storage scale, and logistics cost, satisfaction of consignors. In each site, these data of radiation region are collected, and then after using the selection model, the choice of independent operation mode of distribution or collaborative management mode of distribution of the area can be made through calculation.

2.2 The distribution of benefits in the pattern of collaborative management distribution based on Nash model

In the view of resources Possession rate of the market and the whole benefit, the short term dynamic alliance between the synergy and cooperation of logistics enterprises , achieve far greater economic and social benefits than the business model of single logistics enterprise(WU Lang,2009). In order to make one's own resources effectively utilized, make the maximum benefit from the minimum cost of inputs, so that the collaborative logistics enterprises can reach a consensus on "risk sharing, benefit sharing ".

2.2.1 Model hypothesis

Hypothesis1: **t**he scale economy income produced from cooperative management distribution mode between the railway express freight transportation and other logistics enterprises generated value is greater than the economic benefits and value the independent distribution individual enterprises produce.

Hypothesis2: the profit collaborative logistics enterprises are assigned is greater than the enterprise independent logistics distribution generated.

Hypothesis3: only considering the distribution coefficient and income between each collaborative logistics enterprise, does not take into account other factors.

2.2.2 The establishment of the model

Suppose there are N logistics companies in the collaborative management and distribution alliance. The enterprises proposed a coordination scheme of benefits distribution and the corresponding solutions distribution coefficients α_j

$$\alpha_j = \left(\alpha_{1j}, \alpha_{2j}, \alpha_{3j} ... \alpha_{nj}\right), j = 1,2,3,...n$$

α_{ij} is the profit distribution coefficient which the first i cooperative enterprise get from a coordination scheme of benefits distribution by the first j cooperative enterprise, $0 \le \alpha_{ij} \le 1$, $\sum_{i=1}^{n} \alpha_{ij} = 1$,the distribution coefficient matrix of interest distribution scheme is :

$$\alpha_{ij} = \begin{bmatrix} \alpha_{11}, & \alpha_{12}, & ..., & \alpha_{1n} \\ \alpha_{21}, & \alpha_{22}, & ..., & \alpha_{2n} \\ ..., & ..., & ..., & ... \\ \alpha_{31}, & \alpha_{32}, & \alpha_{33}, & \alpha_{3n} \end{bmatrix}$$

During setting the benefit programs ,the collaborative logistics companies set up their own distribution coefficient of the expect interest. We can suppose distribution scheme of the expected revenue as follows:

$$\alpha_i^+ = \left(\alpha_{11}^+, \alpha_{22}^+, \ldots, \alpha_{nn}^+\right), \sum_{i=1}^{n} \alpha_i^+ \geq 1$$

The collaborative logistics companies exist the lower bound of interest distribution coefficient. The lower bound also determines the benchmark coefficient of cooperation and coordination.We can suppose the program as follows:

$$\alpha_i^- = \left(\alpha_1^-, \alpha_2^-, \ldots, \alpha_n^-\right) = \min\left(\alpha_{1j}, \alpha_{2j}, \ldots, \alpha_{nj}\right)^T, j = 1,2,\ldots,n$$

The expected value of interest distribution coefficient of each company is not equal to 1,so the collaborative logistics companies negotiate amendments expected profit value,we set up χ_i as this coefficient. The final interest distribution coefficient is μ_i , $\sum_{i=1}^{n} \mu_i = 1$,and the final interest distribution coefficient is not less than coordinate reference coefficient α_i^-,so:

$$\mu_i = \alpha_i^+ - \chi_i \text{ and } \mu_i \geq \alpha_i^-$$

We can use Nash model to deal with multilateral negotiation problem and we can get the final benefit allocation scheme, next find the best correction coefficient $\chi_i = \left(\chi_1, \chi_2, \ldots, \chi_n\right)$,Nash model is:

$$\max\left\{\left(\alpha_1^+ - \chi_1 - \alpha_1^-\right)^{w_1}, \left(\alpha_2^+ - \chi_2 - \alpha_2^-\right)^{w_2}, \ldots, \left(\alpha_n^+ - \chi_n - \alpha_n^-\right)^{w_n}\right\} \quad (5)$$

$$W_i = \left(\alpha_i^+ - \chi_i\right) \times \Phi \quad (6)$$

$$s.t \begin{cases} \alpha_i^+ - \chi_i \geq \alpha_i^- \text{ , i=1,2......,n} & (7) \\ \sum_{i=1}^{n} \alpha_i^+ \geq 1 & (8) \\ \sum_{i=1}^{n} \left(\alpha_i^+ - \chi_i\right) = 1 & (9) \end{cases}$$

The fifth formula is objective function, $\alpha_i^+ - \chi_i - \alpha_i^-$ is the difference between an enterprise final profit distribution coefficient and coefficient of reference consultation,and it greater than zero. w_i is an important vector in the whole cooperative enterprise in the Alliance, $\sum_{i=1}^{n} w_i = 1$

The sixth formula evinces the final benefits between the collaborative companies.

From the seventh to the ninth formulas are the constraint conditions. The eighth formula represents the profit allocation coefficient can not less than the coordinate reference coefficient. Otherwise, the companies will not cooperate the programs. The ninth formula evinced the total amount of the distribution coefficients of expected revenue is more than1.When the enterprises set the partition coefficient ,they always consider their own interests. The tenth formula evinced that the total amount of the ultimate benefit distribution coefficient is 1.

2.2.3 The solving way of model transformation

According to the Kuhn-Tucker conditions, We can calculate the correction coefficient χ_i

$$\chi_i = \alpha_i^+ - \alpha_i^- - w_i \cdot \left(1 - \sum_{i=1}^{n} \alpha_i^-\right) \tag{10}$$

The final interest distribution coefficient of the first i cooperative enterprise, μ_i is:

$$\mu_i = \alpha_i^- + w_i \cdot \left(1 - \sum_{i=1}^{n} \alpha_i^-\right) \tag{11}$$

The final income and expenses of the first i cooperative enterprise is W_i :

$$W_i = \left[\alpha_i^- + w_i \cdot \left(1 - \sum_{i=1}^{n} \alpha_i^-\right)\right] \times \Phi \tag{12}$$

The final interest distribution coefficient in the twelfth formulas is composed by the coordinate reference coefficient and compensation coefficient, so according to the cooperative alliance overall income and expenses to calculate the final income and expenses of each cooperative enterprise.

3 Model application

There is a logistics and distribution business from Chengdu to Chongqing, A is railway express company, B is transport company, C is warehousing company. And the estimated total revenue is 4 million RMB. According to the proportion of investment in collaborative alliances ,combine with expert's experience and opinion,and the satisfaction of three partner companies for the distribution of income so that get the benefit allocation scheme of initial business:

$$\mu_i^{'} = \left(\mu_1^{'}, \mu_2^{'}, \mu_3^{'}\right) = \left(0.44, 0.31, 0.25\right)$$

Coordinate the initial program according to the actual distribution business,so company A,B and C put forward the corresponding benefit allocation scheme:

$$\alpha_{ij} = \begin{matrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \end{matrix} \begin{bmatrix} \alpha_{11}, & \alpha_{12}, & \alpha_{13} \\ \alpha_{21}, & \alpha_{22}, & \alpha_{23} \\ \alpha_{31}, & \alpha_{32}, & \alpha_{33} \end{bmatrix} = \begin{bmatrix} 0.45, & 0.30, & 0.25 \\ 0.41, & 0.33, & 0.26 \\ 0.40, & 0.32, & 0.28 \end{bmatrix}$$

we can get the importance of vector of expert whole collaborative alliance based on the expert assessment:

$$w_i = \left(w_1, w_2, w_3\right) = \left(0.50, 0.30, 0.20\right)$$

So the three companies expected revenue distribution scheme is:

$$\alpha_i^{+} = \left(\alpha_{11}^{+}, \alpha_{22}^{+}, \alpha_{33}^{+}\right) = \left(0.45, 0.33, 0.28\right)$$

Three companies benchmark coordination coefficient scheme is:

$$\alpha_i^{-} = \left(\alpha_1^{-}, \alpha_2^{-}, \alpha_3^{-}\right) = \min\left(\alpha_{1j}, \alpha_{2j}, \ldots, \alpha_{nj}\right)^T = \left(0.40, 0.30, 0.25\right)$$

The distribution of benefits in the pattern of collaborative management distribution based on Nash model. Calculate correction coefficient beside on the eleventh formula.So χ_i is :

$$\chi_i = \left(\chi_1, \chi_2, \chi_3\right) = \left(0.025, 0.015, 0.020\right)$$

We can calculate final income distribution coefficient beside on the twelfth formula , μ_i is:

$$\mu_i = (\mu_1, \mu_2, \mu_3) = (0.425, 0.315, 0.260)$$

We can calculate final earnings value of the three companies beside on the seventh formula, W_i (millions) is :

$$W_A = 0.425 \times 4 = 1.7,\quad W_B = 0.315 \times 4 = 1.26,\quad W_C = 0.260 \times 4 = 1.04$$

4 Conclusions

Facing the current logistics market, the "door to door" transportation is quite necessary for the railway express freight company. The option of the both ends of the logistics distribution pattern will affects the efficiency of enterprises in a large extent. The effective utilization of the comprehensive evaluation method makes the appropriate guidance for the railway express freight transportation. In reality according to the distribution capacity of the logistics enterprise service site, the factory can choose the corresponding distribution mode. The logistics companies choose the collaborative distribution model, the logistics companies can allocate the profits by using the advantage of the income allocation model of Nash and the collaborative logistics companies require the higher satisfaction level of the income distribution coefficient and greater acceptance. This situation settles solid foundation for the future logistics enterprise and shares the market resources of the logistics effectively. It has great guiding significance on the business of logistics and distribution in the future.

Reference

WU Zhongkai,YIN Chuanzhong.(2014).The discussion of the High-speed Rail Business Express business in China.*Railway Economic Research.*

LI Ding.(2011).Collaborative delivery research based on Virtual Enterprise. Southwest Jiaotong University.

CHEN Xiaojuan.(2012).The discussion of B2C electronic commerce logistics distribution mode. Science and technology information.

GONG Huang,CUI Shen-bao.(2007).Research on multi objective decision making of TOPSIS enterprise logistics distribution mode.Railway transportation and economy:81-84

WU Fengying.(2011).Analysis and evaluation of the self built logistics system and the third party logistics:71-72

WU Lang.(2009).The distribution of benefits of Dynamic Logistics Alliance based on the asymmetric Nash model.Chinese Township Enterprise Accounting:13-14.

Price Decision in a Two Stage Supply Chain with Carbon Tax and Green Subsidies

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Abstract: We examine the decision problems for one retailer and one manufacturer in a supply chain under the influence of governmental via carbon tax policy and subsidy financial instruments, in which manufacturer produces two kinds of products to a retailer, and the retailer resells them to the customers with price dependent demand. The two-stage game-based models under three different carbon tax policies are constructed to formulate the aforementioned decision problem in a supply chain. Comparison analysis for pricing decision models under different carbon tax policies is performed and some managerial insights are drawn. At last, a numerical example is given to demonstrate the effectiveness of the proposed models and conduct sensitiveness analysis. The impact of manufacturer's production costs, government carbon tax and green subsidy on the profits of manufacture, retailer and supply chain is analyzed.

Keywords: Emission tax; Green subsidy; Stackelberg game.

1 Introduction

Recently, environment problem is increasingly stressed by individual governments. A rich literature has developed for analyzing supply chain pricing decision with the consideration of carbon emissions. Supply chain pricing decision has been analyzed by many scholars. Santanu and Sarmah (2010) analyzes the coordination and competition issues in a two-stage supply-chain system where two vendors compete to sell differentiated products through a common retailer in the same market. The demand of a product not only depends on its own price, but also on the price of the other. Ruo et al. (2013) develops models for the determination of the retail price and the order quantity for the buyer, as well as the production batch size, wholesale discount and/or the credit period offer for the supplier, under five different scenarios.

This paper is also related to product substitution. Sang and Bell (2011) investigate the impact of demand substitution on production quantity levels for the cases of symmetrical and asymmetrical demand substitution. Chen et al. (2013) consider pricing policies for substitutable products in a supply chain with one manufacturer, who sells a product to an independent retailer and directly to consumers through an Internet channel. Banerjee and Chatterjee (2014) analyze the effect of asymmetric product differentiation on the profit ordering of firms in a sequential game. However, these papers don't consider the product substitution resulted from carbon emissions.

Supply chain decision with carbon emissions is increasingly analyzed by existing researchers. Yang and Zhang (2011) propose some strategies on how to advance cooperation satisfaction among enterprises based on low carbon supply chain management in order to enhance the competence of the whole supply chain. Du(2013) studies the decision model for a emission-dependent supply chain consisting of one single emission dependent manufacturer and one single emission permit supplier in the 'cap-and-trade' system. Ala-Harja and Helo(2014) analyse cases from the food industry, mainly order-picking, transportation, warehousing, and distribution aspects from the greening point of view, and consider three case examples of decisions in supply chain design in the food industry .

Since product substitution and governmental green tax and subsidy policies are very meaningful to supply chain management, we focuses on the decisions for manufacturer and retailer in competitive green supply chains while the government carbon tax on manufacturer or retailer and subsidy to consumers are considered. Manufacturer produces two types of substitutable product, one results in high carbon emission and another one results in low carbon emission.

2 Problem Description

We examine the decision problems for one retailer and one manufacturer in a supply chain under the influence of governmental via tax policy and subsidy financial instruments, in which manufacturer produces product 1 and product 2 sold to a retailer, and the retailer resells them to the customers with price dependent demand . We consider product 1 and product 2 as high carbon emission product and low carbon emission product, respectively. We further assume the government levies carbon emission taxes on manufacturer for producing high carbon emission product or retailer for selling high carbon emission product, and provides subsidies to consumers using low carbon emission product. Furthermore, we consider three different carbon tax policies adopted by the government in the supply chain. The first two polices concern the decentralized supply chain under which retailer and manufacturer make their decision separately: government levies carbon taxes on the retailer for selling high carbon product, government levies carbon taxes on the manufacturer for producing high carbon product. The third policy focuses the centralized supply chain under which retailer and manufacturer make their decision jointly. In this case , government can levy carbon taxes on the retailer or on the manufacturer. Both alternatives of levying carbon taxes lead to the same result.

The following notations are used to develop the mathematical model.q_i: the demand for product i， $i = 1,2$.p_i: retail price for product i， s: unit green subsidy for product 2， τ： unit carbon emission tax for product 1， w_i: wholesale price for product i， c_i： manufacturer cost for product i.

Similar to NirvikarSingh et al.(1984), we suppose the demand for product i is a general linear demand function of its own sale price p_i and the rival's sale price p_j, $j \neq i$. $q_1 = a_1 - b_1p_1 + c(p_2 - s)$, $q_2 = a_2 + cp_1 - b_2(p_2 - s)$ .where $b_i > c > 0$, i =1,2. That $b_i > c$ indicates that the change of p_i is more influential on product 's own demand than that of the product j 's sale price p_j is.

3 Model formulation

A two-stage game-based model under each carbon tax policy is constructed in this section to formulate the aforementioned decision problem in a supply chain. In Stage 1, we present the manufacturer's decision by maximizing its profit to obtain the equilibrium wholesale prices w_1 and w_2 for two types of products given τ and s. Based on the government's influence via τ and s as well as the wholesale prices w_1 and w_2, retailer's sale price p_1 and p_2 are determined in Stage 2. To obtain equilibrium solutions of the two-stage game-based model, this work adopts backward induction starting from Stage 3 under the goal of retailer profit maximization, ending with Stage 1 for the solutions of the government's financial intervention. The details of model formulation associated with these three-stages are presented in the following subsections.

3.1 Decision Model 1: Government Levies Taxes on retailer in Decentralized Supply Chain

In this case , retailer's profit function (Stage 2) can be expressed as

$$\pi_s^1 = \sum_{i=1}^{2} q_i p_i - \sum_{i=1}^{2} q_i w_i - q_1 \tau \tag{1}$$

The retailer is assumed to seek profit maximization. we derive the retailer's optimal retail price for given values of w_1 , w_2 , τ and s by applying the first order conditions of the retailer profit function. From $\frac{\partial \pi_s^1}{\partial p_1} = 0$ and $\frac{\partial \pi_s^1}{\partial p_2} = 0$, the retailer's retail price can be obtained as

$$p_1^{1*} = \frac{w_1+\tau}{2} + \frac{b_2 a_1 + c a_2}{2(b_1 b_2 - c^2)} \quad , \quad p_2^{1*} = \frac{w_2+s}{2} + \frac{c a_1 + b_1 a_2}{2(b_1 b_2 - c^2)} \tag{2}$$

Since $\frac{\partial^2 \pi_s^1}{\partial p_1 \partial p_2} = 2c, \frac{\partial^2 \pi_s^1}{\partial p_1^2} = -2b_1 < 0, \frac{\partial^2 \pi_s^1}{\partial p_2^2} = -2b_2 < 0$, the negative definite Hessian is checked as $\frac{\partial^2 \pi_s^1}{\partial p_1^2}\frac{\partial^2 \pi_s^1}{\partial p_2^2} - \left(\frac{\partial^2 \pi_s^1}{\partial p_1 \partial p_2}\right)^2 = 4(b_1 b_2 - c^2) > 0$. It satisfies the second-order condition for retail profit maximum.

Manufacturer's profit function (Stage 1) can be expressed as

$$\pi_f^1 = \sum_{i=1}^{2} q_i w_i - \sum_{i=1}^{2} q_i c_i \tag{3}$$

Similarly, we can obtain the manufacturer's wholesale price for given values of τ and s. From $\frac{\partial \pi_f^1}{\partial w_1} = 0$ *and* $\frac{\partial \pi_f^1}{\partial w_2} = 0$, manufacturer's wholesale price can be obtained as

$$w_1^{1*} = \frac{b_2 a_1 + c a_2}{2(b_1 b_2 - c^2)} - \frac{\tau - c_1}{2}, \qquad w_2^{1*} = \frac{c a_1 + b_1 a_2}{2(b_1 b_2 - c^2)} + \frac{s + c_2}{2} \tag{4}$$

Since $\frac{\partial^2 \pi_f^1}{\partial w_1^2} = -b_1 < 0$, $\frac{\partial^2 \pi_f^1}{\partial w_2^2} = -b_2 < 0$, $\frac{\partial^2 \pi_f^1}{\partial w_1 \partial w_2} = c$, Hessian Matrix is calculated as $\frac{\partial^2\pi_f^1}{\partial w_1^2}\frac{\partial^2\pi_f^1}{\partial w_2^2}-\left(\frac{\partial^2\pi_f^1}{\partial w_1\partial w_2}\right)^2=b_1b_2-c^2>0$. It satisfies the second-order condition for manufacturer profit maximum.

3.2 Decision Model 2: Government Levies Taxes on manufacturer in Decentralized Supply Chain

In this case , retailer's profit function (Stage 2) can be expressed as

$$\pi_s^2=\sum_{i=1}^2 q_ip_i-\sum_{i=1}^2 q_iw_i \tag{5}$$

Compared with the(1), retailer's profit do not have $-q_1\tau$, because government Levies Taxes on manufacturer。From equation $\frac{\partial\pi_s^2}{\partial p_i}=0$, i=1,2。We have the retailer's retail price can be obtained as

$$p_1^{2*}=\frac{w_1}{2}+\frac{b_2a_1+ca_2}{2(b_1b_2-c^2)}\ ,\ p_2^{2*}=\frac{w_2+s}{2}+\frac{ca_1+b_1a_2}{2(b_1b_2-c^2)} \tag{6}$$

Since $\frac{\partial^2\pi_s^2}{\partial p_1\partial p_2}=2c,\frac{\partial^2\pi_s^2}{\partial p_1^2}=-2b_1<0,\frac{\partial^2\pi_s^2}{\partial p_2^2}=-2b_2<0$as Decision Model 1, the negative definite Hessian is checked as $\frac{\partial^2\pi_s^2}{\partial p_1^2}\frac{\partial^2\pi_s^2}{\partial p_2^2}-\left(\frac{\partial^2\pi_s^2}{\partial p_1\partial p_2}\right)^2=4(b_1b_2-c^2)>0$. It satisfies the second-order condition for retail profit maximum.

Manufacturer's profit function (Stage 1) can be expressed as

$$\pi_f^2=\sum_{i=1}^2 q_iw_i-\sum_{i=1}^2 q_ic_i-q_1\tau \tag{7}$$

Compared with the(4), Manufacturer's profit has been added to $-q_1\tau$. Similarly, we can obtain the manufacturer's wholesale price for given values of τ and s. The manufacturers' wholesale prices can be derived from the first-order conditions of the respective manufacturers' profit maximization problems:$\frac{\partial\pi_f^2}{\partial w_1}=0$ and $\frac{\partial\pi_f^2}{\partial w_2}=0$.We get

$$w_1^{2*}=\frac{b_2a_1+ca_2}{2(b_1b_2-c^2)}+\frac{c_1+\tau}{2}\ ,\qquad w_2^{2*}=\frac{ca_1+b_1a_2}{2(b_1b_2-c^2)}+\frac{c_2+s}{2} \tag{8}$$

Consistent with the Decision Model 1, $\frac{\partial^2\pi_f^2}{\partial w_1^2}=-b_1<0$, $\frac{\partial^2\pi_f^2}{\partial w_2^2}=-b_2<0$, $\frac{\partial^2\pi_f^2}{\partial w_1\partial w_2}=c$, Hessian Matrix is calculated as $\frac{\partial^2\pi_f^2}{\partial w_1^2}\frac{\partial^2\pi_f^2}{\partial w_2^2}-\left(\frac{\partial^2\pi_f^2}{\partial w_1\partial w_2}\right)^2=b_1b_2-c^2>0$. It satisfies the second-order condition for manufacturer profit maximum.

3.3 Decision Model 3: Manufacturer and retailer in collaboration

There is no difference Government Levies Taxes on manufacturer or retailer if Manufacturer associates with retailer completely. The profit of manufacturer and retailer can be obtained as

$$\pi_{sf}=\sum_{i=1}^2 q_ip_i-\sum_{i=1}^2 q_ic_i-q_1\tau \tag{9}$$

We can get $\frac{\partial^2 \pi_{sf}}{\partial p_1^2} = -2b_1 < 0$, $\frac{\partial^2 \pi_{sf}}{\partial p_2^2} = -2b_2 < 0$, $\frac{\partial^2 \pi_{sf}}{\partial p_1 \partial p_2} = 2c$, Hessian Matrix is calculated as $\frac{\partial^2 \pi_{sf}}{\partial p_1^2}\frac{\partial^2 \pi_{sf}}{\partial p_2^2} - \left(\frac{\partial^2 \pi_{sf}}{\partial p_1 \partial p_2}\right)^2 = 4(b_1 b_2 - c^2) > 0$. The retail prices can be derived from $\frac{\partial E\pi_{sf}}{\partial p_1} = 0 and \frac{\partial E\pi_{sf}}{\partial p_2} = 0$ as

$$p_1^{3*} = \frac{c_1+\tau}{2} + \frac{b_2 a_1 + c a_2}{2(b_1 b_2 - c^2)}, \quad p_2^{3*} = \frac{c_2+s}{2} + \frac{c a_1 + b_1 a_2}{2(b_1 b_2 - c^2)} \tag{10}$$

Through the calculation of three models, we can get manufacturer's wholesale price, retailer's retail price and the demand for product.

Table1 Manufacturer's wholesale price, retailer's retail price and the demand for product of three models

Variable	Model 1	Model 2	Model 3
p_1^*	$\frac{\tau + c_1}{4} + \frac{3(b_2 a_1 + c a_2)}{4(b_1 b_2 - c^2)}$	$\frac{c_1 + \tau}{4} + \frac{3(b_2 a_1 + c a_2)}{4(b_1 b_2 - c^2)}$	$\frac{c_1 + \tau}{2} + \frac{b_2 a_1 + c a_2}{2(b_1 b_2 - c^2)}$
p_2^*	$\frac{3s + c_2}{4} + \frac{3(c a_1 + b_1 a_2)}{4(b_1 b_2 - c^2)}$	$\frac{c_2 + 3s}{4} + \frac{3(c a_1 + b_1 a_2)}{4(b_1 b_2 - c^2)}$	$\frac{c_2 + s}{2} + \frac{c a_1 + b_1 a_2}{2(b_1 b_2 - c^2)}$
q_1	$\frac{a_1 - b_1(\tau + c_1) + c(c_2 - s)}{4}$	$\frac{a_1 - b_1(c_1 + \tau) + c(c_2 - s)}{4}$	$\frac{a_1 - b_1(c_1 + \tau) + c(c_2 - s)}{2}$
q_2	$\frac{a_2 - b_2(c_2 - s) + c(\tau + c_1)}{4}$	$\frac{a_2 - b_2(c_2 - s) + c(c_1 + \tau)}{4}$	$\frac{a_2 + c(c_1 + \tau) - b_2(c_2 - s)}{2}$
w_1^*	$\frac{b_2 a_1 + c a_2}{2(b_1 b_2 - c^2)} - \frac{\tau - c_1}{2}$	$\frac{b_2 a_1 + c a_2}{2(b_1 b_2 - c^2)} + \frac{c_1 + \tau}{2}$	-
w_2^*	$\frac{c a_1 + b_1 a_2}{2(b_1 b_2 - c^2)} + \frac{s + c_2}{2}$	$\frac{c a_1 + b_1 a_2}{2(b_1 b_2 - c^2)} + \frac{c_2 + s}{2}$	-

From Table1, we know that is no correlation to p_1^*, p_2^*, q_1, q_2 and w_2^* in Model 1 are same to Model 2 . However w_1^* in Model 1 is smaller than in Model 2. q_1, q_2 in Model 3 are larger than in Model 1 and Model 2.

4 Numerical analysis

In this section, a typical numerical analysis will be emerged. we assume a_1=50, a_2=30, b_1=7, b_2=5, and$c$=2, the manufacturer cost c_1=2, c_2=4, nit carbon emission tax for product 1 $\tau = 3$, unit green subsidy for product 2 $s = 2$. We analysis sensitivity of manufacturer cost for product , unit green subsidy for product 2 and unit carbon emission tax for product 1.

Table 2 Sensitivity analysis of c_1, c_2, τ and s to w_1^* and w_2^*

Variables		w_1^*		w_2^*	
		Model 1	Model 2	Model 1	Model 2
c_1	1	4.00	7.00	8.00	8.00
	1.5	4.25	7.25	8.00	8.00
	2	4.50	7.50	8.00	8.00
	2.5	4.75	7.75	8.00	8.00
	3	5.00	8.00	8.00	8.00

c_2	2	4.50	7.50	7.00	7.00
	3	4.50	7.50	7.50	7.50
	4	4.50	7.50	8.00	8.00
	5	4.50	7.50	8.50	8.50
	6	4.50	7.50	9.00	9.00
τ	2	5.00	7.00	8.00	8.00
	2.5	4.75	7.25	8.00	8.00
	3	4.50	7.50	8.00	8.00
	3.5	4.25	7.75	8.00	8.00
	4	4.00	8.00	8.00	8.00
s	1	4.50	7.50	7.50	7.50
	1.5	4.50	7.50	7.75	7.75
	2	4.50	7.50	8.00	8.00
	2.5	4.50	7.50	8.25	8.25
	3	4.50	7.50	8.50	8.50

Table 3 Sensitivity analysis of c_1, c_2, τ and s to p_1^* and p_2^*

Variables		p_1^*			p_2^*		
		Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
c_1	1	8.50	8.50	7.00	10.00	10.00	8.00
	1.5	8.63	8.63	7.25	10.00	10.00	8.00
	2	8.75	8.75	7.50	10.00	10.00	8.00
	2.5	8.88	8.88	7.75	10.00	10.00	8.00
	3	9.00	9.00	8.00	10.00	10.00	8.00
c_2	2	8.75	8.75	7.50	9.50	9.50	7.00
	3	8.75	8.75	7.50	9.75	9.75	7.50
	4	8.75	8.75	7.50	10.00	10.00	8.00
	5	8.75	8.75	7.50	10.25	10.25	8.50
	6	8.75	8.75	7.50	10.50	10.50	9.00
τ	2	8.50	8.50	7.00	10.00	10.00	8.00
	2.5	8.63	8.63	7.25	10.00	10.00	8.00
	3	8.75	8.75	7.50	10.00	10.00	8.00
	3.5	8.88	8.88	7.75	10.00	10.00	8.00
	4	9.00	9.00	8.00	10.00	10.00	8.00
s	1	8.75	8.75	7.50	9.25	9.25	7.50
	1.5	8.75	8.75	7.50	9.63	9.63	7.75
	2	8.75	8.75	7.50	10.00	10.00	8.00
	2.5	8.75	8.75	7.50	10.38	10.38	8.25
	3	8.75	8.75	7.50	10.75	10.75	8.50

Table 4 Sensitivity analysis of c_1, c_2, τ and s to q_1 and q_2

Variables		q_1			q_2		
		Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
c_1	1	6.50	6.50	13.00	7.00	7.00	14.00
	1.5	5.63	5.63	11.25	7.25	7.25	14.50
	2	4.75	4.75	9.50	7.50	7.50	15.00
	2.5	3.88	3.88	7.75	7.75	7.75	15.50
	3	3.00	3.00	6.00	8.00	8.00	16.00
c_2	2	3.75	3.75	7.50	10.00	10.00	20.00
	3	4.25	4.25	8.50	8.75	8.75	17.50
	4	4.75	4.75	9.50	7.50	7.50	15.00
	5	5.25	5.25	10.50	6.25	6.25	12.50
	6	5.75	5.75	11.50	5.00	5.00	10.00
τ	2	6.50	6.50	13.00	7.00	7.00	14.00
	2.5	5.63	5.63	11.25	7.25	7.25	14.50
	3	4.75	4.75	9.50	7.50	7.50	15.00
	3.5	3.88	3.88	7.75	7.75	7.75	15.50
	4	3.00	3.00	6.00	8.00	8.00	16.00
s	1	5.25	5.25	10.50	6.25	6.25	12.50
	1.5	5.00	5.00	10.00	6.88	6.88	13.75
	2	4.75	4.75	9.50	7.50	7.50	15.00
	2.5	4.50	4.50	9.00	8.13	8.13	16.25
	3	4.25	4.25	8.50	8.75	8.75	17.50

The calculation results of table 2 check the results of Table1. It is obvious that The profit of manufacturer and retailer in Model 3 is larger than in Model 1 add in Model 2 , $\pi_{sf} > \pi_s + \pi_f$.If the c_1 rises up, w_1^* , p_1^* and q_2 will rise up too, and q_1, π_s, π_f, π_{sf} will reduce, w_2^* and p_2^* stay the same. If the c_2 rises up, w_2^* , p_2^* and q_1 will rise up too, and, π_s, π_f, π_{sf} will reduce, w_1^* and p_1^* stay the same. If the τ rises up, p_1^* and q_2 will rise up too, and w_1^* , q_1 , π_s , π_f , π_{sf} will reduce, w_2^* and p_2^* stay the same. If the s rises up, w_2^* , p_2^* , q_2 and π_s, π_f, π_{sf} will rise up too, and q_1, will reduce, w_1^* and p_1^* stay the same.

Table 5 Sensitivity analysis of c_1, c_2, τ and s

Variables		π_s		π_f		π_{sf}
		Model 1	Model 2	Model 1	Model 2	
c_1	1	23.75	23.75	47.50	47.50	95.00
	1.5	22.23	22.23	44.47	44.47	88.94
	2	20.94	20.94	41.88	41.88	83.75
	2.5	19.86	19.86	39.72	39.72	79.44
	3	19.00	19.00	38.00	38.00	76.00
c_2	2	29.69	29.69	59.38	59.38	118.75

	3	25.00	25.00	50.00	50.00	100.00
	4	20.94	20.94	41.88	41.88	83.75
	5	17.50	17.50	35.00	35.00	70.00
	6	14.69	14.69	29.38	29.38	58.75
τ	2	23.75	23.75	47.50	47.50	95.00
	2.5	22.23	22.23	44.47	44.47	88.94
	3	20.94	20.94	41.88	41.88	83.75
	3.5	19.86	19.86	39.72	39.72	79.44
	4	19.00	19.00	38.00	38.00	76.00
s	1	17.50	17.50	35.00	35.00	70.00
	1.5	19.14	19.14	38.28	38.28	76.56
	2	20.94	20.94	41.88	41.88	83.75
	2.5	22.89	22.89	45.78	45.78	91.56
	3	25.00	25.00	50.00	50.00	100.00

5 Conclusions

This paper addresses the retailer's retail price and the manufacturer's wholesale price based on government levies carbon taxes on the manufacturer or retailer and offers green subsidy to consumers. Our results show that, retail price, the demand for product and wholesale price for product 2 n Model 1 are same to Model 2. Wholesale price for product1 in Model 1 is smaller than in Model 2. The demand for product and The profit of manufacturer and retailer in Model 3 are larger than in Model 1 and Model 2.

In this work, we only consider the supply chain including manufacturer and retailer under the given of green subsidy and carbon emission tax. The government does not optimize the whole profit of society including consumers, and there are only one manufacturer and one retailer. These aspects are the main limitations of our work, which can be further examined in future word.

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References

Dyuti S. B.(2014), Chatterjee I. Exploring Stackelberg profit ordering under asymmetric product differentiation. Economic Modelling, 36:309-315.

Ala-Harja H, Helo P(2014). Green supply chain decisions – Case-based performance analysis from the food industry. Transportation Research Part E, 69: 97–107.

Singh N.(1984), Vives X., Pricean dquantity competition in a differentiated duopoly. RandJournalofEconomics, 15(4):546-554.

Du R, Banerjee A.(2013), Seung-Lae Kim. Coordination of two-echelon supply chains using wholesale price discount and credit option. Int. J. Production Economics , 143: 327–33.

Kim S.W, Peter C. Bell(2011). Optimal pricing and production decisions in the presence of symmetrical and asymmetrical substitution. Omega, 39:528–538.

Sinha, S.P.(2010). Coordination and price competition in a duopoly common retailer supply chain. Computers & Industrial Engineering, 59:280–295.

Du S., Zhu L, Liang L Ma F.(2013), Emission-dependent supply chain and environment - policy-making in the 'cap-and- trade' system. Energy Policy, 57:61–67.

Xiao T., Jing S., Chen G.(2014). Price and leadtime competition, and coordination for make-to-order supply chains. Computers & Industrial Engineering, 68:23–34.

Yang H., Zhang J.(2011), The Strategies of Advancing the Cooperation Satisfaction among Enterprises Based on Low Carbon Supply Chain Management，Energy Procedia，5: 1225–1229.

Definition of the Radiation Scope of the Logistics Park Based on Applying the Road Accessibility Analysis to a Potential Model

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Abstract: Rational planning and improvement on the operational efficiency of the logistics park depends on the precise of definition of the radiation scope of the logistics park, but there is still a lack of scientific and accurate theoretical method aiming at solving the definition of the radiation scope of the logistics park. Based on the traditional space division model such as potential model in the economic geography as well as giving full consideration to the important role the transport network playing in the logistics activities, the accessibility was introduced into the traditional potential model based on the Euclidean distance metric to modify the distance parameter, and the method of defining the radiation scope of logistics park based on applying the accessibility analysis to potential model was proposed. Finally, on the basis of GIS software, this method was used to define the radiation scope of the five logistics parks of the similar type in Sichuan province. It proved that the application of this method based on GIS software had the advantages of the scientific accuracy as well as the easy acquisition and operation of data, which reflected the higher application value.
Keywords: Potential model; Road accessibility; Logistics park; Radiation scope.

1 Introduction

The radiation scope of the logistics park is the adjacent regions that is located around the logistics park as well as has connections with the logistics activities(including the links such as transport of goods, distribution, warehousing, packaging, handling, distribution processing and related logistics information) of the logistics park. Currently, in the logistics park layout planning, the accurately defining the radiation scope of the logistics park not only has an important impact on its focused business scope and service object, but also plays a vital role in determining the future development type, development strategies and directions. Although the traditional space division theories and methods such as the gravity model (Shao and Xie, 2006) and the breaking-point model (Shao and Xie, 2011)were applied to defining the radiation scope of the logistics park within a certain area, these model simplified the measurement of distance parameter, which resulted in unsatisfactory accuracy in space division. However, the accessibility theory which is widely applied in the planning of the city and its functional areas is the precise method for analyzing the actual space distance. It systematically establishes the links between the regional transportation network and the region, in addition, with the gradual expansion of in-depth of the application of geographic information system (GIS), it further promotes the development of accessibility analysis. Based on the basic principles of the potential model theory and the accessibility theory, defining the radiation scope of the logistics park based on the potential model in which the accessibility analysis is applied is proposed in this study, then the radiation scope of five logistics parks in Sichuan province is defined by integrate quantitative and qualitative scientific means on the basis of GIS technology.

2 Modeling

2.1 Traditional potential model

The potential model which developed from breaking-point theory by P.D. Converse deemed the people movement, cargo movement, information movement and so on between regions resulted from the potential difference in which the cost played a decisive role. Equation (1) is the potential model.

$$F_{ij} = S_j \big/ D_{ij}^{\beta} \; (i \neq j) \qquad (1)$$

Where F_{ij} is the potential energy city j exerts on point i, S_j is the size of city j, D_{ij} is the distance from point i to city j, β is the friction coefficient of the distance.

Initial studies only measured the two parameters such as size of city and the distance respectively by the urban population and the Euclidean distance, however, along with the in-depth research, scholars gradually found the impact that the transport network have on the distance could not be ignored, which means the radiation ability of the object does not simply and smoothly diminish along with the spatial straight line but chooses the direction and path with least resistance to spread. Zhu et al. (2007), Duan et al. (2008) and Shi et al. (2009) studied the distance parameter to some extent and proposed the different measurement method. Therefore, in order to more accurately reflect the impact that the transport network has on the distance parameter, the distance parameter in the potential model is measured based on the concept of accessibility in this study.

2.2 Accessibility

2.2.1 Concept of accessibility

In 1959, Hansen (1959) proposed the concept of accessibility which was defined as the opportunity for the interactions between each node in the transport network, in other simple words, accessibility refers to the convenience the one move from one location to the destination by certain transport systems (Morris et al., 1978) which was also known as reachability and attainability. In the 21st century, with the introduction of GIS spatial analysis method (O'Sullivan et al., 2000), the study of accessibility was further developed. Now it not only plays an important role in the urban transport planning, but also gradually falls within the scope of human geography and regional economics.

2.2.2 Accessibility measurement

With the increasingly closer integration between the accessibility analysis and the GIS technology, measuring the accessibility based on the quantitative methods by GIS has become the commonly used method by the scholars, for instance, Eck et al. (1999) defined the influential scope of the store by GIS technology based on the accessibility concept. In this study, on the basis of GIS raster data, the tool of Cost Distance is used to measure the shortest travel time from any point to the logistics park, which is considered as the accessibility, shown in Equation (2).

$$A_{ij} = \min(C_{ij}^1, C_{ij}^2, C_{ij}^3, \ldots, C_{ij}^n) \qquad (2)$$

Where A_{ij} is the accessibility from point i to logistics park j, C_{ij}^n is the travel time from point i to logistics park j in transport path n, n is the total of all possible transport path from point i to logistics park j.

2.3 Potential model based on the accessibility analysis

The potential model based on the accessibility is established to define the radiation scope of the logistics park by introducing the accessibility to modify the distance parameter in the potential model, shown in Equation (3).

$$F_{ij} = P_j \big/ A_{ij}^{\beta} \; (i \neq j) \qquad (3)$$

Where F_{ij} is the potential energy logistics park j exerts on point i, P_j is the comprehensive strength of logistics park j, A_{ij} is the accessibility from point i to logistics park j, β is the friction coefficient of the distance.

However, due to difficult determination of the dimension obtained in Equation (3), Huff probability model is usually used to effect dimensionless, shown in Equation (4).

$$F_{ij} = {P_j / A_{ij}^{\beta}} \Big/ {\sum_K \left(P_K / A_{iK}^{\beta}\right)} \qquad (4)$$

Where F_{ij} is the probability that area i belongs to logistics park j, A_{ij} is the accessibility from point i to logistics park j, β is the friction coefficient of the distance (usually taken as $\beta = 2$), If the number of the logistics parks is k, the ownership of point i can be determined by comparing to obtain the greatest F_{ik}.

3 Application examples

This study takes the five logistics parks including Xinjin logistics park, Jiazhou logistics park, Ya'an logistics park, Qingbaijiang logistics park and Western China modern logistics park which are of the similar type in *Chengdu-Chongqing Economic Zone Regional Planning* as an example, the potential model based on the accessibility analysis is used to define the radiation scope of the five logistics parks. The geographical location of five logistics parks and the regional road network are shown in Figure 1.

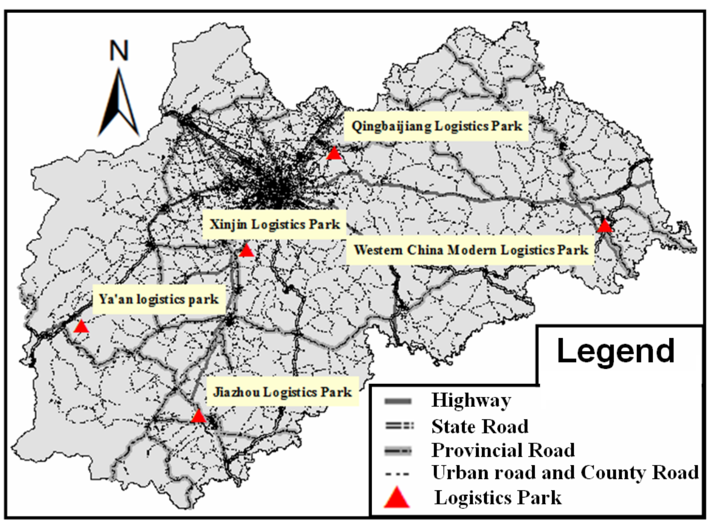


Figure 1. Location of the five logistics parks and the regional road networks

3.1 Determination of the comprehensive strength of the logistics parks

Based on the scientific, comprehensive, representative and operational principles in selecting the indexes as well as combined with the knowledge of social demography, urban economics and urban geography, 11 refinement indexes from the perspective of the logistics park scale as well as the equipment and facility of the logistics service are established to evaluate the comprehensive strength of the logistics park, as shown in Table 1.

After enquiring the relevant statistical data and being estimated by expert, the original data are obtained, as shown in Table 2. Then SPSS software is used to implement principal component analysis to get the comprehensive scores of the five logistics parks. Finally, the minimum-maximum standardized method is used to carry out data conversion to get the comprehensive strengths of the five logistics parks, as shown in Table 3.

Table 1. Index of evaluating the comprehensive strengths of the logistics parks

Influencing factors	Refinement index
Logistics park scale	Regional GDP（X_1）（$10^9\ RMB$）
	Investment intensity（X_2）（$10^9\ RMB/acre$）
	Settled company qualification（X_3）
	Whether it has bonded area（X_4）
	Preferential policy（X_5）
Equipment and facility of the logistics	Quality of equipment and facility（X_6）
	Information network level（X_7）
	Multi-modal transport level（X_8）
	Supporting services level（X_9）
	Environmental level（X_{10}）
	Service price level（X_{11}）

Table 2. The original data of the evaluating indexes of the five logistics parks

Logistics parks \ Index	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}
Xinjin logistics park	200	0.005	4	2	4	4	5	2	4	3	3
Jiazhou logistics park	60	0.004	3	1	3	3	4	2	3	4	2
Qingbaijiang logistics park	233	0.005	4	1	4	4	5	3	4	3	3
Ya'an logistics park	25	0.01	3	2	4	4	4	2	4	4	3
Western China modern logistics park	500	0.01	4	1	4	4	5	3	4	4	2

Table 3. Comprehensive strengths of the five logistics parks

Logistics parks	Comprehensive score	Comprehensive strength（P_i）
Xinjin logistics park	0.735	4.04
Jiazhou logistics park	-2.305	1
Qingbaijiang logistics park	0.476	3.781

Ya'an logistics park	0.61	3.915
Western China modern logistics park	0.483	3.788

3.2 Determination of the logistics park accessibility

In this study, ArcMap GIS software is used to analyze the logistics park accessibility. Based on the 4 kinds of roads of different speed, such as the highway, the state road, the provincial road, the urban roads and county road, "Cost Distance" tool is utilized to generate the accessibility grids, as shown in figure 2.

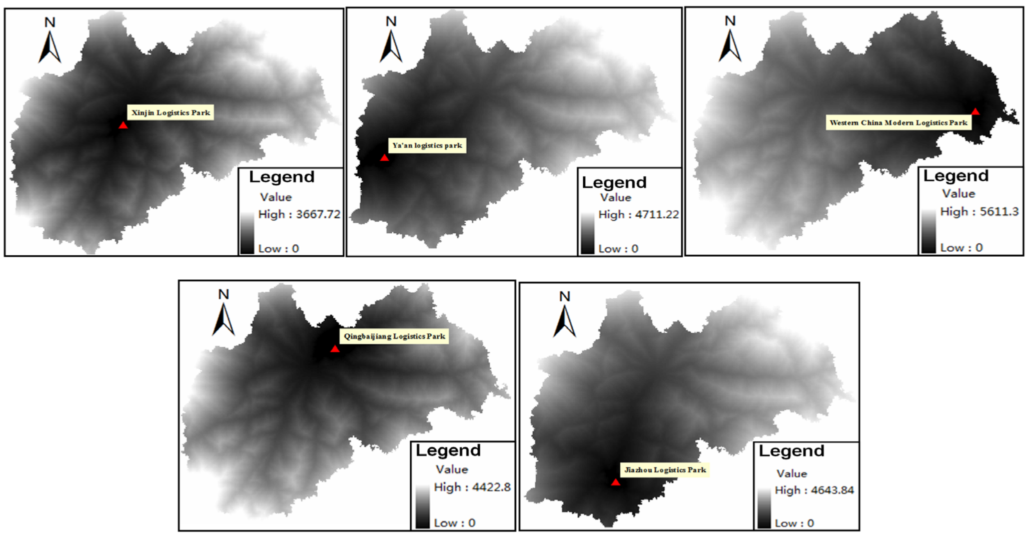
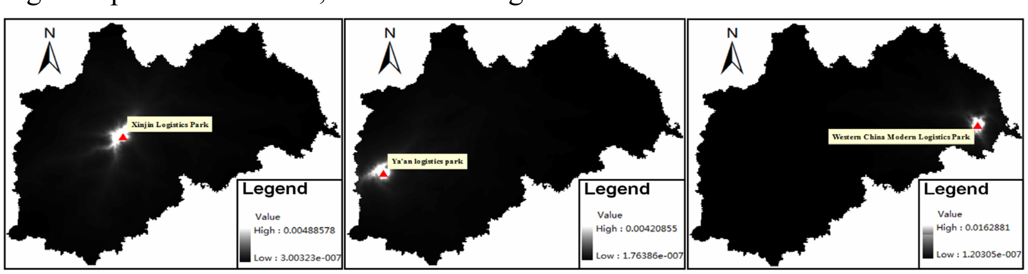


Figure 2. Accessibility grids of the five logistics parks

3.3 Definition of the Radiation Scope of the Logistics Park

The comprehensive strengths of the five logistics parks obtained in part 3.1 and the accessibility grids generated in part 3.2 are substituted into Equation（3）to generate their potential value charts by the raster calculator tool, as shown in Figure 3. Then the *Highest Position* tool is used to compare the potential value F_j in the same grid to determine the ownership of the grid, thus the radiation scope of the five logistics parks are defined, as shown in Figure 4.



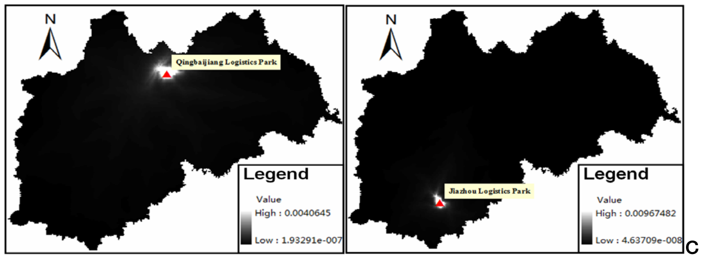


Figure 3. Potential value charts of the five logistics parks

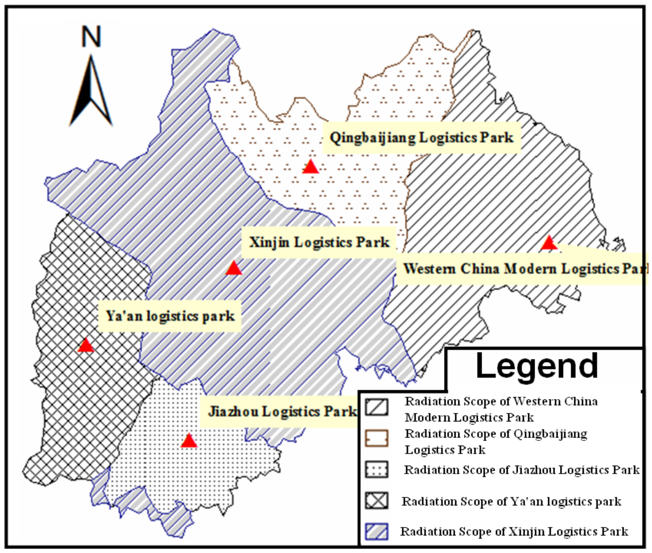


Figure 4. The radiation scope of the five logistics parks

4 Conclusions

The premise of the existence of the logistics park is the cargo transport as well as the cargo transport is based on the transport network, so it determines the definition of the radiation scope of logistics parks must not simply use the potential model based on Euclidean distance. Therefore, the accessibility is introduced into the potential model to modify the distance parameter to propose the potential model based on the accessibility analysis to define the radiation scope of the logistics park, which is a more rational and scientific method for defining the radiation scope of logistics park. This method more accurately reflects the essence of the distance parameter in the potential model as well as overcomes the inaccuracy caused by Euclidean distance in the traditional potential model, and it can be proved in the example analysis that when both the comprehensive strength is huge enough and the accessibility is good enough, the radiation scope of the logistics park defined based this model can across the closed barrier region formed by the other logistics parks, which is also in line with people's general awareness for this issue.

5 Recommendations for Future Research

Some improvements can be done based on in this study, for example, this study focused on the accessibility only based on road network, in which the other modes of transport network was neglected, so analysis result of the accessibility is incomplete. In addition, the reasonability of the index system to evaluate the comprehensive strength of the logistics park need to be further proved.

References

Duan, Q. L., and Xue, M. Y. (2008). "The Evolution of Urban Economic Effect Regions in Jiangsu Province since Three Decades of Reform and Opening Up." *Social Sciences in Nanjing*, 8(5), 141-147.

Hansen, W.G. (1959). "How accessibility shapes land-use." *Journal of the American Institute of Planners*, 25, 73-76.

Morris, J.M., Dumble, P.L., Wigan, M.R. (1978). "Accessibility indicators for transport planning." *Transportation Research*, 13, 91-109.

O'Sullivan D., Morrison A., Shearer J. (2000). "Using desktop GIS for the investigation of accessibility by public transport: An isochrones approach." *International Journal of Geographical Information Science*, 14(1), 85-104.

Shao, Y., and Xie, R. H. (2006). "Service Area of Logistics Park Based on Gravity Model." *Logistics Technology*, (7), 131-132.

Shi, L., and Cui, Y. (2011). "Method study on the definition of scope of Logistics Service Center." *Railway Transport and Economy*, 33(12), 69-73.

Shi, Q. Y., Song, D. X., and Li, Q. (2009). "The Evolution of Urban Economic Effect Regions in Shandong Province." *Urban Problems*, (5), 65-70.

Van Eck J. R., De Jone T. (1999). "Accessibility analysis and spatial competition effects in the context of GIS-supported service location planning." *Computer, Environment and Urban System*, 23, 75-89

Zhu, J., Guan, W. H., Jiang, Z. X., and Zhen, F. (2007). "The Evolution of Urban Economic Effect Regions in Jiangsu Province since 1978." *Acta Geographica Sinica*, 62(10), 1023-1033.

Location-Allocation Model of Maritime Emergency Supplies Repertory under Joint of Government and Enterprise

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Abstract: It studies the location-allocation problem of maritime emergency supplies repertories under the joint of government and enterprises. A bi-level optimization model with the objective of minimizing cost is proposed, the first level model solves the location-allocation problem of maritime emergency supplies repertories; the second level model solves the distribution of emergency supplies in the alliance based on the results of first level model. In view of the model, it designs a genetic algorithm with elite reserve strategy. The numerical example results indicate that the model and the algorithm are feasible.

Keywords: Joint of government and enterprise; Maritime emergency supplies repertory; Location–allocation; Genetic algorithm.

1 Introduction

Emergency management becomes a hot topic with water emergencies occur frequently, where reasonable configuration of emergency resources will ensure the timely and effective rescue after the emergency occurs. In comparison with the traditional emergency system, maritime emergency system has big difference and is more complicated with the influence of maritime natural conditions. (Li, 2006) studied the location model of rescue vessel on the sea based on the large number of data sets acquired from the Canadian Coast Guard Search and Rescue branch. (Azofra, 2007) studied the placement of sea rescue resources and they formalized a general methodology based on gravitational models which allowed us to define individual and zonal distribution models. (Goerlandt, 2012) described recent advances in modeling the sea rescue services using discrete-event simulation and the Monte Carlo technique. (Lehikoinen,2013) developed a Bayesian Network to examine the recovery efficiency and optimal disposition of the Finnish oil combating vessels in the Gulf of Finland, Eastern Baltic Sea. (Venäläinen, 2014) studied the evaluation of emergency response in the Gulf of Finland and studied the influence of water and wind to the speed of rescue vessels.

To meet the emergency demands caused by frequent natural disasters and large-scale emergencies, the government should fully utilize the power in society and establish socialized emergency storage system which combines national and civil inventories. In recent years, China advocated the government and enterprises to establish multi-level and multi-mode of the storage mode to save cost and improve efficiency. (Chen, 2012) built the system of China relief reserve, the system of national emergency supplies reserve consists of two parts: the national reserves and corporate in-kind agreement reserves. (Ma,2011) proposed that when given the real situation of China and in the process of establishing the socialized relief storage system, attentions should be focused on relief classification and storage mode selection, pricing problem in government-enterprise cooperation and location-allocation problem with multiple storage modes. (Ma,2014) used mathematical model to establish a cooperative game premise condition, then analyses the emergency material storage cooperative game between the government and the enterprise and establishes binding cost apportionment and punishment measures to get a stable cooperation, so that both sides obtain the biggest benefit.

Based on above literatures, we study the pre-occurrence location-allocation problem of maritime emergency supplies repertories under the joint of government and enterprises, which determines the location of water emergency supplies repertories, the cooperation enterprises and the emergency supplies in them. Within the scope of the study defined above, the proposed model and approach is unique with the following distinctive features:

(1) The coverage radius of maritime emergency supplies repertory is determined by the actual speed of salvage vessel, the emergency response time and the natural conditions such as wind, water current. (2) Probability distribution of emergency demand is used. Based on the gravity model, it puts forward the allocation method of demand between the repertories. (3) We establish the bi-level optimization model under the joint of government and enterprises with the objective of minimizing cost. (4) In view of the model, a genetic algorithm with elite reserve strategy is designed and a case studies is given.

2 Problem description

A general overview of pre-occurrence location of emergency resources can be described in figure 1.

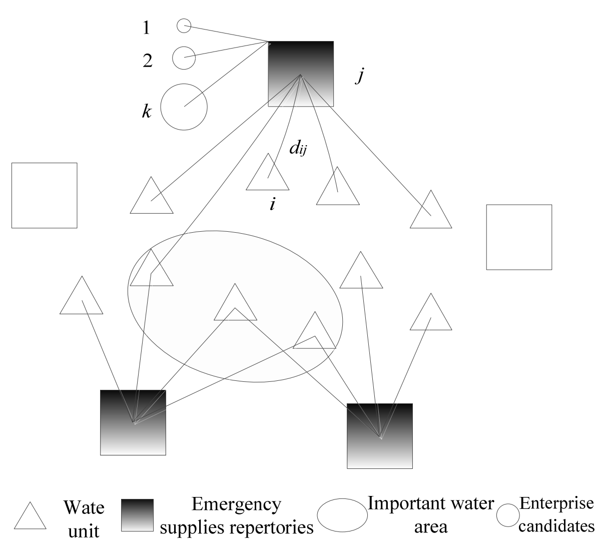

Figure 1. Water emergency supplies repertory location-allocation

The water area is divided into several water units and each unit is represented by its center, $i = 1,2,\cdots I$ is the index of water units. Some water units are in the important water area and they should be covered by at least two times. There are several candidates of maritime emergency supplies repertories, $j = 1,2,\cdots J$ is the index of candidates. d_{ij} is the distance between water unit i and candidate j. There are a number of enterprise candidate points, $k = 1,2,\cdots K$, each candidate can only cooperate with an emergency supplies repertory and a material repertory can cooperate with multiple enterprises.

2.1 Coverage radius of emergency supplies repertory

Maritime emergency supplies are transported by salvage vessels. So the coverage radius of emergency supplies repertory is equal to the maximum distance that the salvage vessel can achieve under the wind, water current and other natural conditions within the emergency response time(We assume that the travel path is rectilinear). So the actual sailing speed of salvage vessel is a result of the vector superposition, as shown in figure 2.

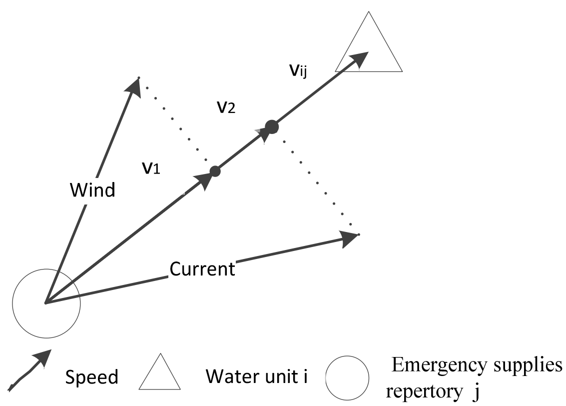

Figure 2. The velocity vector superposition

$$v'_{ij} = v_{ij} + v_1 + v_2 \quad (1)$$

v_{ij} is the sailing speed of salvage vessel from emergency supplies repertory j to water unit i without the influence of natural conditions; v_1 is the influence of wind; v_2 is the influence of water current; v'_{ij} is the actual sailing speed of salvage vessel considering the influence of wind and water current. Here we use the constant wind and constant water current from the meteorological statistics.

$$r_{ij} = v'_{ij} t \quad (2)$$

r_{ij} is the coverage radius of repertory j towards water unit i. If the distance between the water unit and the candidate is larger than the coverage radius of the candidate, we consider that the candidate will not provide emergency service for this water unit, if $d_{ij} \le r_{ij}$, then water unit i can be covered by the candidate j .

2.2 Allocation of demand between emergency supplies repertory

If a water unit is covered by several repertories, its demand for emergency resources should be allocated to them. Most of the literatures consider the allocation of emergency resources using all-or-nothing assignment. Emergency event has great uncertainty and the probability distribution of demand is more suitable. Based on the gravity model, we put forward the improved probability distribution method.

$$u_{ij} = \eta_{ij} w_j^2 V_{ij} \big/ d_{ij} \tag{3}$$

u_{ij} is the attraction that water unit i can fell from emergency supplies repertory j . w_j^2 is the service quality of emergency supplies repertory j , w_j^2 is known as a priori. If water unit i could not be covered by emergency supplies repertory j , then it cannot fell the attraction of emergency supplies repertory j , the parameter η_{ij} can achieve that goal. η_{ij} is a binary variable, for water unit i and emergency supplies repertory j , if $d_{ij} \le r_{ij}$, then $\eta_{ij} = 1$, otherwise $\eta_{ij} = 0$.

$$M_{ij} = q_i u_{ij} \Big/ \sum_{j \in N_i} u_{ij} \tag{4}$$

q_i is the demand for emergency supplies of water unit i . M_{ij} is the proportion of water unit's demand occupied by emergency supplies repertory j .

2.3 Joint of government and enterprises

The corporate in-kind agreement reserves are divided into production-oriented enterprises reserve (combined of production capacity reserves and physical reserve) and sales-oriented enterprise reserves (mainly physical reserves) such as large supermarkets (Chen, 2012). In our study, we focus on the sales-oriented enterprise reserves. After the allocation of emergency reserves, the government physical reserve is first considered. If the capacity of government physical reserve cannot satisfy the demand, the enterprise reserve is considered. In this paper government gives subsidies to the cooperation enterprises for their participation.

3 Model formulations

3.1 Model assumptions

(1) Salvage vessels do not involve round-trip transportation; (2) The travel path of salvage vessel is rectilinear; (3) The readiness is equal for all vessels; (4) Government gives subsidies to cooperation enterprises for their participation.

3.2 Parameters

$i = 1,2,\cdots I$ is the index of water units; $j = 1,2,\cdots J$ is the index of candidates; $k = 1,2,\cdots K_j$ is the set of enterprise candidates corresponding repertory j ; r_{ij} is the coverage radius of repertory j towards i; d_{ij} is the distance between water unit i and candidate j; $N_i = \{j | d_{ij} \le r_{ij}^k\}$ is the set of emergency supplies repertories that can cover water unit i; η_{ij} is a binary variable; y is a binary variable, if the candidate j is selected, then $y_j = 1$, otherwise $y_j = 0$; w_i^1 is the importance of water unit i; w is the threshold of w_i^1, if $w_i^1 \ge w$, then water unit i should be covered more than once; w_j^2 is the service quality of emergency supplies repertory j; u_{ij} is the attraction that water unit i fells from emergency supplies repertory j; q_i is the demand for emergency supplies of water unit i; M_{ij} is the proportion of water unit's demand occupied by emergency supplies repertory j; Q_j^1 is the maximum capacity of emergency resources reserve j; Q_k^j is the maximum inventory of enterprise k can provides; C_j is the fixed construction cost of emergency supplies repertory j; c_j is the unit reserve cost of emergency supplies repertory j; x_k^j is the supplies that k enterprise reserves for j emergency repertory; a_k^j is the subsidies that j emergency repertory gives to k enterprise for unit emergency supplies.

3.3 Model

Based on the previous analysis, we establish the bi-level optimization model. The first level model is:

$$\min \mathrm{Z} = \sum_{j=1}^{J} y_j C_j + \sum_{j=1}^{J}\sum_{i=1}^{I} M_{ij} c_j + \mathrm{Z}_1 \quad (5)$$

$$\sum_{j \in N_i} y_j \ge 1 \quad (6)$$

$$\sum_{j \in N_i, w_i^1 \ge w} y_j \ge 2 \quad (7)$$

$$u_{ij} = \eta_{ij} * w_j^2 * v'_{ij} / d_{ij} \quad (8)$$

$$M_{ij} = q_i u_{ij} \Big/ \sum_{j \in N_i}^{J} u_{ij} \quad (9)$$

Objective (5) is the total cost, the first part is the fixed construction cost of emergency supplies repertories, the second part is the reserve cost of the emergency supplies, the third part is the cost of subsidies that government gives to enterprises. It is necessary to take into account the fairness and efficiency when configure the emergency resources, so we propose that the location of maritime emergency supplies repertories should not only achieve the full coverage of the water units, but also achieve the multi-coverage of the key water units. Constraint (6), (7) can achieve that. Constraint (8), (9), we have introduced in section 2.2.

The second level model is:

$$\min Z_1 = \sum_{j=1}^{J}\sum_{k=1}^{K_j} a_k^j x_k^j \quad (10)$$

$$\sum_{j=1}^{J} M_{ij} - Q_j \geq 0 \quad (11)$$

$$\sum_{k=1}^{K_j} x_k^j = \sum_{j=1}^{J}\sum_{i=1}^{I} M_{ij} - Q_j \quad (12)$$

$$x_k^j \leq Q_k^j, x_k^j \geq 0 \quad (13)$$

Objective (10) is the total subsidies that government gives to enterprises; constraint (11) achieves that when the allocation amount of emergency supplies is greater the capacity of emergency repertory, we choose the joint of government and enterprises; constraint (12) achieves that amount of enterprise reserve is equal to the shortage of demand of emergency repertory. Constraint (13) is the constraint of x_k^j.

4 Heuristic algorithm

The bi-level programming model is difficult to solve, the first level model is a nonlinear programming problems and the second level model is a linear programming problem. Genetic algorithm is one of the best heuristic algorithms that can achieve global search (Goerigk,2014, Zegordi,2009, Gelareh,2011). So we design a genetic algorithm (GA) to solve the first level model and use *linprog* function in MATLAB to solve the second level model.

4.1 Genetic algorithm

(1) The chromosome coding, initial population and fitness function

The genetic algorithm uses binary encoding, if the candidate is selected, then the genetic is 1, otherwise 0. The initial population is generated randomly. If the chromosome is feasible, it will be kept in the population. When the number of the chromosomes reaches the population, we get the initial population. $f = I - Z$, f is the fitness value of the chromosome, Z is the objective function value of the chromosome, I is a relatively large constant.

(2) Elitist individuals

In each generation, the algorithm selects top-ranking individuals as the elite individuals which will be kept separately. Then carry on selection, crossover and mutation. The elite individuals replace the individuals with the relatively low fitness value, and go into the next generation.

(3) Penalty function

If the individual is infeasible, then a penalty function is used. $f' = f - P$, P is a constant variable, f' is the new fitness of the chromosome.

(4)Genetic operators and termination condition

The algorithm uses the roulette method to choose the individuals that can enter the next generation. Use single-point crossover and two-point mutation operation. When the iteration reaches the maximum number (when the fitness of the algorithm is stable), the calculation finishes.

4.2 Linear programming function

We use the function *(x，fval)= linprog (c,A,b,Aeq,beq,lb,ub,options)* to solve the second level model. The calculation results return to the genetic algorithm.

5 Model application

The water area is divided into 20 water units, there are 10 candidates of maritime emergency supplies repertories and each repertory have 3 candidate enterprises, as shown in Table 1-3. We assume that the speed matrix of salvage vessels sailing to each water units from the emergency supplies repertory candidates is known, as shown in Table 4.We assume other parameters, as $w = 5$, $T = 4$ minutes.

Table 1. The data of waters of units

NO.	Coordinates	Importance	Demand	NO.	Coordinates	Importance	Demand
1	(1,1)	4	9	11	(1,6)	2	9
2	(3,1)	3	8	12	(3,6)	3	10
3	(5,1)	7	10	13	(5,6)	4	9
4	(7,1)	9	7	14	(7,6)	8	8
5	(9,1)	3	10	15	(9,6)	1	9
6	(1,3)	2	8	16	(1,9)	1	6
7	(3,3)	4	9	17	(3,9)	3	10
8	(5,3)	4	8	18	(5,9)	5	9
9	(7,3)	6	10	19	(7,9)	7	7
10	(9,3)	3	9	20	(9,9)	2	9

Table 2. The data of emergency supplies repertory candidates

NO.	Coordinates	Service quality	Fixed construction cost	Unit reserve cost	Capacity
1	(0,1)	5	8	0.8	30
2	(0,9)	5	9	0.85	30
3	(3,0)	6	10	0.9	30
4	(5,0)	6	11	0.95	30
5	(7,0)	6	12	0.8	30
6	(10,2)	7	12	0.85	30
7	(10,6)	7	11	0.85	30
8	(10,8)	7	10	0.9	30
9	(2,10)	6	9	0.95	30
10	(8,10)	6	8	0.95	30

Table 3. The data of the candidates enterprise

NO	Corresponding repertory	Subsides of unit supplies	Capacity	NO	Corresponding repertory	Subsides of unit supplies	Capacity
1	1	0.6	10	16	6	0.6	10
2	1	0.7	30	17	6	0.7	30
3	1	0.65	50	18	6	0.65	50
4	2	0.6	30	19	7	0.6	30
5	2	0.7	50	20	7	0.7	50
6	2	0.65	10	21	7	0.65	10
7	3	0.6	50	22	8	0.6	50
8	3	0.7	30	23	8	0.7	30
9	3	0.65	10	24	8	0.65	10
10	4	0.6	30	25	9	0.6	30
11	4	0.7	10	26	9	0.7	10
12	4	0.65	50	27	9	0.65	50
13	5	0.6	10	28	10	0.6	10
14	5	0.7	30	29	10	0.7	30
15	5	0.65	50	30	10	0.65	50

Table 4. Velocity matrix table

		Emergency supplies repertory candidates									
		1	2	3	4	5	6	7	8	9	10
Water units	1	9.8	10	10	9.8	9.9	9.9	10	10	10	10
	2	9.5	9.5	9.5	9.5	9.7	9.7	9.5	9.8	9.5	10
	3	10.5	9.9	9.9	9.8	9.8	9.8	9.9	9.5	9.9	9
	4	10	9.7	9.7	9.5	10	10	9.7	10.5	9.7	9
	5	9.5	9.8	9.8	10.5	10.2	10.2	9.8	10	9.8	9
	6	9.9	10	10	10	10	9.8	10	9.5	10	10
	7	9.7	10.2	10.2	9.5	9.5	10	10.2	9.9	10.2	10
	8	9.8	9.9	10	9.8	9.9	10.2	9.5	9.7	9.9	9.9
	9	10	9.7	10.2	10	9.7	10	9.9	9.8	9.7	9.9
	10	10.2	9.8	9.9	10.2	9.8	9.5	9.7	10	9.8	9.7
	11	10.1	10	9.7	10.1	10	9.9	9.8	10.2	10	9.8
	12	10.3	10.2	9.8	10.3	10.2	9.7	10	10.1	10.2	10
	13	9.8	10	10	9.8	10.1	9.8	10.2	10.3	10.1	10.2
	14	9.7	9.5	10.2	9.7	10.3	10	10.1	9.8	10.3	10
	15	9.9	9.9	10	9.9	9.8	10.2	10.3	9.7	9.8	9.5
	16	10	9.7	9.5	10	9.7	10.1	9.8	9.9	9.7	9.9
	17	10.1	9.8	9.9	10.1	9.9	10.3	9.7	10	9.9	9.7
	18	10.2	10	9.7	10.2	10	9.8	9.9	10.1	10	9.8
	19	10	10.2	9.8	10	10.1	9.7	10	10.2	10.1	10
	20	9.8	9.9	10	9.8	10.2	9.9	10.1	10	10.2	10.2

Numerical experiments are carried out in MATLAB on a desktop PC with 2.93 GHz dual-core processor, 4GB RAM and 32-bit Microsoft Windows 7 ultimate operating system. The population of GA is 50, the length of the chromosome is 10, the crossover probability is 0.9, the mutation probability is 0.1, the largest iteration is 200. The program was run 50 times, the results were stable and the average computing time is 194 seconds.

The candidates 1,5,7,9 are selected to construct maritime emergency reserves bases, actual capacity are 36,51,47,41, total cost is 175.5, enterprise 1,13,15,19,25 are selected, the actual reserves are 6,10,11,17,11.We can figure out that the final location results can achieve the full coverage of the water units and the multi-coverage of the key water units, as shown in Tab.5

Table 5. The coverage of water unites

NO.	1	2	**3**	**4**	5	6	7	8	**9**	10
Importance	4	3	**7**	**9**	3	2	4	4	**6**	3
Times	2	2	**2**	**2**	2	1	2	3	**2**	2
NO.	11	12	13	**14**	15	16	17	**18**	19	20
Importance	2	3	4	**8**	1	1	3	**5**	7	2
Times	2	2	3	**3**	2	1	1	**2**	2	1

Remark: the water units with the importance greater than 5 are bold

6 Conclusions

We study the location-allocation problem of maritime emergency supplies repertories under joint of government and enterprises. We establish the bi-level optimization model under the joint of government and enterprises with the objective of minimizing cost and design a genetic algorithm with elite reserve strategy. The numerical example results indicate that the model and the algorithm are feasible. We assume that the subsidies given to the cooperation enterprises is known as a priori, but the computation of subsidies is very important and we will study in next.

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References

Araz, C. Selim, H. Ozkarahan, I., (2007). A fuzzy multi-objective covering-based vehicle location model for emergency services. *Computers & Operations Research*, 34:705–726.

Chen T, Huang J, (2012). Exploratory research on the system of China relief reserve. *Systems Engineering Procedia*, 5:99–106.

Gelareh S., Nickel S., (2011). Hub location problems in transportation networks, *Transportation Research Part E: Logistics and Transportation Review*, 47:1092-1111.

Goerigk M., Deghdak K., Heßler P., (2014). A comprehensive evacuation planning model and genetic solution algorithm, *Transportation Research Part E: Logistics and Transportation Review*, 71:82-97.

Goerlandt F., Torabihaghighi F., Ståhlberg K., Jemli J., Kujala P., (2012). Simulation model for evaluation of effectiveness of maritime SAR services. *11th International Probabilistic Safety Assessment and Management Conference and the Annual European Safety and Reliability Conference*, Helsinki, Finland, 7:5508-5517.

Lehikoinen A., Luoma E., Mäntyniemi S., and Kuikka S., (2013). Optimizing the Recovery Efficiency of Finnish Oil Combating Vessels in the Gulf of Finland Using Bayesian Networks. *Environmental Science & Technology*, 47 (4):1792-1799.

Li L., (2006). Rescue vessel location modeling. MSc thesis, Department of Industrial Engineering, *Dalhousie University*, Halifax, Canada.

Ma X; Chen T; Huang J, (2011). Several Problems on Establishing Socialized Relief Storage System. *Journal of Engineering Studies*, 3(1):82-84.

Ma X G, Zhan X h, Liu T J., (2014). Game analysis of cooperation between government and enterprise on storing emergency supplies. International Conference on Logistics Engineering and Management. *System Planning, Supply Chain Management and Safety (ICLEM 2014)*, Shanghai, China,9-11 Oct.

Venäläinen E., (2014). Evaluating voluntary emergency response in the Gulf of Finland. MSc thesis, *University of Helsinki*, Department of Geosciences and Geography, Helsinki, Finland.

Zegordi S.H., Nia B.M.A., (2009). A multi-population genetic algorithm for transportation scheduling, *Transportation Research Part E: Logistics and Transportation Review*, 45:946-959.

Selection of Express-Logistical Operation Mode in a High-Speed Railway Organization

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Abstract: Express logistics by means of high-speed railway faces challenges, such as the lack of infrastructural facilities, freight transportation limits, low efficiency of upstream-downstream industries and the furious competition of logistics industry. Considering the factors of regional differences, misallocation of resources and income levels, we designed the follow three operation modes for high-speed railway logistics: completely-opened mode, agent-cooperated mode and self-employed mode. The fuzzy synthetic evaluation based on set-valued statistics was applied for evaluating and choosing the three modes. This led us to the conclusions. First, the completely-opened mode is suitable in the areas where logistics market saturation and maturity are high. Second, outsourcing the distribution business is the best choice in the areas where its' distribution resources are insufficient, high-speed railway organization should cooperate with the local logistics agencies. At last, the self-employed mode is suitable only in this case that business outlets, transportation network, logistics center and logistics information system and other resources of high-speed railway organization are extremely sufficient.

Keywords: High-speed railway; Express logistic; Operation mode; Fuzzy synthetic judgment.

1 Introduction

In express industry, high-speed railway is one of most effective and ideal way to transport express items. High-speed railway is rather punctual, because it is not influenced by traffic jams and air traffic control. Specifically, it has the following advantages: cost advantage, high reliability, wide spectrum of services and high speed. In the meantime, there are many disadvantages and challenges. First, lack of infrastructure is a serious difficulty. Second, transportation is limited to small batch of goods. Thirdly, the service level of upstream and downstream is relatively low. Determining how to evade these risks and how to choose reasonable operation modes are significant for high-speed railway organization to increase competitiveness.

2 Analysis of affecting factors and dimension

2.1 The affecting factors

(1) Demands of express

The express demand for high-speed railway are the service needs of high quality and high efficiency. In addition, it is necessary to promote synergies in the development of manufacturing industry, business industry and logistics industry, because a large volume of import and export trade is one major factor for express demands.

(2) Logistics resource

It is very important that express enterprises establish logistics facilities at each node city in the whole high-speed railway network. Besides, the quantity and location of logistics distribution center, the saturated degree of express market, the talented person's comprehensive quality, and logistics enterprise's managerial skill in one area all above will influence the forms and patterns of the development of high-speed railway express.

(3) Average disposable income of local residents

The average disposable income of local residents determines the consumption level, so it could be used as a important indicator of the economic development in a region.

2.2 The dimensions of logistics business

(1) Ownership and control power

The organization could control wholly or partly logistics activities in a region. Of course, it is possible for out of control situations to occur, then the organization just provides the high quality transportation resources.

(2) The dominance of logistics activities

When high-speed railway organization controls the express logistics business partly, the dominance of logistics activities reflect its status in the whole express logistics system of market, business and management.

(3) The regional span

It should not take the identical general development mode among central city, terminal type city, and non-node cities of the high-speed railway network. The most fundamental reason is that the regional spans are different.

Considering the factors all above, we designed the follow three modes for high-speed railway organization to operate logistics express.

3 Three models of operation mode

3.1 The completely-opened mode

In this mode high-speed railway organization should open fully its high-quality resources of railway transportation for the society, and just provide transit services between initial station and destination. All of the logistics process will be handle by courier companies. The mode is shown in Figure 1.

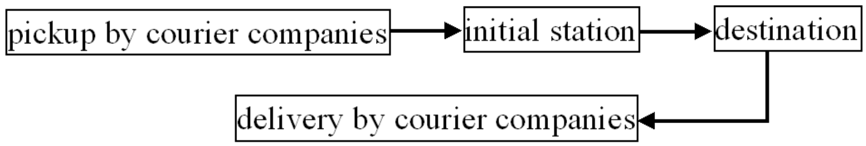

Figure 1. The completely-opened mode

3.2 The agent-cooperated mode

In this mode high-speed railway organization will completely outsource its delivery business to logistics agency. This mode is shown in Figure 2.

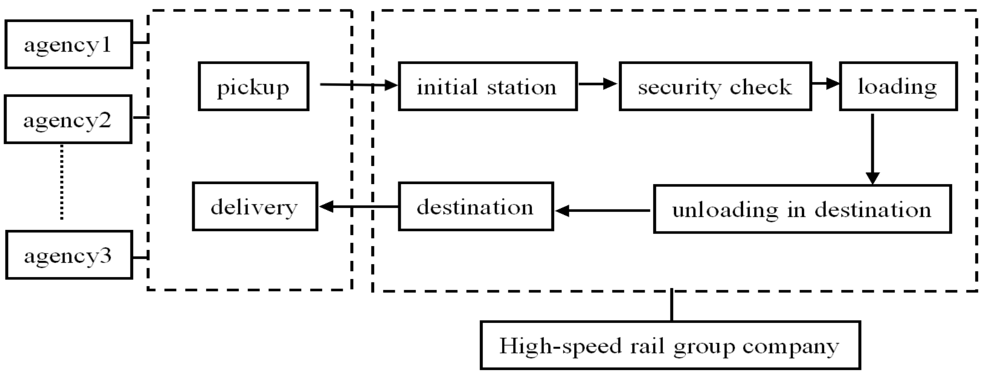

Figure 2. The agent-cooperated mode

3.3 The self-employed mode

In this mode high-speed railway organization can provide integrative logistics services or even customized logistics services for manufacturers, trading companies and E-commercial enterprises. The prerequisites for these is that high-speed railway organization must have enough operations and distribution centers, integrated high-speed railway network and professional logistics information system around the country. This mode is shown in Figure 3.

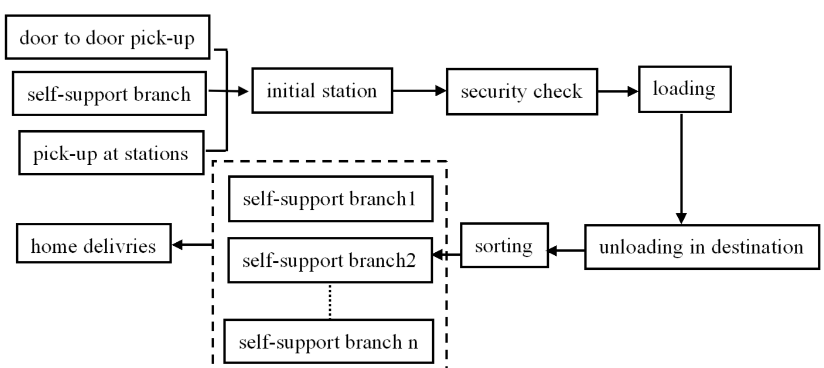

Figure 3. The self-employed mode

4 Fuzzy synthetic evaluation based on set-valued statistics

4.1 Description of the model

Considering the factors of no determinacy, randomness and fuzziness in the process of evaluation, we used the fuzzy synthetic evaluation based on set-valued statistics to evaluate three operation modes. The results of each probabilistic test is a definite point in the phase space, but the results of set-valued statistics is a subset. We assume the sample assembly is A, the set of evaluation indexes is C, the set of experts is D.

Firstly, the statistical estimation of arbitrary index c_i ($c_i \in$ C, i= 1, 2,…,m) from a expert will be denoted as a_i, the statistical estimation of number j (j = 1, 2,…,n) expert we denote as $[u_{i1}{}^{(j)}, u_{i2}{}^{(j)}]$, and $[u_{i1}{}^{(j)}, u_{i2}{}^{(j)}] \subseteq a_i$. The superposition of n intervals can be described as formula1.

$$\overline{i_{ai}}(u) = \frac{1}{n}\sum_{j=1}^{n} i\left[u_{i1}^{(j)}, u_{i2}^{(j)}\right](u) \qquad (1)$$

$$i\left[u_{i1}^{(j)}, u_{i2}^{(j)}\right](u) = \begin{cases} 1, & u_{i1}^{(j)} \le u \le u_{i2}^{(j)} \\ 0, & else \end{cases} \qquad (2)$$

Secondly, the average estimation of arbitrary index c_i from n experts can be denote as:

$$\overline{u_i} = \frac{\int_{u_i^{'}}^{u_i^{''}} u\overline{i_{a_i}}(u)du}{\int_{u_i^{'}}^{u_i^{''}} \overline{i_{a_i}}(u)du} \qquad (3)$$

In the formula, $u_i^{'} = \min\left(u_{i1}^{(1)}, u_{i1}^{(2)}, ..., u_{i1}^{(n)}\right)$, $u_i^{''} = \min\left(u_{i2}^{(1)}, u_{i2}^{(2)}, ..., u_{i2}^{(n)}\right)$.

So, we found:

$$\int_{u_i^{'}}^{u_i^{''}} u\overline{i_{a_i}}(u)du = \frac{1}{2n}\sum_{j=1}^{n}\left[(u_{i2}^{(j)})^2 - (u_{i1}^{(j)})^2\right] \qquad (4)$$

$$\overline{u_i} = \frac{1}{2}\cdot\frac{\sum_{j=1}^{n}\left[(u_{i2}^{(j)})^2 - (u_{i1}^{(j)})^2\right]}{\sum_{j=1}^{n}\left[u_{i2}^{(j)} - u_{i1}^{(j)}\right]} \qquad (5)$$

Thirdly, we can calculate the synthetic determination of arbitrary sample from all the specialists.

$$\overline{u} = \left[\overline{u_1}, \overline{u_2}, ..., \overline{u_n}\right] \quad (6)$$

Finally, we can get the scores of fuzzy synthetic determination through reasonable function.

4.2 The index system

When the high-speed railway enterprises choose their operating mode for express logistics, the following factors should be taken into account. These factors includes: the characteristics of the customer, economic development of the area, the demand of express logistics, the logistics resources and express logistics business dimension. We combine a number of experts in the table of operating mode selection assessment to evaluate the indicators, and sums up the indicator set of the following evaluation system, it is shown in table 1.

Table 1. The evaluation indicators system

Level 1 indicators	Level 2 indicators	Weight
X_1 Economic status indicators （0.1）	Y_1 Overall economic development level of the area	0.05
	Y_2 Per capita income level of the area	0.05
X_2 Express logistics demand （0.25）	Y_3 The popularity of the Internet and Online shopping intention indicators	0.075
	Y_4 The development of E-commerce logistics	0.062
	Y_5 Import and export trade factors	0.063
	Y_6 The logistics industry and manufacturing, business and other multi-industry linkage	0.05
X_3Logistics resource （0.40）	Y_7 Transportation infrastructure factors	0.064
	Y_8 The construction of the nodes in the high speed rail network	0.064
	Y_9 The number and layout of logistics distribution center	0.064
	Y_{10} Logistics express delivery market saturation of the area	0.056
	Y_{11} Express logistics information resources integration level	0.056
	Y_{12} Express business operation and management level of the area	0.048
	Y_{13} Logistics talent resources	0.048
X_4 Logistics business dimensions （0.25）	Y_{14} Regional span	0.037
	Y_{15} Control level of logistics activities	0.075
	Y_{16} Dominance level	0.033
	Y_{17} The ownership	0.10

4.3 Analysis of statistical data

We select three representative cities (or area), Ⅰ is a highly developed coastal cities, Ⅱ is a relatively developed inland provincial capital city, Ⅲ is a less developed cities. We evaluate the various indicators of these three cities with the opinions of five experts, then we calculate the comprehensive evaluation value based on formula (5). Finally we get the comprehensive evaluation values statistically, it is shown in table 2.

Table 2. Comprehensive evaluation values of Ⅰ, Ⅱ and Ⅲ city

Indicator \ City	Ⅰ	Ⅱ	Ⅲ
Y_1	0. 9200	0. 8100	0. 7100
Y_2	0. 8768	0. 7568	0. 6420
Y_3	0. 8540	0. 7750	0. 7230
Y_4	0. 8830	0. 7250	0. 6180
Y_5	0. 9326	0. 8107	0. 7125
Y_6	0. 8764	0. 7795	0. 6256
Y_7	0. 8859	0. 7596	0. 6896
Y_8	0. 8527	0. 7708	0. 6970
Y_9	0. 8650	0. 7705	0. 6605
Y_{10}	0. 8580	0. 7404	0. 6340
Y_{11}	0. 8423	0. 7333	0. 6352
Y_{12}	0. 8674	0. 7750	0. 6503
Y_{13}	0. 8912	0. 7821	0. 6924
Y_{14}	0. 9012	0. 7942	0. 7836
Y_{15}	0. 7125	0. 8365	0. 8328
Y_{16}	0. 7016	0. 7821	0. 7789
Y_{17}	0. 7013	0. 8050	0. 8102

4.4 Calculation and selection of the judge function

We used the average-weighted type of comprehensive evaluation function to calculate the result. We assumed that the normalized weight vector $W = (w_1, w_2, ..., w_m) \in I^m$, that means the expression of the comprehensive evaluation could be $f(\overline{u_1}, \overline{u_2}, ..., \overline{u_m}) = \sum_{i=1}^{m} w_i \overline{u_i} \times 100$. We put the comprehensive evaluation values of every indicator in the functional respectively, then we can figure out the comprehensive evaluation value of the three cities: 86.28, 75.49 and 66.34.

5 Conclusions

Here we could draw the following conclusions.

(1) The score of comprehensive evaluation is proportional to the level of economic development, stage of industrialization and income per head. This show that the market capacity of high-speed railway express logistics demands is bigger in developed areas.

(2) In city Ⅰ, because of the market saturation is higher and express enterprises are more mature, the control level of high-speed railway organization is weaker here. It shows that areas like city Ⅰ suit to the completely-opened mode.

(3) Though most indexes are different, but the dimensions of logistics business is resemblance between city Ⅱ and Ⅲ. The reason is that high-speed railway organization don't have its own terminal distribution network all over the whole country. So, outsourcing the distribution business is the best choice for high-speed railway in the areas where its' distribution resources are insufficient, therefore, high-speed railway organization should cooperate with the local logistics business.

(4) The self-employed mode is suitable only in the case that business outlets, transportation network, logistics center and logistics information system all resources of high-speed railway organization are highly intensive.

References

Chopra S. & Meindl P (2001). "Supply chain management-strategy planning and operation. *Prentice hall*, 37-38

Luo Xiaofang (2005). "Fuzzy synthetic evaluation based on set-valued statistics and its application." *Mathematica in practice and theory*, 9(35):42-47

Menter J. T, Flini J. H (2001), "Logstics service equality as a segment customized process." *Journal of Marketing*, 65(4):82-101

Ravi Shankar, V. Ravi (2008). "Analysis of interaction among variables of reverse logistics: a System Dynamics approach." *International journal of logistics systems and management*, 4(1):1-20

Sami Kara, Berman Kayis (2008). "Proactive logistics risk management-a system dynamics modelling approach." *International Journal of Risk Assessment and Management*, 10(3):224-237

Optimization Research of Sales and Delivery Processes Based on ExtendSim

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Abstract: In order to reduce the logistics cost of manufacturing enterprises and improve the utilization efficiency of warehousing and customer satisfaction, this paper researched enterprise's sales and delivery process according to the related theory of process optimization. In this paper, the existing business processes of the company and work flow chart are demonstrated. Problems in this process are brought up including forklift's whilst distance increased and unbalanced utilization rate because of lacking of loading platforms by using value chain analysis method. ECRSI optimization approach is employed to improve this problem, instead of existing separated loading port, the U-shaped loading platform have been added to assist sales and delivery process. Extendsim is used to contrast and evaluate simulated pre and post optimization sales and delivery processes. The results show that cargo area's average waiting time, average queue length, maximum waiting time and maximum queue length are greatly reduced compared with existing process; The backlog of goods and congestion in cargo area has improved significantly; forklift's utilization rate is more balanced and the total efficiency improved significantly. The optimized sales and delivery process will help to improve enterprise's comprehensive competitiveness.

Keywords: Business process; Value chain; Loading platform; Simulation; Optimization.

1 Introduction

Every advanced management mode just provides advanced management concept and methods for enterprises, but every enterprise has different background and culture, and cannot imitate blindly. Regardless of the enterprise management mode, all need process to support it. Every advanced management mode is inseparable from the excellent process, and excellent process provides support and assistance for advanced management mode. The organizational structure of the vast majority of enterprises in our country are based on the theory of division of labor pattern, therefore, enterprise's operating process is divided into relatively independent departments by function (WEN, 2010). Process optimization changes these processes in the organization and management, makes these processes are fragmented again and banded together to become a continuous process, through the process of integration and optimization, to achieve customer service, cost and efficiency of global optimization.

Marketing is the starting point of business activity, have a decisive effect on the business of technology, production, finance, personnel and other management, only successful marketing strategies can pull in front of all aspects of implementation of the strategy, the delivery part of the enterprise value chain is particularly important. However, most projects are concentrated in personnel, payroll and warehouse management, delivery management rarely involved. This situation occurs mainly because of long-standing delivery management work is not being taken seriously, but at the same time, delivery is tedious work and gets indirect benefits, it is also an important factor (SHANG, 2009).

Factors affecting the sales delivery efficiency are complex; there are both external and internal factors. External factors from the market factors, the internal cause are the human resources, technology ability restriction problem. Some are the direct factors, some are the indirect factors. Multi-factor effect is difficult to quantitative calculation, it is difficult to establish accurately mathematical model. Through simulation, the method of multiple statuses of return flow and the dynamic change the allocation of resources; can achieve the purpose of optimizing the process efficiency. Reproducing the status quo to run multiple processes and modifying the allocation of resources dynamically through the simulation method, to optimize the process efficiency. Through the comparison of multiple process simulation software, this article chooses Extendsim as the platform to simulate the sales and delivery process.

2 Analysis of the existing problems and optimization design

2.1 Analysis of the existing problems of sales and delivery process

S company in Xian is a large private manufacturing enterprise, S company has developed rapidly in recent years, and sales of the annual growth rate are over 20%. However, at the same time of rapid growth, some problems stand out in company. On the one hand, the phenomenon of damage and shortage is serious, on the other hand, the low efficiency and low utilization rate of equipments cause the high cost of the enterprise.

S company’s current sales delivery process is when an order is received and need to delivery, firstly, the main planner and administrator notify the transport group (outsourcing) to arrange the vehicles, then warehouse keeper load goods, the system operator determines whether it’s the finished goods or not, when customers accept goods, they feedback to the company, finally, it is the financial settlement.

Business operation’s objective is to input resources into customer value. Value activities are the basic way of survival and development. Value chain analysis with its unique perspective and framework is playing an increasingly important role in the strategy making at all levels of the enterprise. This paper will apply the value chain analysis method to analyze the company's sales and delivery process, to identify critical control point and put forward the scheme to reduce the non value added links.

(1) The performance indicators of sales and delivery process

S company's transportation outsources to a third party logistics company, so the company is mainly responsible for inspection before receiving and delivering. This paper analyzes the key performance indicators of sales and delivery process, Table 1 shows the key indicators as the control targets of sales and delivery process.

Table 1. The performance indicators of sales and delivery process

Category	Indicators	Definition
Quality	Product loss rate	The ratio of product loss's number to the actual distributions
	The qualified rate of products	The ratio of qualified product quantity to the actual number distribution products
	The accuracy of the product's quantity	The ratio of the actual delivery products to plan delivery products
Timeliness	Punctuality	The goods delivery on time to the total number of delivery
Service	The professionalism of the service	Professional processing abnormal situation
	Traceability of responsibility	The convenience of investigation for responsibility when found the goods damaged, not qualified

(2) The key point of sales and delivery process

Table 2 shows the main inputs and outputs of controlling the activities.

Table 2. The key point and main control method of sales and delivery process

The key points of the inlet and outlet	Input	Output	The main controlling method
Vehicle scheduling	Inform the shipping company to arrange vehicles, fill in the outbound order, feedback the cargo's volume weight, destination and time requirements	Vehicle selection, positioning	The real-time track transportation, KPI index evaluation, formulate the measures for vehicle scheduling management
Loading	The number of inventory, damage detection. Packing	Send information feedback, traveling real-time monitoring	Assign responsibilities , GPS applications, determine the feedback mechanism
Customer acceptance	Feedback after receiving, customer acceptance	Send the receiving report, feedback, back problems	Determine the accountability measures

Sometimes, customers will find sub-quality goods when they received, some are caused by the company itself in the design, production, packaging, loading and unloading, some are due to the third party logistics company's transportation. For now, if the customer asks to return money or to have re-delivery, S company takes a loss completely for two situations.

In addition, S company lacks of loading platforms, leading to large-scale outbound activities inconvenient and inefficient, also forklifts whilst distance increased, not only waste the space-time resources, but also caused an increase in the company's operating cost.

2.2 Optimization of sales and delivery process

MTO enterprises have a variety of line optimization way, such as improving the equipments' running speed, increasing equipments and working shifts, optimizing order process. Generally speaking, the enterprises will be from costs, expenses and implementation complexity to consider optimization (ZHANG, 2010).

At present, the main methods of process optimization are ESIA, ECRSI and SDCA (WANG, 2014). In the practice, enterprises need to do everything to reduce the non-value added activities, adjust the core value-added activities, the basic principle is ESIA. The main role of ECRSI is to analyze processes and judge whether the process can be eliminated, combined, rearranged, simplified and increased, to make the process more reasonable, more simple, more time- saving. SDCA balances the process, then checks the process to ensure its accuracy, and finally makes a reasonable analysis and adjustment, so the process can meet the requirements.

Extendsim itself provides "Optimizer" block as a tool to optimize the model, from the perspective of scientific data provides a reference for decision makers. In this paper, due to the randomness of the orders and the date of delivery constraints, the optimization solution only is considered to improve equipment running speed, increase equipments. Thus, this paper puts forward the following optimization.

① Set up pre-delivery inspection area. This paper uses the Increase program in ECRSI to set up pre-delivery inspection area. Thus, the company can move outbound goods into pre-delivery inspection area before transporting, the goods confirmed on site by third party logistics company attendants and the company's technical staff, and took photos as evidence. If no external damage, at this case the cargo's security responsibilities transfer to third party logistics company and goods are packaged and loaded by the third-party logistics company. If the damage occurring after the transport (except for technical issues), the third party logistics company is fully liable.

② Transform loading platform. At present, S company only has two loading platforms, which leads to the peak period of the exit and entry is not convenient. In order to reduce the backlog of goods and vehicles waiting time during peak-hour, this paper proposes an improved scheme to transform original H-shaped loading platform (separated loading port) into U-shaped loading platform after considering the costs, expenses, implementation complexity and other factors. Thus, in the U-shaped loading platform, forklift 1 unloads at Port a, forklift 2 loads at Port b. If forklift a is empty and forklift 2 leaves filled with goods, but Truck B hasn't unloaded yet, at this time forklift 1 can be directly drive to the loading Port b to load Truck B through the 2nd forklift's road and sent goods into warehouse staging area, while forklift 2 can operate into the U-shaped loading platform to do next loading activity through 1st forklift's road. Comparison diagram as shown in Figure 1 and Figure 2.

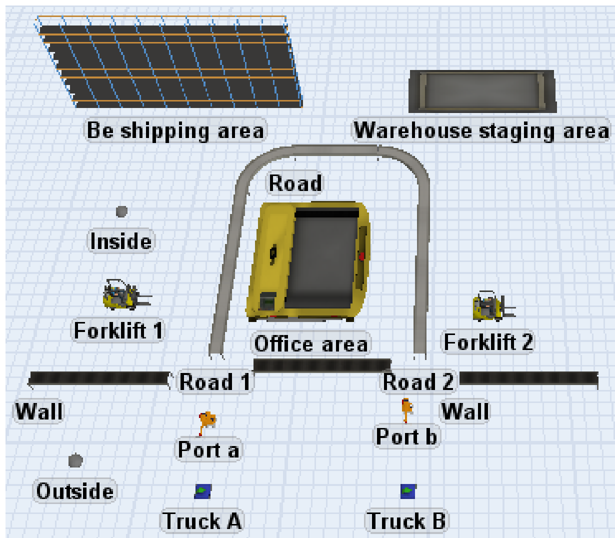

Figure 1. H-shaped loading platform

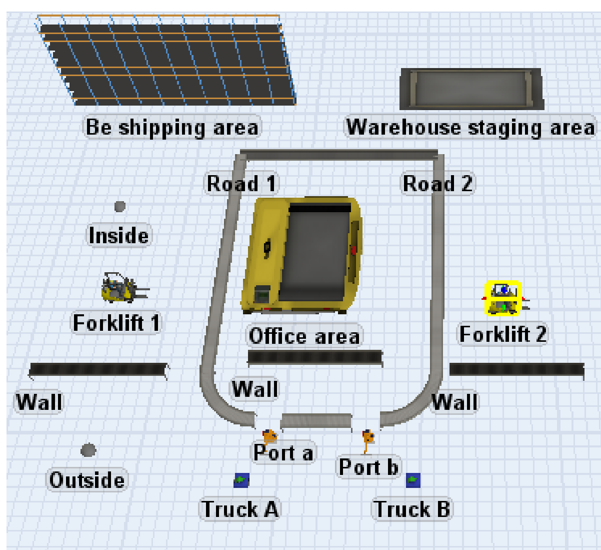

Figure 2. U-shaped loading platform

3 Simulation of sales and delivery process with Extendsim

The model of sales and delivery includes a variety of objects, among them, trucks, forklifts, transport channels are important objects, and they are also the key in the process of modeling.

3.1 Extendsim and its modeling

Extendsim simulation is developed by the Imagine That Company in the United States; it entered the market in 1988. It uses C language to write it's program and develops a certain number of blocks for different functions, and be packaged to form Extendsim block library for different business processes. According to the characteristics of enterprise business processes and workflow, Extendsim build a special logistics block library with it's reusability. Extendsim forms logistics business simulation environment under the combined effect of these two types of block library. In practice, Extendsim forms the simulation results and outputs it when we input the corresponding parameters combining with the assessment objectives (QIN, 2011).

The block of create that from Item library; its main function is to produce items and record amount of logistics entered into the delivery process. The block of Queue that from Item library, its main function is to allocate scratch space and store items momentarily. The block of Activity is used to process items. The block of Select Item 0ut from Item library, its main function is to output items selectively and generates a random number that obeys distribution. The block of Exit that from Item library, its main function is to end the simulation and record shipments.

3.2 The simulation under H-shaped loading platform

This paper sets up the Number of running is 1, the End time is 2880, namely the running time of the whole model for 2 days, the Global time units is minutes.

In Extendsim7, the block of Activity is used to simulate goods, the goods created from Create library are allocated according to the ratio of 4:6 through the block of Select Item 0ut, that is 40% of goods are stored, 60% of goods are delivered. For storage goods, in order to compare the goods backlog before and after optimization facility, we set up the parameters of the Queue block is unlimited. Forklift 1 that from the block of Activity were assigned to finish product stocking randomly, and set up total time is 5 min, the maximum capacity is 1, which means that this task can only deal with a forklift. Similarly, for delivery goods, we set up the same parameters as the model of goods inbound. According to the company's existing sales and delivery process, this paper builds the model of sales and delivery process, as shown in Figure 3.

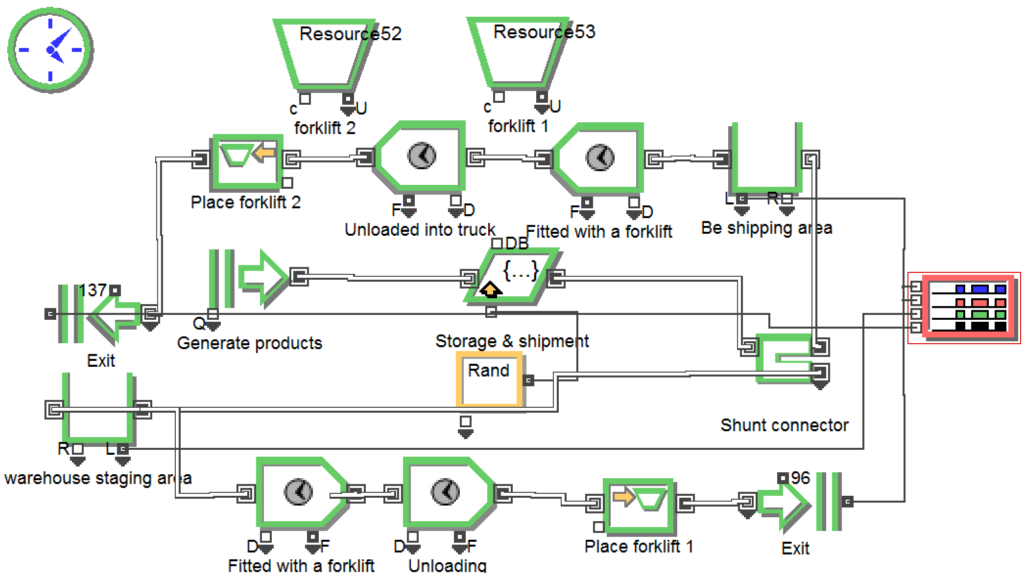

Figure 3. The simulation model of H-shaped loading platform

3.3 Data analysis

The block of Plotter and Discrete event that from Plotter library is used for statistics for the simulation results. This paper analyzes the block of Exit, Resource pool and Queue, the specific simulation results as shown in Table 3.

Table 3. The simulation results of H-shaped loading platform

Block	Attribute	Arrival	Leave	utilization	The average length of the queue	The average waiting time	Maximum waiting time	Maximum queue length
Be shipping area	Queue	158	151	0.9098158	4.8429105	48.51859	136.72568	15
warehouse staging area	Queue	78	78	0.1896133	0.2566219	4.8215217	21.02486	4
forklift 2	Resource Pool	×	×	0.9895042	×	×	×	×
forklift 1	Resource Pool	×	×	0.4986752	×	×	×	×

Table 3 shows that a total of 236 products entered into emulation platform, a total of 78 products are stored and a total of 142 products are delivered, the simulation completed a total of 220 pieces. In the delivery process that is the busiest periods, the emulation platform is congested with goods, and there are 16 products were not finished until 2880 minutes. In the above counts modules, the highest utilization rate is forklift 2, but the utilization rate of forklift 1 still has much room for improvement. Both average waiting time and the maximum waiting time of shipping area are the longest. So the company should improve the efficiency of delivery and shorten the processing time.

3.4 The results of U-shaped loading platform

In the U-shaped loading platform, what is different from the H-shaped loading platform is that forklift 1 and forklift 2 can carry on the handling operation flexibly through the U-shaped channel. So in the model of U-shaped loading platform, we set up the maximum capacity is 2, which means that this task can deal with two forklifts. The specific simulation results as shown in Table 4.

Table 4. The simulation results of U-shaped loading platform

Block	Attribute	Arrival	Leave	utilization	The average length of the queue	The average waiting time	Maximum waiting time	Maximum queue length
Be shipping area	Queue	156	156	0.092435	0.1101608	1.0672624	11.601423	3
warehouse staging area	Queue	90	90	0.065018	0.0810674	1.2824765	14.986176	4
forklift 2	Resource Pool	×	×	0.810396	×	×	×	×
forklift 1	Resource Pool	×	×	0.8397846	×	×	×	×

Table 4 shows that a total of 246 products enter into emulation platform, the simulation completed a total of 245 pieces. In the delivery process that is the busiest periods, the emulation platform runs smoothly and there is no congestion almost, and there are only one product were not fully finished until 2880 minutes. In the above counts modules, the utilization frequency of blocks still is forklift 2, and the utilization frequency of forklift 1 is improved greatly. Both the average waiting time and the maximum waiting time of be shipping areas are reduced sharply. Judging from the statistics module, the processing efficiency of the process has improved.

3.5 Discussion of results

We can draw the following conclusions by comparing Table 3 and Table 4.

① During the 2880 minutes, the U-shaped loading platform processing total number is 245, it increased by 11.36% comparing with 220 pieces that disposed in the H-shaped loading platform.

② Be shipping area's average waiting time, the average length of the queue, the maximum waiting time, maximum queue length In the U-shaped loading platform were significantly reduced than before. The average waiting time is reduced from 48.51859 to 1.0672624, decreased by 47.451328 minutes.

③ The average length of the queue is reduced from 4.8429105 to 0.1101608, decreased by 4.7327497.

④ The maximum waiting time is reduced from 136.72568 to 11.601423, decreased by 125.12444.

⑤ The maximum queue length is reduced from 15 to 3, decreased by 12.

Through the above analysis, it can be seen that the situation of backlog has improved significantly in the U-shaped loading platform, the utilization rate of forklift 1 increases to 83.97846%, utilization rate of forklift 2 falls to 81.0396%, two forklifts' utilization rate is more balanced and the total efficiency improved significantly. It shows that the U-shaped loading platform is superior to the H-shaped loading platform.

4 Conclusions

This paper analyzes the S company's current existing problems and applies ECRSI method to optimize the process. Finally, this paper simulates the before and after the optimization of the process by Extendsim, then gets a new simulation results and analysis, it proves the feasibility of the optimization scheme, it also has a certain significance for enterprises in the same industry.

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References

GAO Kai. (2010). "Multi-echelon inventory system simulation based on Extendsim". *Logistics Engineering and Management*, 32(3):47-48.

NIE Shitao. (2010). "Research and amelioration of the production lion of the fish can *based* on simulation". *South China University of Technology*, Guangzhou.

QIN Tianbao. (2011). "Application oriented simulation modeling and analysis with *ExtendSim* (Second Edition)". *Tsinghua University Press,* Beijing.

SHANG Mingcheng. (2009). "Optimization method and application of delivery *process* oriented overall effectiveness". *Modern Manufacturing Engineering,* 6(12):27-28.

WANG Qiufeng. (2014). "Research on business process improvement in L Company *logistics* department". *Donghua University*, Shanghai.

WEN Tiejun. (2010). "The research of production management process optimization in *LS* forging and heat treatment company". *Xi'an University of Technology,* Xi'an.

ZHANG Caiyun, TAI Yuhong. (2015). "Improving of fuel pump assemble line based on *Extendsim*". *Logistics Sci-Tech,* 1(9):95-96.

ZHANG Ming, WANG Minghu. (2003). "A research on the value chain analytic method under strategic costs". *Journal of Shanghai University of Finance and Economics,* 5(4):47-49.

ZHANG Zhengchao, LIU Yu. (2010). "Research in simulating and optimizing the *bottleneck* process of MTO enterprises". *Computer Science*, 37(12):102-103.

The Re-Engineering of Iron and Steel Enterprise Procurement Processes Based on the ABC Method

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Abstract: The material input and output dynamic process of iron and steel enterprises is made up of the procurement process, the production process and the sale process, and the procurement process running success or not will directly affect the enterprise final product pricing and the whole profit of the supply chain. This paper is based on the basic principle of ABC method, procedure, standard and analysis process. On the base of a detailed investigation of a certain iron and steel group logistics management process, I explore and find problems that exist in the current iron and steel enterprises procurement process. To solve these problems, the article uses ABC method to reconstruct the purchasing process of iron and steel enterprise, and chooses the performance evaluation method to evaluate the re-engineering of purchasing process, next step analyze the economic benefit of iron and steel enterprise. The results shows that the re-engineering of procurement process based on ABC method can improve the flexibility and robustness of the iron and steel enterprise, and ensure the timeliness and the quality of the supplying raw material, improve the ability of the enterprise internal work together. It also can significantly enhance the core competitiveness of the enterprise.
Keywords: ABC method; Procurement; Process re-engineering; Performance evaluation.

1 Introduction

Material purchasing is an important part of the iron and steel enterprise production and management, the mission of material procurement department is to provide quality and economy productions by production quality, quantity, timely and economically for the manufacture, engineering, maintenance, labor insurance, etc, so it will guarantee the production and construction of the iron and steel enterprise go on wheels; To check and ratify the needed materials according to the predetermined plan on production and construction; To choose suppliers, organize purchase and import at home and abroad through formulating purchase plan, and also to arrange reasonable reserve; For the sake of improving planning accuracy, reducing reserves possession, accelerating the capital turnover, reducing the purchasing cost by making organization for the material supply management system. Traditional way of purchasing is opaque, and vulgar. Due to the factor such as system or mechanism, traditional purchasing mode has many places incompatible with modern purchasing, which affected the efficiency and effectiveness of procurement; meanwhile it also resulted in the high purchase and transportation cost. Enterprise material purchasing is involved in the enterprise itself, and at the same time is significantly related to the relationship between enterprise and suppliers, so how to optimize the iron and steel enterprise procurement logistics processes to reduce costs, improve enterprise competitiveness is the current problem that urgently need to be addressed (WU, 2014).

We can use time efficiency, SCM and ABC method to reengineer the purchasing process of iron and steel enterprise. Compared with other methods, it is more appropriate to use ABC method which is abbreviation of activity-based costing. Activity-based costing of theoretical framework is proposed by GeorgeJ Staubus, who is a professor in the United States. In recent years, our country mainly combine with case analysis in the research of activity-based costing or discuss its application in a particular industry (YU, 2007). To restructure purchasing management business process for steel enterprise by using ABC method can make the loss and waste of enterprise in the process of purchasing be in the lower limit, raise the sciences and effectiveness nature of the decision-making, planning, control, and promote the continuous improvement of enterprise management level .

2 The purchasing process by some iron and steel enterprises and problems in it

For most of the iron and steel enterprise before a group has its own set of material supply management system, organization structure and business processes, and there are certain differences between each other. But the main business process is roughly same, it includes making the procurement plan based on the requirements, selecting suppliers and signing procurement contracts, registration, checking incoming materials to the warehouse, settlement and payment delivery. Material supply department is not only responsible for purchasing goods, but also is responsible for the warehousing distribution, namely buy, pipe, tube recycle, save tube (ZHOU, 2009). The procurement business processes is as shown in Figure 1.

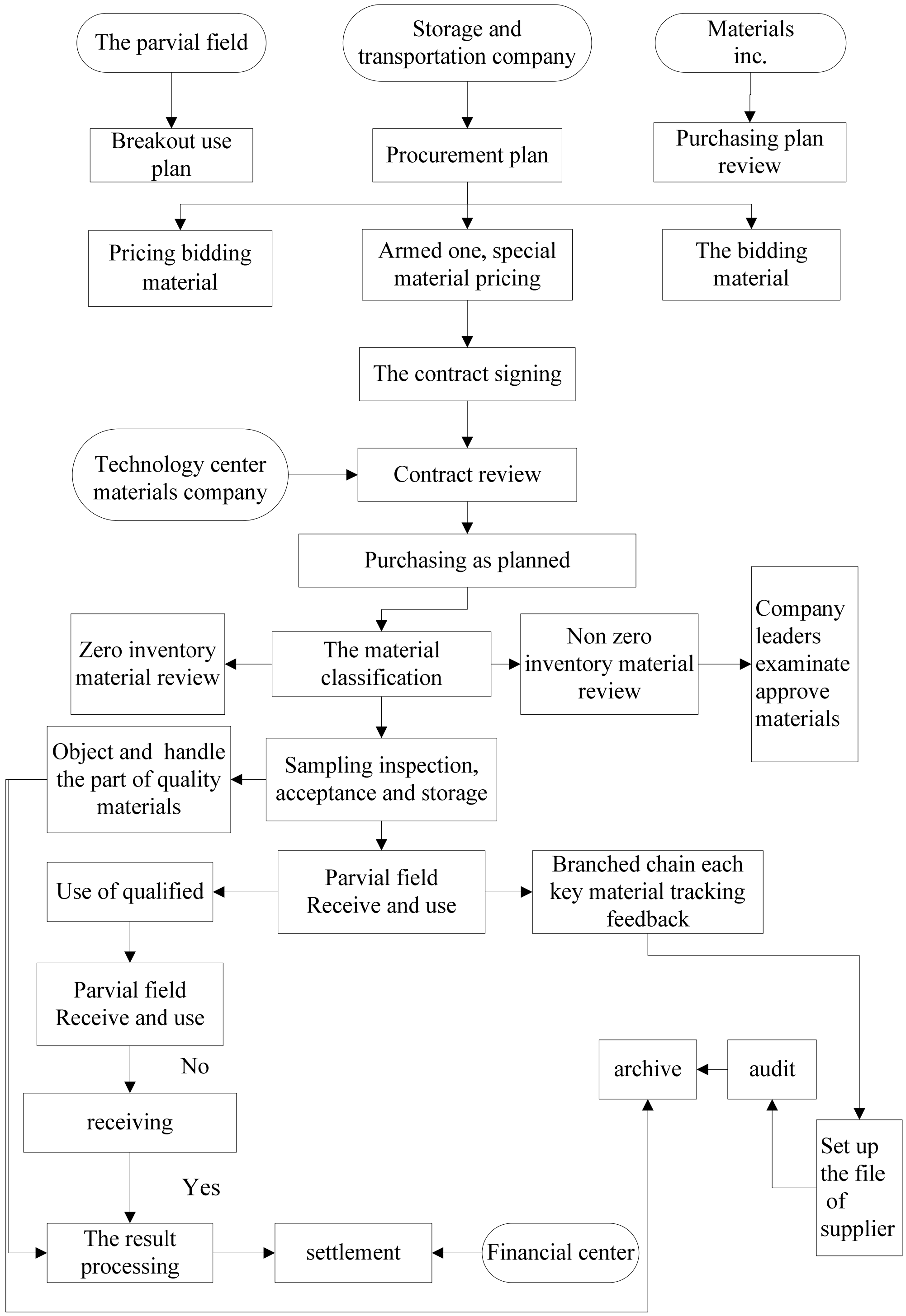

Figure 1. The current procurement flow chart

Traditional way of enterprise purchasing is opaque and vulgar, Due to the factor such as system or mechanism, traditional purchasing mode has many places incompatible with modern purchasing, which affected the efficiency and effectiveness of procurement, at the same time it also led to the high purchase and transportation cost. Enterprise supplies Procurement is involved in the enterprise itself, meanwhile it also has a major impact on relationship with suppliers. Specific analysis is as follows:

1) Each stock company has decentralized procurement, and is short of economies scale.

In case of decentralized management, Each company independently participates in carving up such companies external resources as supply and sales market resources, thus to form a number of the supply chain competition. The joint-stock company takes decentralized procurement, it causes that the company is unable to form Into scale, so after restructuring, unified purchasing process and supplier resources, implementing the centralized group Purchasing is the primary problem of group purchasing management to solve (MA, 2003).

2) The information cannot be shared.

Because the private information between Purchaser and supplier, enterprise purchasing department and related departments, management and implementers, is without integration, purchasing information does not implement effective sharing . as a result, it can't track procurement accurately, including purchase requisition, purchase vouchers, inquiry quotation; transport Processing, the goods processing, quality control and so on (LI, 2003).

3) Lack of restriction, easy to cause the black-box operation.

Purchase transaction authorization, issuance, approval, implementation and recording is without reasonable division of labor according to position, Purchase behavior lacks of restriction and transparency is insufficient. Enterprise makes the necessary separation for quality testing and payment right, which is respectively in charge of the quality inspection department and the financial department, but there is no separation in the pricing power, materials purchase price is lack of centralized management control. Purchase price is mainly determined by the buyer who negotiate with suppliers by using historical comparison information, enterprise purchase price is lack of monitoring, which brings about the materials procurement back with high price but poor quality, has the serious influence to the enterprise cost management and the quality of the product. The choice of suppliers and the signing of contract are completed by the buyer; the procurement in charge by special People, in the choice of suppliers, the subjectivity, optional gender and randomness is big, and the procurement process may be driven by interests, then appear black-box operation, giving up good for second-rate, and further situation.

4) Acceptance inspection is an important later check of purchasing department,

quality control is difficult.

Quality and delivery time is another two important factors for purchaser to consider, but in the current procurement mode, it is difficult for purchaser to participate in the supplier's production and quality control activities, to solve the quality and delivery of the goods period only through afterwards control method, and the control is very difficult. The union between purchaser and supplier is limited to temporary procurement, production organization and quality control activities related to each other is not transparent. So you need to make examination and acceptance through all sorts of relevant standards, such as international standards, industry standards. The cooperation lacking of the quality control will cause that the increasing difficulty to goods quality control of the purchasing department, to invest a lot of Time and energy, to pay the too big cost of various management.

5) Pyramid organization has disadvantages.

The traditional special steel enterprise's organization is set up according to the function, vertical organization is overmuch, the institutions is relatively, generally overstaffed, in central business processes to produce such problems as too much increment of the intermediate links and low efficiency, which does not accord with the requirement of supply chain management flat. The enterprise manage mode based on the theory of "division of labor theory", its organization form is the level of the pyramid, top-down hierarchical control structure. This organization institutions are the productions that determined by the planned economy and the backward management technology, it is function-centered, while don't care the process. The organizational structure determines the management process and information transmission channel; it caused the information transmission slowly, and in the statistical report process of each link, makes information distortion due to the influence of selfish departmentalism. These non value-added operations not only consume resources, but also affect the decision-making speed and even lead to policy mistakes (LU, 2005).

3 The application of the ABC method in a certain iron and steel enterprises procurement process reengineering

On the basis of procurement logistics process analysis for a certain iron and steel group, using ABC method to make procurement logistics process reengineering and to analysis, the results are shown in Table 1.

Table 1. The current procurement process analysis

Serial number	Business process description	Job classification	Whether it is necessary
(1)	Breakout plan was proposed	Non value-added homework	Necessary activities
(2)	Summary procurement plan	Non value-added homework	Necessary activities
(3)	Materials purchasing plan by the company	Non value-added homework	Non-essential activities
(4)	Determine the material purchasing plan	Non value-added homework	Non-essential activities
(5)	Sign the contract	Non value-added homework	Necessary activities
(6)	Review the contract	Non value-added homework	Necessary activities
(7)	Perform purchasing plan	Non value-added homework	Necessary activities
(8)	Material classification audit	Non value-added homework	Necessary activities
(9)	Non zero inventory material for examination and approval of leadership	Non value-added homework	Non-essential activities
(10)	Sampling inspection, acceptance and storage	Non value-added homework	Non-essential activities
(11)	The quality objection handling	Non value-added homework	Non-essential activities
(12)	receiving	Non value-added homework	Necessary activities
(13)	Finance settlement center	Non value-added homework	Necessary activities

There much control phenomenon after the event in the process of making procurement plans, such as after making procurement plan of storage and transportation company, the manager of the material company office have to check for acceptance, in fact, it should be made purchasing plan by the material and supply company according to the sales and inventory. Eliminating the process such as procurement staff to clean up, to Carries on the statistical, to contact the relevant unit staff, to understand inventory, delivery time, quality and technical requirements and so on, to put forward to implement Examination and approval opinions, and then reported to the branch leadership and a series of unnecessary return process after the procurement staff received purchasing plan. So we should strengthen procurement planning of beforehand and matter controls, synchronize the information, coordination of transmission, improve the efficiency of process operation. The investigation questionnaire for material purchasing process showed that the audit, material pricing and contract review of the purchasing plan whose execution of required number is 7, 9, 5, and 6 respectively, accounting for 75% of the total number of the whole process. In addition, pricing for supplies needs for a long time, generally 1 to 2 days, contracting review is 3 to 10 days, quality objection processing is about 15 days, signing a contract with suppliers is to 1 (province) to 15 (province) days, and the information passing basically do not have the way of application of information processing, which affects the efficiency and effectiveness of the procurement, leads to the procurement costs rise.

Therefore, the purchasing logistics reengineering is according to the following steps:

Activity Elimination. It means to eliminate the job without additional value assignment. Take effective measures to eliminate for the job that have been made sure have no additional value assignment.

Activity Selection. It means to select the best among the multiple different assignments chain, and different strategies often produce different assignments.

Activity Reduction. It is a way to improve enterprise management cost and resources, that is to say, to improve the work efficiency of the necessary or improve the work without additional value that cannot be eliminated in a short time Homework.

Activity Sharing. It is the use of improving efficiency of necessary work by Economies of Scale, that is, improving the operation of input-output ratio, so it can reduce operation reason distribution rate and the cost shared by a product (CHENG, 2012).

Through the above analysis, we can make reengineering as the follows, the information of the current procurement logistics process (1) and (3) is passed to the storage and transportation company through the meter Computer, materials sourcing companies received purchasing plan from the internet, then they will inform upstream suppliers about the purchase plan, suppliers need to prepare the goods as required, negotiate pricing, then the two sides sign a purchase contract, the buyer is responsible for purchasing, manufacturing department is responsible to prepare the goods, at the same time, notify the financial center for financial settlement. The purchase logistics process after reconstruction is as shown in Figure 2.

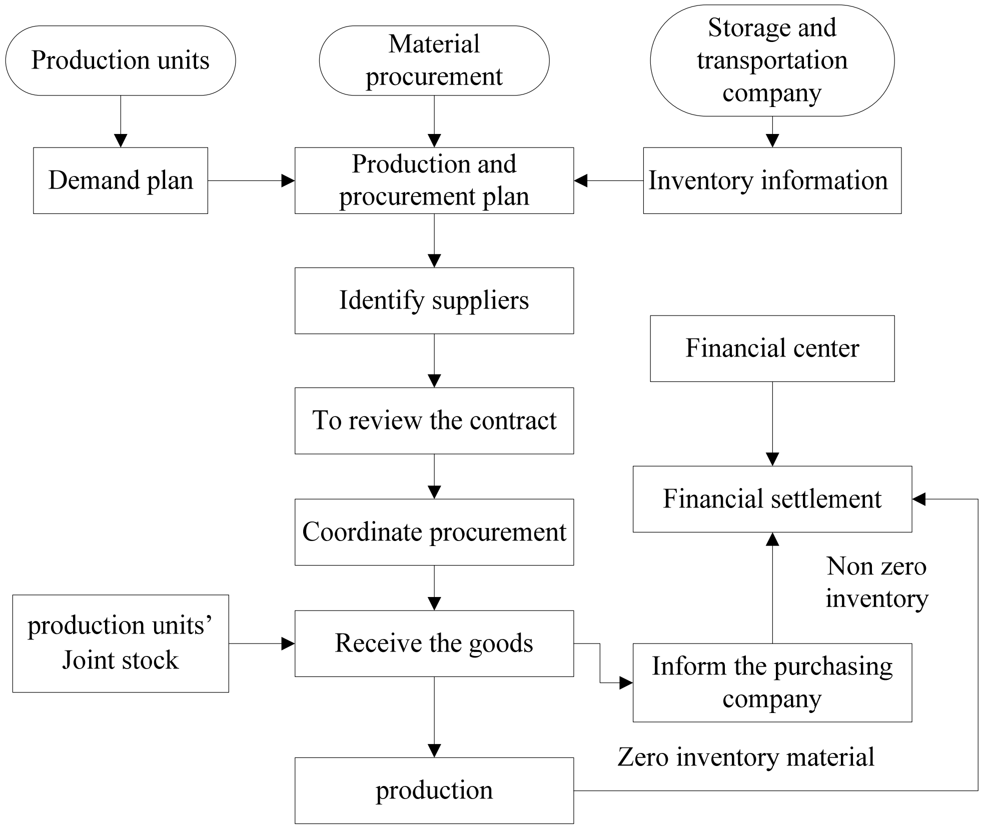

Figure 2. Procurement logistics flow chart after reconstruction

Using information technology to reduce the time for making purchasing plan, audit, material pricing, as well as the contract review time, in this way, it can improve the efficiency and effectiveness of procurement, and the materials directly into the production department t, reduce the purchasing department work pressure and avoid the activity process that do not add value, it is useful to achieve fine operation. Through the reconstruction of purchasing process, it can reduce the non value-added work, can save the time of purchase, simplify the working process of the purchase, and thus reduce the purchasing cost.

4 Reviewing for a certain iron and steel enterprises after the procurement process reconstruction

In the program of iron and steel enterprise management, effective performance evaluation and management is indispensable, the performance evaluation is to evaluate enterprise's production and operation activities by regularly or not regularly, based on facts, it can help the enterprise find weak link in enterprise management, put forward the improvement measures and goals, make the enterprise to progress for long. After reconstructing the purchasing process by using ABC method, it has the following four aspects carries on the analysis of performance appraisal.

1) The evaluation of lead time. Lead time is a kind of effective comprehensive indicator of considering the whole organization structure and operation. How to reduce procurement lead time involves many aspects, such as too long setup time, frequent downtime, not coordinate schedule, not reliable suppliers, too long transportation time, and a series of problems such as mass inventory may result in the long purchasing lead time. Long lead time show that the transport cycle performance, processing cycle, long storage period in the supply chain is long, and lead to the high cost. Due to process reengineering, the information of the current procurement logistics process (1) and (3) is passed to the storage and transportation company through the meter Computer, materials sourcing company received the purchasing plan from the internet, thus information transmission speed faster, which can reduce the time that required to interview, therefore it will shorten the lead time. Cost drivers, and the concept of value added/non-value added work is put forward by homework cost method, which recognizes the cost of production of measurement should be based on the decomposed into cost drivers homework, so as to give prominence to the key assignments/operation process resources. According to the requirement, reduce the value increment non-essential activities, it can save a series of unnecessary roundtrip process of procurement staff such as to clean up, statistics, contact the relevant unit staff, understand the inventory, delivery time, quality and technical requirements, etc., put forward suggestion on, examination and approval and submitted to the branch leadership after receiving purchasing plan; At the same time, the materials directly into the production department can shorten the storage period. Thus greatly reduce the procurement lead time.

2) The evaluation of flexibility. Flexibility refers to the system can adjust range of ability to external or internal interference caused by the change. Simple understanding of the supply chain flexibility refers to the abilities that it can rapidly and economically process uncertain situation that happened in the production and business operation of the environment or caused by environment uncertainty, it is generally composed of buffer, adaptation and innovation ability. Due to the operation of the supply chain is under uncertainty environment, when the customer demands change; the flexibility of supplier becomes the key factor for its survival. High flexibility can improve customer satisfaction, increase the strain capacity on demand, reduce the overdue orders and the possibility of missed opportunities, but also enhance the ability to develop new markets and products (HAO, 2004).

Through the analysis of the procurement lead time, as a result of the purchasing lead time greatly shortened, procurement staff have the production plan in timely and accurate information, so they'll have plenty of time to focus on value analysis and selecting sources, research, negotiation strategy and understanding the production problems. Therefore, when something changes, there are more full time in relatively to adjust reaction, at the same time, using information technology can increase flexibility and the core competitiveness of enterprises.

3) The evaluation of robustness, robustness is namely Conservatism; it refers to the robustness and strong degree in the process of change. For the supplier, robustness means that even if the client demand changes to a certain extent, the supplier will still be able to guarantee the product quality, delivery, normal operation, so as to guarantee the stability of the whole supply chain operation in the cooperation between suppliers with the clients (WANG, 2004).

4) The evaluation of cost. From the perspective of supply chain operation, the cost of purchasing supply system used to be reflected with supply chain assembly commonly, including supply chain communication cost, inventory cost and supply chain total transportation cost of external costs, reflecting the cost of the supply chain operation efficiency. it will reduce the non value-added homework, reduce waste throughout the supply chain, reduce the transportation cost through refactoring; By reducing the order to delivery cycle, production and logistics process can be finished in a short time, all entities in the supply chain can run more efficiently, Thus finally to reduce inventory; To improve the corresponding cash turnover by reducing order delivery cycle.

5 Conclusions

For iron and steel enterprises, the process that to product for sale and to purchase for the production is an interlocking input/output dynamic process of materials, which in turn makes up the procurement process, production process and marketing process. From a logistics point of view, the success of the initial procurement process operation will directly affect the enterprise production and sales pricing of the final product and the entire final profit of supply chain. It increases the flexibility and robustness, avoids the situation that it appears the suspension of equipment production, smelting process because of the lack of material which can cause huge economic losses, and ensures the continuous production of iron and steel enterprises through the implementation of ABC method for the reconstruction of the procurement process. Considering the strategic cooperation with suppliers, the characteristics such as the intensive capital of iron and steel enterprise, raw material fuel capital takes up big volume and the large transportation, so as to guarantee the quality of raw materials and timeliness in the process of implementing ABC method. Through the implementation of ABC method, which is beneficial to make a detailed and specific analysis and control on how to use the resources step by step, and to optimize operation chain, value chain and the combination of production quantity and variety, so as to optimize the allocation of resources, to give play to various synergy among various departments and technology and production process, finally to improve the core competitiveness of the enterprise.

Acknowledgments

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References

CHEN Lei. (2012). “AK enterprises procurement business process reengineering research”. *Jilin University*, Changchun.

HAO Yingguang, WANG Jiaqiang, LIU Xiaobing. (2004). “Iron and steel enterprise material purchasing strategy based on value chain study” .*Modular machine tool and automation processing technology*, 10(4): 20-22.

LI Qingyu, ZHU Hong. (2003). “Group of iron and steel enterprise supply chain customer order batch optimization technology research”. *Industrial engineering and management*, 8(2), 28-30.

LU Ying, GUO Yajun, GAO Junjun. (2005). “Large iron and steel enterprises process reengineering thinking”. *Industrial engineering and management*, 10(1): 42-45.

MA Shihua, LIN Yong. (2003). “Supply chain management”. *Higher Education Press*, Beijing.

WANG Junjie, SHEN Feng. (2004). “Iron and steel enterprise process reengineering and information technology support”. *Journal of Lanzhou*, 8(6): 16-19.

WU Jianhong. (2014). “The activity-based costing method in the enterprise application”. Shanxi University of finance and economics, Shanxi.

YU Ziyong. (2007). “The application of ABC at advanced steel manufacture corporation in China”. *China university of petroleum*, Beijing.

ZHOU Anquan. (2009). “Logistics process reengineering: integrated mode and application” *Science Press*, Beijing.

Third-Party Cold Chain Logistics Cost Accounting Based on Activity-Based Costing

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Abstract: Compared to the general logistics, the cold chain logistics is more expensive and the cost structure is more complex. It plays an important role in logistics. The importance of the logistic cost determines that it must be as accurate as possible, which requires higher requirements for accounting methods. In order to carry out cost accounting better, this paper uses activity-based costing and multistage mode, assembling the indirect cost into operations according to resource driver, forming the ABC library. The cost allocation rates are determined by the activity driver. The cost in the ABC library is assigned to various cold chain logistics service according to the cost allocation rates. In this way, we can obtain the cost object, which is the indirect cost of the third-party cold chain logistics services. Based on activity-based costing, this paper establishes a cost accounting model for the third-party cold chain logistics enterprises. Apply this model to one of the third-party cold chain logistics enterprises and analysis the cost accounting. Research results show that cost accounting based on activity-based costing is more accurate, truthful and objective compared to traditional cost accounting methods for indirect cost. The cost method is conducive to control cost effectively and to make better decisions for enterprises.

Keywords: Cold chain logistics; Activity-based costing; Cost accounting; Multistage mode.

1 Introduction

With the increasing demand for fresh food and frozen food, the cold chain markets have good development prospects. However, cold chain logistics faces enormous pressures and challenges. High logistics costs seriously affect the economic efficiency of the third-party cold chain logistics enterprises.

The third-party cold chain logistics enterprises combine cold chain process, cold chain storage, cold chain transportation and cold chain distribution to meet the demands of the customers. By reducing costs, the third-party cold chain logistics enterprises improve work efficiency and service level, which enhance its competitiveness.

As the third profit headspring, logistics costs control is directly related to the profit of the third-party cold chain logistics enterprises. How to reduce costs and increase profits is the key for a third-party cold chain logistics enterprise. In this way, it is necessary to find ways to control logistics costs.

2 The problems of the third-party cold chain logistics enterprises applying the traditional cost management.

From the perspective of functional forms, the costs of cold chain logistics include the costs of distribution processing, packing, storage, transport and handling. From the perspective of payment forms, the costs of cold chain logistics include the costs of materials, labor, equipment, and the costs of integrated management. Some costs can be shown from statistics directly, which are the direct costs. The other costs cannot be calculated directly, which are indirect costs. Indirect costs can be estimated in a certain proportion according to experiences.

The traditional cost management is applicable for the enterprises which have less operating varieties, less intermediate operation, low proportion of indirect costs. The traditional cost management is difficult to assign indirect costs accurately, so it is not applicable for the third-party cold chain logistics enterprises. For higher indirect costs of the third-party cold chain logistics enterprises, the single cost distribution standard has warped the costs information of logistics enterprises. Traditional cost management allocates indirect costs to business subjectively on the basis of production or working hours.

3 The multistage mode of activity-based costing

Activity-based costing method is centered on activity. In the cost accounting process ABC focus on activity. Compared to the traditional method, activity-based costing method in cost accounting has more thorough changes.

Activity-based costing recognizes and measures the cost, dynamically reflecting all the activities. It provides useful information for strategy, planning and control to eliminate worthless-added activity, improve “value-added” activity and minimize wastes. In this way, the management can be improved. Activity-based costing is based on “activity consumes resources, product consumes activity”. Therefore, it includes resources, activity, product, service, motivation and activity motivation.

An enterprise's resources include direct labor, direct material, production and maintenance costs (wage costs such as purchasing personnel), indirect manufacturing costs and production costs (such as advertising). Resources enter into the activity which is the unit of work with a certain correlation. Activities COST pools are the cost collection of of resources consumed in homogeneous assignments. The cost objects are the final point and sufferers of costing businesses. Cost drivers are the facts leading cost. Cost drivers can be divided into two categories which include resource drivers and activity driver by Activity-Based Accounting.

In multi-stage model, activities are not directly consumed by the cost object, but consumed by other activities. Other activities are consumed by the cost objects.

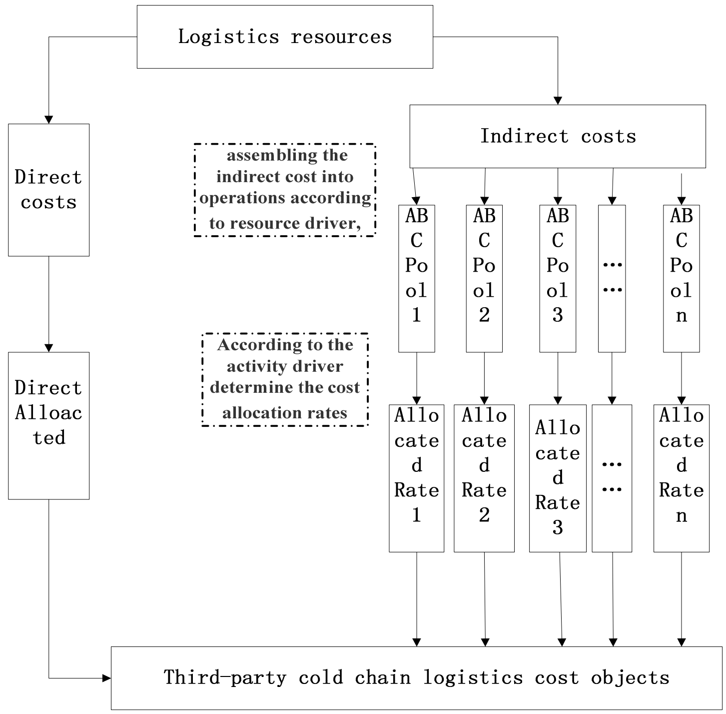

Figure 1. Multi-stage Model of ABC

4 The implementation of activity-based costing in cost accounting of the third-party cold chain logistics enterprises

Take the example of one third-party cold chain logistics enterprise W. The operation mode of company W is mainly achieved through the cold chain logistics services contract signed. The income and the balance of the project costs are the project's profit. Total costs directly derived from the financial statements of the company. However, we cannot accurately calculate the costs of every project. So, logistics enterprise cannot set reasonable price. Now we account the costs of company W using activity-based costing.

Company A and company B have the same requirements for frozen processing activity and packaging activity. But for the refrigerated distribution activity, they have different demands. Company A requests 1300 of product distributed to 130 every three days. Company B requests 1300 of product distributed to 87 every two days.

In order to meet the requirements of company A and B, 300 square meters in the warehouse are used to store company A's products, and 200 square meters in the warehouse are used to store company B's products（assuming that company A and company B have the same distance to W and every link has not caused damage and no penalty cost）.

The costs of the third-party cold chain logistics are made up of the costs of direct materials, the costs of direct labor and special cold chain costs. Special cold chain costs refer to the penalty cost for damage or improper distribution time. The cold chain logistics costs are relatively easy to be collected directly to specific services. Based on the activity driver determines the cost allocation rates, activity-based costing is used to allocate huge indirect costs. The cost in the ABC library is assigned to various cold chain logistics service according to the cost allocation rates. In this way, we can obtain the cost object, which is the indirect cost of the third-party cold chain logistics services.

4.1 Analysis of third-party cold chain logistics activities

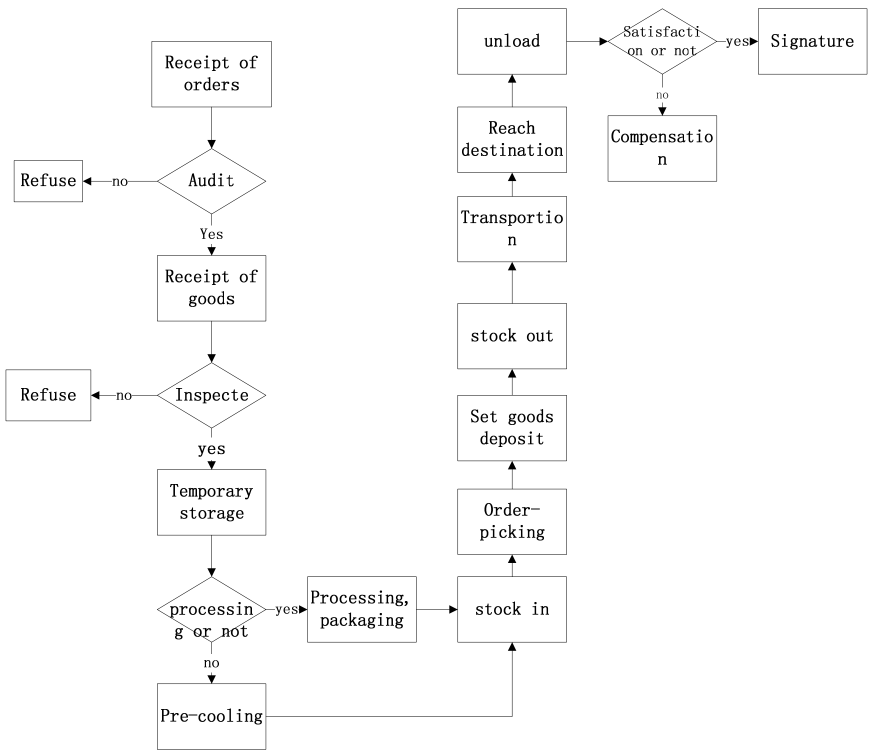

Figure 2. Business process diagrams of W

From the figure1 we can get that the activity of the third-party cold chain logistics can be named: Contract processing activity, frozen processing activity, Packaging activity, Purchase materials activity, Stock in activity, frozen storage activity, Stock out activity and Refrigerated distribution activity.

4.2 Identify resources

Major resource projects include: the costs of resources, the labor costs, electric power changes, fuel costs, depreciation costs and office expense. The costs of resources: material fees of purchasing an appropriate packing. It belongs to direct costs and can be collected directly to the cost object.

The labor cost: the calculation of labor costs is the number of employees involved in logistics operations and corresponding salary multiplied by. Manager salary to direct costs, and can be collected directly to the cost object.

Electric power changes: the amount of electricity can be determined by a company's meter directly. The quantity multiplied by the units of electricity is electric power changes. The power consumption is considerable including the normal office, electricity consumption frozen (reservoir), cold storage and cold-chain equipment.

Fuel costs: fuel fees are mostly spent on frozen processing machinery, material handling equipment and the vehicles of refrigerated transportation. Fuel fees can be obtained directly from the financial statements.

Depreciation costs: It mainly refers to the depreciation of the plant, machinery, equipment, warehouse and fixed assets. Depreciation cost allocation mainly accord to the fixed assets calculated using time limit in the company.

Office expenses: It mainly refers to the cost, which the company spends in the project contract processing, warehouse management, project management, and other project.

4.3 Allocation of resources to the various logistics activities

Table 1. The costs of resources of W company

materials Costs	Labor costs	Electricity tariffs	Fuel costs	Depreciation costs	Office expenses	total
7320	109300	12532	12788	3343	880	132843

(There are 600 Yuan in labor cost that is responsible for the wages of company A's and company B's manager. This belongs to the direct costs of direct labor, and it can be collected directly. Labor cost is involved in indirect distribution: 109300-6000=103300 Yuan.)

(1) The allocation of labor costs

Resource driver of labor cost is the number of employees. The rate of resource driver is average of salary. Hence, the resource cost is the salary levels and the number of employees multiplied by.

Table 2. The allocation of labor costs of W company

The activity name	Resource driver	The number of resource driver	The rate of resource driver	Resource c osts（Yuan）
Contract processing activity	The number of e mployees	2	2500 Yuan/person	5000
Frozen processing activity		7	2400 Yuan/person	16800
Packaging activity		7	2400	16800

			Yuan/person	
Purchase materials activity		4	2500 Yuan/person	10000
Stock in activity		7	2400 Yuan/person	16800
Frozen storage activity		5	2300 Yuan/person	11500
Stock out activity		4	2400 Yuan/person	9600
Refrigerated distrib u-tion activity		7	2400 Yuan/person	16800
total		43		103300

（2）The allocation of electric power changes

Resources driver is the kilowatt-hour. The rate of resource driver is the unit price. Electric power changes of W company are the kilowatt-hour and the unit price multiplied by.

Table 3. The allocation of electric power changes of W company

The activity name	Resource driver	The number of resource driver	The rate of resource driver	Resource costs （Yuan）
Frozen processing activity	kilowatt-hour	2250kilowatt-hour	1Yuan/ kilowatt-hour	2250
Packaging activity		1337kilowatt-hour		1337
Stock in activity		490kilowatt-hour		490
Frozen storage activity		6740kilowatt-hour		6740
Stock out activity		690kilowatt-hour		690
Refrigerated distribu -tion activity		1025kilowatt-hou r		1025
total		12532		12532

（3）The allocation of costs of fuel costs

Fuel costs of company W are mostly spent on frozen processing machinery, material handling equipment and the vehicles of refrigerated transportation. Resource driver is working hours. The rate of resource driver is devices per hour fuel consumption costs (Assuming that frozen processing machinery and material handling equipment have the same fuel consumption costs).

Table 4. The allocation of costs of fuel costs of W company

The activity name	Resource driver	The number of resource driver	The rate of resource driver	Resource costs （Yuan）
Packaging activity	Working hours	12 hours	12788/192=66.6	799.4
Tock activity		49 hours		3263.6
Stock activity		52 hours		3463.4
Refrigerated distribution activity		79 hours		5261.6
total		192 hours		12788

(4) Depreciation costs of company W

Depreciation costs of fixed assets are mainly calculated based on the length of procurement of equipment or plant's life. This belongs to the direct costs, and it can be collected directly.

Table 5. The allocation of depreciation costs of W company

The activity name	Resource costs（Yuan）
Frozen processing activity	1050
Packaging activity	260
Stock activity	295
Frozen storage activity	790
Stock activity	385
Refrigerated distribution activity	563
total	3343

(5) The allocation of office expense of company W

Office expenses are exclusive costs, which can be obtained directly from the financial statements, and assigned directly to the related logistics jobs.

Table 6. The allocation of office expense of W company

The activity name	Resource costs（Yuan）
Contract processing activity	205
Packaging activity	296
Refrigerated distribution activity	379
total	880

Summarily, we can get the cost of every activity:

Table 7. Activity cost of each logistics operation of W company

The activity name	Labor c osts	Electricity tariffs	Fuel costs	Depreciation costs	Office expenses	total
Contract process -ing activity	5000	——	——	——	205	5205
Frozen processing activity	16800	2250	——	1050	——	20100
Packaging activity	16800	1337	——	260	——	18397
Purchase materials activity	10000	——	799.4	——	296	11095.4
Stock in activity	16800	490	3263.6	295	——	20848.6
Frozen storage activity	11500	6740	——	790	——	19030
Stock out activity	9600	690	3463.4	385	——	14138.4
Refrigerated distrib ution activity	16800	1025	5261.6	563	379	24028.6
total	103300	12532	12788	3343	880	132843

4.4 Assignment costs to each cost object

Firstly, we need to determine the activity driver of each cost object:

Table 8. The activity driver of logistics operation of W company

The activity name	Activity driver
Contract processing activity	Contract number
Frozen processing activity	Number of products
Packaging activity	Number of products
Purchase materials activity	Number of products
Stock in activity	The number of stock in
Frozen storage activity	Warehouse area
Stock out activity	The number of stock out
Refrigerated distribution activity	The number of distribution

Table 9. The quantity of activity driver of each logistics operation of W company

Activity driver	total	The number of resource driver	
		A	B
Contract number	2	1	1
Number of products	2600	1300	1300
The number of stock in	20	10	10
Warehouse area	500	300	200
The number of stock out	25	10	15

The number of distribution	25	10	15

The rate of activity driver= the costs of activity / the total number of resource driver. We can get the rate of resource driver.

Table 10. The activity driver rate of each logistics operation of W company

The activity name	The costs of activity	The total number of resource driver	The rate of resource driver
Contract processing activity	5205	2	2602.5
Frozen processing activity	20100	2600	7.73
Packaging activity	18397	2600	7.07
Purchase materials activity	11095.4	2600	4.27
Stock in activity	20848.6	20	1042.43
Frozen storage activity	19030	500	38.06
Stock out activity	14138.4	25	565.54
Refrigerated distribution activity	24028.6	25	961.14

When we get the rate of resource driver and the total number of resource driver of contract A and B, we can obtain the indirect costs of contract A and contract B.

Table 11. The logistics costs assigned to cost object A and B

The activity name	The rate of resource driver	Contract A		Contract B	
		The number of resource driver	Assigned amo unt	The number of resource driver	Assigned am ount
Contract processing activity	2602.5	1	2602.5	1	2602.5
Frozen processing activity	7.73	1300	10050	1300	10050
Packaging activity	7.07	1300	9198.5	1300	9198.5
Purchase materials activity	4.27	1300	5547.7	1300	5547.7
Stock in activity	1042.43	10	10424.3	10	10424.3
Frozen storage activity	38.06	300	11418	200	7612
Stock out activity	565.54	10	5655.4	15	8483.1
Refrigerated distribution activity	961.14	10	9611.4	15	14417.1
Total	64507.8			68344.2	

The costs of the third-party cold chain logistics are made up of two parts: direct costs and indirect costs. Direct costs include direct material costs, direct labor costs and special cold chain costs. Direct costs are assigned to cost objects according to the number of products. In this case, A and B have the same contract numbers. Direct material costs is 7320，so MA=3660，MB=3660 .Direct Labor costs: LA=3000, LB=3000. Special cold chain costs: CA=CB=0. Indirect costs p: IA =64507.8, IB=68344.2.

Costs object A = $M_A + L_A + C_A + I_A$=3660+3000+0+64507.8=71167.8;

Costs object B = $M_B + L_B + C_B + I_B$ =3660+3000+0+68344.2=75004.2.

Company A and Company B has the same contract numbers, which is 1300. So, costs per unit of A contract is 54.7(71167.8/1300) and costs per unit of B contract is 57.7(75004.2/1300).

5 Conclusions

This paper applies this model of ABC to one of the third-party cold chain logistics enterprises and analysis the cost accounting. We can get:

(1) Applying the activity-based costing to third-party cold chain logistics cost, specific resource consuming can be mastered clearly.

(2) Determine the cost of each project of cold chain logistics. Logistics enterprise can get reliable product cost information. They can set reasonable price.

(3) Through accounting, we can get whether the fame of costs is reasonable and workout a reasonable and effective solution to reduce costs, and improve the economic efficiency of enterprises.

References

Hu Lingling(2011),Apply Activity-based Costing to the Costing Management of Third-party Logistics Company. IEEE.

Su Lihao(2012). The Researched on Water Project Cost Accounting Based on Activity-based Costing. IEEE.

Wei Tongtao(2010), Cost Accounting Method of Third-Party Logistics Company Based on Activity-Based Costing. Kunming. Kunming University of Science and Technology.

Wang Lingyan(2006). The Study of Cost Control in Logistics Enterprise Based on Activity- Based Cost . Dalian. Dalian Maritime University.

Wu Dan(2009), Application research on TD-ABC in TPL Enterprise Cost Accounting. Lanzhou. Lanzhou University.

Yan Xiaofang(2010)，Study on Third Party Logistics Cost Accounting under Activity-Based Costing.Jiangxi. Jiangxi University of Finance and Economics .

Zheng Peng(2011),Application of the Activity-Based Costing for Third-Party

Logistics Companies.IEEE.

Contract Design of Income Distribution for Banks and Logistics Enterprises in Uniform Credit Financing Mode

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Abstract: Considering the financial feature of logistics enterprises, this paper discusses the uniform credit financing mode that allows banks and logistics enterprises to have comprehensive cooperative relations based on the existing inventory financing products. Introducing the idea of "two sides decide the market", the paper analyzes the problem of income distribution in the capital supply chain that consists of commercial banks, logistics enterprises and loan enterprises. In the contract, this paper uses Stackelberg game theory of complete information to analyze the behavior of banks and logistics enterprises, and then applies backward induction method to get the risk bearing rate of logistics enterprises, the loan-to-value ratio and bank lending rate. The result indicates that, under uniform credit financing model which depends on logistics enterprises to determine loan-to-value ratio and banks to determine lending rate accordingly can expand the demand of financing market and create more benefit for all participants. Finally, the sensitivity analysis of small enterprises' compliance rate and pledge' realizability demonstrates that the interest relationship in the model is compatible with the reality.
Keywords: Uniform credit; Stackelberg model; Benefit analysis.

1 Introduction

In the business of supply chain finance, the third party logistics can provide not only basic inventory financing business, but also credit guarantee business which otherwise known as uniform credit financing. In this financing model, the banks give 3PLs a certain credit limit according to the enterprise scale, operating performance and credit rating of the 3PLs. Then the 3PLs break credit limit down to small businesses, and these small businesses use real documents and inventory as a counter guarantee. The uniform credit financing model allows 3PLs to have more choices in making decisions and simplifies the business process largely.

With the increasingly complex structure of supply chain, the income distribution mechanism among its members has brought to public attention. Cossin, Huang (2003) studied the determination of loan-to-value ratio of banks. Klapper(2004) analyzed the mechanism and function of inventory financing that used for the little and middle enterprises. Buzacott, Zhang (2004) who are the first put inventory financing mode into production decision. Li Yixue et al. (2007) gave a quantitative interest ratio decision model aimed at the pledge with random price. Wang Yong et al. (2010) discussed the 3PLs' incentive problems for banks in consider of fairness preferences. Zhou Xuenong(2010) stood in the perspective of supply chain financing and studied the contract design problem of inventory financing. Yi Xuehui et al. (2011) discussed the banks' pricing problem under the condition that the core enterprises provide repurchase guarantee. Ma Zhonghua et al. (2011) considered how 3PLs can maintain yield by adjusting the regulatory decisions at the time the banks increase the interest rate. The above research findings are significant for us to understand inventory financing business deeply and provide much beneficial reference in solving decision-making problems of all the participants. However, most of studies are based on the viewpoint that the banks dominate the market unilaterally, this paper will study the contract design problem in the framework that banks and the 3PLs have comprehensive cooperation.

2 The Model

2.1 Model Assumptions

There is no collusion between 3PLs and loan enterprises in the situation that banks develop comprehensive cooperative relations with 3PLs. Under uniform credit financing model, the 3PLs provide credit guarantee for loan enterprises according to the full understanding of pledge. So if loan enterprises can't repay the loan, the 3PLs should be responsible for pledge realization. And if the 3PLs do not provide credit guarantee, the banks will not choose to lend.

For easy analysis, the paper only considers two extreme cases: the loan enterprises repay the principal and interest fully and the loan enterprises do not repay any principal and interest. The model assumptions are as follows:

(1) The loan enterprises invest borrowings in projects, the probability of success is p . Assume that if the project is successful, the loan enterprises will be certain to repay the loan, and if the project is fail, the loan enterprises will default.

(2) The loan enterprises need B quantity of money to invest in a project, equity fund is $B\alpha$, α ($0<\alpha<1$) represents the proportion of equity fund, so the amount that the loan enterprises need to borrow is $(1-\alpha)B$.

(3) The amount of guarantee provided by 3PLs is equal to $(1-\alpha)B$, and the loan enterprises should provide $\frac{(1-\alpha)B}{\omega}$ pledge as a counter guarantee. ω is pledge rate, then the risk bearing ratio of 3PLs is $\Delta\beta=\frac{B(1-\alpha)-\frac{B(1-\alpha)}{\omega}\beta}{B(1-\alpha)}=1-\frac{\beta}{\omega}$, β ($0<\beta<1$) is the liquidity of pledge.

(4) Banks determine their optimal loan interest rate after observing the behavior of 3PLs.

(5) The 3PLs supervise pledge for banks, and the banks pay corresponding supervision fee at the same time. Assume the supervision fee is proportional to the value of pledge, and that proportion is φ.

(6) Assuming that the demand of the whole finance market is a function of the ratio of enterprises' own resources and loan interest rate, that is

$$D(\alpha, r) = \theta - \mu\alpha - \sigma r \quad (1)$$

Where θ is an intrinsic value of financing amount, μ represents the sensitivity of enterprises' own resources, and σ represents the sensitivity of interest rate.

2.2 Model Building

In this Stackelberg game model of uniform credit financing business, there are only 3PLs and banks who actually participate in the game, and the 3PLs' action profile is (guarantee, not guarantee), the banks' action profile is (lend, not lend). Banks will be reluctant to lend, if 3PLs do not provide guarantee, so in order to gain benefit, the 3PLs have to provide guarantee. In this situation, there are four income profile for 3PLs and banks, they are:

① （0,0）;

② （0,0）;

③ （$(\theta-\mu\alpha-\sigma r)\frac{B(1-\alpha)}{\omega}\varphi,\ (\theta-\mu\alpha-\sigma r)B(1-\alpha)(r-\frac{\varphi}{\omega})$）;

④ （$(\theta-\mu\alpha-\sigma r)B(1-\alpha)(\frac{\varphi}{\omega}-\Delta\beta),(\theta-\mu\alpha-\sigma r)B(1-\alpha)(\Delta\beta+\frac{\beta-\varphi}{\omega}-1)$）.

Thus the expected profits of banks and 3PLs are as follows:

$$\pi_1 = (\theta-\mu\alpha-\sigma r)B(1-\alpha)[p(r-\frac{\varphi}{\omega})+(1-p)(\Delta\beta+\frac{\beta-\varphi}{\omega}-1)] \quad (2)$$

$$\pi_2 = (\theta-\mu\alpha-\sigma r)B(1-\alpha)[p\frac{\varphi}{\omega}+(1-p)(\frac{\varphi}{\omega}-\Delta\beta)] \quad (3)$$

3 Model Solutions

We use backward induction method to gain the game's Nash equilibrium. Firstly, considering the case that $\Delta\beta$ is given, and the optimal loan interest of banks is r^*. Take π_1 partial respect to r, and make it equal to zero, then we can get banks' rules of action as follows:

$$r^*(\Delta\beta)=\frac{p[\theta-\mu\alpha+(\Delta\beta+\frac{\beta}{\omega}-1)\sigma]-(\Delta\beta+\frac{\beta-\varphi}{\omega}-1)\sigma}{2\sigma p} \quad (4)$$

Substituting the Eq.(4) value into Eq.(3) , and make Eq.(3) equal to zero, we can get:

$$\Delta\beta^*=\frac{p[\theta-\mu\alpha+(1-\frac{\beta}{\omega})\sigma]-(\frac{2\varphi-\beta}{\omega}+1)\sigma}{2(p-1)\sigma} \quad (5)$$

From model assumptions we can know that $\Delta\beta=1-\frac{\beta}{\omega}$, so

$$\omega^*=\frac{2\varphi\sigma-(p-1)\sigma\beta}{p(\theta-\mu\alpha)-(p-1)\sigma} \quad (6)$$

Then substituting the Eq.(5) value into Eq.(4) , can get:

$$r^*=\frac{p(3\theta-3\mu\alpha+\frac{\beta}{\omega^*}\sigma-\sigma)-\frac{\beta}{\omega^*}\sigma+\sigma}{4\sigma p} \quad (7)$$

Finally, substituting r^* and $\Delta\beta^*$ value into π_1 and π_2, we can get:

$$\max\pi_1=\frac{B(1-\alpha)}{16p\sigma}[p(\theta-\mu\alpha-\frac{\beta}{\omega^*}\sigma+\sigma)+\frac{\beta}{\omega^*}\sigma-\sigma]^2 \quad (8)$$

$$\max\pi_2=\frac{B(1-\alpha)}{8p\sigma}[p(\theta-\mu\alpha-\frac{\beta}{\omega^*}\sigma+\sigma)+\frac{\beta}{\omega^*}\sigma-\sigma]^2 \quad (9)$$

4 Equilibrium Analysis

4.1 The Equilibrium

In the above model, the 3PLs' risk bearing ratio is required to be less than the loan interest rate, and the market demand is greater than zero, so $0<\Delta\beta^*<r$, $D(\alpha,r^*)>0$. With the increase of loan enterprises' performance probability, the risk the banks and 3PLs faced will be decreasing, thus we can get $\beta<1$, $\mu\alpha+2\sigma\frac{\varphi}{\omega}<\theta$.

The interest rate should make not only banks' profit but also market demand to be greater than zero, that is

$$\begin{cases} p(r-\frac{\varphi}{\omega})+(1-p)(\Delta\beta+\frac{\beta-\varphi}{\omega}-1)\geq 0 \\ \theta-\mu\alpha-\sigma r\geq 0 \end{cases}$$

So we can get:

$$\frac{\varphi}{p\omega} \le r \le \frac{\theta-\mu\alpha}{\sigma} \tag{10}$$

While in the traditional pledge financing mode, the 3PLs do not provide financing guarantee, so $\Delta\beta = 0$, substitute it into Eq.(4), then we can get the banks' optimal interest rate.

$$\hat{r}^* = \frac{p[\theta-\mu\alpha+(1-\frac{\beta}{\omega})\sigma]+\sigma(\frac{\varphi-\beta}{\omega}+1)}{2p\sigma} \tag{11}$$

Substituting r^* and $\hat{r}^*$ into Eq.(1) respectively, and subtracting two $D(\alpha,r)$, then the difference value is as followed:

$$\Delta D = D(\alpha,r^*) - \hat{D}^*(\alpha,\hat{r}^*) = \sigma(\hat{r}^* - r^*)$$
$$= \frac{-p[\theta-\mu\alpha+3(\frac{\beta}{\omega}-1)\sigma]+\sigma(\frac{2\varphi-\beta}{\omega}+1)}{4p} \tag{12}$$

From Eq(5)and $\Delta\beta > 0$, so $p[\theta-\mu\alpha+3(\frac{\beta}{\omega}-1)\sigma] < p[\theta-\mu\alpha+(1-\frac{\beta}{\omega})\sigma] < \sigma(\frac{2\varphi-\beta}{\omega}+1)$, thus $\Delta D > 0$, and it shows that the market demand in two-sided market is greater than one-sided market dominated by banks.

4.2 Sensitivity Analysis

The following pages will focus on analyzing influence the loan enterprises' compliance rate p has on the equilibriums above. When analyzing 3PLs' risk bearing ratio, banks' interest rate, market demand and corporate profits, we set other parameters to fixed defaults, the results shown in figure 1-4 respectively.

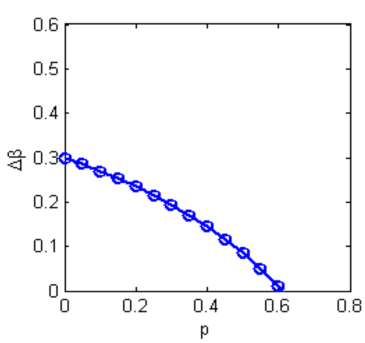


Fig.1 The influence of p on $\Delta\beta$
$(\theta=\mu=\sigma=1, \alpha=0.3, \beta=0.7, \varphi=0.15)$

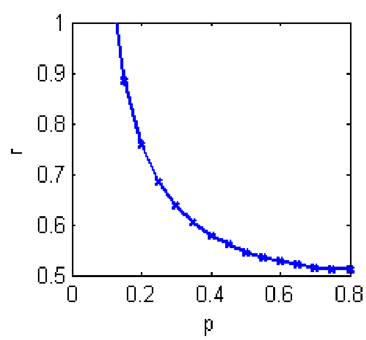
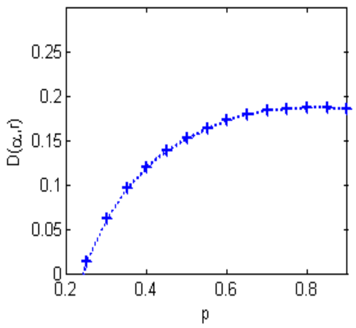


Fig.2 The influence of p on r
$(\theta=\mu=\sigma=1, \alpha=0.3, \beta=0.7, \varphi=0.15)$



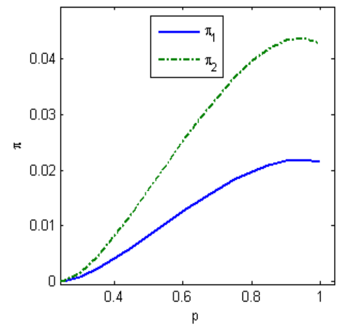


Fig.3 The influence of p on $D(\alpha,r)$ ($\theta=\mu=\sigma=1,\alpha=0.3,\beta=0.7,\varphi=0.15$)

Fig.4 The influence of p on π_1 and π_2 ($B=\theta=\mu=\sigma=1,\alpha=0.3,\beta=0.7,\varphi=0.15$)

These results indicate that the higher the loan enterprises' compliance rate p, the lower the 3PLs' risk bearing ratio and banks' interest rate. On the contrary, the market demand and corporate profits are in proportion to p.

5 Conclusions

Different from the former study, this paper puts forward a uniform credit financing mode in the two-sided framework that 3PLs decide risk bearing ratio first, then the banks decide interest rate accordingly. The result indicates that the two-sided mode can expand financing demand, flourish financing market and provide theory and practice support for the application of the uniform credit financing mode.

References

Cossin D., Huang Z J, Nerin D A, Gonzalez F. (2003). "A Framework for Collateral Risk Control Determination." *European Central Bank Working Paper*, 209:1-47.

Guo Z. Q. (2012). " Small and micro businesses' financing model based on supply chain finance——on the platform of 3PL. " *Financial Theory and Practice*, (01), 77-79.

He J, Jiang X L, Wang J. (2012). "Analysis of stackelberg game between banks and logistics enterprises in inventory financing. " *Finance and Trade Research*, (3), 125-130.

John A. Buzacott, Rachel Q. Zhang. (2004). "Inventory Management with Asset-based Financing." *Management Science*, 50(9), 1274-1292.

Leora Klapper (2004). "The Roal of Reverse Factoring in Supplier Financing of Small and Medium Size Enterprises." *World Bank*, September, 102-103.

Li Y. X., Feng G Z, Xu Y. (2007). "Research on loan-to-value ratio of inventory financing under randomly-fluctuant price." *System Engineering Theory and Practice*, 27(12), 42-49.

Ma Z. H., Zhu D L. (2011). " Research of the logistics enterprises decision-making in the inventory financing. " *Journal of Systems Engineering*, 26(03),

346-351.
Wang Y., Xu P. (2010). "The incentive mechanism of banks to 3PL considering the factor of justice preference based on FTW of principal-agent mode." *Journal of Industrial*, (01), 95-100.
Yi X. H, Zhou C. F. (2011). "Pricing decisions on inventory financing of the banks with core enterprises' buy-back guarantee." *Systems Engineering*, 29(01), 38-44.
Zhou X. N. (2010). " Financial management of supply chain. " *System Engineering*, (08), 85-88.

Analysis of International Logistics Demand in Sichuan

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Abstract: Under the background of development of international trade in Sichuan province, Sichuan province is actively developing international logistics to raise trade. International logistics demand, presents obvious growth in recent years. In this thesis, from both the macro (economic, policy, industrial, etc.) and micro (logistics, transportation operations, etc.) levels, using the method of gray correlation analyze the influencing factors of international logistics demand. Then, calculate the correlation between influencing factors and international logistics demand. Secondly, according to current situation of international logistics development of Sichuan province, analyze the trends and causes of international logistics demand change of Sichuan province and on the brief analysis of the future development trend of international logistics in Sichuan province.

Keywords: International logistics; Influencing factors; Grey correlation; Development trend.

1 Introduction

In recent years, China actively develop international trade, international logistics demand will get higher and higher. And one of the most impressive things is that China proposed building “the Silk road economic belt” and “the 21st Century Maritime Silk Road”, which means the international logistics is desperately in great demand. Thus, doing research on influencing factors of international logistics demand is contribute to promote international logistics development. In academia, Many experts and scholars study on logistics and its impact, more specifically, the relationship between regional economy and logistics. However, the study of international logistics demand and study on the affecting factors of international logistics demand is rare.

International logistics is formed on the basis of international trade development. Xiao Liang pointed out that international trade is the premise to promote the international logistics development and international logistics is a necessary condition of the development of international trade (Xiao Liang, 2013). Many scholars adopted the empirical studies on the relationship between international logistics and international trade. LI Ang used VAR model analysis the promoting function of international trade to the international logistics in different period (Li Ang, 2014). Zhang Xueliang use VECM model to explore the supply and demand equilibrium relationship between international trade and logistics (Zhang Xueliang, 2012). CHEN Yang, Button and other scholars studied on the relationship between logistics industry and international trade relations development (Chen Yang, 2013; Kenneth Button, 2003, etc.). The empirical analysis results show that there is a close relationship between international logistics and international trade, relying on each other and common development

There are obvious relationships among international logistics, international trade, regional economic development and comprehensive transportation. Wang Binyi discusses the two aspects of influence international logistics from positive factors such as the economic growth, technology development, deregulation, and barrier factors such as market competition, market barriers (Wang Binyi, 2006). Xue Bing using the grey correlation analysis of the Xinjiang international logistics demand influence factors, such as the economic development level, the freight turnover and so on (Xue Bing et al., 2013).Yang Yi using Panel–VAR and impulse response function analysis relationship between regional foreign direct investment and logistics (Yang Yi, 2014). Research results show that the more significant impact the international logistics has, the more different the Impact Angle and levels is. But the influence degree needs further research.

In conclusion, there are many studies of international logistics is more, but the researches about the specific international logistics index to measure international logistics demand levels are insufficient. This thesis will use the amount of import and export goods to measure international logistics demand levels, then discuss the influence degree of each index from regional macro-economic environment, the regional logistics development environment, and at last, give advice on regional international logistics development.

2 International logistics influence factor

In the thriving of modern logistics, under the effect of some external factors just like regional economic development, circulation trade present situation, the characteristics of industrial structure, the strength of fixed investment and logistics development environment, the regional logistics service would be obviously different. In view of the international logistics demand, it could be not only affected by the factors of regional domestic economy industry, but also the development of international trade. Therefore based on this thesis, we will combine the motivation of international logistics demand and the existing research results (Xiao Liang, 2013; Xue Bin et al., 2013; Wang Binyi, 2006), and the influence factors of international logistics demand be divided into five types, such as social economic, industrial structure, fixed investment, trade development, logistics development. The concrete impact factor analysis is as follows.

(1) Social economic

Social economy and logistic development have strong association. Social economy could have a great impact on the development of the logistics by some indexes such as GDP, PGDP, RCL (Resident Consumption Level), PCDI (per capita disposable income).

(2) Industrial structure

Industrial structure mainly performed through three times Industry increase, which reflect the status of different industries logistics demand.

(3) Fixed investment

Fixed investment intensity can reflect the investment of the construction of the regional economy, which can perfectly reflect regional future logistics development potential by using gross fixed asset formation and Transportation Investment of the whole society.

(4) Trade development

Trade development mainly includes domestic trade development and foreign economic development, which reflects the circulation situation in different extent and shows the demand for logistics.

(5)Logistics developing

Logistics developing environment mainly about Logistics infrastructure construction, which includes Logistics infrastructure and related logistics equipment, through highway, railway, aviation and other mileage and freight car ownership such and such.

3 International logistics impact analysis model

In this thesis, the grey correlation degree of each index is calculated by using the grey correlation model. Grey correlation model is a new method which can be used to study few data, poor information and uncertainty problems. Through generating, exploitation and extracting the part of the valuable information, we can achieve a correct description of system behavior, evolution and effective monitoring. The basic idea is according to the sequence curve geometry similarity to determine whether the contact closely first, and based on grey correlation space, we can use grey incidence coefficient, grey relational grade, grey incidence sequence analysis system advantage, then calculate the correlation coefficient of each scheme and ideal scheme. According to the correlation coefficient, the relational grade can be obtained. Finally, sorted according to the size of the relational grade and draw the conclusion. Grey relational grade calculating steps are:

(1) To establish the reference sequence and compared sequence

Assuming the system character as reference sequences, reference sequences is dependent variable sequences, denoted by $X_0 = \{x_0(k) \mid k = 1, 2, \ldots, n\}$;comparative sequences is variable sequences, denoted by $X_i = \{x_i(k) \mid k = 1, 2, \ldots, n\}$.

(2) Variables dimensionless

According to the grey theory, the sequence units and dimension is not unified, so, there need to use dimensionless method. The specific method is as follows:

Mean method:

$$X_i' = X_i / \overline{x_i} = (x_0 / \overline{x_0}, x_1 / \overline{x_1}, \ldots, x_m / \overline{x_m})$$

Initial value method:

$$X_i' = x_i / x_i(1) = (x_0 / x_0(1), x_1 / x_1(1), \ldots, x_m / x_m(1))$$

Standardization method:

$$X_i' = \frac{x_i(k) - \overline{x_i}}{\sqrt{var(x_i)}}$$

(3) Calculate absolute difference sequences

Absolute value of difference value between reference sequences $\Delta_0'(k)$ and comparative sequences $\Delta_i'(k)$ at the k point $(k = 1, 2, \ldots, n)$ is absolute difference sequences $\Delta_{0i}'(k)$. Calculation formula:

$$\Delta_{0i}(k) = \left| x_0'(k) - x_i'(k) \right|, \quad \Delta_i = (\Delta_{01}(k), \Delta_{02}(k), \ldots, \Delta_{0m}(k))$$

(4) Calculate maximum difference and minimum differential

$$M = \max_i \max_k \Delta_{0i}(k), \quad m = \min_i \min_k \Delta_{0i}(k)$$

(5) Calculate grey incidence coefficient

$$\gamma_{0i}(k) = (m + \varepsilon M) / [\Delta_{0i}(k) + \varepsilon M], \varepsilon \in (0.1); \quad k = 1, 2, \ldots, n; \quad i = 1, 2, \ldots, m$$

Among them, ε is resolution coefficient, which used to weaken distortion caused by the maximum value. In this thesis, the values is 0.5.

(6) Calculate grey correlation

$$\gamma_{0i} = \frac{1}{n} \sum_{k=1}^{n} \gamma_{0i}(k), i = 1, 2, 3, \ldots, m$$

4 Data Analysis

This thesis selects the indicators from 2008-2013 in Sichuan province logistics related data, comparing with the total import and export goods (Table 1).

Table 1. Sichuan province logistics related data

Type	Index	Unit	2008	2009	2010	2011	2012	2013
	international logistics freight volume	Tons	89	111	148	143	149	154
social economic	GDP	Billion	1260	1415	1719	2103	2387	2626
	PGDP	Yuan	15495	17339	21182	26133	29608	32454
	RCL	Yuan	6072	6863	8182	9903	11280	12485
	PCDI	Yuan	12633	13839	15461	17899	20307	22368
industrial structure	AGDP	Billion	222	224	248	298	330	337
	EVA of the second industry	Billion	582	671	867	1103	1233	1347
	EVA of the tertiary industry	Billion	456	520	603	701	824	942
Trade development	total volume of imports and exports	Billion USD	22	24	33	48	59	65
	total imports	Billion USD	13	14	19	29	38	42
	total export	Billion USD	90	10	14	19	21	23
	total retail sales of consumer goods	Billion	495	576	681	801	927	1036
	FDI	Billion USD	3	4	7	11	11	11
	Foreign economic turnover	Billion USD	2	3	4	5	6	6
Fixed investment	FAI	Billion	760	1202	1358	1512	1804	2105
	Transportation industry FAI	Billion	700	138	177	214	246	267
Logistics development	The railroad total mileage	10000km	0.3	0.3	0.4	0.4	0.4	0.35
	Highway mileage	10000km	22.4	24.9	26.6	28.3	29.3	30.2
	Inland river total mileage	10000km	1	1	1.1	1.2	1.2	1.2
	The civil aviation total mileage	10000km	27.9	28	37.5	40.7	48.8	53.6

According to the grey correlation analysis calculation steps, this thesis selects international logistics freight volume of Sichuan province as the reference sequence.

$X_0 = (89,111,148,143,149,154)$

Select other indicators as comparison sequence, respectively X_1 - X_{19} . According to the grey system theory, all series will be dimensionless using Initial value method. Calculate absolute difference sequences and grey incidence coefficient (Table 2).

Table 2. Grey incidence coefficient

	$\gamma_{0i}(1)$	$\gamma_{0i}(2)$	$\gamma_{0i}(3)$	$\gamma_{0i}(4)$	$\gamma_{0i}(5)$	$\gamma_{0i}(6)$
$\gamma_{01}(k)$	1.00	0.94	0.87	0.97	0.91	0.86
$\gamma_{02}(k)$	1.00	0.94	0.87	0.97	0.90	0.85
$\gamma_{03}(k)$	1.00	0.95	0.87	0.99	0.92	0.87
$\gamma_{04}(k)$	1.00	0.93	0.82	0.91	0.97	0.98
$\gamma_{05}(k)$	1.00	0.90	0.79	0.89	0.92	0.91
$\gamma_{06}(k)$	1.00	0.96	0.92	0.88	0.83	0.78
$\gamma_{07}(k)$	1.00	0.95	0.86	0.97	0.94	0.86
$\gamma_{08}(k)$	1.00	0.93	0.92	0.79	0.68	0.64
$\gamma_{09}(k)$	1.00	0.93	0.90	0.78	0.63	0.59
$\gamma_{10}(k)$	1.00	0.95	0.95	0.81	0.77	0.72
$\gamma_{11}(k)$	1.00	0.96	0.88	1.00	0.92	0.85
$\gamma_{12}(k)$	1.00	0.99	0.83	0.56	0.59	0.60
$\gamma_{13}(k)$	1.00	0.93	1.00	0.81	0.76	0.70
$\gamma_{14}(k)$	1.00	0.86	0.95	0.85	0.75	0.67
$\gamma_{15}(k)$	1.00	0.74	0.71	0.59	0.53	0.50
$\gamma_{16}(k)$	1.00	0.89	0.86	0.88	0.86	0.79
$\gamma_{17}(k)$	1.00	0.94	0.81	0.86	0.85	0.84
$\gamma_{18}(k)$	1.00	0.89	0.79	0.84	0.81	0.80
$\gamma_{19}(k)$	1.00	0.90	0.86	0.93	0.97	0.92

Then, calculate grey correlation (Table 3).

Table 3. Grey correlation

Type	Index		Type	Index	
social economic	GDP	0.9258	Logistics development	The railroad total mileage	0.8804
	PGDP	0.9227		Highway mileage	0.8836
	RCL	0.9323		Inland river total mileage	0.8544
	PCDI	0.9366		The civil aviation total mileage	0.9298
industrial structure	AGDP	0.9000	Trade development	total volume of imports and exports	0.8264
	EVA of the second industry	0.8950		total imports	0.8030
	EVA of the tertiary industry	0.9301		total export	0.8667
Fixed investment	FAI	0.8475		total retail sales of consumer goods	0.9342
	Transportation industry FAI	0.6783		FDI	0.7606

	--	--		Foreign economic turnover	0.8667

5 Discussion of Results

The results of calculations show that the correlation of the indicators are strong, and per capita disposable income has the highest correlation. The data shows that as the residents' income increase, the material demand will improve, so the logistics demand will increase, and will drive the international ascend through putting. The results show that the influence from big to small in turn is social economic, industrial structure, logistics developing, trade development and fixed investment.

The large correlation between the social economy and the international logistics quantity shows the high related degree between the local economic development and the local international logistics demand. With the regional economy development, regional logistics and international logistics demand will increase. Regional economic development reflects the social overall demand of logistics, which also affects the international logistics development. As regional social and economic growth, therefore, the international logistics will must be stronger.

In view of the index of industrial structure, the correlation degree of the third industry is the largest. With the transformation of economic development in Sichuan province and service industry development, to some extent, regional international logistics demand will increase. As a result, regional economic industrial structure adjustment will affect international logistics. These adjustments must be reasonable international logistics development level to adapt to economic development, and need to develop international logistics to adapt to changes in economic structure

In view of the logistics developing, construction of logistics infrastructure can promote the development of logistics. With the development of international logistics, international aviation logistics demand will increase, thus expanding airline mileage is a necessary condition for the promotion of international logistics development.

For trade development, domestic and international trade directly affect the level of development of regional logistics market demand. As the extent of the circulation of strengthening regional consumption, logistics demand will growth rapidly, and it will develop domestic trade and pull logistics. Therefore, with the development of foreign economic and trade, international logistics will further enhance the level of demand.

Fixed investment, to some extent, helps to stimulate economic growth, enhances regional logistics infrastructure service levels, while demand growth will help the logistics, but no significant change in the short term.

In summary, the international logistics is an important part of modern logistics. There is a close link with the various aspects of the regional social and economic. With the maturity of regional socio-economic development and logistics development environment, in improving the investment environment and trade, regional demand for external products will be further strengthened. Meanwhile, in the context of economic globalization and trade international background, international logistics will be the basis to promote international trade development support to enhance the protection of the regional economy. Therefore, enhancing the regional economic development, improving trade and investment environment, optimizing logistics and resource allocation will effectively promote the development of international logistics.

6 Conclusions

This thesis analyzes from multiple perspectives affect international demand for logistics. The comparative study of the international logistics by using grey correlation method shows that the influence of different indicators. Through the analysis we know that the regional economic, industrial and so on have a certain degree of influence on the international logistics development. By understanding their impact, we can effectively find the best way to develop international logistics. This thesis uses gray relational analysis as a research method. Among them, the reference sequence selection is yet to be further. Future research should be aimed at a number of international logistics and a number of regional social development, looking for more deep relationship, for logistics and economic development to provide good advice.

References

Chen Yang (2013). Study on Collaboration between Logistics Industry and International Trade in China, *Logistics Technology,* 32(4), 170-172.

Li Ang (2014). An Empirical Analysis of the Relationship Between International Trade and Logistics In Our Country Based on the VAR Model. *Market Modernization,* (7), 70-72.

Button K., & Taylor S. (2000). International air transportation and economic development. *Journal of Air Transport Management*, *6*(4), 209-222.

Yamaguchi K. (2008). International trade and air cargo: Analysis of US export and air transport policy. *Transportation Research Part E: Logistics and Transportation Review*, *44*(4), 653-663.

Wang Binyi. (2006). Analysis of the Factors Affecting the Development of International Logistics. *Group Economics Research,* 2006(11), 344-345.

Xiao Liang. (2013). *International Logistics*, Higher Education Press, Beijing, 5-7.

Xue Bing, Duan Xiufang, Zhang Yu (2013). Analysis of Demand of International Logistics in Xinjiang, Journal of Xinjiang Vocational University, 21(4), 16-21.

Yang Yi. (2014). Study on Dynamic Correlation between Growth of Logistics Industry and FDI in China. *Logistics Technology,* (3), 309-311.

Zhang Xueliang. (2012). Study the Interaction between Logistics and International Trade, *Journal of Commercial Economics*, 29-31.
Devlin J., Yee P. (2003). Global links to regional networks: trade logistics in MENA countries. *MENA Trade and Investment in the New Economy*, 4, 77.

Location Selection of a Great Sports Event Logistics Distribution Center Based on GIS and a Genetic Algorithm

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Abstract: The location selection of logistics distribution center is of important strategic significance to optimize modern logistics system. This kind of algorithm based on GIS and genetic algorithm is established on the basis of analysis of traditional location selection algorithm of logistics distribution center. First of all, the elementary logistics distribution center selection and its influence factors are determined. Then influence factors of location selection are analyzed by means of GIS spatial analysis techniques and a serial of candidate sites are obtained. Finally, the best logistics distribution center location was obtained on the basis of genetic algorithm. With the development of modern great sports event, it has been focused on the politics, economy and culture to great sports event. The sponsor takes importance on how to hold the great sports event successfully. So this paper studies on the location selection of great sports event logistics distribution center in combination with GIS and genetic algorithm by means of the method of theory model and example analysis. The conclusion is that the location selection of great sports event logistics distribution center based on GIS and genetic algorithm can benefit to the development of modern great sports event and provide some valuable reference theoretically and practically and shorten the cost of great sports event logistics.

Keywords: GIS; Genetic algorithm; Location selection of logistics distribution center; Spatial analysis; Great sports event.

1 Introduction

Logistics distribution center is a turning and conjunction spot of in the course of logistics distribution to those equipment and organization. It is very important strategic significance how to optimize the location selection of logistics distribution. Meanwhile, no matter what they want to construct, remake and hire distribution center. It will spend a lot of money and time to decide to select logistics distribution center location. So it is very important to location selection of logistics distribution center how to optimize the location selection of logistics distribution center. Of course, the better method of location selection of logistics distribution center is the best beneficial result from the logistics distribution center to requirement spot through assembly, transfer and distribution. However, once the location selection of logistics distribution center is improper, it will result the traffic jam, impact the normal operation of logistics distribution center and also the negative effect. In a way, it depends on the operative achievements of logistics distribution center to the advantage and disadvantage of logistics distribution center. In the fact, the location selection model of logistics distribution center is mainly divided into continuous model, dispersive model and comprehensive location selection model. To the continuous model, it might ignore the geographical feature, environmental condition and traffic status by the “centre of gravity” method. To the dispersive model, these location selection spots of logistics distribution center, they might be selected finally, are only limited to several spots and it will lose some key location selection spot. To the comprehensive location selection model, it will depend on the experience and knowledge of some experts by “Delphi” method. The subjective idea will impact the location selection of logistics distribution center and finally this kind of location selection model might be lack of the objective character. To the contrary, GIS can show relative data by the electronic map and it might eliminate improper location spot obviously. It can analyze some factors impacting location selection of logistics distribution center by quantified analysis method to reduce the subjective factor. So this paper will get some candidate location selection spots by GIS. Furthermore, it will get the best excellent spot of location selection of logistics distribution center by genetic algorithm.

On the other hand, with the development of modern society culture and economy everyone takes importance into the sports training and their own healthy, every country and department at all levels propel sports development and people healthy level to hold some great sports event (YUAN Jixue, LIU Jian, XU Fang, 2009). However, if the great sports event wants to be held successfully, it concerns a lot of factors, such as great sports event propaganda, great sports event organization and safety guarantee, especially location selection of great sports event logistics distribution center and so on. So this paper will discuss how to select the location of great sports event logistics distribution center in combination with GIS and genetic algorithm in order to propel the development of the great sports event.

2 Determination Object of Location Selection in Great Sports Event Logistics Distribution Center

The flow chart of location selection of great sports event logistics distribution center will be described in detail as follows:

Trough the flow chart of location selection of great sports event logistics distribution center in Figure 1, it might be made of seven phases. First is object of distribution center location selection. Second is data preparing by GIS mainly, such as spatial information of basic geography and dissertation information of logistics. Third is factors of impacting location selection including natural environmental factor, condition of basic facility, operational environmental factor and others. Fourth is GIS platform which is key point of spatial analysis. The main spatial analysis methods include spatial check, buffering district analysis, superimposing analysis and etc. Fifth is candidate spot of location selection and there are several possibilities to candidate spot of location selection. One is not candidate spot of location selection. Two is a series of non continuous candidate spots of location selection. Three is unique candidate spot of location selection. It might take advantage of genetic algorithm to optimize the selection of these non continuous candidate spots once it appears non continuous candidate spots of location selection. Finally the idea will be tested by investigation on the spot. So it will discuss how to optimize the location selection of logistics distribution center in modern great sports event according to above-mentioned steps (LIN Na, LI Zhi, 2010).

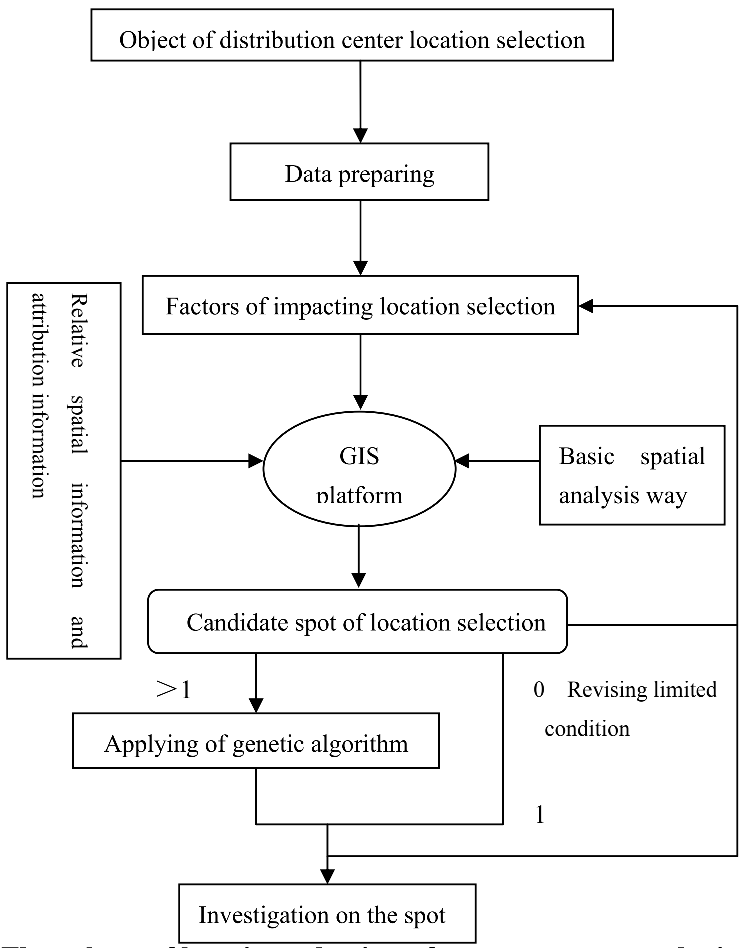

Figure 1. Flow chart of location selection of great sports event logistics distribution center

It should consider long range planning principle, basic requirement of location selection and lowest operative cost to determination object of location selection in great sports event logistics distribution center. The whole operative cost of distribution center should conclude governing cost, stock cost and transportation cost and others. In these cost, it is not close relation between the location selection of logistics distribution center in great sports event and governing and stock cost. In contrast, there are very close relation between the transportation cost and the location selection of logistics distribution center in great sports event. Of course, transportation cost includes the expense from commodity supplying base to distribution center and the expense from distribution center to requirement spots. So it is to get the lowest transportation cost to determination object of location selection in great sports event logistics distribution center.

3 Preparing Relative Data to Location Selection of Logistics Distribution Center in Great Sports Event

It needs to collect a lot of data information to location selection of logistics distribution center. Normally, it concerns some spatial information of basic geography and dissertation information of logistics in this paper. To the information, it might be figure, table and electric data information. Some data can be used immediately and the other must be converted into another formation to content GIS system (XU Fang, YUAN Jixue, JIANG Chaozhe, 2011). So it is very important to prepare relative data about location selection of logistics distribution center in great sports event and furthermore, it can also optimize the location selection of logistics distribution center.

4 Main Factors Impacting the Location Selection of Logistics Distribution Center in Great Sports Event

The location selection of logistics distribution center should consider natural environmental condition, basic equipment condition, operative environment factor and other factor according to the theory of modern logistics. In Table 1, they might also be divided into smaller index to above-mentioned four main impacting factors. Meanwhile, smaller index has own evaluation norm. Actually, there are some different traits to smaller index in different objects and it all depends on reality condition. It is hard to appear in the map to above-mentioned many factors and this paper will analyze those factors which is close relation between them and geography spatial condition by GIS.

Table 1. Main Factors Impacting the Location Selection of Logistics Distribution Center in Great Sports Event

Impacting factors	Evaluation norm
Natural environment	Meteorological condition: temperature, wind strength and direction, raining condition and etc
	Geologic condition: suitable for building requirement
	Hydrology condition: away from inundating river
	Topography condition: falling gradient placid, fitting building
Basic facilities	Traffic convenient, supplying water, electricity and gas which are content to the normal standard
Operative environment	Government policy: policy permission
	Enterprise condition around distribution center: suitable density
The others	Environment protection: protect natural and humanity environment
	Sustainable development

5 Candidate spot of location selection in great sports event logistics distribution center based on GIS

GIS platform is key point of spatial analysis. The main spatial analysis methods include spatial check, buffering district analysis, superimposing analysis and etc. Now GIS platform including ArcGIS, MapInfo has relative perfect spatial analysis function. Such as spatial check can find all enterprise around certain district to know their density, buffering district analysis can understand the condition of dweller spot, superimposing analysis can superimpose some buffering district. By these methods, there are several possibilities to candidate spot of location selection. One is not candidate spot of location selection. Two is a series of non continuous candidate spots of location selection. Three is unique candidate spot of location selection.

6 Draw the Best Location Selection of Great Sports Event Logistics Distribution Center by Genetic Algorithm

Genetic algorithm is a kind of simulating biological genetic and evolution phenomenon which the nature choice and adaptation existence are its basic principle. This kind of algorithm depends on biological evolution mechanism and genetic theory by advantage of simple encoding technology and reproducing mechanism to solve some complex problem. The steps in detail as follows: First is to determine the object function. Second is to choose encoding tactics. Third is to produce initial groups. Fourth is to set fitness function. Finally it should carry out genetic manipulation.

Mathematic model can be described as following to this question (YUAN Jixue, LIU Jian, KANG Lian, XU Fang, 2008):

$$MinC = \sum_{i=1}^{m} Fi \qquad i = 1,2,3,\cdots,m$$

Where:

F_1 means the total costs of transportation from supplying base to distribution center of great sports event logistics.

F_2 means the transportation distance from supplying base to distribution center of great sports event logistics.

F_3 means the total costs of transportation from distribution center of great sports event logistics to requirement spot.

F_4 means the transportation distance from distribution center of great sports event logistics to requirement spot.

Subject to:

It should be linear function to transportation cost from supplying base to distribution center and from distribution to requirement spot.

7 Conclusions

This paper analyzes impacting factors of great sports event logistics distribution center by GIS platform and genetic algorithm. By GIS platform some impacting factors will be analyzed and it also draws some candidate spots. Meanwhile, it also set up selection location of great sports event logistics distribution center in order to get lowest transportation cost. Finally, it might get the best location selection spots of great sports event logistics distribution center. In a long run, it will be useful of great sports event development.

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References

LIN Na, LI Zhi (2010). "Study on Location Selection of Logistics Distribution Center Based on GIS and Genetic Algorithm." *GIS Technology,* 5,110-114.

XU Fang, YUAN Jixue, JIANG Chaozhe (2011). "Dynamic Transport Routing Planning in Logistics of Sports Tour Resource Based on MAS and GIS."

ASCE, 7, 23-25.
YUAN Jixue, LIU Jian, KANG Lian, XU Fang (2008). “Research of Olympics Logistics Distribution Center Location Model under Electronic Commerce.” *ASCE*, 1, 191-196.
YUAN Jixue, LIU Jian, XU Fang (2009). “Management System of Modern Great Sport Events Transportation Based on GIS.” *ASCE*, 3, 2668-2673.

An Analysis of the Co-Integration Relationship between Port Logistics and Economic Growth in the Ningbo Region

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Abstract: In order to clarify the relationship between port logistics and economic growth, based on data of port logistics and economic development in Ningbo from 1990 to 2013, the dynamic correlation and causality between Ningbo's port logistics and economic growth has been analyzed via co-integration and Granger test. The empirical results reveal that there is a long-run stationary relation between port logistics and economic growth in Ningbo; and a unidirectional causality between the both, namely, both cargo throughput and container throughput of Ningbo port are Granger causes of economic growth, and container throughput is Granger cause of cargo throughput, not vice versa. According to the experimental results, conclusions and suggestions are put forward from the sustainable level.
Keywords: Port logistics; Economic growth; Co-integration analysis; Granger causality test.

1 Introduction

The measure of "Invigorating the city through the port, which will, in turn, stimulates the port" has become an evolving rule of port city. The development of port logistics promotes economic prosperity of its city, and economic growth provides support and guarantee for port logistics development.

In recent years, the relationship between port logistics development and economy growth has become a research focus. In the aspect of theory research, main achievements have been made by using factor endowment theory, economies of scale theory, investment multiplier theory, growth pole theory and city economic growth theory, which qualitatively clarified the interactive effects of port logistics and economic growth (Zhang, 2007; Zhang, W.B., 2007); in the aspect of empirical analysis, the existing results mainly used correlation analysis, co-integration analysis, Granger causality test to quantitatively analyze the interactive relationship between the both(Huang, 2011; Li, 2009; Liang, 2011; Liu, 2014; Shan et al., 2014; Shen, 2013; Sui, 2012; Zhou et al., 2008). The results show that, in most studies, there is a strong correlation between port logistics and city economy, the development of port logistics bring opportunities for the economy growth of its city, and meanwhile, the latter can also provide powerful support for the former.

Port is Ningbo's strategic and leading resource, after years of development, Ningbo Port has become one of the world's busiest ports. Its cargo throughput and container throughput were 0.526 billion and 1.87 million TEU in 2014, ranked fourth and fifth respectively in the world (Yang, 2015). Port logistics in Ningbo plays an important role in promoting its economic growth. By the end of 2013, Ningbo's GDP ranked 17th among 52 cities nationally (Shan, 2014) and 10th among 35 major cities as for its headquarter economic development ability (Zhou, 2014).

Nowadays, the impact of Ningbo's port logistics on its economy has become increasingly prominent; however, relevant research is relatively rare. In order to clarify their relationship, based on data of port logistics and economic development of Ningbo over the period 1990-2013, the dynamic correlation and causality between the both has been analyzed via co-integration and Granger test. According to the results, relevant suggestions are put forward from the sustainable level.

2 Variables Selecting and Data Processing

Considering time scope, representation and availability of the data aimed for co-integration analysis, as well as the indexes of port logistics and city economy chose by existing research (Huang, 2011; Li, 2009; Liang, 2011; Liu, 2014; Shan et al., 2014; Shen, 2013; Sui, 2012; Zhou et al., 2008), this paper selects port cargo throughput (denoted by PT) and container throughput (denoted by CT) as Ningbo's port logistics indexes, adopts GDP as its economy index. Original data are obtained from "Ningbo Statistical Yearbook", as shown in table 1.

Table 1. Economy and port logistics indexes of Ningbo from 1990 to 2013

Year	PT (million tons)	CT (ten thousand TEU)	GDP(billion yuan)	CPI	RGDP(billion yuan)
1990	25.54	2.20	14.14	100.00	14.14
1991	33.90	3.60	16.99	106.80	15.91
1992	43.67	5.30	21.31	119.83	17.78
1993	53.21	7.90	31.51	150.99	20.87
1994	58.50	12.50	45.97	186.47	24.65
1995	68.53	16.00	60.27	222.08	27.14
1996	76.38	20.20	78.41	245.18	31.98
1997	82.20	25.70	87.91	254.74	34.51
1998	87.07	35.30	95.28	254.23	37.48
1999	96.60	60.10	101.71	254.49	39.97
2000	115.47	90.20	114.46	255.25	44.84
2001	128.52	121.30	127.88	253.46	50.45
2002	153.98	185.90	145.33	251.43	57.80

2003	185.43	277.20	174.93	254.45	68.75
2004	225.86	400.50	210.95	261.32	80.72
2005	268.81	520.81	244.73	266.55	91.82
2006	309.69	706.79	287.44	271.61	105.83
2007	345.19	935.00	341.86	282.21	121.14
2008	361.85	1084.63	394.65	296.32	133.19
2009	383.85	943.45	432.93	294.54	146.99
2010	412.17	1300.35	516.30	305.44	169.04
2011	433.39	1451.24	605.92	321.62	188.40
2012	453.03	1567.14	658.22	327.09	201.23
2013	495.92	1677.37	712.89	334.29	213.26

In order to eliminate the influence of price on GDP, set Consumer Price Index (denoted by CPI) as 100 in 1990 and use it to deflate annual GDP so that GDP is valuable, denoted by $RGDP$, as shown in table 1. The variation trend of $RGDP$, PT and CT are shown in Figure 1, which present a nonlinear growing trend.

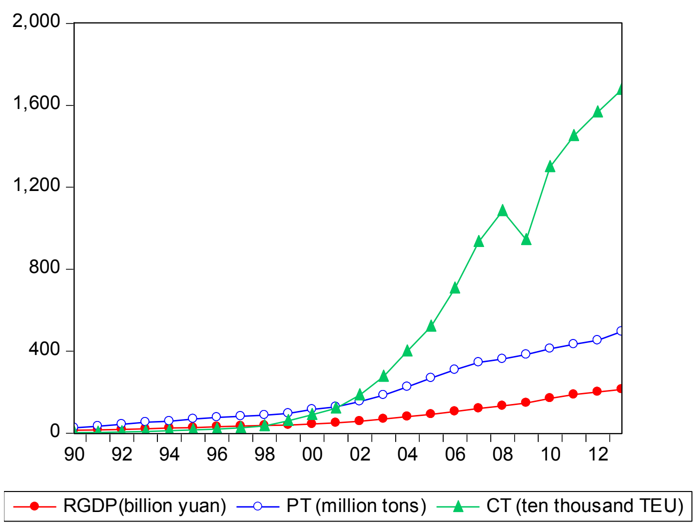

Figure 1. Time trends of three variables over 1990-2013

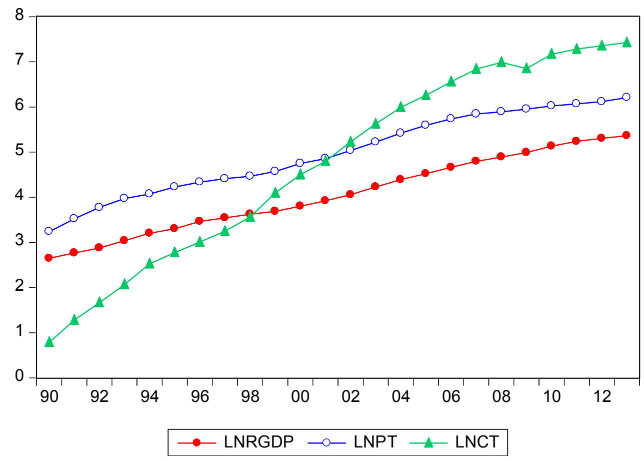

Figure 2. Time trends of natural logarithm of three variables over 1990-2013

Co-integration analysis requires all indexes perform a property of homogeneity, while economic and logistics indexes usually cannot meet the requirement. The natural logarithmic forms of these variables are used in the regressions to take into account the possibility of a nonlinear relationship between the two indexes, as well as ensure the estimated coefficients are robust to the co-integration of variables (Shan et al., 2014), therefore, this paper transformed the selected variables into natural logarithms, which denoted by $LNPT$, $LNCT$ and $LNRGDP$ respectively, and their variation trend are shown in figure 2.

3 An empirical analysis of the relationship between port logistics and economic growth in Ningbo

3.1 Stationarity test

Using econometric analysis software Eviews7.2 to test the correlation between $LNRGDP$, $LNCT$ and $LNPT$, the coefficient matrix are shown in table 2. The correlation coefficients between $LNRGDP$ and $LNPT$, $LNRGDP$ and $LNCT$ are 0.9941 and 0.9880 respectively, and the correlation coefficient between $LNPT$ and $LNCT$ is 0.9956, which means the three are closely related.

Table 2. Correlation coefficients of variables

	LNRGDP	LNPT	LNCT
LNRGDP	1	0.9941	0.9880
LNPT	0.9941	1	0.9956
LNCT	0.9880	0.9956	1

In order to avoid spurious regression caused by the nonstationarity of time series, unit root test is necessary before co-integration analysis (Cai et al., 2010). This paper adopts ADF test and the results are show in table 3. Where D is the first order difference, DD is the second order difference, and (c,t,k) are intercept term, time trend and lag terms respectively; intercept term and time trend are determined by sequence graphs, while lag terms determined by the software.

Table 3. Results of ADF test

Variables	Types(c, t, k)	ADF Statistics	Prob.*	Critical Value (5%)	Conclusion
LNRGDP	(c, t, 2)	-2.3500	0.3920	-3.6450	nonstationary
DLNRGDP	(c, 0, 0)	-2.7279	0.0854	-3.0049	nonstationary
DDLNRGDP	(0, 0, 0)	-6.6029	0.0000	-1.9581	stationary
LNPT	(c, t, 1)	-1.8820	0.6295	-3.63290	nonstationary
DLNPT	(c, 0, 0)	-2.7005	0.0898	-3.0049	nonstationary
DDLNPT	(0, 0, 0)	-4.8816	0.0000	-1.9581	stationary
LNCT	(c, t, 0)	0.5705	0.9988	-3.6220	nonstationary
DLNCT	(c, 0, 0)	-2.6398	0.1005	-3.0049	nonstationary
DDLNCT	(0, 0, 0)	-6.8430	0.0000	-1.9581	stationary

From table 3, we can know that all ADF statistics are greater than the critical value under the level test, it means that all the series are nonstationary; but all of them become stationary after second difference. Thus $LNRGDP$, $LNCT$ and $LNPT$ are second integrated series, namely $LNRGDP \sim I(2)$, $LNPT \sim I(2)$ and $LNCT \sim I(2)$. Therefore, it is necessary to conduct co-integration test.

3.2 Co-integration test

If two nonstationary time series are of the same difference, then there might be a long-term stable equilibrium relationship between them. This paper employs the E-G two-step-test to verify whether the residual series are stationary.

Firstly, regression analysis was conducted on $LNCT$ and $LNPT$, so that the long-term relationship between them can be determined, the results are as follow:

$$LNPT = 2.9929 + 0.4169 * LNCT + e1 \quad (1)$$

As can be seen, every 1% growth of container throughput devoted 0.416902% to cargo throughput growth, for container transport is one of main transport modes in Ningbo Port, thus the contribution of container throughput to GDP was covered by cargo throughput, so their contribution should be discussed respectively.

Secondly, regression analysis on $LNRGDP$, $LNCT$ and $LNPT$ was conducted, the results are as follow:

$$LNRGDP = -0.6151 + 0.9406 * LNPT + e2 \quad (2)$$

$$LNRGDP = 2.2032 + 0.3914 * LNCT + e3 \quad (3)$$

Thirdly, test stationary of the residual series. According to co-integration theory, if there exist co-integration relationship between dependent and independent variables, then residual series et that composed of the independent variable parts which cannot be explained by dependent variable are also required to be stable. There ADF is used to determine the stability of residual series and the results are shown in table 4.

Table 4. The stationary test of residual series

Variables	Difference	ADF Value	1%level	5% level	10% level	prob.*	Conclusion
e1	1	-4.1886	-2.6743	-1.9572	-1.6082	0.0002	stationary
e2	1	-3.8846	-2.6743	-1.9572	-1.6082	0.0005	stationary
e3	1	-3.1098	-2.6743	-1.9572	-1.6082	0.0035	stationary

From table 4, we can know that ADF values of residual series is less than the critical values of 1%, 5% and 10% level, therefore, it can be estimated that t residual series are stationary, and there are long-term equilibrium relationship between $LNCT$, $LNPT$ and $LNRGDP$. Besides, the results indicate a 1% increase in port cargo throughput is associated with a 0.9406% increase in per capita GDP growth; a 1% increase in container throughput devoted a 0.3914% increase to GDP. But it is not sure whether there exists causal relationship between $LNRGDP$, $LNCT$ and $LNPT$, therefore, it need to be verified by causal relationship test.

3.3 Granger causal relationship test

In this paper, using Granger test with Eviews7.2 to test whether there are causal relationship between $LNRGDP$, $LNCT$ and $LNPT$, and the lag value is 2, test results are shown in table 5.

Table 5. Results of granger casual test

Null Hypothesis:	Obs	F-Statistic	Prob.	Conclusion
LNPT does not Granger Cause LNRGDP	22	9.8366	0.0015	Accept
LNRGDP does not Granger Cause LNPT		0.3136	0.7349	Refuse
LNCT does not Granger Cause LNRGDP	22	3.8275	0.0424	Accept
LNRGDP does not Granger Cause LNCT		1.5371	0.2434	Refuse
LNCT does not Granger Cause LNPT	22	6.0816	0.0102	Accept
LNPT does not Granger Cause LNCT		1.6791	0.2160	Refuse

As is show in table 5, under the 5% of significance level, there is unidirectional causal relationship between port logistics and economic growth in Ningbo, namely cargo throughput and container throughput are Granger cause of economic growth, not vice versa. Thus port logistics has a positive effect on the host city's economic development, which is consistent with theoretical predictions, while economic growth has no direct effect on port logistics. In addition, container throughput is Granger cause of cargo throughput and not vice versa.

4 Conclusions and suggestions

As analyzed above, there is a strong association between port logistics and economic growth in Ningbo. On the one hand, the development of port logistics not only promotes the efficiency of economic operation, but also provide a guarantee for the healthy and ordered development of Ningbo's economy; on the other hand, as one of the composite industry with "linkage effect", port logistics forms a new growth pole and improves Ningbo's investment environment by multiplier effect, which directly propelled economic prosperity of Ningbo region.

However, the interaction coefficient of Ningbo's port cargo throughput to GDP is much greater than that of container throughput, which is a blow for Ningbo to construct deep pivot port and container ocean mainline port. Adding the competition from Zhoushan, Wenzhou, Shanghai and Xiamen, it is critical for Ningbo Port to focus on transformation and upgrading, enhance its container throughput status by combining ports, logistics and shipping lines as the leading part, speeding up the construction of port logistics infrastructure and promoting effective cohesion of logistics nodes, standardizing the development of port logistics industry to create a beneficial macro environment. Moreover, the government and relevant departments should take actions to guide industrial development and promote communication between the supplying and purchasing parties. In general, only policies, soft and hard environment are available and the government cooperates closely with enterprises, can port logistics benefits more for Ningbo's economic development.

Acknowledgement

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References

Cai, A.J., Zhu, C.G. (2010). "Co-integration and Granger causality test on the relationship between foreign trade and economic growth in Jiangsu coastal area." *Causality Test of Modern Property (A)*, 6, 5-7+48.

Huang, C.F., Lei, Y.， and Wu, Y. (2011). "Empirical analysis of relationship between inland transport and regional economic growth based on co-integration." Port ＆Waterway Engineering, 6, 106-111.

Li, Z.F. (2009). "Co-integration on the relationship of port logistics and economic development in the coastal region of Jiangsu province illustrated by the example of Lianyungang." Cases and Management for Science and Technology, 6, 4-7.

Liang, Y.H., Chen, W.J. (2011). "The Development of Shenzhen Port and Its Influential Factors——An Empirical Study Based on Co-integration Model." Journal of Industrial Technological Economics, 8, 14-20.

Liu, C., Zhang, J.L. (2014). "Study on Synergetic Development between Port Logistics and its Hinterland Economy in Wuhan City." Logistics Engineering and Management, 36(10), 67+107-109

Shan, J., Yu, M., and Lee, C.Y. (2014). "An empirical investigation of the seaport's economic impact: Evidence from major ports in china." Transportation Research Part E: Logistics and Transportation Review, 69(0), 41-53.

Shan, S. (2014). "Chinese cities GDP ranks in 2013." http://www.cnpop.org/popdata/otherdata/201404/00001400.html.

Shen, Q.W., Han, Z.L., and Guo J.K. (2013). "Research on the relationship between port logistics and urban economic growth: a case study of Dalian." Geography and Geo Information Science, 1, 69-73.

Sui, B.W., Zhu F.Y. (2012). "Modeligg and Analysis of Relationship between Port Logistics and Economic Growth in Guangxi Beibuwan." Logistics Technology, 31(8), 282-285.

Yang, X.X. (2015), "Ningbo Port: the bridgehead of rail-sea intermodal transport." Chinese quality news, http://www.cqn.com.cn/news/zgjyjy/1010471.html

Zhang, S.Y. (2009). An econometric analysis of the relationship between China's coastal port logistics and the economic growth. China waterway (second half), 10, 47-49.

Zhang, W.B. (2007). "Economic Geography and Transportation Conditions with Endogenous Time Distribution amongst Work, Travel, and Leisure." Journal of Transport Geography, 12, 24-43.

Zhou, J. (2014). "The headquarters economic development capacity of Ningbo ranks first phalanx nationally." Oriental net finance and economics. http://finance.eastday.com/c9/2014/0620/1453974362.html.

Zhou, P. D., Zhou, J.Q. (2008). "A study on relation between port & airport logistics and regional economic growth in three area." Journal of Guangzhou University (SOCIAL SCIENCE EDITION), 9, 45-50.

Management System Implementations and Application Research of Supply Chain Enterprise Based on Multi-Agent Technology

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Abstract: Following network popularization, many researchers paid more and more attention to the development of Electronic Commerce in twenty-first century. They hope make greatly development for goods flow and information flow which consist of factory, supplier, retailer and users which develops the management of the net information so as to make up an efficient supply chain management. The paper introduces the technique about J2EE and JADE which is needed in the system. The paper also described the mechanism of the Agents in detail.

The paper also described the mechanism of the Agents in detail. Moreover the paper describes the methods of the integration of the JADE and J2EE.The paper designs the logic design of between the J2EE and JADE and the way from the client to the Agent. Methods using JADE and J2EE technology of realizing the combination of supply chain management system of Agent technology based on the development work of chain enterprises.
Keywords: Agent; J2EE; JADE.

1 Introduction

The business model of B2B (Business to Business) in the next five years will account for more than 78% of the whole electronic commerce market. While the management of the supply chain is a key in the model of B2B. With the factors of production between each other the multiple companies can increase productivity and profits of the whole business activities. In the process of developing electronic commerce the problem about the management of the supply chain is becoming increasingly fierce. How to coordinate the relationship of manufactures, retails, supplies and customers has become a key issue for the success or failure of electronic commerce. While traditional simple management model obviously can't meet the needs of the big market. A series of complex factors, such as vast data amount, complex web of supply relationship and so on, are all affecting the benefits of every enterprise and every user. Therefore, the research on the relationship of the supply chain has a very high use value. At the same time, Multi-Agent technology is a hot topic discussed in the field of distributed artificial intelligence in recent years. Multiple Agents with autonomous and intelligent characteristics coordinate, negotiate, and collaborate together in hope of accomplishing all kinds of cooperation efficiently. It is said to be very effective. But we can't make the research on Agent technology only be stayed in the aspect of theory. We must make it be combined with modern advanced technology to solve many practical problems. The combination of Multi - Agent technology and electronic commerce is just such an attempt. We make the advanced Multi-Agent technology be limited to a specific application domain in order to do research on it. This way not only can enrich its academic value but also can solve practical problems better at the same time. It is also the purpose of academic research.

2 Implementation Technology

FIPA97 only has studied static Agent. FIPA98 begins to make specifications for Mobile Agent technology. At present the set of FIPA specifications has been already quite mature and stable. It is worth mentioning that FIPA is a specification which can be used publicly. It is not a specific application technology, but it is general technology with the aim of different application fields. It is not an independent technology, but it is a basic set of specifications. The set of specifications makes the developer be able to develop a complex system with highly cooperative ability. At present the latest public standard is FIPA 2000. By the integration of Language--Behavior (Speech Act) theory, predicate logic and common ontology, it provides a standard method for us to understand the communications between the Agents. Its basic content includes the following several aspects. The middleware supports include Agent registration, location service, communication service, mobility and security support. Agent communication languages include semantic, interaction protocol, responsibility and so on. The interactions with the local software will make enterprise legacy in system or database be wrapped up. The communication between agents with people defines the communication content and communication mode.

3 The Management System Implementations of the Supply Chain with Chain Enterprise Based on Multi-Agent Technology

3.1 Problem Description

As mentioned above, we can make the planning process in the supply chain of chain enterprise be divided into two levels, that is to say, the upper level is the preliminary planning and coordination, and the lower level is the local planning and scheduling. Next we simulate the preliminary planning process partially. We identify four Agents in the system, namely the Agent of inventory, the Agent of production, the Agent of order and the Agent of transportation. Figure 1 shows the coordination process which may appear in the coordination of preliminary planning. Among them, arc label is the coordination process, and the arrow points to the participants of the coordination from the direction of the initiators of the coordination. In addition, we introduce an intermediary Agent. Every function doesn't have the direct interaction between the Agents, and it has the direct interaction by the intermediary Agent.

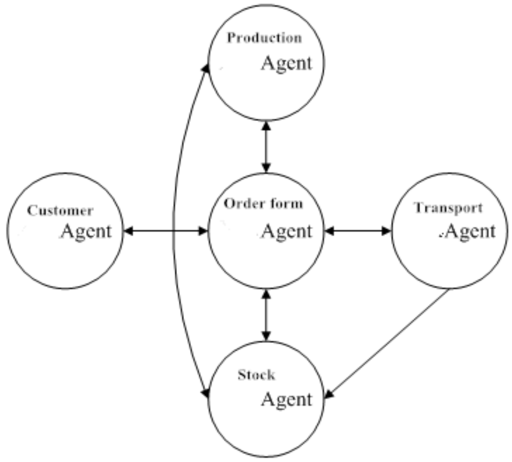

Figure 1. The Coordination Process which may appear in the Coordination of Preliminary Planning

3.2 The Implementation Mechanism of Agent

Because multiple Agents which constitute the supply chain of chain enterprise have the similar structure and implement mechanism, next we set up a general Agent model to describe its implementation process. After the Agent receives the message from other Agents in the outside, we should decide how to deal with according to the responded task list first, that is to say, we should determine which executable module. After we know how to deal with, we get the data which are needed in the process of dealing with the message from the public data area and make them be stored on the blackboard. Then we use our own knowledge to perform the current task. If it is executed successfully, we will send the executive results to the public data area. We will send a message with successful execution to the external Agent, or else we will send a message with failed execution to the external Agent, including the information with the failed reasons.

Algorithm: the message processing of the Agent.

Input: the message from external Agent.

Output: the message which is sent to the external Agent.

Methods: Step l The Agent receives the message from the external Agent. Step2 We analyzes the content of the message and determines the executable module and the needed data according to the responded task list. Step3 We extract data from public data area and make them be stored on the blackboard. Step4 With the guidance of knowledge, we perform the current task. Step5 If it needs collaboration with other Agent in the in the implementation process, then we will send the message about the requested collaboration to other Agents. Step6 If the executive task is finished. Step7 We will make the data on the blackboard be written into the public data area. Step8 We sends the task the external Agent and completes the message. Step9 If the executive task fails; we will send a message with failed execution to the external Agent.

3.3 The Management System Agent Implementations of the Supply Chain with Chain Enterprise Based on Multi-Agent Technology

3.3.1 The Technology Integration of Using J2EE and JADE

(1)The Dedicated JADE Application Server

Because JADE has become an application service project provided by the application server among the application servers which support JADE, so the support of JADE is more perfect. It can achieve seamless integration with J2EE application server. If we choose this plan, the project which is designed and developed can have high efficiency to realize the integration of design, development, and implementation. However, considering that JADE is still an open project and the standard is not entirely uniform, the first scheme refers to reducing the flexibility of the JADE to achieve its efficiency. In addition, the cost of dedicated application server is higher than the cost of general application server. And maintenance personnel must receive additional training.

(2)The Integrated JADE of General Application Server

The second scheme makes the application of JADE be combined with general application server. The application developers develop the interface of JADE and general application server so as to realize the integration of the two. In this way the developed project can be applied to the latest development environment of JADE, so the flexibility is improved. Contrary to the dedicated application server, because the build-in components which the application server has itself don't be adopted, the implementation efficiency with the application of JADE project is lower than the dedicated server. However, considering that the general application server has many technical supporters, making the integration JADE on the general application server doesn't need to spend a lot of time to train maintenance personnel again, at the same time the development of a network application system based on JADE doesn't need to make large-scale update and upgrade with the software and hardware of previous system and it also saves the costs to a certain extent. This paper adopts the second scheme to learning platform to realize the learning platform of the project.

3.3.2 The Way of the Client Access Agent

We use the client with the integrated JADE application to access Agent. Due to the openness of the J2EE platform, we can use the client with the integrated JADE application to access the Agent in the system. Because the two sides all conform to the JADE standard, in fact it is the communication model of different Agent platforms which meets the standard of JADE. This paper will not discuss deeply about this mode.

We use JSP/Servlets to access Agent. Because JADE becomes a component of the application server after it is compiled, JSP considers the Agent in the JADE to be JavaBean's access. At the same time, it gives the functions of the startup at the client side and closing Agent.

3.3.3 The Communication between Agent and EJB

Because the business logic is stored in the EJB container/server, we need the Agent of communication and EJB container server to communicate, and invoke the EJB object and accept the return results of business execution. Therefore, this paper develops corresponding communication interfaces, and respectively realizes the communication between the user and Agent and between Agent and EJB container server. The work process of communication interface can be seen as follows.

(1)The user client sends the application of invoking business logic to Agent in the web access page.

(2)The web page deals with Agent and accepts the application, and then it sends the invoking application to the Agent of communication.

(3)The Agent of communication creates a new EJB object by the Home interface of the EJB which is provided by the EJB container server.

(4)Home interface creates an EJB object and invokes the access business logic of the EJB object to perform related business operations.

(5)Home interface makes the results which the EJB object quotes be returned to the Agent of communication.

(6)The Agent of communication makes the return result with execution be given to the web page to deal with Agent.

(7)After the web page deals with Agent, it gives the return result with execution to the user.

3.4 The Deployment and Running Environment of the Supply Chain with Chain Enterprise Based on Multi-Agent Technology

The development and running environment of the supply chain with chain enterprise can be seen as follows.

Operating System: Microsoft Windows Server 2000.

Database: SQL SERVER 2000.

J2EE application server: WebLogic8.1.

The Web server: Tomcat5.0.

Java development tools: Eclipse3.1.

Among them, Eclipse is one of the best Java development tools at present. It makes the supports of J2EE and XML are go-ahead. WebLogic Server is by far the most excellent BEA application server. Tomcat is also a powerful free open source Servlet container.

As far as the deployment structure of supply chain management system is concerned, in the general situation the client only needs to install IE and doesn't need to employ other programs. Engine is deployed on the J2EE application server. The system also needs a Web server that supports JSP and Servlet. In the general situation J2EE application server and Web server can share a machine. Relational database server can be deployed on another server, and it can also share a single server with the J2EE application server or Web server.

5 Concluding

Research on traditional management system of the supply chain are often limited to a closed market environment and competitive environment. And we assume that there is a common goal between every enterprise or the entity in the supply chain so that we make the study of the management system of the supply chain be simplified into a simple hierarchical scheduling problem. However, the application environment of the actual supply chain system often conflicts with the assumptions above. First, each individual (enterprise) in the supply chain is driven by their own interests and each individual pursues to maximize their own interests.

When their own goals conflict with the overall goal of the supply chain, generally they will abandon the overall interests. Second, in the real supply chain environment, each entity in the supply chain decide to join or leave the supply-chain system at any time according to their own judgments. This paper makes Agent technology and Multi-Agent technology be introduced into the application of the management system about the supply chain to be more fit the actual operation of the supply chain. This way can make the supply chain software reflect the real status about the reality of supply chain.

This paper introduces the application and the adopted technology of the management system of the supply chain with chain enterprise based on multi-Agent technology and describes the implementation of the supply chain management system core. It analyzes FIP technology and JAD technology. It introduces the structure and function of J2EE platform. In addition, with the combination of FIP technology and AD technology, we make it be used to the application of Bokang mobile phone chain sales field.

References

Agility Forum Technical Report(1997).Next Generation Manufacturing-A Framework To Action.AgilityForum,Next Generation Manufacturing Project.

Finin T., Mckay D,Fritzson R(1994). KQML: An Information and Knowledge Exchange Protocol.KnowledgeB uilding and Knowledge Sharing, Ohmsha and IOS Press.

Finin T., Labrou Y., Mayfield J(1997). KQML as an Agent Communication Language.SoftwareA gent,M ITP ress:291-316.

Fank Plastria.Emilio Carrizosa. Optimal location and design of a competitivefacility.Mathematical Programming,2004,100(2):58-64

Joseph M, Kelly T(1996). Intelligent Supply Chain Management, Information Integration and Case Studies.The Fifth National Agility Conference,AgilityForum , (CD-ROM).

Munindar P. Singh(1998). Agent Communication Language: Rethingking the Principle s.IEEE Computer, ,Vo l.31(12):40 -47.

Weixin Yao. Logistics Network Structure and Design for a Closed-loop SupplyChain in E. Commerce. International Journal of Business Performance Management,2005(4):370-380

Mile Mismatch Correction Method of Track Geometry Data and Its Application

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Abstract: Track geometry state is one of the important indexes to measure the comfort and stability of train. However, large amount of field data analysis indicates that the mile mismatch exists in different measurement of track geometry data in the same track section, which may cause a great adverse impact on analysis and mastering the development rules of track geometry. To solve such problems, a mile mismatch correction method based on the identification of curve characteristic and track geometry data characteristic is proposed. First, according to curve characteristics and the corresponding response on track geometry data while train passes, the mile error between track geometry data and curve can be calibrated. Then, in association with the method of least-squares and dynamic programming, a mile match calculation model is built and used to match the miles of track geometry data inspected at different time in the same section. The mile match method is developed by MATLAB and tested by track geometric data from several railway lines. The practice results show that the method is accurate, efficient and reliable.

Keywords: Railway track; Track geometry; Mile mismatch; Correction method.

1 Introduction

Track geometry state is one of the important indexes to measure the comfort and stability of train. The present method to detect track geometry state includes manual inspection, static detector measurements and track geometry measurements. While the track geometry measurements hold dominant position with its detection speed and high efficiency. However, large amount of field data analysis indicates that the mile mismatch exists in different measurement of track geometry data in the same track section, which may cause a great adverse impact on analysis and mastering the development rules of track geometry. Thus, mile mismatch correction is necessary to eliminate the adverse effect brought by mile drift.

In response to this phenomenon, relevant works have been done extensively, and larger progress has been achieved. Based on the least-square method, SUI Guodong from Tongji University have calculated mileage offset for each unit section, which followed by monolithic translation to correct the mile mismatch. The formula is as follows:

$$\min U = \sum_{i=1}^{n}[Y_{1i} - Y_{2(i+x)}]^2$$
$$s.t. -200 \leq x \leq 200, x \in Z$$

XU Guiyang, a researcher at the China Academy of Railway Sciences, analyzed the mileage drift with correlation coefficient. The formula is as follows:

$$\rho(k) = \frac{\sum_{i=0}^{N-1} x_0(i) x_j(k+i-1)}{\sqrt{\sum_{i=0}^{N-1}(x_0(i))^2}\sqrt{\sum_{i=0}^{N-1}(x_j(k+i-1))^2}}$$
$$k = 1,2,\cdots,800$$

WANG Kui have made some progress in analyzing the similarity of track geometry measurements wave forms with grey theory.

Summarizing the results of the above stated three research, their shared assumption is that the mileage drift between different measurements in the same section (generally 1 km) is constant, while it's nonlinear with the increasing mileage actually. Thus, this article has presented a track geometry measurements correct method on the basis of massive measurement results.

2. The reason and characteristics of mileage drift

The mileage positioning and marking are realized through grating encoder fixed on the axle. As the rotation of wheel, grating encoder will constantly output pulse. Then position could be determined by calculating its number after the system receives the pulse. But deviation can't be eliminated because of wheel idle, slipping, wheel diameter size change caused by rail wear and random failure on grating encoder. The cumulative error may larger with increasing distance. Influences on sampling position by wheel idle and slipping will be showed in the figure below.

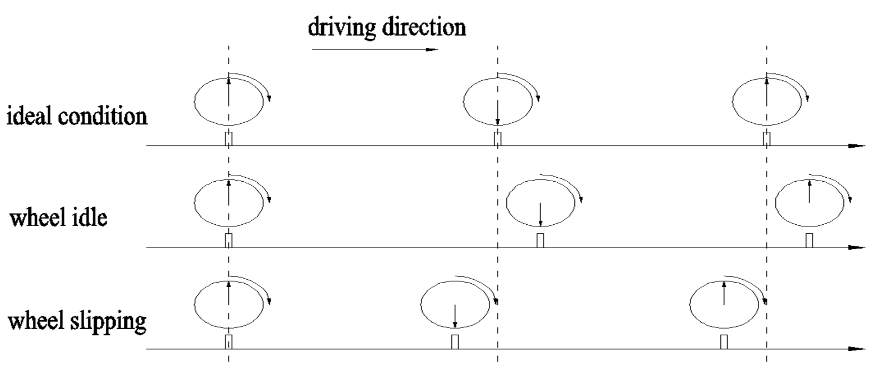

Fig.1 Influences on sampling position by wheel idle and slipping

The characteristics of mileage drift are as follows:

(1) Mileage deviation should not be neglected and the maximum deviation reaches 100m.

(2) In macroscopic view, mileage drift in the same direction as a whole while drift distance is similar for each mileage scatter within the same section.

(3) In microscopic view, the amount of drift distance is nonlinear with the increasing mileage, which means the drift distance is different in different points.

3. Mile mismatch correction method

The procedures of mileage correction include three steps: data pre-processing, mile correction based on the identification of curve characteristic and track geometry data characteristic.

3.1 Data pre-processing

Limited by test conditions, outliers, trends generally exist in test data. In order to ensure accuracy and reliability of the results, this article will eliminate outliers and trends at first.

3.2 Mile correction based on the identification of curve characteristic

Based on large data analysis, there is a one-to-one correspondence between curve and super-elevation waveform in track geometry data. The super-elevation waveform appears as trapezoid in curve section while digital fluctuations near 0 in the line section which shows in the figure below.(ZH, HY, YH and HZ respective the point of tangent to spiral, spiral to curve, curve to spiral, spiral to tangent in the picture)

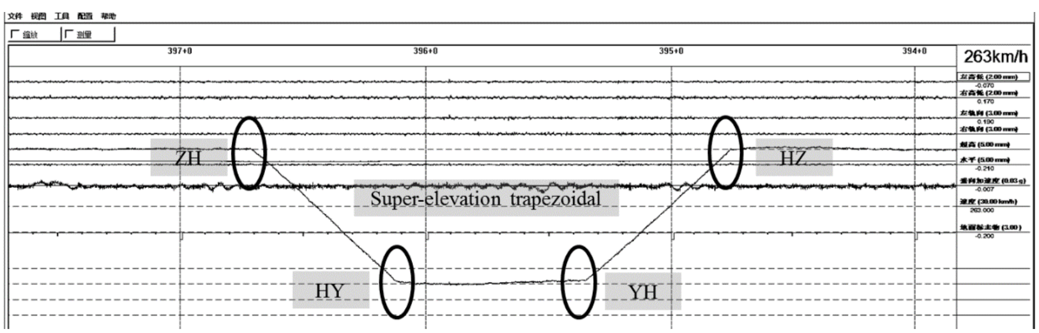

Fig.2 correspondence between curve and super-elevation trapezoidal

Based on the above analysis, super-elevation data could be used to identify the curve which followed by the mile match between identified curve and account. For the reason that mile drift with 100m which is far less than the length of the curve, adjacent curve won't be mismatched.

Name the ZH, HY, YH, HZ points as the characteristics of the curve. This four feature points can be extracted in the super-elevation wave for every curve and take the average of drift miles in ZH, HY, YH, HZ as mile correction amount. And then, based on the second characteristic of mileage drift, correct every points with this amount in this curve to establish the first match.

3.3 Mile correction based on track geometry data characteristic

Due to the deterioration on the state of track geometry is a very slow process, the change trend of track geometry state are basically identical without track maintenance or within two times of maintenance, and the mile correction based on track geometry data characteristic is feasible as a result. And railway engineer's experience and statistics showed that the gauge change smallest between several track geometry parameters in the same period. So gauge is preferred.

Based on the above analysis, in association with the method of least-squares and dynamic programming, a mile match calculation model is built and used to match the miles of track geometry data inspected at different time in the same section.

Take two adjacent track geometry data after the first match as the sample and divide the segment between adjacent feature points by number of unit section (generally 200m per section). Then the correction of every unit section will be calculated by least squares method and dynamic programming to establish the whole mile match.

Set the first track geometry measurements as the sequence $Y_1 = \{(x_1(i), y_1(i)) | i = 1,2,3,\cdots,n\}$, which is chosen as the standard sequence. Its length is the variable n. The sequence $x_1(i)$ means mileage. The sequence $y_1(i)$ means measurements. Set the second track geometry measurements as the sequence $Y_2 = \{(x_2(j), y_2(j)) | j = 1,2,3,\cdots,m\}$. Its length is the variable m. Sequences which length is n are chosen from the sequence Y_2. These sequences are set as $Y' = \{(x_2(j_g), y_2(j_g)) | j_g \in [1,m], j_g \in Z; g = 1,2,3,\cdots,n; x_2(j_{g+1}) > x_2(j_g)\}$. Find the best subsequence Y^* which has the highest similarity with Y_1 in Y' by the means of least-squares method, and Y^* should be considered as the matching result. The formula is as follows:

$$min\, U = \sum_{i,g=1}^{n} [y_2(j_g) - y_1(i)]^2 \tag{1}$$

$$Y' = \{(x_2(j_g), y_2(j_g)) | j_g \in [1,m], j_g \in Z; g = 1,2,3,\cdots,n\} \tag{2}$$

4. Instance analysis

To verify the reliability and validity of mileage correction method, a software is prepared according to the method and analysis is carried out based on a large number of measurements. Some of the results are chosen to be introduced.

Data source: measurements of Hangzhou-Changsha Line on July 31, 2014 and August 6, 2014.

In the first mileage correction, the mileage of the chosen measurements is K270~K272. Mileage drift is corrected using the super-high of the measurements, as shown in Fig.3 and Fig.4.

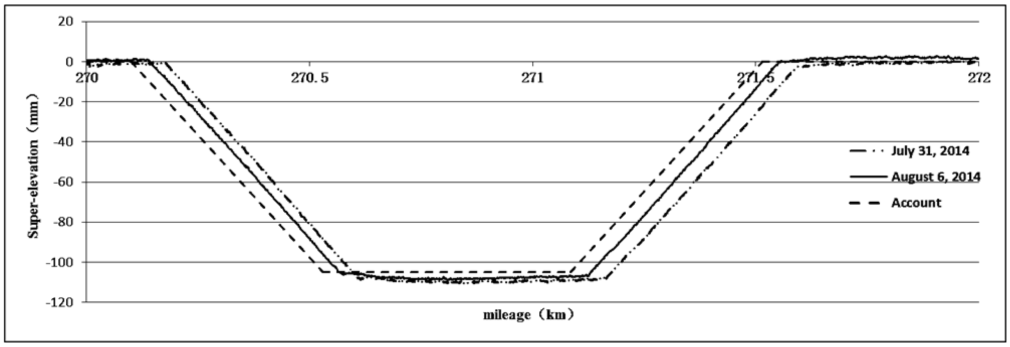

Fig.3 two measurements before the first correction

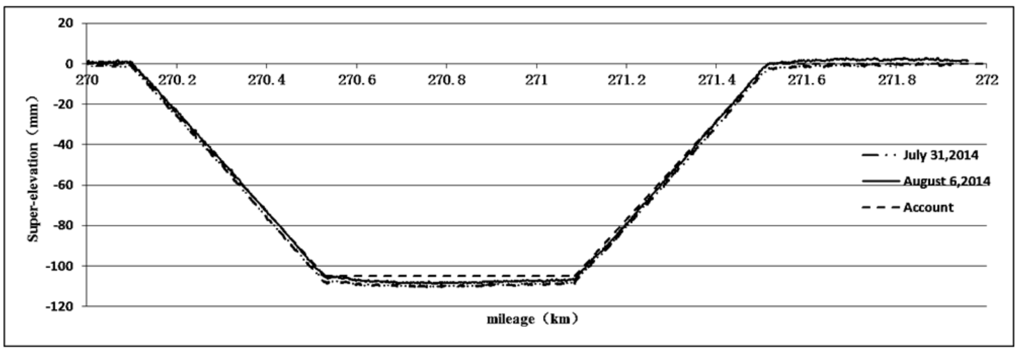

Fig.4 two measurements after the first correction

As shown in Fig.3, two measurements both have mileage drift. The mileage deviation of measurement on July 31, 2014 is 92m, while the other is 51m. Because of wheel slip and idling, the mileage deviations of different curves are different. As shown in Fig.4, two measurements match well with account after the first mileage correction.

In the second mileage correction, the mileage of the chosen measurements is K283+176~ K283+176. Mileage drift is corrected using the gauge of the measurements, as shown in Fig.5 and Fig.6.

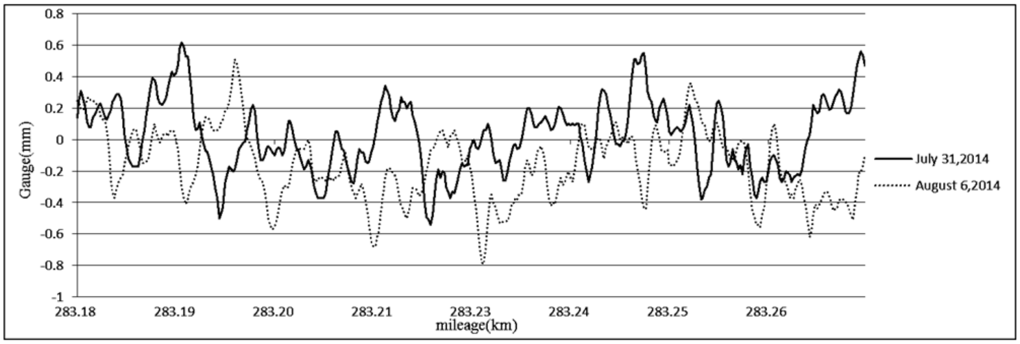

Fig.5 two measurements before the second correction

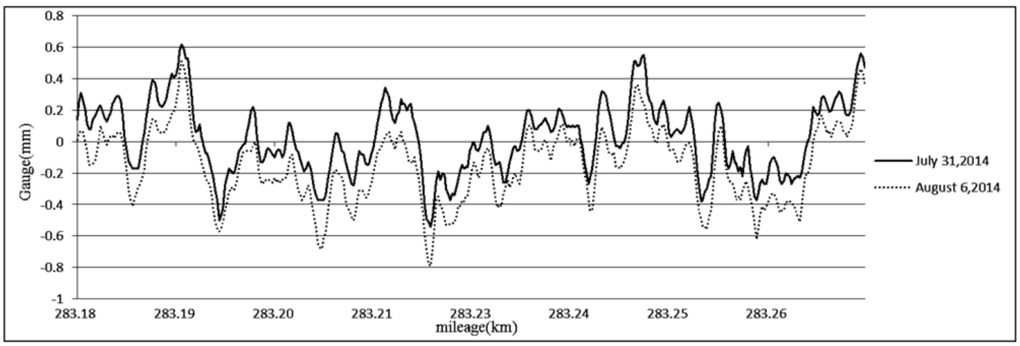

Fig.6 two measurements after the second correction

As shown in Fig.5 and Fig.6, two measurements match well after the second mileage correction, which ensures the accuracy of mileage when analyzing track geometry measurements.

5. Conclusion

For the mileage drift of track geometry measurements, a track geometry state data mileage deviation correction method is proposed. The method is based on curve characteristic parameters and identification of track geometry measurements characteristic parameters. According to several calculation results, a few times of track geometry measurements match better after mileage correction, which shows that the correction method is effective. Thus, this method will be very helpful to guide the maintenance operation, accurately analyze and grasp the development regular of track geometry measurements.

References

SUI Guodong, LI Haifeng, XU Yude(2009). "Mileage Calibration Algorithm of Track Geometry Data." *Traffic information and security*

WANG Kui(2011). "Research of Track Geometry Measurements Mileage Correction Using Grey Correlation Analysis Method." *Chinese railways*

XU Guiyang, SHI Tianyun, LIU Jinchao, QU Jianjun (2013). "Research on Automatic Preprocessing Methods For Track Geometry Inspection Data of High Speed Railway." *China railway science*

XU Peng (2012). "Mileage Correction Model for Track Geometry Data from Track Geometry Car & Track Irregularity Prediction Model." *Beijing Jiaotong University*

YU Jiawei(2014). "Study on Calculation Method of the Railway Curve Lining Based on Track Geometry Car Inspection Data." *Southwest Jiaotong University*

Turnout Geometry Linetype Design System Based on the Plane-Parameter Theory

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Abstract: Besides small radius curves and rail joints, railway turnout is one of the weak parts of railway track structure. Due to its complex geometry linetype, turnout becomes one of decisive factors to define the speed that is possible by means of the diverging route of the turnout. A sophisticated system was developed, which could effectively complete the turnout geometry linetype design and drawing. The foundational theory and the method applied in this system were described and illustrated respectively in this paper, the structure and the functions of this system were explained in detail. This system can achieve the calculation of turnout plane parameters and the drawing of its geometry linetype accurately and rapidly, so it improves the design quality and efficiency greatly.
Keywords: Turnout geometry linetype; Plane parameter theory; Design system; Structure and function.

1 Introduction

Turnout represents one of the important elements of railway infrastructures providing flexibility of the system by enabling railway trains to switch from one track to another at a railway junction. The rapid development of high-speed railway in China demands faster trains, which make turnouts sensitive to kinds of damages and increased maintenance services. Since turnout geometry linetype is the main factor influencing the speed of train passing through a turnout on the divergent route (Lichtberger B., 2005), great efforts should be made to optimize the design method of turnout geometry linetype. Many literatures have researched on the track geometry (Sadeghi J., and Askarinejad H., 2009; Shu X. G., and Wilson N., 2008) and the turnout geometry optimization (Burgarin M. R., Garcia J. M., and Diaz-de-Villegas, 1994; Burgarin M. R., Garcia J. M., and Diaz-de-Villegas, 2002). There are also some researches on track and turnout geometry measurements (Madejski J., 2005; Sadeghi J., Fathali M., and Boloukian N., 2009; Drozdziel J., and Sowinski B., 2002). However, all these studies above did not cover turnout geometry linetype design or provide automated tools to complete turnout geometry draw efficiently. In China the current calculation and draw of turnout geometry linetype depend on designer’s experiences, which is not a standard design method and leads to low efficiency and low precision especially when it is used to design a large number turnout of spiral segment. For these reasons, this paper use an appropriate method to develop the automatic design-draw system of turnout plane geometry, which makes the design work convenient and highly efficient for designers to fulfill.

2 Foundational theory and key technology

2.1 Turnout geometry linetype design

Turnout geometry linetype design includes the following steps: ①Select suitable geometry linetype, calculate the relevant parameters, and make the corresponding limiting value judgment; ②On the basis of information in ①, select a right cutting way for switch rail, a proper crossing type and a suitable sleeper distribution; ③Complete the drawing of the turnout parameters for geometry linetype, uncompensated lateral acceleration and its changing rate of the curve on the divergent track (Shi Y. J., 2001); ④Do the three steps above repeatedly before the geometry linetype design is preferable. The whole design process above provides a premise to realize a more detail design and the general draw of the turnout.

2.2 The geometry linetype selection and design method

Based on different design parameters, curve types of turnout branch can be classified into constant radius curves, clothoids and a combination of these types of curves. Small-size turnouts mainly with constant radius curve and partly with double radii curve can satisfy the safety and comfort when trains pass through turnouts. Compared with the constant radius curve, the spiral segment has some advantages: ①the curvature radius increases with the curve length increasing. Because of this, the uncompensated lateral acceleration and its changing rate descend; ②when train switches between the straight and the divergent track, the centrifugal force, the vertical and the lateral impact forces would not appear or disappear suddenly. In this situation, riding instability is avoided and the vibration is reduced, so the riding comfort is improved. As to large-size turnouts with the speed of 160km/h or more when train passes over turnout branch, the long closure rail makes it possible to apply the spiral segment. So turnouts with circle-spiral segment or spiral segment-circle-spiral segment curves are suggested in the paper.

The circle-spiral segment turnout with the spiral segment is taken as an example to describe its geometry linetype design method. One side of the turnout with circle-spiral segment curve is shown in Figure 1.

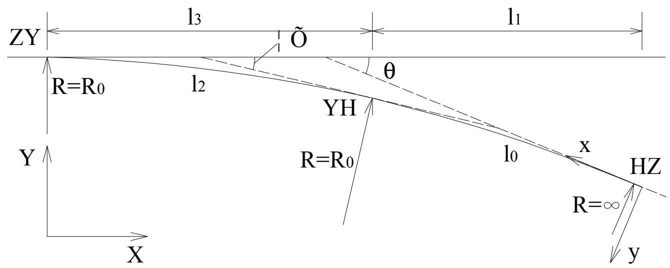

Figure 1. Geometry sketch of the turnout with circle-spiral segment curve

Where θ denotes crossing angle, which is the angle between stock rail and the tangent at point HZ, Φ is the angle between stock rail and the tangent of the constant radius curve at point YH, and is also the one between stock rail and the tangent of the spiral segment curve at the same point YH. R_0 is the radius of the constant radius curve, and is also the radius of the end of the spiral segment. As point ZY coordinate (X, Y) in the integral coordinate axis is (0, Y_0), the coordinate (X_{YH}, Y_{YH}) of point YH on the constant radius curve can be calculated as shown in formula (1).

$$\left.\begin{aligned} X_{YH} &= R_0 \sin\phi \\ Y_{YH} &= Y_0 - R_0\left(1-\cos\phi\right) \end{aligned}\right\} \quad (1)$$

If the length of the spiral segment curve is l_0, a local coordinate axis is established, of which the point HZ is the origin, the upswept direction of the tangent is x axis direction, and the downward direction being perpendicular to the x axis is y axis direction. For the cubic clothoid, the quintic and the septic spiral segment curves, the point coordinates (x_l, y_l) at the end of the spiral segment with the length l in the local coordinate axis are respectively expressed in formulas (2), (3) and (4).

$$\left.\begin{aligned} x_l &= l - \frac{l^5}{40R_0^2 l_0^2} \\ y_l &= \frac{l^3}{6R_0 l_0} \end{aligned}\right\} \quad (2)$$

$$\left.\begin{aligned} x_l &= l - \frac{l_0^3}{2R_0^2}\left(\frac{l^7}{7l_0^7} - \frac{l^8}{8l_0^8} + \frac{l^9}{36l_0^9}\right) \\ y_l &= \frac{l_0^2}{6R_0}\left(\frac{3l^4}{2l_0^4} - \frac{3l^5}{5l_0^5}\right) \end{aligned}\right\} \quad (3)$$

$$\left.\begin{aligned} x_l &= l - \frac{l_0^3}{2R_0^2}\left(\frac{25l^9}{36l_0^9} - \frac{3l^{10}}{2l_0^{10}} + \frac{14l^{11}}{11l_0^{11}} - \frac{l^{12}}{2l_0^{12}} + \frac{l^{13}}{13l_0^{13}}\right) \\ y_l &= \frac{l_0^2}{6R_0}\left(\frac{3l^5}{l_0^5} - \frac{3l^6}{l_0^6} + \frac{6l^7}{7l_0^7}\right) \end{aligned}\right\} \tag{4}$$

When $l=l_0$ in the formulas above, the (x_l, y_l) is equal to the (x_{YH}, y_{YH}), which is the local coordinate of the point YH on the spiral segment. Then by using the crossing angle θ, the (x_{YH}, y_{YH}) can be changed into the integral coordinate axis. Finally, based on the formulas (1) the coordinate of the point HZ is determined as shown in formulas (5). In the integral coordinate axis, the coordinates of all other points on the spiral segment curve can be obtained using the same method mentioned above.

$$\left.\begin{aligned} X_{HZ} &= X_{YH} + (x_{YH}\cos\theta + y_{YH}\sin\theta) \\ Y_{HZ} &= Y_{YH} - |\, y_{YH}\cos\theta - x_{YH}\sin\theta\,| \end{aligned}\right\} \tag{5}$$

The parameters of key points in the turnout geometry linetype are determined based on the formulas above, then select the right switch rail and crossing, and choose a proper layout for turnout sleepers. Finally, draw the foundational geometry linetype with the use of all the data calculated above.

2.3 Case analysis for the turnout geometry design system

Based on the design method, two cases are formulated with the premise whether the turnout number is known or not, the flowchart is shown in Figure 2.

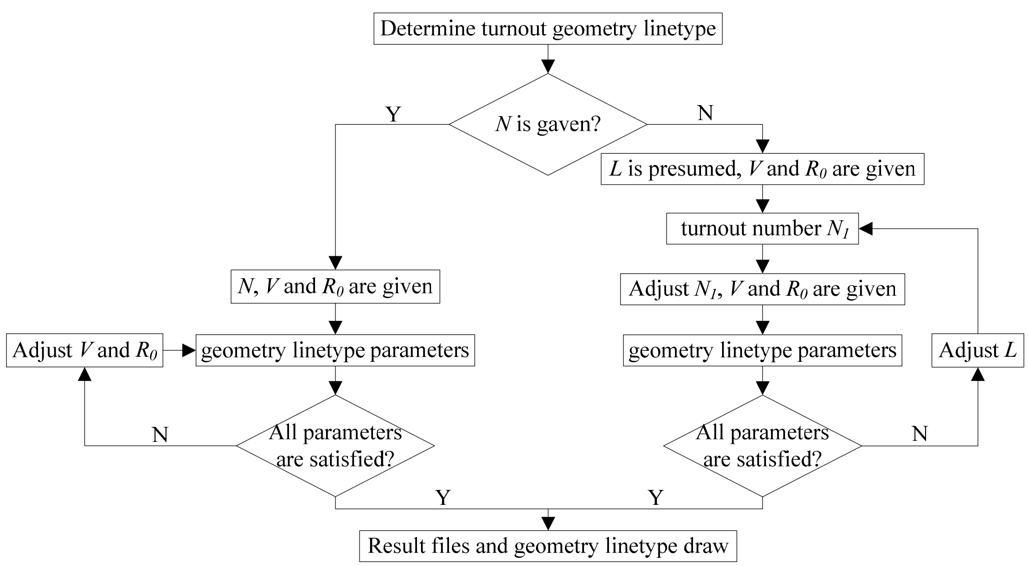

Figure 2. The flowchart for turnout geometry linetype design

(1) If the turnout number is given, the design steps are carried out according to the following steps. Step one: based on the plane-parameter method, all curve parameters involved are obtained on the basis of the speed *V* through turnout branch and the curve radius R_0. Step two: the optimal design could be obtained by evaluating all parameters from adjusting the curve radius, the cutting style of the switch rail, the crossing layout and the turnout sleeper layout. Step three: when all parameters can satisfy the stability, the geometry linetype should be draw in the end.

(2) If the turnout number is unknown, the steps are different from those in (1). Step one: the assumed curve length *L* is given, and then a turnout number is obtained with the consideration of the speed *V* through turnout branch. Step two: based on the turnout number, calculate the corresponding curve length. Step three: adjust the curve length in step two to match to the speed *V*, and then select a right curve radius to calculate a turnout number again. Don’t stop the three steps above until the design can satisfy all the requirements. Finally the geometry linetype is drawn.

3 The system function

The turnout geometry linetype design and draw system consists of the calculation module and the draw module. It can accomplish plane parameters calculation and the geometry draw for various geometries and design demands. The plane parameters are obtained by the calculation module and the results files by the draw module. Then use AutoCAD software to draw the geometry linetype. The details on the function are provided below.

Depending on whether turnout number is given or not, the system can provide geometry linetype designs for turnouts with four kinds of curves including constant radius curve, double radii curve, circle-spiral segment curve and spiral segment-circle-spiral segment curve. Some parameters including turnout geometry, number, or curve length, the radius of constant radius curve, speed through turnout branch, turnout sleeper layout, proper switch rail and nose rail, need be given by Users. According to given parameters and specific track conditions (track gauge, rail size, single crossover zone or not, and so on), the system can deal with the following five terms of work: calculate and check geometry parameters of turnout main and branch; determine switch rail cutting profile and make small-radius-curve track gauge widening design; display switch rail robust of its different parts, turnout sleeper layout; draw turnout plane geometry. The switch rail cutting profiles include five types which are semi-tangent, tangent, semi-secant, secant, and semi-tangent. The turnout sleeper layout involves three kinds which are the straight-line layout, the sector layout, and a layout being vertical to the crossing angle in the crossing zone. All the designs above show that the system provides a highly accurate tool to design and draw turnouts with various numbers and geometry fast and efficiently, which makes it convenient to fulfill turnout details design. The flowchart shown in Figure 3 outlines the steps taken in executing the system functions.

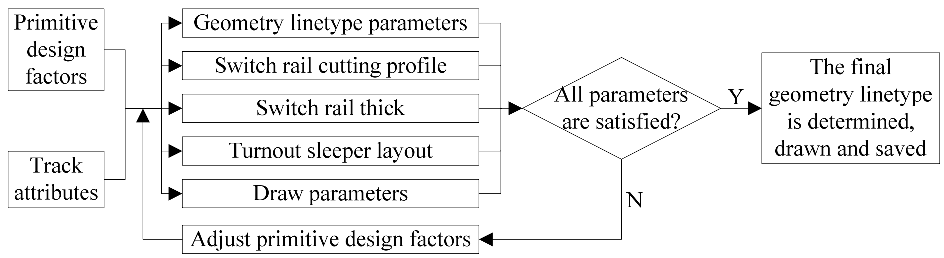

Figure 3. The flowchart of the system function operating

4 Conclusions

This system is an attempt to improve the efficiency of the current design of turnout geometry linetype. Based on plane parameters method, all analytic formulas for a variety of turnout geometry linetype are derived, and then they are solved via computer program according to two cases which are determined depending on whether turnout number is known or not. The plane parameter method is of clear derivation, easy to be grasped, and can meet the required precision of designs with all limiting values for stability design being satisfied. Due to all advantages above, this method is appropriate to be used in the initial design of turnouts.

The system interface is of great availability and high definition. The system involves most turnouts-design functions, of which the Auto draw module is quite useful to improve the efficiency and makes it possible to compare many design cases at the same time. Applied for many times, the system is greatly valuable and meaningful to turnouts design especially to the large-size turnouts with spiral segment curves. The system is a helpful tool to be widely used in turnouts design.

Acknowledgements

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References

Burgarin M. R., Garcia J. M., and Diaz-de-Villegas. (1994). “Geometric-dynamic optimization in turnout switches.” *Transactions on the Built Environment*, 6: 329-336.

Burgarin M. R., Garcia J. M., and Diaz-de-Villegas. (2002). “Improvements in railway switches.” *Proceedings of the Institution of Mechanical Engineers Part F: Journal of Rail and Rapid Transit*, 216(4): 275-286.

Drozdziel J., and Sowinski B. (2002). “Pre-processing of wheel and rail geometry in simulation software.” *Computers in Railways VIII*, 623-632.

Lichtberger B. (2005). “Track compendium.” *Eurail Press*, Germany, 363-381.
Madejski J. (2005). “Light rail, tram track and turnout geometry measurement and diagnostic tools.” *WIT Transactions on The Built Environment*, 77: 185-194.
Sadeghi J., and Askarinejad H. (2009). “An investigation into the effects of track structural conditions on railway track geometry deviations.” *Proceedings of the Institution of Mechanical Engineers Part F: Journal of Rail and Rapid Transit*, 223(4): 415-425.
Sadeghi J., Fathali M., and Boloukian N. (2009). “Development of new track geometry assessment technique incorporating rail cant factor.” *Proceedings of the Institution of Mechanical Engineers Part F: Journal of Rail and Rapid Transit*, 223(3): 255–263.
Shi Y. J. (2001). “Study on plane design parameters of turnouts for Qinghuangdao-Shengyang special passenger railway line.” *Journal of the China Railway Society*, 23(4): 94-97.
Shu X. G., and Wilson N. (2008). “Simulation of dynamic gauge widening and rail roll: effects on derailment and rolling contact fatigue.” *Vehicle System Dynamics*, 46(S): 981-994.

Transient Analysis of Track Circuits

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Abstract: In order to realize the transient analysis of track circuits, the general solution of current and voltage of each rail to earth are obtained from the Laplace transform of track circuits transmission equation. In the condition of sending end and receiving end of track circuits with arbitrary impedance, the receiving end current and voltage solution in time domain are obtained by the Laplace inverse transform. With difference of ballast resistance, frequency, transmission distance and signal resource type, the transient response of current and voltage in receiving end are simulated. It shows that the solution in time domain conform to the transmission characteristic of track circuits and provide a novel method to realize transient analysis of track circuits.
Keywords: Track circuits; Transmission equation; Solution in time domain; Laplace inverse transform.

1 Introduction

Most of studies frequently focus on the analysis of the electric quantity of track circuits receiving end in spatial domain, because track circuits operation modes are distinguished by the electric quantity of receiving end. However, when the surroundings of ballast is very bad, such as long tunnel,it is difficult to distinguish the operation modes of track circuits by the electric quantity. when the operation modes of track circuit have changed, actually , the electric quantity of track circuits receiving end transit from transient response to steady response.it is a interesting problem to study whether the operation of track circuits can be differentiated by the transient response. The key to solve this problem is how to get the transient solution of track circuits transmission line equation.

Usually, the transient solution of transmission line equation are got by analytical method and numerical method. Analytical method research is relatively less and most papers use numerical method to solve transmission line equation. Numerical methods is mainly divided into the time domain method and frequency domain method. By discreting spatial and time, the time domain method firstly gets difference equations or ordinary differential equations of transmission line partial differential equation, and the solution is obtained by iterative algorithm. According to complex frequency domain models of transmission line, the frequency domain method firstly gets the general solution of transmission line in complex frequency-domain, and the solution is obtained by inverse fast Fourier transform

(IFFT) or inverse Laplace transform (ILT) .Those methods have complex problem is that different zero and pole points with different load of track circuit make computatial difficult.

For the reason of leakage current existing between rail and earth, track circuits has a certain difference with power transmission line, so we can't adopt the general solution of power transmission line in time domain. As a result, firstly, the general solution of track circuits transmission line equation in complex frequency domain are got in this paper. Secondly, according to boundary conditions of track circuits in normal mode, propagation constant is approximately calculated with Taylor formula, and the solution of convolution type is obtained in time domain. Lastly, with difference initial parameters of track circuit, the simulation proves that this method conforms to transmission characteristic of track circuits. This method does not consider the zero and poles point and suitable for arbitrary loads of track circuit transient analysis.

2 Track circuit transmission equation

Rail line is uniform transmission line, which has two asymmetric leakage current branches. one current branch directly leaks into earth from one rail and the other flows into other rail through ballast. When the basic operation modes of track circuits are analyzed, rail line usually is regard as circuit which is consisted by three wires, two rails and earth. Rail can be regard as longitudinal impedance and mutual inductive reactance , and earth can be regard as wire with big sectional area and zero impedance. Rail line differential equivalent circuits is shown in Figure 1.

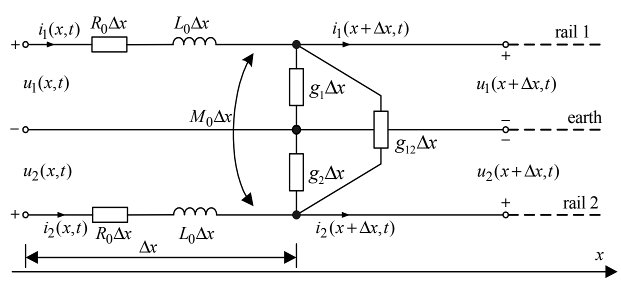

Figure 1. Differential equivalent circuits diagram of rail line

where: R_0 is singnle rail effective resistance, Ω/km ; L_0 is singnle rail internal inductance, H/km ; M_0 is mutual inductance between rail1 and rail 2, H/km ; g_1 is leakage conductance between rail1 and earth, $(\Omega\cdot\text{km})^{-1}$; g_2 is leakage conductance between rail2 and earth, $(\Omega\cdot\text{km})^{-1}$; g_{12} is leakage conductance between rail1 and rail2, $(\Omega\cdot\text{km})^{-1}$; x is the length of track circuit, km ; $i_1(x,t), i_2(x,t)$ are current of each rail to ground, A ; $u_1(x,t), u_2(x,t)$ are voltage of each rail to ground, V .

According to the KVL, the following equations are obtained:

$$u_1(x,t)-u_1(x+\Delta x,t)=\left[R_0 i_1(x,t)+L_0\frac{\partial i_1(x,t)}{\partial t}+M_0\frac{\partial i_2(x,t)}{\partial t}\right]\Delta x \tag{1}$$

$$u_2(x,t)-u_2(x+\Delta x,t)=\left[R_0 i_2(x,t)+L_0\frac{\partial i_2(x,t)}{\partial t}+M_0\frac{\partial i_1(x,t)}{\partial t}\right]\Delta x \tag{2}$$

$$i_1(x,t)-i_1(x+\Delta x,t)=\left\{g_1 u_1(x,t)+g_{12}\left[u_1(x,t)-u_2(x,t)\right]\right\}\Delta x \tag{3}$$

$$i_2(x,t)-i_2(x+\Delta x,t)=\left\{g_2 u_2(x,t)+g_{12}\left[u_2(x,t)-u_1(x,t)\right]\right\}\Delta x \tag{4}$$

Dividing both sides of Eq. 1-4 by Δx ,and when Δx approaches to zero, partial differential equations of track circuits transmission line can be expressed by:

$$\frac{-\partial u_1(x,t)}{\partial x}=R_0 i_1(x,t)+L_0\frac{\partial i_1(x,t)}{\partial t}+M_0\frac{\partial i_2(x,t)}{\partial t} \tag{5}$$

$$\frac{-\partial u_2(x,t)}{\partial x}=R_0 i_2(x,t)+L_0\frac{\partial i_2(x,t)}{\partial t}+M_0\frac{\partial i_1(x,t)}{\partial t} \tag{6}$$

$$\frac{-\partial i_1(x,t)}{\partial x}=g_1 u_1(x,t)+g_{12}\left[u_1(x,t)-u_2(x,t)\right] \tag{7}$$

$$\frac{-\partial i_2(x,t)}{\partial x}=g_2 u_2(x,t)+g_{12}\left[u_2(x,t)-u_1(x,t)\right] \tag{8}$$

Eq. 5-8 are partial differential equations with constant coefficient.Under the certain initial conditions and boundary conditions,the unique solution $u_1(x,t)$, $u_2(x,t)$, $i_1(x,t)$ and $i_2(x,t)$ can be determined. Eq. 5-8can be written to Eq. 9-12 in complex frequency domain:

$$\frac{-\mathrm{d}u_1(x,s)}{\mathrm{d}x}=\left(R_0+L_0 s\right)i_1(x,s)+M_0 s i_2(x,s) \tag{9}$$

$$\frac{-\mathrm{d}u_2(x,s)}{\mathrm{d}x}=\left(R_0+L_0 s\right)i_2(x,s)+M_0 s i_1(x,s) \tag{10}$$

$$\frac{-\mathrm{d}i_1(x,s)}{\mathrm{d}x}=u_1(x,s)\left(g_1+g_{12}\right)-u_2(x,s)g_{12} \tag{11}$$

$$\frac{-\mathrm{d}i_2(x,s)}{\mathrm{d}x}=u_2(x,s)\left(g_2+g_{12}\right)-u_1(x,s)g_{12} \tag{12}$$

The general solution of Eq. 9-12 are as follows:

$$u_1(x,s)=F_1(s)\mathrm{e}^{\gamma_1(s)x}+F_2(s)\mathrm{e}^{-\gamma_1(s)x}+F_3(s)\mathrm{e}^{\gamma_3(s)x}+F_4(s)\mathrm{e}^{-\gamma_3(s)x} \tag{13}$$

$$u_2(x,s)=F_1(s)\mathrm{e}^{\gamma_1(s)x}+F_2(s)\mathrm{e}^{-\gamma_1(s)x}-F_3(s)\mathrm{e}^{\gamma_3(s)x}-F_4(s)\mathrm{e}^{-\gamma_3(s)x} \tag{14}$$

$$\begin{aligned} i_1(x,s)=&\frac{-1}{ZB_1(s)}F_1(s)\mathrm{e}^{\gamma_1(s)x}+\frac{1}{ZB_1(s)}F_2(s)\mathrm{e}^{-\gamma_1(s)x}\\ &-\frac{1}{ZB_2(s)}F_3(s)\mathrm{e}^{\gamma_3(s)x}+\frac{1}{ZB_2(s)}F_4(s)\mathrm{e}^{-\gamma_3(s)x}\end{aligned} \tag{15}$$

$$i_2(x,s)=\frac{-1}{ZB_1(s)}F_1(s)e^{\gamma_1(s)x}+\frac{1}{ZB_1(s)}F_2(s)e^{-\gamma_1(s)x}+\frac{1}{ZB_2(s)}F_3(s)e^{\gamma_3(s)x}-\frac{1}{ZB_2(s)}F_4(s)e^{-\gamma_3(s)x} \tag{16}$$

where: $\gamma_1(s)=\sqrt{ks+b}$, $\gamma_2(s)=-\sqrt{ks+b}$, $\gamma_3(s)=\sqrt{ms+c}$, $\gamma_4(s)=-\sqrt{ms+c}$, $k=(M_0+L_0)g_1$

$b=R_0g_1$, $k=(M_0+L_0)g_1$, $m=(L_0-M_0)(g_1+g_{12})$, $c=R_0(g_1+g_{12})$, $ZB_1=\frac{\gamma_1(s)}{g_1}$, $ZB_2=\frac{\gamma_3(s)}{2g}$, $g=0.5(g_1+2g_{12})=r_d^{-1}$. g is leakage conductance of ballast, $(\Omega\cdot\text{km})^{-1}$; r_d is ballast resistance, $\Omega\cdot\text{km}$. Eq. 9-12 are the general solution of current and voltage of each rail to ground in complex frequency domain.Accoding to the boundary conditions of track circuits operation modes, $F_1(s)$, $F_2(s)$, $F_3(s)$ and $F_4(s)$ can be determined.

3 Complex frequency-domain solution of track Circuits in normal operation

Equivalent mode of track circuits in complx frequency-domain is shown in Figure 2. Two rail sections of length l with arbitrary terminal loads $Z_1(s)$ and $Z_L(s)$ and excited by the source $u_s(s)$.

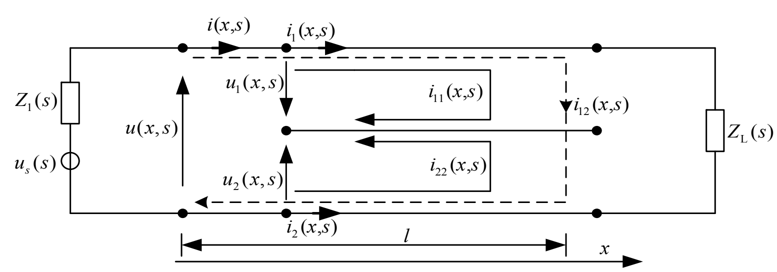

Figure 2. Equivalent mode of track circuits in complx frequency-domain

Based on loop circuit method,the following equation are appropriate for a symmetrical track circuits:

$i_{11}(x,s)=i_{22}(x,s)$; $i(x,s)=i_{12}(x,s)$; $i_1(x,s)=i_{11}(x,s)+i_{12}(x,s)$; $i_2(x,s)=i_{22}(x,s)\quad -i_{12}(x,s)$.

Thus,the $u(x,s)$ and $i(x,s)$ can be expressed as:

$$\begin{cases} u(x,s)=u_1(x,s)-u_2(x,s) \\ i(x,s)=\frac{1}{2}\left[i_1(x,s)-i_2(x,s)\right] \end{cases} \tag{17}$$

Substitution of Eq.13-16 into Eq. 17 yields:

$$\begin{cases} u(x,s) = 2F_3(s)e^{\gamma_3(s)x} + 2F_4(s)e^{-\gamma_3(s)x} \\ i(x,s) = \frac{1}{ZB_2(s)}\left[F_4(s)e^{-\gamma_3(s)x} - F_3(s)e^{\gamma_3(s)x}\right] \end{cases} \tag{18}$$

When $x = 0$,we have

$$\begin{cases} u(0,s) = 2F_3(s) + 2F_4(s) \\ i(0,s) = \frac{1}{ZB_2(s)}\left[F_4(s) - F_3(s)\right] \end{cases} \tag{19}$$

When $x = l$,we have

$$\begin{cases} u(l,s) = 2F_3(s)e^{\gamma_3(s)l} + 2F_4(s)e^{-\gamma_3(s)l} \\ i(l,s) = \frac{1}{ZB_2(s)}\left[F_4(s)e^{-\gamma_3(s)l} - F_3(s)e^{\gamma_3(s)l}\right] \end{cases} \tag{20}$$

According to Figure 2,the following expression are obtained based on KVL:

$$\begin{cases} u(0,s) = u_s(s) - i(0,s)Z_1(s) \\ u(l,s) = i(l,s)Z_L(s) \end{cases} \tag{21}$$

Substitution of Eq. 19 and 20 into Eq. 21 yields:

$$\begin{cases} 2F_3(s) + 2F_4(s) = u_s(s) - \frac{Z_1(s)}{ZB_2(s)}\left[F_4(s) - F_3(s)\right] \\ 2F_3(s)e^{\gamma_3(s)l} + 2F_4(s)e^{-\gamma_3(s)l} = \frac{Z_L(s)}{ZB_2(s)}\left[F_4(s)e^{-\gamma_3(s)l} - F_3(s)e^{\gamma_3(s)l}\right] \end{cases} \tag{22}$$

The solution of Eq. 22 is:

$$\begin{cases} F_3(s) = \frac{n_2(s)k(s)u_s(s)}{e^{2\gamma_3(s)l} - n_1(s)n_2(s)} \\ F_4(s) = \frac{k(s)u_s(s)e^{2\gamma_3(s)l}}{e^{2\gamma_3(s)l} - n_1(s)n_2(s)} \end{cases} \tag{23}$$

where $n_1(s)$ is the incidention coefficient, which is defined as:

$$n_1(s) = \frac{Z_1(s) - 2ZB_2(s)}{2ZB_2(s) + Z_1(s)}.$$

$n_2(s)$ is the reflection coefficient , which is defined as:

$$n_2(s) = \frac{Z_L(s) - 2ZB_2(s)}{2ZB_2(s) + Z_L(s)}.$$

$k(s)$ is defined as:

$$k(s) = \frac{ZB_2(s)}{2ZB_2(s) + Z_1(s)}.$$

Substituting Eq. 23 into Eq. 18 ,we get:

$$\begin{cases} u(x,s) = \dfrac{e^{-\gamma_3(s)x} + n_2(s)e^{-\gamma_3(s)(2l-x)}}{1 - n_1(s)n_2(s)e^{-2\gamma_3(s)l}} \cdot k(s) \cdot u_s(s) \\ i(x,s) = \dfrac{e^{-\gamma_3(s)x} - n_2(s)e^{-\gamma_3(s)(2l-x)}}{1 - n_1(s)n_2(s)e^{-2\gamma_3(s)l}} \cdot \dfrac{k(s) \cdot u_s(s)}{ZB_2(s)} \end{cases} \tag{24}$$

3 Transient Analysis of Track Circuits in Normal Operation

Based on Taylor formula, propagation function $\gamma_3(s)$ and surge impedance can be approximated as:

$$\gamma_3(s) = \sqrt{c}\sqrt{\frac{m}{c}s + 1} \approx \sqrt{c} + \frac{m}{2\sqrt{c}}s \tag{25}$$

$$ZB_2(s) \approx \frac{\sqrt{c}}{2g} + \frac{m}{4g\sqrt{c}}s \tag{26}$$

$Z_1(s)$ can be defined as:

$$Z_1(s) = a + bs \tag{27}$$

$Z_L(s)$ can be defined as:

$$Z_L(s) = a_1 + b_1 s \tag{28}$$

Substituting Eq.25-28 into $n_1(s)$ and $n_2(s)$,respectively, the following explicit formulas for $n_1(s)$ and $n_2(s)$ are obtained:

$$n_1(s) = k_0 \cdot \frac{1 + k_1 s}{1 + k_2 s} \tag{29}$$

$$n_2(s) = m_0 \cdot \frac{1 + m_1 s}{1 + m_2 s} \tag{30}$$

where the following definitions are used:

$$k_0 = \frac{ga - \sqrt{c}}{ga + \sqrt{c}}; k_1 = \frac{2gb\sqrt{c} - m}{2gb\sqrt{c} - 2c}; k_2 = \frac{2gb\sqrt{c} + m}{2gb\sqrt{c} + 2c}; m_0 = \frac{ga_1 - \sqrt{c}}{ga_1 + \sqrt{c}}; m_1 = \frac{2gb_1\sqrt{c} - m}{2gb_1\sqrt{c} - 2c};$$
$$m_2 = \frac{2gb_1\sqrt{c} + m}{2gb_1\sqrt{c} + 2c}.$$

For the convenience of calculation, Eq. 25 can be writed as:

$$\begin{cases} u(x,s) = \dfrac{P_1(s) + P_2(s)}{1 - P_3(s)P_4(s)} \cdot k(s) \cdot u_s(s) \\ i(x,s) = \dfrac{P_1(s) - P_2(s)}{1 - P_3(s)P_4(s)} \cdot k_i(s) \cdot u_s(s) \end{cases} \tag{31}$$

where $P_1(s)=\mathrm{e}^{-\gamma_3(s)x}$, $P_2(s)=n_2(s)\mathrm{e}^{-\gamma_3(s)(2l-x)}$, $P_3(s)=n_1(s)n_2(s)$, $P_4(s)=\mathrm{e}^{-2\gamma_3(s)l}$, $k_i(s)=k(s)/ZB_2(s)$.

When $|\xi|<1$, $(1-\xi)^{-1}=1+\xi+\xi^2+\ldots\xi^n=\sum_{n=0}^{\infty}\xi^n$,due to $P_3(s)P_4(s)<1$, Eq.25 can be expressed as:

$$\begin{cases} u(x,s)=[P_1(s)+P_2(s)]\cdot\left[1+P_3(s)P_4(s)+\left[P_3(s)P_4(s)\right]^2+\ldots+\left[P_3(s)P_4(s)\right]^n\right]k(s)u_s(s) \\ i(x,s)=[P_1(s)-P_2(s)]\cdot\left[1+P_3(s)P_4(s)+\left[P_3(s)P_4(s)\right]^2\ldots+\left[P_3(s)P_4(s)\right]^n\right]k_i(s)u_s(s) \end{cases} \quad (32)$$

According to ILT ,the following inverse Laplace transform pairs exist:

$$P_1(t)=L^{-1}\left[P_1(s)\right]=\frac{1}{2}x\sqrt{m}\pi^{-\frac{1}{2}}t^{-\frac{3}{2}}\exp\left(-\frac{mx^2}{4t}-\frac{ct}{m}\right);$$

$$P_4(t)=L^{-1}\left[P_4(s)\right]=\frac{1}{2}l\sqrt{m}\pi^{-\frac{1}{2}}t^{-\frac{3}{2}}\exp\left(-\frac{ml^2}{4t}-\frac{ct}{m}\right);$$

$$P_3(s)=k_0m_0\left[\frac{1}{(1+k_2s)(1+m_2s)}+\frac{(k_1+m_1)s}{(1+k_2s)(1+m_2s)}+\frac{k_1m_1s^2}{(1+k_2s)(1+m_2s)}\right],$$

$$P_3(t)=L^{-1}\left[P_3(s)\right]=\frac{k_0m_0}{k_2-m_2}\left[(1-\frac{k_1+m_1}{k_2}+\frac{k_1m_1}{k_2^{\,2}})e^{-\frac{1}{k_2}t}-(1-\frac{k_1+m_1}{m_2}+\frac{k_1m_1}{m_2^{\,2}})e^{-\frac{1}{m_2}t}\right];$$

$$n_2(t)=L^{-1}(m_0\cdot\frac{1+m_1s}{1+m_2s})=\frac{m_0m_1}{m_2}\delta(t)-\frac{m_0(m_2-m_1)}{m_2^{\,2}}\left[e^{-\frac{1}{m_2}t}\right];$$

$$P_2(t)=\left[\frac{m_0m_1}{m_2}\delta(t)-\frac{m_0(m_2-m_1)}{m_2^{\,2}}e^{-\frac{1}{m_2}t}\right]*\left[\frac{1}{2}(2l-x)\sqrt{m}\pi^{-\frac{1}{2}}t^{-\frac{3}{2}}\exp\left(-\frac{m(2l-x)^2}{4t}-\frac{ct}{m}\right)\right];$$

$$k(t)=L^{-1}\left[k(s)\right]=\frac{q_0q_1}{q_2}\delta(t)-\frac{q_0}{q_2^{\,2}}\left[(q_2-q_1)e^{-\frac{1}{q_2}t}\right];$$

$$k_i(t)=L^{-1}\left[k_i(s)\right]=\frac{2q_0g}{q_2\sqrt{c}}e^{-\frac{t}{q_2}}$$

Where:

$$q_0=\frac{\sqrt{c}/2g}{a\ +\sqrt{c/g}},\ q_1=\frac{m}{2c},\ q_2=\frac{2gb\sqrt{c}+m}{2ga\sqrt{c}+2c}.$$

As a result, transient solution of Eq.32 are given by the form of convolution:

$$\begin{cases} u(x,t)=[P_1(t)+P_2(t)]*\left[\delta(t)+P_3(t)*P_4(t)+\left[P_3(t)*P_4(t)\right]^2+\ldots\left[P_3(t)*P_4(t)\right]^n\right]*k(t)*u_s(t) \\ i(x,t)=[P_1(t)-P_2(t)]*\left[\delta(t)+P_3(t)*P_4(t)+\left[P_3(t)*P_4(t)\right]^2+\ldots\left[P_3(t)*P_4(t)\right]^n\right]*k_i(t)*u_s(t) \end{cases} \quad (33)$$

In this section, two examples are provides to illustrate the transient solution of track circuits meet the character of track circuits.

Example1:we assume following parameters for track circuits: rail type P_{60} ; $a = 1\Omega$; $n = 3$; $f = 1\text{kHz}$; $b = 1\times10^{-5}\,\text{H}$; $a_1 = 10\Omega$; $b_1 = 2\times10^{-5}\,\text{H}$; $l = 1\text{km}$; $u_s = 10\sin(\omega t)$. With different of ballast resistance, the transient response of current and voltage in receiving end are shown in Figure 3 and Figure 4. With different of frequency, the transient response of current and voltage in receiving end are shown in Figure 5 and Figure 6.

The attenuation constant α and phase constant β are defined as:

$$\begin{cases} \alpha = \sqrt{\dfrac{1}{2\cdot rd}\left(\sqrt{R_0{}^2 + \omega^2 L_0{}^2} + R_0\right)} \\ \beta = \sqrt{\dfrac{1}{2\cdot rd}\left(\sqrt{R_0{}^2 + \omega^2 L_0{}^2} - R_0\right)} \end{cases} \tag{34}$$

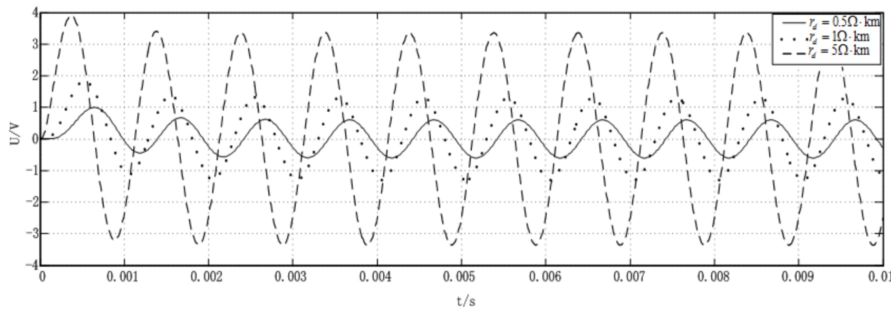

Figure 3. The transient response of voltage in receiving end with different ballast resistances

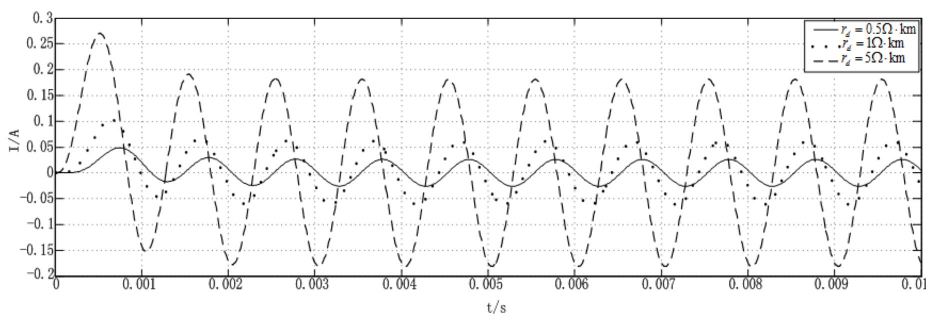

Figure 4. The transient response of current in receiving end with different ballast resistances

From the Eq.34 we know that, when the ballast resistance rd increases, the attenuation constant α and phase constant β decreased. According to wave velocity $v = \omega/\beta$, wave velocity increases with the ballast resistance. The results of Figure3 and Figure4 completely meet this law. Figure 3 and Figure 4 also show that ballast resistance is smaller, the waveform distortion is greater and the steady state response time is longer.

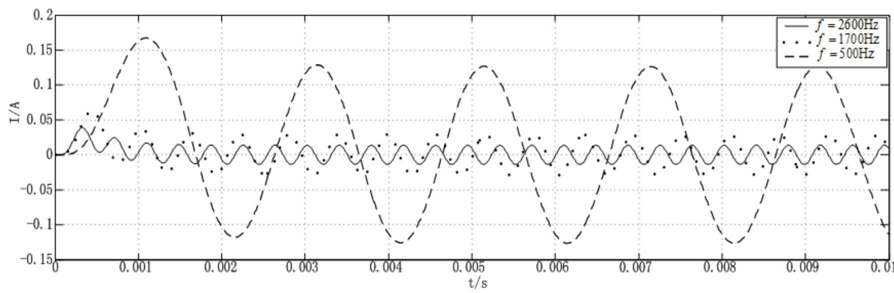

Figure 5. The transient response of voltage in receiving end with different of frequency

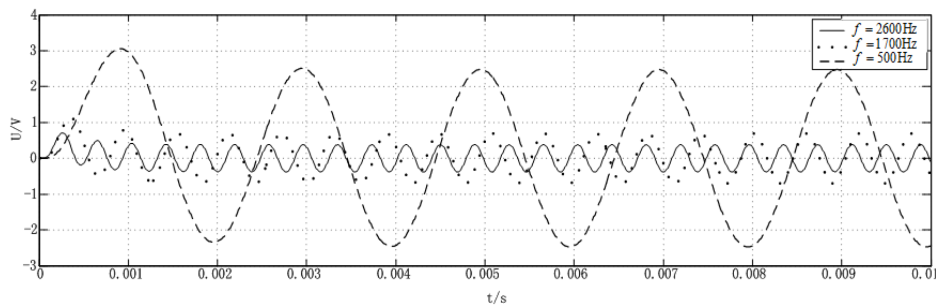

Figure 6. The transient response of current in receiving end with different of frequency

According to Eq.34 ,with the increasing of frequency, the attenuation constant α increase,and the results of Figure 5 and Figure 6 completely meet this law. Figure 5 and Figure 6 also show that frequency is higer, the waveform distortion is smaller and the steady state response time is longer.

Example2:we assume following parameters for track circuits: rail type: P_{60} ; $a = 1\Omega$; $n = 3$; $b = 1\times10^{-5}\,\mathrm{H}$; $a_1 = 10\Omega$; $b_1 = 2\times10^{-5}\,\mathrm{H}$; $l = 1\mathrm{km}$; $f = 1\mathrm{kHz}$; ballast resistance $1\Omega\cdot\mathrm{km}$.

The resouce is rectangular pulse signal shown as Figure 7 .With different of ballast resistance, the transient response of voltage in receiving end and middle are shown in Figure 8.

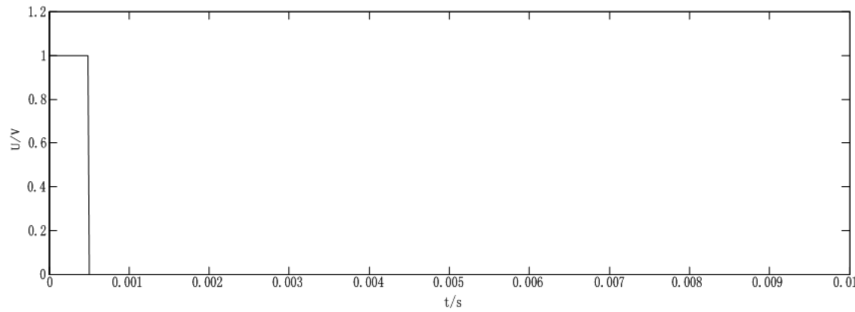

Figure 7. Rectangular pulse signal

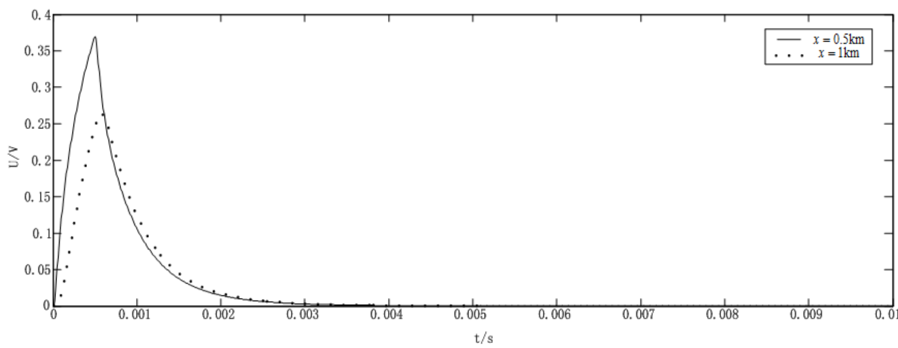

Figure 8. The transient response of rail surface voltage in different points

In the process of voltage wave transmission from middle of track circuits to receiving end, we note that the waveforms of voltage is distorted and attenuate by examining Figure 8.

Example1 and example2 prove that solution in time domain conform to the transmission characteristic of track circuits.

4 Conclusions

The general solution of current and voltage of each rail to ground are obtained from the Laplace transform of track circuits transmission equation，when sending end and receiving end of track circuits load arbitrary impedance,and the solution in time domain of current and voltage of rail surface in receiving end are obtained.At the same time,the following conclusion are valide:

(1) Wave velocity of current or voltage increases with the ballast resistance.

(2) If ballast resistance is smaller, the waveform distortion is greater and the steady state response time is longer.

(3) If frequency is higer, the waveform distortion is smaller and the steady state response time is longer.

(4) rectangular pulse signal has heavily distorted and attenuate.

(5)The simulation conform to the transmission characteristic of track circuits, which prove that this method is suitable to analyze trancient of track circuits.

Acknowledgement

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References

Antonio Orlandi, Clayton R. Paul. (1996). " FDTD analysis of lossy multiconductor trans-mission lines terminated in arbitrary loads." *IEEE Trans. Electromagn. Compat.* 38 ,388-398.

Edward C. Chang, Sung-Mo Kang. (1992). " Computationally efficient simulation of a lossy transmission line with skineffect by using numerical inversion of laplace transform." *IEEE Trans On CAS-I* **39** ,861-868.

Frederick M.Tesche. (2007) . "Development and use of the BLT equation in the time domain as applied to a coaxial cable." *IEEE Trans. Electromagn. Compat.* 49,3-11.

Frita Oberhettinger,Larry Badii.(1973). "Tables of Laplace transforms." *Spronger-Verlag Berlin Heidellberg, New York*.pp.258.

GUO Yu-shun. (2002). "Transmission Line Model for Transient Simulation Derived Using the NILT Technique. "*Acta Electronica Sinica.* 30,381-385.

J. A. Roden, C. R. Paul, W. T. Smith, S. D. (1996) . Gedney. "Finite difference time domain analysis of lossy transmission lines." *IEEE Trans. Electromagn. Compat.* 38 ,15-24.

Wang Wei ,Zhou Dong-ming, Liu Pei-guo etal. (2013). "transient analysis of transmission line with arbitrary loads based on the split-step Crank-Nicolson-FDTD method. " *Journal of Electronics & Information Technology* 235, 209-214.

ZHANG You-peng, ZHAO Bin, TIAN Ming-xing . (2012). "Transmittal signal frequency of centre-fed ballastless track circuit," *Journal of Southwest Jiaotong University.*47 ,7-11.

ZHANG You-peng,ZHAO Bin,TIAN Ming-xing,etal. (2012). " Study on the maximum transmission distance of centre-fed boundless track circuits." *Journal of the China Railway Society* 34 ,65-69.

Fuzzy Comprehensive Evaluation of Risks in Subway Station Construction

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Abstract: In accordance with the theory of accident cause and system safety, this paper systematically analyzes various risks in subway station construction and divides them into four categories. They are: (1) risks of construction environment (including architectural complex environment, hydro-geological environment, meteorological environment, traffic flow, etc.); (2) risks of construction technique (including deformation monitoring, special safety program, safety disclosure, etc.); (3) risks of construction organization (including personnel, safety system, safety mechanism, safety culture, etc.); (4) special risks (including template, scaffold, support, electricity, hoisting, towering machine, etc.). Moreover, the paper analyzes and determines the methods and standards to judge the severity level (including slight, great, serious, very serious, and disastrous) and probability level (including very likely, likely, occasional, unlikely, and very unlikely), to research the method of calculating every single risk value r_i through consequence rating a_i and probability rating f_i of each risk accident. On this basis, it considers using risk weight (w_{Ri}) and expert weight (w_{Ei}) for comprehensive evaluation of project risks. Additionally, the paper explores the method of applying the results of project risk evaluation and studies reasonable application of the project's single risk ranking management, dynamic management of risks, and integrated assessment value of risks. By taking People's Square Station of Metro Line 1 in Shijiazhuang City, Hebei Province, China for example, the paper applies expert scoring method and analytical calculation method to analyzing single risk and evaluating the project's comprehensive risks, which is of great significance to safety management and risk control in similar subway station constructions.
Keywords: Subway station; Construction risks; Fuzzy evaluation; Risk weight.

1 Research Background

With the rapid development of Chinese economy and society, traffic congestion and air pollution problems have become more and more serious. In order to improve the traffic environment, many cities have begun to develop subways since last ten years , among which subway stations are the key project. The stations are places where passengers take public vehicles and transfer, so they are generally located in a bustling center of the cities and many of them are constructed beside intersections. Normally, the stations are large-scale projects and the nearby buildings and underground utilities are complex and mixed. In addition, the engineering geology and hydrogeological conditions are unstable, and the constructions involve complex conditions and the schedules are usually tight. All these increase the safety risks. Therefore, it is of significant importance to monitor and detect the safety risk during construction process of subway stations.

2 Analysis of Risk Source

According to accident causation, the risks of transfer station with complex conditions are divided into four types: environment risk, technical risk, organization risk and special risk.

(1) Surrounding environment risks: including risks of neighboring building (structure) damage, adjacent utility damage, hydrogeological risks, weather conditions, traffic dynamic load risk and risks of interference. We can use quantitative analysis and expert assessment method to rank the risk consequence(Luo Furong,2011).

(2) Technical risk: including risks related to safety plans, monitoring and excavation. We can apply quantitative analysis and expert assessment method to rank the risk consequence(Liang Qinghuai et al.,2012).

(3) Organization risks: including risks related to personnel, security system, security organizations, security culture construction, security disclosure, supervision and implementation. We can adopt expert assessment method to rank the risk consequence.

(4) Special risks: include risks of special operations, special equipment and other possible risks, involving risks related to template, operations high above the ground, scaffolding, temporary power, crane operation, towering equipments, man-made digging and temporary projects. Analyses and evaluation made by experts can be used to rank the risk consequence.

3 Individual Risk Consequence Severity Rating and Hierarchical Control

3.1 Individual Risk Assessment Method

Severity of each risk factor is analyzed and scored by invited experts (slight, larger, serious, very serious or catastrophic),then the possibility of accident induced by each risk is given （very likely, likely, occasional, unlikely or impossible). For each risk, its risk value can be assessed according to accident result and occurrence ranking and added value of ranked risks and accident probability as follows:

$$r_i = a_i f_i + S_c(a_i) + S_P(f_i) \quad (1)$$

Where r_i ---- The evaluation vale of risk *i*.

a_i ----- The consequence grating of risk *i*; it is zero when there is no consequence.

f_i ----- The probability grating of risk *i*.

$S_c(a_i)$ -----The added value of risk *i* accident consequence, and this coefficient is the dependent variable of accident consequence grading.

$S_c(f_i)$ ------ The added value of risk *i* accident probability, and this coefficient is the dependent variable of accident probability grading.

3.2 Identification of Added Value of the risk

AHP method is used to identify the risk grating added-value of accident consequence and risk grating added-value of accident probability. Questionnaires were sent to 22 experts and 15 were returned and used for further analysis. Reconsidering all the risk values, the probability accident occurrence was rated by five levels: "slight", "large", "serious" and "very serious" and "catastrophic" and the corresponding value is 0, 0.97, 2.97, 6.07 and 9.97. Since the values of accident occurence and probability should be integer, which makes the calculation easier, the approximate value of risk grating added-value of accident consequence will be 0, 1, 3, 6 and 10 respectively. The accident probability grating consists of five levels: "impossible", "very unlikely", "accidental", "likely" and "very likely", and the corresponding added-value is 0, 0.93, 2.83, 5.87 and 9.8 and also the approximate value will be 0, 1, 3, 6 and 10, respectively.

3.3 Method to Identify the Weighted Average Value of Individual Risk

The risk evaluation values given by experts are different. When calculating one individual risk, therefore, expert weights (w_E) should be taken into consideration, and adopt weighted average valueis used here, as: :

$$R_i = \sum_{j=1}^{m} (w_{Ej} r_{ij}) \tag{2}$$

where, j ---the number of expert;

m ---the number of experts.

R_i --- weighted average value of risk *i*.

r_{ij} ---the evaluation value of risk *i* given by No. *j* expert.

w_{Ej} ---the importance of No. *j* expert in the comprehensive evaluation of project risk.

$$\sum_{j=1}^{m} w_{Ej} = 1$$

3.4 Hierarchical Control of Individual Risk

As obtaining the above mentioned results, risk values can be calculated, , as shown in Table 1.

In the Table 1, the oblique line (for the risk value 1 and 3) stands for low risk that can be ignored and no measures need to be taken. The dark graticule line (the risk value is 6 and 10) represents moderate risk that can be acceptable. Generally no measures need to be taken but risk control and monitoring is needed. The diagonal graticule line (the risk value is 15 and 21) indicates high risk that should be avoided. Monitoring measures must be taken to prevent this type of risk, and the risk-control cost should not be higher than the post-risk damage. The lower oblique line (the risk value is 28, 36 and 45) stands for an extremely high risk that is unacceptable. Effectivemeasure should be taken to avoid this type of risk. Otherwise, measure will have to be taken at all loss to reduce this type of risk to undesirable scale.

Table 1. Parameter for Risk Value Calculating

Consequence Rating / Probability Rating		Slight	Large	Serious	Severer	catastrophic	Added-value of Risk Probability
		1	**2**	**3**	**4**	**5**	
Very Likely	**5**	15	21	28	36	45	**10**
Likely	**4**	10	15	21	28	36	**6**
Occasional	**3**	6	10	15	21	28	**3**
Unlikely	**2**	3	6	10	15	21	**1**
Impossible	**1**	1	3	6	10	15	**0**
Comprenhensive risk level		**0**	**1**	**3**	**6**	**10**	

According to the risk value in Table 1, the following suggestions can be presented for safety consideration: when $R_i \le 3$, it is considered low risk; when $3 < R_i \le 10$, it is regarded as a moderate risk; when $10 < R_i \le 21$, it is considered high risk; when $R_i > 21$, it is regarded as high risk. In practical operation, when we evaluate the risk value, we can control the risk according to the standard in Table 1, thus enabling hierarchical management of individual risk.

4 Project Risk Comprehensive Evaluation and Dynamic Integrated Control

The stations, building structure, surroundings and construction technologies on the same subway line are often quite different from each other. For the sake of comprehensive evaluation of risk, unified evaluation method and indicators should be applied. This paper suggests using three indicators to have a comprehensive evaluation of the risks: average risk evaluation value $\overline{R}$, high risk rate P_{hr}, and extremely high risk rate P_{hrst}.

Average risk evaluation value:

$$\overline{R} = \frac{\sum_{i=1}^{N} R_i}{N} \tag{3}$$

where N—— The sum total of project risks.

i—— The serial number of risks.

R_i—— The weighted evaluation average of risk i.

High risk rate

$$P_{hr} = \frac{N_{hr}}{N} \quad \text{formula (4)}$$

where N—— The sum total of project risks.

N_{hr}—— The number of high risks.

Extremely high risk rate

$$P_{hrst} = \frac{N_{hrst}}{N} \quad \text{formula (5)}$$

where N—— The sum total of project risks.

N_{hrst}—— The number of extremely high risks.

The evaluation indicators above are for wholeness evaluation and can be used as the basis for strengthening security management. According to the three indicators, the employer and supervision unit can pay close attention to the examination and supervision of the items with higher risks. With the progress of the project, the risks are changing, so are the probability and severity. After effective risk management measures, the original risks can be controlled, but new risks may appear. Therefore, dynamic risk assessment and management is necessary during the construction process (Wang Fan,2013).

5 Case of Fuzzy Evaluation

As one of major stations of Subway Line 1, the Remin Square Station, is located at the intersection of East Zhongshan Road and Jianshe Road in Shijiazhuang, China. Passengers from Subway Line 1 can transfer to Subway Line 2 at this station. The layout of this station is the shape of "L" and the underground structure is shape of rectangle. A commercial area lies to the northeast of the crossroad and there is a two-layer frame structure underground. The main structure is underground and adopts cover-excavation method. This stations is located on loess-like silty clay, loess-like silt and sand bed. The underground water level is lower below the baseboard, so no lowering of watertable. The East Zhongshan Road and Jianshe Road are located at the heart of the city, where there is huge traffic flow and traffic jam and the bounding wall may influence the traffic. The layouts of the neighboring facilities are complicated and the foundation trench may cause deformation of the neighboring buildings. There are underground structures, pipelines, rain rills, sewers, water pipes, communication pipes and heat distribution pipelines in the construction area. So any improper operation may cause damage to these facilities. As for the special conditions mentioned above, expert survey (involving 24 sources of risk) was designed and five experts were invited to evaluate the risks. The evaluation results were averaged, as shown in Figure 1.

Figure 1 shows that the weighted average of the hydrogeological risk evaluation is 1.4, within the range between 0 and 3, indicating a low risk; the weighted average evaluation values of the risks of weather conditions, damage of neighboring pipelines, safety tests, and special security programs, nearby road surface, personnel safety and safety organization are 5.4、8.0、8.0、8.8、9.0、9.0、9.2 respectively, within the range (3,10], suggesting moderate risk; the weighted average evaluation values of the risks of traffic dynamic load, temporary electricity utilization, safety culture construction, aerial operation, scaffold utilization, temporary project, damage of neighboring buildings (structures), construction interference and implementation are 10.6,11.0,11.7,17.0 , 17.0,18.0,19.2,21.0 and 21.0 respectively, within the range (10, 21], suggesting high risk; the weighted average evaluation values of the risks of security system risk, project supervision, templates, excavation of foundation pit and supporting techniques, lifting operation, deformation supervision and aerial equipments are 21.5,22.7,22.7,25.5,26.9,32.0 and 38.9 respectively, which are greater than 21, suggesting high risk. According to the evaluation results above, the construction unit can carry out level-to-level management of each individual on the basis of its risk rating.

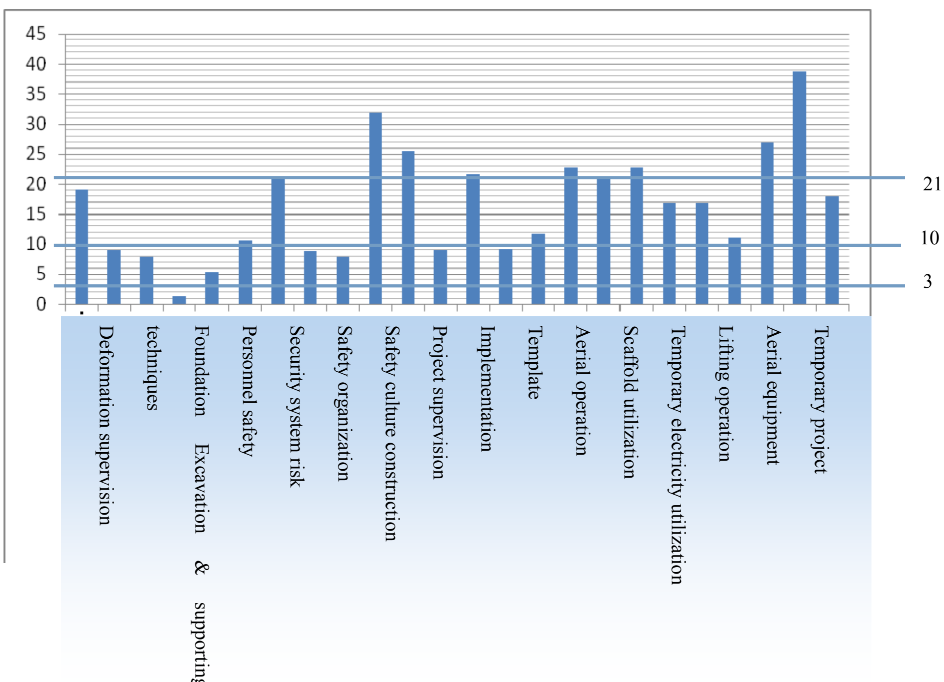

Figure 1. Bar Chart of Average Value of Individual Risk Evaluation at Renmin Square Station

4 Conclusions

This paper has proposed the concept of added value of consequences of the accident risk and the concept of added value of accident probability risk for the first time in the world, and that its calculation method are discussed in this paper.

The above method was used to risk assessment and management in construction of People's Square Station of Metro Line 1 in Shijiazhuang City, Hebei Province, China. It realizes that risk is always controllable, and that accidents always can be prevented, which is of great significance to safety management and risk control in similar subway station constructions.

References

Liang Qinghuai, Li Zhongwen, Wang Su (2012). Safety Management and Technology of Subway Construction. *China Building Industry Press*.

Luo Furong(2011).Implementation Guide to Safety Risk of Track Traffic Project Construction. China Building Industry Press.

Wang Fan(2013). Safety Risk Modeling and Evolution Research of Subway Construction. Huazhong University of Science and Technology.

Influence of Shield Tunnel Construction beneath a Railway on a Culvert-Embankment Transition Zone

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Abstract: Since the uneven settlement and the variation of the track stiffness are inherent problems of transition zones, the construction of the shield tunnel in the vicinity of the transition zone may aggravate the track geometry deterioration, maintenance demand and poor ride quality. In view of the importance of the problem, the influence of the shield tunnel construction on the subgrade uneven settlement is investigated. Results show that the reinforce treatment of the foundation is required and the recommended treatment measure is appropriate to control the uneven settlement of the subgrade in the vicinity of the transition zone.
Keywords: Transition zone; Shield tunneling; Uneven settlement.

1 Introduction

Transition zones between railway tracks on embankments and structures are often associated with accelerated rates of geometry deterioration, high maintenance demand and poor ride quality (Read and Li, 2006). These problems may be aggravated by the construction of the shield tunnel beneath the transition zone. Nowadays the expansion of the city rail transit leads to more and more constructions of the metro shield tunnel beneath existed railway lines. When they are constructed in the vicinity of the transition zone, the influence will be not only on the track geometry deterioration, but also on the safety of the substructure such as bridges or culverts.

The construction of the shield tunnel will inherently lead to the disturbance of the surrounding soil e.g. the ground loss, the variation of the pore pressure and the redistribution of the soil initial stress. As a result the equilibrium state of the surrounding soil is destroyed and the deformation of the ground surface appears. The beginning of the study on the ground deformation induced by shield tunnel constructions is Peck formula (Peck, 1969) summarized from in site observations. Based on the work of Peck some revision of the parameters (Mair et al., 1993, Attewell and Selby, 1989) were carried out and new empirical formulas (Sagaseta, 1987) were put forward. Furthermore, analytical and semi-analytical methods are also widely employed to investigate the stratum displacement induced by the excavation of the shield tunnel. Most of these methods are based on cavity expansion theory (Verruijt and Booker, 1996).

With the development of computer technologies, the complicated influence of the shield tunnel excavation on the deformation of structures and soils can be investigated by numerical simulation methods. Compared with the empirical formulas and analytical methods, more comprehensive effect parameters of the shield tunnel excavation can be considered by the numerical simulation method e.g. finite element method and finite difference method. Mroueh and Shahrour (2003) investigated the interaction between tunneling in soft soils and adjacent structures with FE method. Gong et al. (2014) evaluated the safety of the elevated high-speed railway influenced by the excavation of the nearby shield tunnel with a 3D FE model. With the similar numerical simulation method Huo et al. (2011) investigated the characteristics and control technologies of the deformation of the existed railway tracks influenced by the construction of the metro tunnel beneath them. Although numerous research works have been taken to investigate the railway substructure deterioration and the subgrade settlement induced by the shield tunneling beneath the railway track, surprisingly little research has been carried out to identify the influence on the transition zone. In this paper this issue is investigated based on a project of a metro shield tunnel constructed beneath a culvert-embankment transition zone.

2 Background

The double line of shield tunneling of Metro line 2 in Hangzhou is planned to be constructed beneath an existed railway line (see Fig. 1 and Fig. 2). The double metro lines are almost perpendicular with the existed railway line as shown in Fig. 1. The intersection angle is 92 degree and the position of the intersection is in the vicinity of a railway culvert. The buried depth of the tunnels is 16.84m. In this section the tunnels are constructed in the silt clay layer and the clay layer (see Fig. 2). The distance between centers of these two tunnels is 12m and the smallest distance between the tunnel and the culvert is 10m as shown in Fig. 2. The external and the inner diameters are 6.2m and 5.5m, respectively. The double tunnels are entitled as left line and right line, respectively (see Fig. 2). The left line will be constructed earlier than the right line and the excavation direction of them is from west to east.

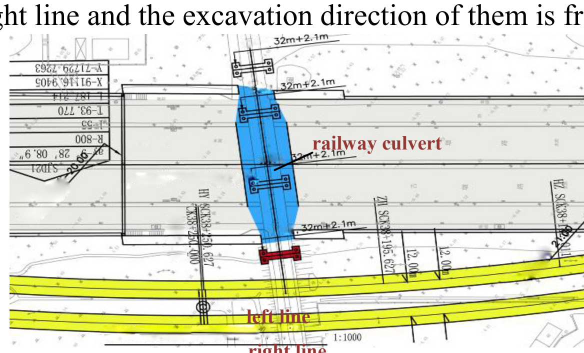

Figure.1. Top view of the intersection section

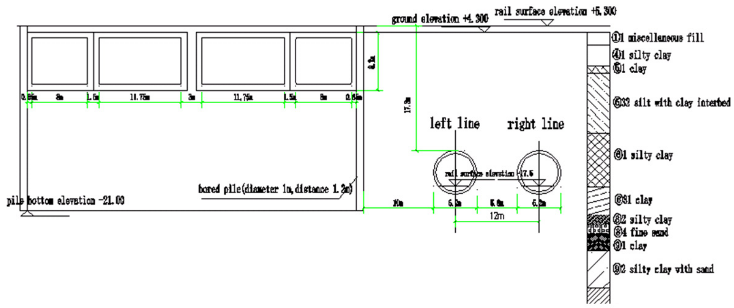

Figure.2. Cross section of the shield tunnel

In order to investigate the deformation of the transition zone induced by the shield tunneling, a steady-state analysis is taken by a 3D FE model (Shan et al., 2013).

3 Model

A 3D FE model is employed. The length, the width and depth of the model are 160m, 100m and 50m, respectively. The material model of the soil is hardening soil model. For the culvert, tunnel segment and piles the linear elastic model is implemented. The culvert, segment and the pile are simulated by plate element. The subgrade filler and soils are simulated by solid elements. In order to simulate the interaction of the soil and the structure, contact elements are employed on the interface between soils and structures. The origin of coordinate lies in the connection of the culvert and the transition zone as shown in Fig. 3. The coordinate axes X, Y, Z represent the longitudinal, transverse and vertical direction, respectively (see Fig. 3). Material parameters are shown in Table 1.

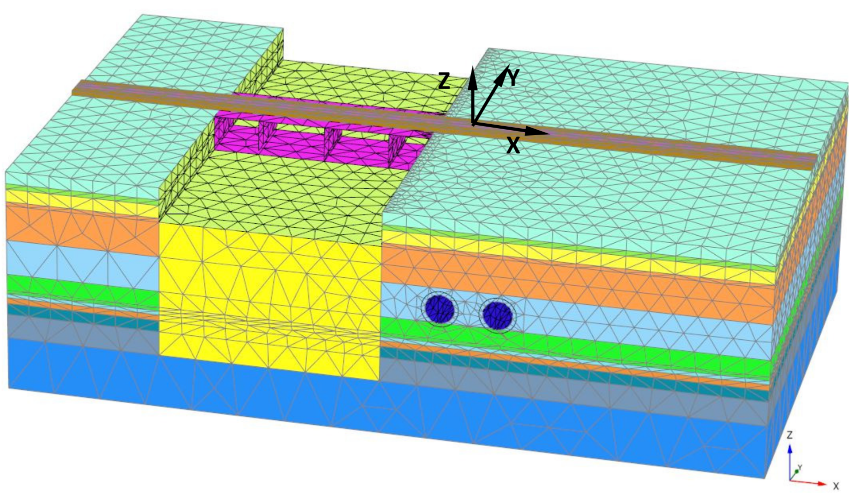

Figure 3. Finite element model the intersection section

Table 1 Material parameters

stratum	density (kN/m^3)	cohesion (kPa)	internal friction angle	Young 's modulus (Mpa)	Poisson ratio
①1 miscellaneous fill	1850	9	18.5	18	0.23
④1 silty clay	1750	9.5	12	8.4	0.4
⑤1 clay	1940	35.4	15.3	27	0.33
⑤32 silt with clay interbed	1900	10	25	15	0.28
⑥1 silty clay	1780	13.5	12.5	22.8	0.41
⑥31 clay	1790	15	12	24	0.4
⑧2 silty clay	1880	25	16	42	0.35
⑧4 fine sand	2000	1	20	78	0.26
⑨1 clay	1940	40	15	72	0.31
⑨2 silty clay with sand	1960	6	30	66	0.31

4 Boundaries and load conditions

Nodes on the bottom surface of the model are fixed. For the nodes on the side surfaces, the displacement of the x and y directions are fixed only the z direction is free.

The load conditions are shown in Fig. 4 which is employed as the design criteria of the new constructed railway track. The load distribution is transformed into uniform load on the ballast surface in this simulation.

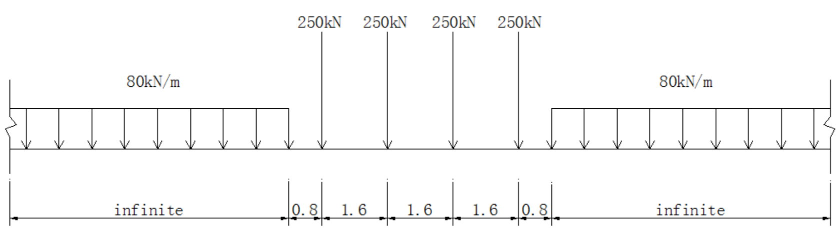

Figure 4. Train load

5 Calculation process and results

With the 3D FE model the excavation of the soil, the segment installation and the tail void grouting are simulated. The length of the excavation for each calculation step is 1.2m, which is equal to the length of a ring of segments. Step by step the whole process of the shield tunneling under-crossing the existed railway line can be simulated. For each calculation step the soil and structure deformations can be obtained. In order to investigate the most significant influence of the shield tunneling on the deformation of the transition zone, 8 key calculation steps are chosen following the planned construction sequence listed in Table 2.

Table 2. Construction steps

	construction of the left line
step 1	shield machine arrives at the west edge of the railway subgrade
step 2	shield machine arrives at the region under the subgrade
step 3	shield machine arrives at the east edge of the railway subgrade
step 4	construction of the left line is complete
	construction of the right line
step 5	shield machine arrives at the west edge of the railway subgrade
step 6	shield machine arrives at the region under the subgrade
step 7	shield machine arrives at the east edge of the railway subgrade
step 8	construction of the right line is complete

With the stratum loss rate of 0.8% the railway subgrade surface displacement as a function of the x coordinate is shown in Fig. 5. For each construction step a settlement curve can be observed. These settlement curves are not strict symmetry as classical empirical Peck curve. For the construction steps of the left tunnel, the largest settlement point of the subgrade surface appears above the center of left tunnel cross section. With the construction of the right tunnel, the largest settlement point of the settlement curve move to the middle between the left line and the right line step by step. For each settlement curve, the most abrupt change of the settlement appears in the first 10m from the connection between the culvert and the subgrade. The slop of the settlement curve in this area is larger than that of other sections due to the existence of the culvert structure.

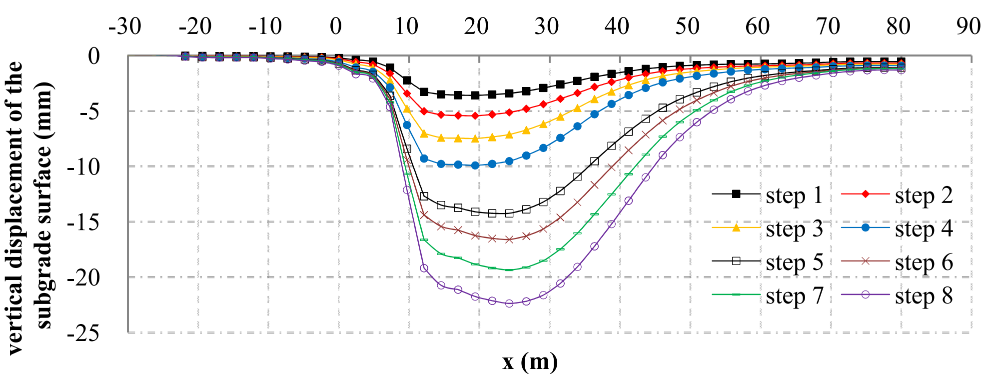

Figure 5. Railway subgrade surface displacement induced by shield tunneling

Fig. 5 shows that during the construction of the tunnels the largest settlement of the subgrade surface is 22.1mm, which is larger than the critical value of the largest subgrade settlement in the standard. Since the normal speed of the shield tunneling is

7.2m/24h, the maximum subsidence rate of the subgrade surface is 6.3mm/24h, which also exceed the required value of the standard. Consequently, in order to meet the requirement of the subgrade surface settlement signed in the standard as well as the subsidence rate, reinforcements of the transition zone should be designed and recommended.

The grouting reinforcement is recommended in the culvert-embankment transition zone. As illustrated in Fig. 6 the grouting reinforcement area can be divided into the main reinforcement zone and the secondary reinforcement zone by chemical churning piles. The reinforced vertical distance of piles is from ground surface to the bottom of the stratum ⑧$_{2}$ silty clay. The piles reinforcement zone is composed of 5 rows of piles with the diameter of 0.8m and the interlock amount of 0.2m (see Fig. 6). The function of piles reinforcement zones is to ensure the reinforcement quantity of the main reinforcement zone, which is reinforced by grouting method between the piles reinforcement zones. From the bottom of stratum ⑤$_{1}$ clay, which is 5m beneath the rail, to the bottom of stratum ⑥$_{31}$ clay (see Fig. 6). The distance between the piles and the center line of the railway is 10 meter. Two secondary reinforcement zones are constructed outside chemical churning piles with the same reinforce deepness of the main reinforcement zone.

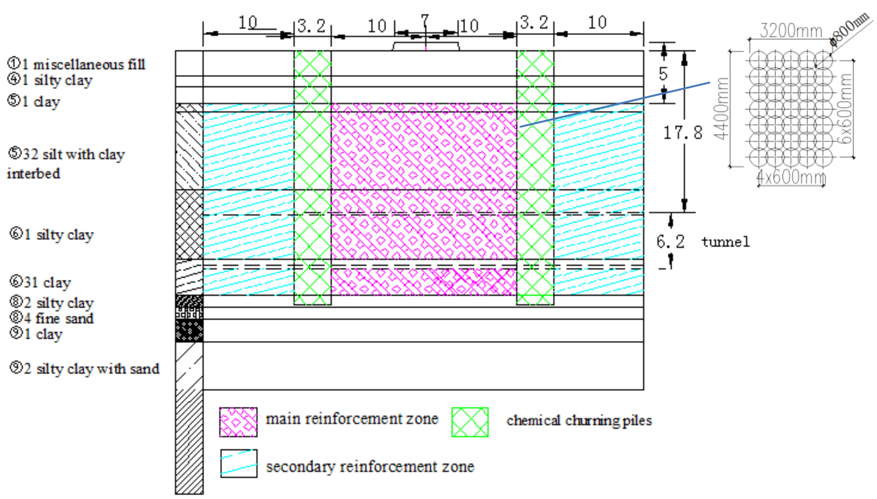

Figure 6. Grouting reinforcement

After the reinforce treatment the maximum deformation of the subgrade surface during the shield tunneling is 7.3mm and the subsidence rate is 1.5mm/24h. Compared with the critical value listed in the standard with 10mm for maximum settlement and 4mm/24h for limited subsidence rate, respectively, the reinforce treatment recommended is appropriate to control the uneven settlement of the subgrade in the vicinity of the transition zone.

6 Conclusions

The influence of the construction of shield tunnels beneath a culvert-embankment transition zone on the uneven settlement of the subgrade is investigated by FE method. Three conclusions can be drawn:

1) For each construction step the settlement curve is not symmetry as classical empirical Peck curve due to the existence of the culvert structure. The most abrupt change of the settlement appears in the first 10m from the connection between the culvert and the subgrade.

2) With the stratum loss rate of 0.8%, the largest settlement of the subgrade surface is 22.1mm and the maximum subsidence rate of the subgrade surface is 6.3mm/24h. They are larger than the critical value listed in the standard.

3) In order to meet the requirement of the standard, a reinforce treatment of the transition zone is recommended. Results showed that the recommended treatment is effective to control the uneven settlement of the subgrade in culvert-embankment transition zones.

Acknowledgement

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References:

Attewell, P. B. and Selby, A. R. (1989). Tunneling in compressible soils: large ground movements and structural implications. *Tunneling and underground space technology*, Vol. 4(4): 481-487.

Gong, Q., Shan, Y., You, X. and Zhou S. (2014). Shield tunneling analysis and measures under elevated high-speed railway. *Proceedings of the Eighth International Symposium on Geotechnical Aspects of Underground Construction in Soft Ground*, Seoul, Korea, 303-308.

Huo J., Wang, B. and Zhou S. (2011). Safety analysis of foundation reinforcement scheme for shield tunnel under-passing intercity railway. *China Railway Science*, Vol. 32(5), 71-77. In Chinese

Mair, R. J., Taylor, R. N. and Bracegirdle, A. (1993). Subsurface settlement profiles above tunnels in clay. *Geotechnique*, Vol. 43(2), 315-320.

Mroueh, H. and Shahrour, I. (2003). A full 3-D finite element analysis of tunneling-adjacent structures interaction. *Computers and Geotechnics*, Vol. 30(3), 245-253.

Peck, R. B (1969). Deep excavations and tunneling in soft ground [A]. *In: Petrasovits G, Mecsi J, Proceedings of the 7th International Conference on Soil Mechanics and Foundation Engineering [C]*, Mexico, State of the Art

Volume, Sociedad Mexicana de Mecanica de Suelos, A. C, Mexico City, 225-290.

Read, D., Li, D. and The Transportation Technology Center, Inc. (TTCI) in Pueblo, Colorado (2006). Research Results Digest 79: Design of Track Transitions. *Transit Cooperative Research Program*.

Sagaseta, C (1987). Analysis of undrained soil deformation due to ground loss. *Geotechnique*, London, England, Vol. 37, 301-320.

Shan, Y., Albers, B. and Savidis, S. A. (2013) Influence of different transition zones on the dynamic response of track-subgrade systems. *Computers and Geotechnics*, Vol. 48:, 21-28.

Verruijt, A. and Booker, J. R. (1996). Surface settlements due to deformation of a tunnel in analysis half plane. *Geotechnique*, Vol. 46(4), 753-756.

Random Vibration Analysis of the Underframe Structure on a High-Speed Train

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Abstract: Build a dynamic analysis model about the coupling system of the vehicle and the underframe suspension structure. Different combination methods are employed in order to analyze the random vibration of the interior suspension structures of underframe structure, then 2 kinds of analysis model are built: the first one is the traditional analysis model of which elastic combination is ignored between the interior suspension structures, the combination are considered to be rigid combination; the second one is the model of which elastic combination is considered between interior suspension structures. In this paper the example is a structure of the traction converter under the car-body of high-speed train and the eccentric load of the electric machine installed in the structure of the traction converter is simplified and applied on the rotor spindle of the electric machine. The railway vehicles accurate random vibration analysis method is employed to analyze the random vibration on the 2 kinds of the analysis model. Calculated results indicated that the stress of the traction converter mainly focus on 3 frequency band that are 2Hz, 6Hz and 60Hz, correspond respectively the mainly vibration frequency of the car-body, rigid-body vibration frequency of the traction converter caused by the suspension stiffness between the car-body and underframe and the basic frequency of the eccentric load of the electric machine which is considered as the most significant impact. As the rubber damper is employed at the combination between the suspension steel beam and case in the traction converter the dynamics index of vibration and stress of the first one is superior to the second one which the rigid combination is employed and the impact caused by the eccentric load of the electric machine is obvious attenuated.
Keywords: Underframe equipment; Suspension method; Traction converter; Random vibration; Random stress.

At present, the underframe equipment is mostly suspended under the car-body of the high-speed train. In order to reduce the impact of the underframe equipment to the car body vibration, the elastic damping system is employed on the most high-speed train. The underframe equipment as an important part of the vehicle is also affected by the vibration of the running vehicle, especially the vibration will be more intense when the vehicle runs at high-speed. The underframe equipment should be also received enough attention when the researchers focused on the stability and the reliability of high-speed running vehicle, because it not only affect the performance of the equipment and the fatigue life of the structure, but also feeds back to the car body, affect the comfort of the passengers and even damage to the structure of the car body.

At present the research on the dynamics of coupling system between underframe equipment and car body generally based on the rigid-flexible coupling dynamic model, the structure of car body and bogie are considered as the flexible body, the structure of car body is mainly simplified as Euler-Bernoulli Beam or Timoshenko Beam, the underframe equipment and the wheelset are all simplified as the rigid body, then the rigid-flexible coupling dynamic model of the vehicle is built for the modal analysis(Yu, 2012. Yang, 2012) or the vibration analysis(Wu, 2012. Gong, 2011). Based on the analysis, in order to provide reference for the related design or optimizing of the underframe equipment, the vehicle dynamics performance is affected by underframe equipment distribution, suspension structure, suspension method, suspension stiffness and damp, other related parameter and so on is researched. The vibration of underframe equipment has been more and more attention due to the complexity of underframe equipment and the increase of vehicle speed, but the vibration of the interior structure of the underframe equipment couldn't be analyzed by the aforementioned research.

In this paper the railway vehicles accurate random vibration analysis method is employed. The car body of the high-speed train and the underframe equipment are considered as two separate parts, based on each finite element model instead of the beam structure that is the car body simplified and the rigid body that is underframe equipment simplified. Then Build a dynamic analysis model about coupling system of vehicle and underframe suspension structure. The simplified eccentric load of the electric machine which installed in the structure of the traction converter is applied on the rotor spindle of electric machine. The random vibration is analyzed by the different suspension methods between the interior suspension structures of the underframe structure and then the stress is also analyzed, so that the random vibration and the stress of interior suspension structures can be understood. As the vehicle run at high speed the dynamics performance of the coupling system of the vehicle and underframe structure and the coupling system of the interior structures of the underframe structure under the random vibration conditions can be simulated more accurately by the method which is employed in this paper, thus a number of references about the design and the simulation of the underframe structure are provided.

1 The Analysis System of Random Vibration of Car Body And Underframe Structure

In this paper the underframe structure is considered as one separate body. To build the accurate analysis coupling system of the random vibration of the car body and the underframe structure is based on the railway vehicles accurate random vibration analysis method. The finite element model of the underframe structure is employed and the combination between the car body and the underframe structure is simplified. The finite element model can reflect the interior structure well, so that the response of the interior structure can be analyzed. The theory, the formulas and the methods of analysis system had been introduced(Tong, 2013, 2014. Guo, 2014), Figure 1 for analysis flow chart.

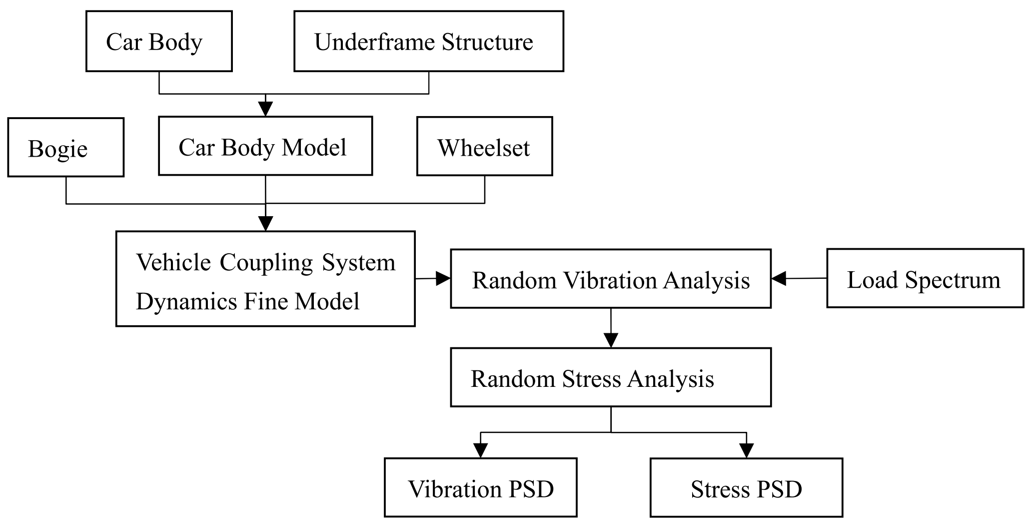


Figure 1.Flow diagram of analysis

2 Structure Dynamics Model

In this paper what employed are a type of the high-speed train of the car body, the bogie, the wheelset and a type of traction converter which is suspended under the car body and the material of which are steel and aluminum. Figure 2 for the FEM of traction converter, the combination is simplified. Figure 3 for the dynamics calculate model of vehicle coupling system including the car body, the bogie, the wheelset and the traction converter. The total number of the node of the vehicle coupling system FEM is 460656, including the car body is 298213, the traction converter is 39255, one bogie is 48634 and one wheelset is 6480.

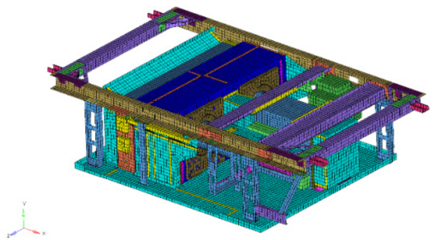


Figure 2. the FEM of traction converter

Figure 3. Dynamics calculate model of vehicle coupling system

3 Dynamics Analysis on Coupling System of Vehicle and Underframe Structure

The traction converter is combined with the slot of the underframe of the car-body by the rubber damper, figure 4 for the position of the traction converter under the car body. The vibration of the car body is equal to the source, the traction converter will be vibrated by the energy of the vibration is input to it through the rubber damper. The main source of the vibration of the car body is the wheel-rail excitation which is caused by the track irregularity. The energy of the excitation is reached the car body through the wheel, first suspension system, the bogie and the secondary suspension system, figure 5 for the dynamics analysis of the coupling system of the vehicle including the traction converter.

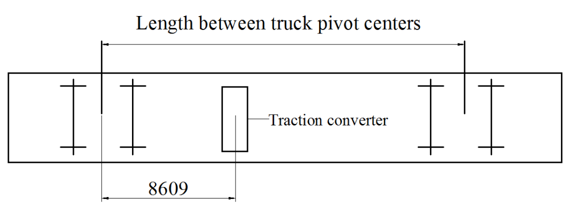


Figure 4. the position of traction converter under the car body

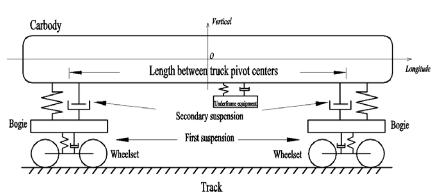


Figure 5.the dynamics analysis of the coupling system of the vehicle including the traction converter

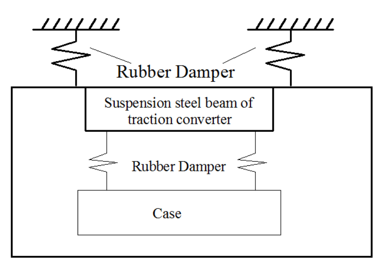


Figure 6.the interior structure of the underframe structure

The traction converter is combined with the car body by the V-liner clamp, this kind of combination has been widely used in engineering. Although the feature of the elastic combination of the V-liner clamp can be considered by the traditional method of the multi-body dynamics analysis, but it is difficult to make accurate analysis on the variation of vibration which is caused by the subtle interior structural change of the underframe structure. This is because that the elastic suspension structure is still designed in the underframe structure, for this kind of complex elastic suspension structure has been simplified as rigid body by employing the traditional method of the multi-body dynamics analysis, thus the interior structure cannot be reflected, so that it is difficult to analyzed the interior structure of this kind of complex structure, figure 6 for the interior structure of the underframe structure. The question can be solved well by employing railway vehicles accurate random vibration analysis method and the analysis about the variation of the structural vibration which is caused by the load change can be also solved well in the design process.

4 The calculation result analysis

In this paper the model which is a high-speed train, so the speed of calculation is set at 350 km/h which is the highest speed of actual operation state, then based on the speed German low interference spectrum is used, the excitation frequency range is 0 to 120 Hz, and the simplified eccentric load of the electric machine which is simplified as 3 direction which are lateral ,vertical ,longitudinal is applied on the rotor spindle of the electric machine.

The 2 kinds of analysis model are that:

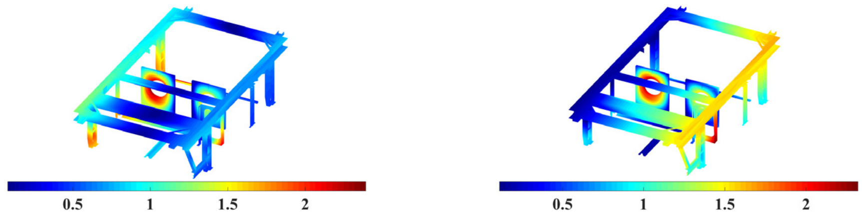
(1) Analysis model 1 is the traditional analysis model of which elastic combination between interior suspensions structures is ignored, the combination are considered to be rigid combination.

(2) Analysis model 2 is the model of which elastic combination is considered between interior suspension structures.

The calculation results include the lateral, vertical, longitudinal Root Mean Square (RMS) and the stress standard deviation are showed respectively as the traction converter is made of steel and aluminum. As the results show there are significant differences between the 2 kinds of models.

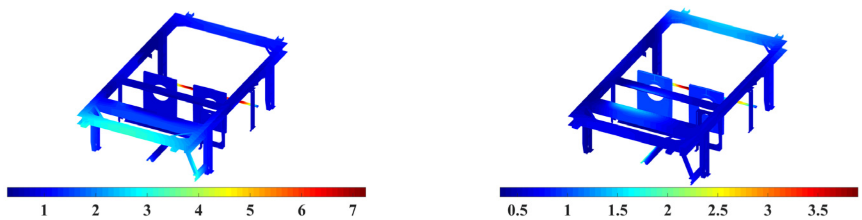
4.1 The calculation results of the steel structure

Figure 7, 8 and 9 show the lateral, vertical, longitudinal acceleration RMS of the steel structure.



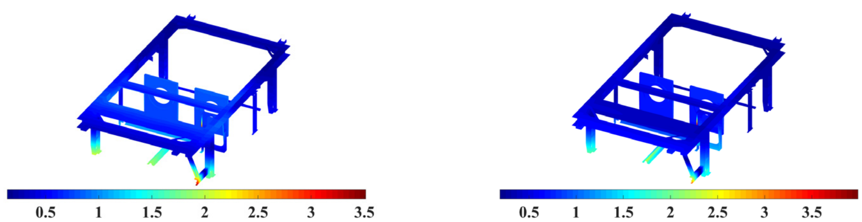
Analysis model 1 Analysis model 2

Figure 7.The lateral acceleration RMS of the steel structure



Analysis model 1 Analysis model 2

Figure 8.The vertical acceleration RMS of the steel structure

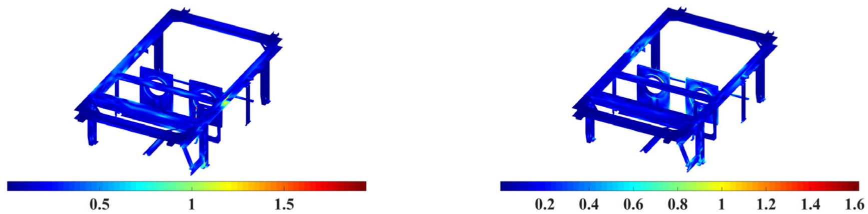


Analysis model 1 Analysis model 2

Figure 9.The longitudinal acceleration RMS of the steel structure

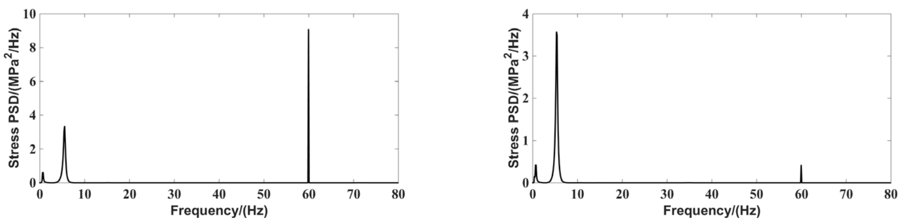
As shown in figure 6 the numerical value of the lateral and longitudinal acceleration RMS are no significant difference between the two, but the distribution of the lateral acceleration RMS is significant difference between the two .Due to the structure of the traction converter is not a symmetrical structure, so the distribution of the lateral RMS is also not symmetrical. It is indicates that the structural lateral vibration of the traction converter is influenced a lot by employing elastic combination methods. In the aspect of vertical, the numerical value of the analysis model 1 decrease by 50% than the analysis model 2, the results show that what direction the elastic combination influence most is the vertical which is focused much in the design process of underframe structure.

Figure 10 and 11 show the stress RMS of the steel structure and the PRMS of the point of the maximum stress RMS of the steel structure.



Analysis model 1 Analysis model 2

Figure 10.the stress RMS of the steel structure



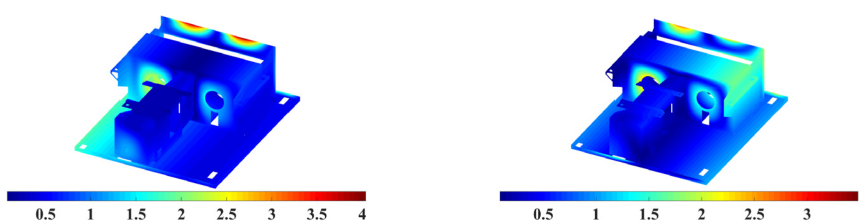
Analysis model 1 Analysis model 2

Figure 11.The PRMS of the point of the maximum stress RMS of the steel structure

From the compare of the stress RMS between the two it can be seen that the value of the maximum stress RMS of analysis model 1 is greater than analysis model 2, as figure 11 shows that the value of analysis model 1 at 60 Hz is much greater than analysis model 2.The frequency of the rotation of the fans is 60 Hz, so it is indicates that the steel structure of the traction converter is affected a lot by the eccentric load of the fans.

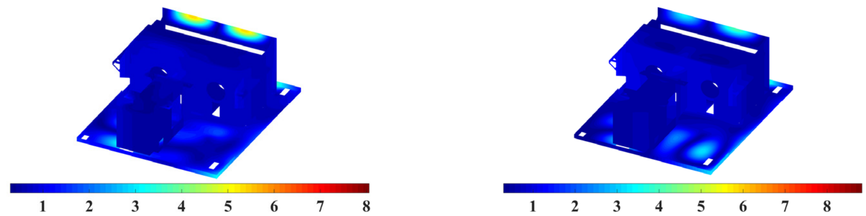
4.2 The calculation results of the aluminum structure

Figure 12, 13 and 14 show the lateral, vertical, longitudinal acceleration RMS of the aluminum structure.



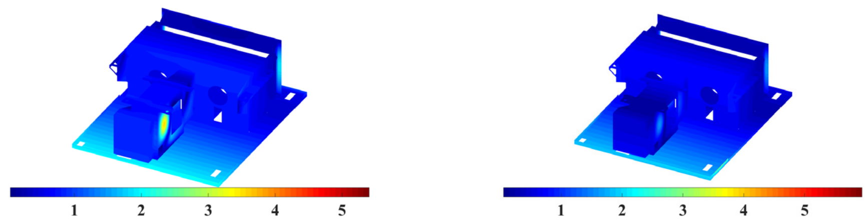
Analysis model 1 Analysis model 2

Figure 12.The lateral acceleration RMS of the aluminum structure



Analysis model 1 Analysis model 2

Figure 13.The vertical acceleration RMS of the aluminum structure

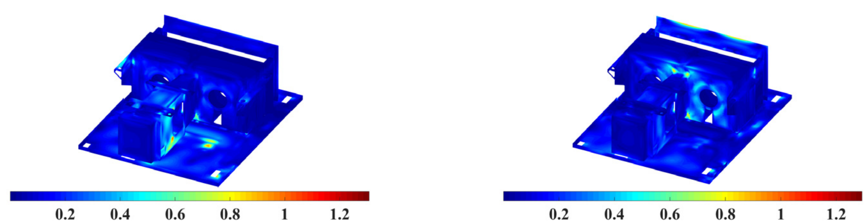


Analysis model 1 Analysis model 2

Figure 14.The longitudinal acceleration RMS of the aluminum structure

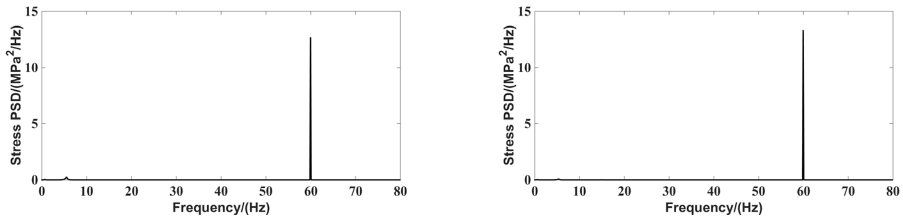
As the calculation results of aluminum structure show the difference of the acceleration RMS of the two is small, it is mainly due to that most of the aluminum structures are suspended structures, so the vibration of the aluminum structure is influenced a little by employing the different combination.

Figure 15 and 16 show the stress RMS of the aluminum structure and the PRMS of the point of the maximum stress RMS of the aluminum structure.



Analysis model 1 Analysis model 2

Figure 15.The stress RMS of the aluminum structure



Analysis model 1 Analysis mode 2

Figure 16.The stress PRMS of the point of the maximum stress RMS of the aluminum structure.

As the calculation results show the difference of the stress RMS of the two is also small. The values of the stress PRMS of the two at 60Hz are approximate equal. It is indicates that the elastic combination does little contribution to decaying the influence caused by the eccentric load of fans as which is set up on the aluminum structure. In the actual structure, the reinforcing plates are set up at where is the maximum stress RMS of the aluminum structure of the analysis model 2, but there are not the reinforcing plates are set up at where is the maximum stress RMS of the aluminum structure of the analysis model 1.In conclusion the influence of the elastic combination for the steel structure is greater than the aluminum structure.

5 Conclusions

1) The stress of the traction converter mainly focus on 3 frequency band that are 2Hz, 6Hz and 60Hz, correspond respectively the mainly vibration frequency of the car-body, rigid-body vibration frequency of the traction converter caused by the suspension stiffness between the car-body and underframe and the basic frequency of the eccentric load of the electric machine which is considered as the most significant impact.

2) As the rubber damper is employed at the combination between the suspension steel beam and the case in the traction converter the dynamics index of vibration and stress of the first one is superior to the second one which the rigid combination is employed and the impact caused by the eccentric load of the electric machine is obvious attenuated.

References

Gong, D. (2011). "*Impacts of Handing Equipments on Vertical Riding Stability of Elastic High-Speed Train Bodies*". Chinese Journal of Construction Machinery, 2011, 9(4): 404-409

Guo, H. F. (2014). "The BTM of Comprehensive Inspection Train Random Stress Analysis". Journal of Dalian Jiaotong University, 2014, 35(S1): 17-21

Tong, W. (2013). "*Random Vibration We11-Meshed Structure Analysis of 25T Soft Berth Coaches*". Journal of Dalian Jiaotong University, 2013, 34(5): 58-62(2014). "*Simulation on Fatigue Life of Bogie Frames for 25T Cushioned Sleeping Cars Based on Precise Algorithm of Random Vibration*". Rolling Stock, 2014, 52(8): 10-12

Wu, H. C. (2012). "*Influence of Equipment under Car on Carbody Vibration*". Journal of Traffic and Transportation Engineering, 2012, 12(5): 50-56

Yang, G. W. (2012). "*Analysis of Effect of Equipment with Flexible Suspension on Modal of Train Car-body in the Preparation Conditions*". Railway Locomotive and Car, 2012, 32(4): 37-40

Yu, J. Y. (2012). "*The Influence of the Hanging Device on Complete Car's Model*". Noise and Vibration Control, 2012, 5: 97-99

Dynamic Response Analysis of CRTSII Bi-Block Ballastless Track on a Viaduct of a High-Speed Railway

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Abstract: According to the CRTSII bi-block ballastless track structure commonly used in high-speed railway, a 3D finite element model of CRTSII bi-block ballastless track structure on viaduct is established. Then characteristics of vertical displacement of the rail in frequency domain and dynamic responses of the ballastless track structure can be obtained by transient dynamic analysis, based on the finite element software (the speed of the train are 200, 250, 300 and 350 km/h respectively). Analysis results show that: (1) Without considering track irregularity, the frequencies corresponding to the peak of the vertical displacement of rail are approximately equal to the multiples of v/L_a, so the peak frequency can be adjusted by changing the speed when the length of a train is certain; (2) The vertical displacement of the track slab is less than 60% of the rail, and its vertical acceleration is only 2.1%, showing that fasteners play a good effect on reducing vibration; (3) Without other damping measures except fasteners, the vertical displacements of the track slab, supporting layer and viaduct are very close, but their vertical accelerations are some different; (4) The speed of the train has a great impact on the vertical acceleration, and the maximum vertical accelerations of the rail, track slab, supporting layer and viaduct at 350 km/h are 1.68, 1.82, 1.96, 1.65 times of 200 km/h respectively; (5) The vertical compressive stress of the track structure has a turning point.
Keywords: High-speed railway; CRTSII bi-block ballastless track; Characteristics of frequency domain; Dynamic characteristics.

1 Introduction

The technologies of high-speed railway in China have slowly become mature, and high-speed railway has become a viaduct connecting the world and our country. In recent years, many scholars have analyzed ballastless tracks commonly used in high-speed railway, but most of them are ballastless tracks on subgrade or slab ballastless tracks on viaduct (Sun Lu, 2014). Researches about bi-block ballastless track especially CRTSII bi-block ballastless track on viaduct are relatively few.

In this paper, a 3D finite element model of CRTSII bi-block ballastless track structure on viaduct is established. Characteristics of vertical displacement of rail in frequency domain and dynamic responses of each components of the track structure at different speeds are discussed. And references for dynamic optimization of bi-block ballastless track structure design are provided.

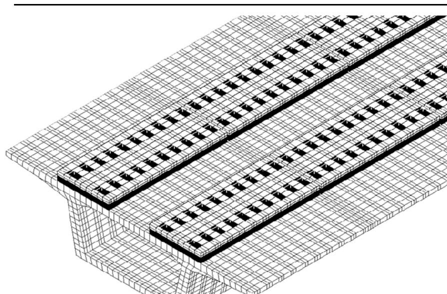
2 The finite model of CRTSII bi-block ballastless track and viaduct

2.1 The numerical analysis model and calculation parameters

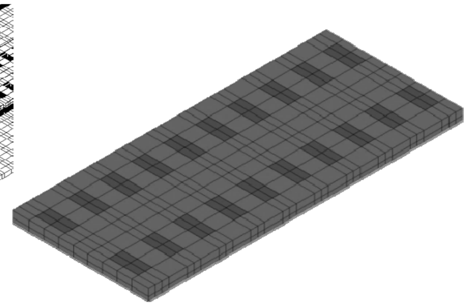
The CRTSII bi-block ballastless track on viaduct mainly consists of rail, fastener, slab, bi-block sleeper, supporting layer and viaduct etc. In this paper, all parameters are selected according to literature (Qu Cun, 2011) and (Zhu Yongjian, 2010), as shown in Table 1. The ends of rail are fully constrained, and the ends of viaduct are simply supported. The rail is represented by an Euler beam, and the fastener is represented by a liner spring-damper element, and the bi-block, slab, supporting layer and viaduct are represented by solid elements, as shown in Figure 1.

Table 1. Parameters of the CRTSII bi-block ballastless track structure modal

Components	Parameters	Values
Rail	Young's modulus (Pa)	2.1×10^{11}
	Density (kg • m^{-3})	7830
	Cross-section area (cm^2)	77.45
	Poisson's ratio	0.3
Fastener	Stiffness (N • m^{-1})	5×10^{7}
	Damping (N • s • m^{-1})	2.2656×10^{4}
	Spacing (m)	0.654
Bi-block sleeper	Young's modulus (Pa)	3.6×10^{10}
	Density (kg • m^{-3})	2500
	Length×Width×Thickness (m×m×m)	0.6×0.28×0.13
	Poisson's ratio	0.2
Slab	Young's modulus (Pa)	3.25×10^{10}
	Density (kg • m^{-3})	2500
	Length×Width×Thickness (m×m×m)	6.44×2.8×0.21
	Poisson's ratio	0.2
Supporting layer	Young's modulus (Pa)	5×10^{9}
	Density (kg • m^{-3})	2500
	Width×Thickness (m×m)	2.8×0.26
	Poisson's ratio	0.2
Viaduct	Young's modulus (Pa)	3.45×10^{10}
	Density (kg • m^{-3})	2500
	Length (m)	32
	Poisson's ratio	0.2



(a) Partial enlargement



(b) Bi-block track slab

Figure 1. Sketch of finite element model of CRTSII bi-block ballastless track structure on viaduct

2.2 Train loads

Considering the track irregularity or not, the train loads in this paper are divided into two types. The first wheel/rail force is selected according to CRH2 high-speed train, without considering track irregularity, taking axle load as 14 t, so the static load of one wheel is 70 kN, used to analyze the characteristics of vertical displacements of the rail in frequency domain (considering 8 trains). The second wheel/rail force is calculated by vehicle-track coupling dynamic model (Zhai Wanming, 2007), which considers track irregularity (the German high-speed spectrum). When the CRH2 high-speed train runs at 300 km/h, the wheel/rail force of one wheel is shown in Figure 2, which is used to analyze the dynamic responses of the track structure (considering only 1 train).

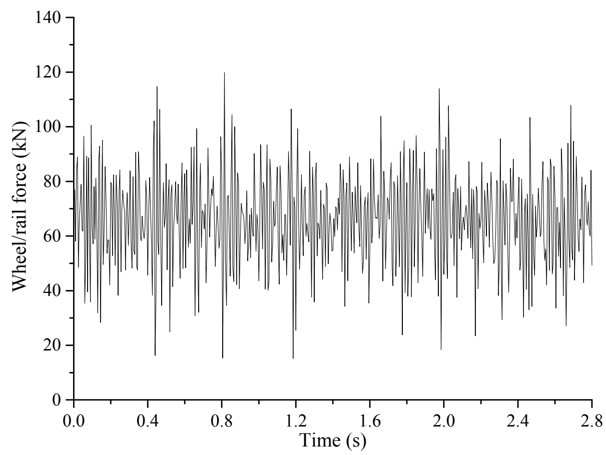


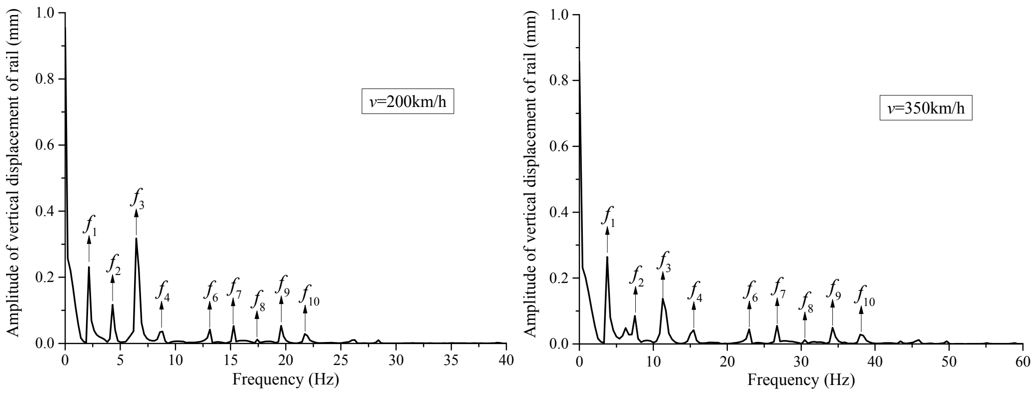
Figure 2. Time history of wheel/rail force

3 Analysis of dynamic responses of CRTSII bi-block ballastless track structure on viaduct

3.1 Analysis of characteristics of vertical displacements of the rail in frequency domain

When analyzing the vertical displacements of the track structure, we can ignore the effect of the track irregularity (Song Xiaolin, 2012). So in this section, the first wheel/rail force is selected to analyze the characteristics of the vertical displacements of rail in frequency domain when 8 trains pass by the track structure.

By doing Fourier-transform to the vertical displacements at four different speeds (200, 250, 300 and 350 km/h) respectively, the amplitude-frequency characteristic curves of them can be obtained. Because the amplitude-frequency characteristics at different speeds are similar, only two of them are shown in Figure 3. It is obvious that there are 9 peaks in the curve (marked in Figure 3), the corresponding frequencies shown in Table 2.



(a) 200 km/h (b) 350 km/h

Figure 3. Frequency spectra of vertical displacement of rail

Table 2. The frequencies corresponding to the amplitudes of vertical displacements of the rail (Hz)

Speed (km/h)	f_1	f_2	f_3	f_4	f_6	f_7	f_8	f_9	f_{10}
200	2.15	4.30	6.44	8.83	13.12	15.27	17.42	19.57	21.72
250	2.69	5.37	8.06	11.04	16.42	19.10	21.79	24.48	27.16
300	3.23	6.45	9.68	13.26	19.71	22.94	26.16	29.39	32.62
350	3.76	7.52	11.27	15.03	22.96	26.72	30.48	34.24	37.99

It can be seen in Table 2 that the 9 frequencies all approximately satisfy $f_1 \approx v/L_a$, $f_2 \approx 2f_1$, $f_3 \approx 3f_1$, $f_4 \approx 4f_1$, $f_6 \approx 6f_1$, $f_7 \approx 7f_1$, $f_8 \approx 8f_1$, $f_9 \approx 9f_1$ and $f_{10} \approx 10f_1$ (L_a is the length of a train). As shown in Figure 3, the amplitudes corresponding to f_1, f_2 and f_3 are bigger than the others, and there is no peak at the frequency corresponding to $5f_1$.

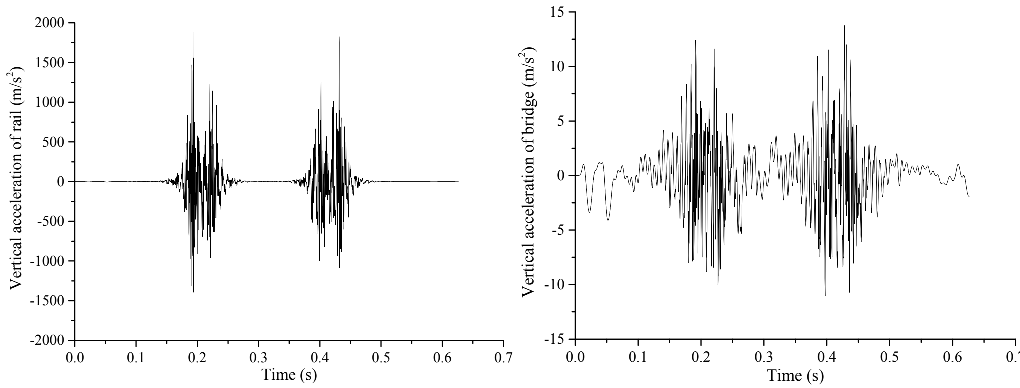
Based on the above analysis at four kinds of different speeds, it is known that there are 9 peaks on amplitude-frequency characteristic curves of the vertical displacements of rail, when 8 trains passing by the track structure with speed v, where the first peak frequency is v/L_a (L_a is the length of a train), and other peak frequencies approximately are integer times of the first peak frequency. And the conclusions are consistent with literature (Song Xiaolin, 2012) and (Xu Peng, 2011).

3.2 Analysis of dynamic characteristics

This part mainly analyzes the dynamic responses of each components of CRTSII bi-block ballastless track structure at four kinds of different speeds. Dynamic analysis indexes are shown in Table 3.

Table 3. The dynamic analysis indexes of CRTSII bi-block ballastless structure on viaduct

Components	Dynamic analysis indexes
Rail	Vertical displacement (absolute), Vertical acceleration
Slab	Vertical displacement, Vertical acceleration, Vertical compressive stress
Supporting layer	Vertical displacement, Vertical acceleration, Vertical compressive stress
Viaduct	Vertical displacement, Vertical acceleration, Vertical compressive stress



(a) The vertical acceleration of rail (b) The vertical acceleration of viaduct

Figure 4. Dynamic response of CRTSII bi-block ballastless track structure on viaduct at 300 km/h

Table 4. Dynamic responses of CRTSII bi-block ballastless track structure on viaduct at different speeds

Speed (km/h)	Vertical--	200	250	300	350
Rail	Displacement (mm)	1.09	1.04	1.06	1.11
	Acceleration (m/s^2)	1311.7	1746.5	1883.4	2202.4
Slab	Displacement (mm)	0.5870	0.6008	0.6221	0.6617
	Acceleration (m/s^2)	27.3	36.3	42.1	49.8
	Stress (kPa)	1104.78	1130.44	1132.48	1130.01
Supporting layer	Displacement (mm)	0.5872	0.6010	0.6223	0.6622
	Acceleration (m/s^2)	13.7	17.2	24.1	26.9
	Stress (kPa)	181.94	186.66	187.05	185.80
Viaduct	Displacement (mm)	0.5877	0.6015	0.6228	0.6629
	Acceleration (m/s^2)	0.92	1.24	1.37	1.52
	Stress (kPa)	32.17	33.38	33.47	32.74

As shown in Table 4, speed has a small influence on the vertical displacement of the slab, supporting layer and viaduct, and has a much smaller influence on the rail. The peak vertical displacements of the slab, supporting layer and viaduct at 350 km/h are 11.86% more than 200 km/h. The peak vertical displacements of the slab, supporting layer and viaduct at four kinds of different speeds are very close, and are all less than 60% of the peak vertical displacement of the rail.

It can be seen in Table 4 that the peak vertical compressive stresses of the slab, supporting layer and viaduct increase or decrease 2.3%, 2.6%, 3.8% at most respectively when speed increases 50 km/h (from 200 km/h to 350 km/h). But they don't strictly increase as the speed increases, the maximums all appear at 300 km/h. The peak vertical compressive stresses of the viaduct at four kinds of different speeds are 17.8% of the supporting layer and 2.9% of the slab.

It can be known from Table 4 that the speed of train has a great influence on all components of track structure, and the peak vertical accelerations of the rail, slab, supporting layer and viaduct at 350 km/h are 1.68, 1.82, 1.96 and 1.65 times of 200 km/h. The peak vertical accelerations of the slab at four kinds of different speeds are only 2.1% of the rail, showing that the fastener system has a very obvious effect on reducing vibration. And the peak vertical acceleration decreases from slab down to supporting layer to viaduct, decreasing 47.8% and 67.3% respectively.

4 Conclusions

(1) Without considering track irregularity, the frequencies corresponding to the peak of the vertical displacement of rail are related to the speed of train (v) and the full-length of a train (L_a), approximately equal to the multiples of v/L_a. So the peak frequency can be adjusted by changing the speed when the length of a train is certain, and we may consider changing the length to adjust the peak frequency in future design.

(2) The vertical displacements of the rail and the vertical compressive stress of the top surface of slab, supporting layer, and viaduct don't strictly increase as the speed increases, and there is a turning point.

(3) The peak vertical displacements of the slab, supporting layer and viaduct at four kinds of different speeds are very close, and all less than 60% of the rail; The vertical accelerations of each components of track structure are gradually reduced from top to bottom, and the vertical acceleration of the slab is only 2.1% of the rail, showing that fasteners play a good effect on reducing vibration.

(4) The speed of train has a big influence on all components of track structure, and the peak vertical accelerations of the rail, slab, supporting layer and viaduct at 350 km/h are 1.68, 1.82, 1.96 and 1.65 times of 200 km/h.

Acknowledgements

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References

Qu Cun (2011). Analysis of influence factors on CRTSI double-block ballastless track CWR on long-span viaduct of high-speed railway. Journal of Railway Engineering Society, 3, 46-51.

Sun Lu (2014). Dynamic response analysis of CRTSII ballastless track structure of high-speed railway. Journal of Southeast University: Since and Technology, 44(2), 406-412.

Zhu Yongjian (2010). The general speed train/the vertical dynamic characteristics of research on bi-block ballastless track. Southwest Jiaotong University.

Song Xiaolin (2012). Vertical displacement distributions of ballastless track infrastructure of high-speed railways. Journal of Civil Engineering, 45(5),

162-168.
Zhai Wanming (2007). Vehicle-track coupling dynamics. Since Press.
Xu Peng (2011). Study on vibration of train-track-subgrade coupled system and running safety of train in earthquake. Southwest Jiaotong University.

Track Measuring Methods in Maglev Engineering

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Abstract: In maglev engineering, the control network for monitoring function modules' deformations is the basis for accurately measuring the absolute position of the maglev guideway beams and the function modules. It is also the theoretical foundation for adjusting the guideway beams' position after operations. This paper introduces control network (CPIII) and demonstrates the feasibility of control network (CPIII) applied in monitoring deformations of function modules on guideway beams after the maglev project being operated, considering the main technology requirements and the layout features of control network (CPIII). Aiming at the special construction of function modules and providing that their measurement accuracy is ensured, the bury positions of function modules' location marks and measuring methods are specially designed. The bury positions of function modules' location marks and the layout and the measuring methods of the control network which monitors function modules' deformations were proposed.
Keywords: Maglev engineering; The control network for monitoring function modules' deformations; Track control network (CPIII).

1 Introduction

The maximum design speed of maglev train is 500 km/h. To ensure the safe operation of maglev train system, lines, guideway beams and function modules must have necessary accuracy, especially the function modules which are mounted on both sides of the guideway beams. Function modules positioning accuracy must meet ± 1mm, however, general measurement methods can not meet the requirements of such a high accuracy. To improve the accuracy of deformation monitoring, the control network for monitoring function modules' deformations must be used. To ensure the accuracy of the control network for monitoring function modules' deformations, the layout and the measuring methods of the control network and beam positioning marks must be specially designed.

2 Classifications of maglev engineering survey control network

There is no clear specification of the control network for monitoring function modules' deformations, by drawing on the specification of unballasted track control network, hoping to improve the methods of monitoring function modules.

Maglev engineering survey control network can be divided into three parts which are basic control network, primary datum point control network and densified control network (CHENG, 2009).

During the construction, basic horizontal control network is the basis for initial measurement and fitting measurement, and the spacing between two adjacent control network masks is about 9 km. Primary datum point control network is the basis for the construction of pier's foundation, the positioning of bearing and the positioning of guideway beam. The spacing between two adjacent control network masks is about 2-3 km, and all the marks shall be connected with positive centering observation pier. To meet the accuracy requirements of construction phase of route and precision positioning stage of guideway beam, densified control network must be set up in different construction stages such as construction of substructure, stakeout of bearing and precision adjustment of the guideway beams. The spacing between two adjacent densified control network masks is about 150-400 m.

3 Unballasted track control network

Unballasted track control network can be divided into horizontal control network and elevation control network and use the method of stepwise control forming control network. Control network use the method of hierarchical distribution network and controlling step by step. This method can restrict the transfer and accumulation of errors.

3.1 The accuracy requirements of unballasted track control network

Unballasted track control network includes basic horizontal control network (CPI), route horizontal control network (CPII), track control network (CPIII) (**Table 1**) (LI, 2012). Different levels of control network' functions and the main technical indicators are as follows:

(1) CPI mainly provides reference coordinates for surveying, construction, operation and maintenance.

(2) CPII mainly provides control reference for surveying, construction.

(3) CPIII mainly provides control reference for the laying of unballasted track and maintenance operations.

Table 1. Main technical indicators

Control network	Measurement methods	Measurement category	Point spacing	Relative mean square error of adjacent points
CPI	GPS	2	≤4km	10
CPII	route	3	400-800	8
CPIII	Free station angular intersection		50-70m	1

3.2 Establish and observation of track control network (CPIII)

The spacing between two adjacent CPIII fixed points is generally 60m. The height of adjacent CPIII fixed points should be roughly equal, and laying position should maintain a certain height difference in the orbital plane (**Figure 1**).

CPIII control network use the measurement method of free station linear angular intersection and shall be checked for the fixed points' unchanged position though the CPI and CPII fixed points. CPIII control network need to survey a CPII fixed point each 600m and each CPII fixed point need to observe at least 3 times (LIU, 2007).

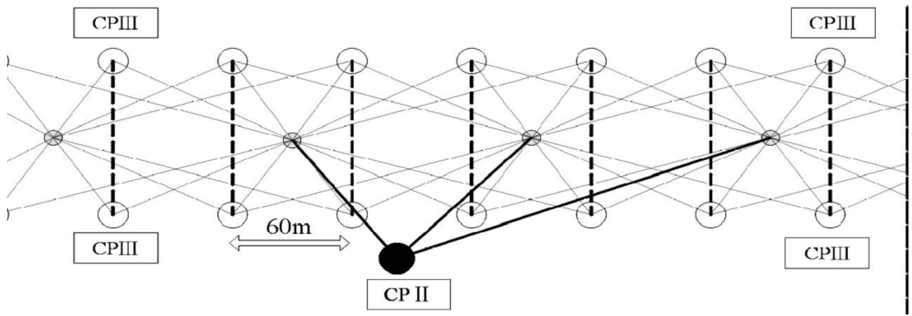

Figure 1. CPIII "the method of resection" network diagram

4 The feasibility analysis of using track control network (CPIII) in monitoring function modules' deformations.

The spacing between two adjacent maglev primary datum point control network masks is about 2-3 km and is close to the spacing between two adjacent basic horizontal control network masks (≤4km). The spacing between two adjacent maglev densified control network masks is about 150-400 m and the spacing is close to the spacing between two adjacent route horizontal control network masks. Track control network (CPIII) mainly provides control reference for the laying of unballasted track and maintenance operations (XIA, 2010).

So maglev engineering survey control network and unballasted track control network can survey analogously and the function of track control network (CPIII) can be applied to monitor the deformations of function modules on guideway beams after the maglev project being operated. Based on the known maglev engineering survey control network (basic control network, primary datum point control network, densified control network), control network for monitoring function modules' deformations is specially designed which is matched with the characteristics of maglev track and is similar to track control network (CPIII).

5 Bury positions and measuring methods of function modules' location marks

Aiming at the special construction of function modules and providing that their measurement accuracy is ensured, the bury positions of function modules' location marks and measuring methods are specially designed.

5.1 Bury positions of function modules' location marks

Dowel hole is precisely machined by CNC machine tools in the guideway beams, and the machining precision is ± 0.02 mm. In the construction of Shanghai magnetic suspension demonstration operation line, we use the dowel hole on both sides of the guideway beams to locate the position of the magnet suspension path precisely (**Figure 2**). When laying the fixed point, dowel holes can also be used (CHEN, 2009).

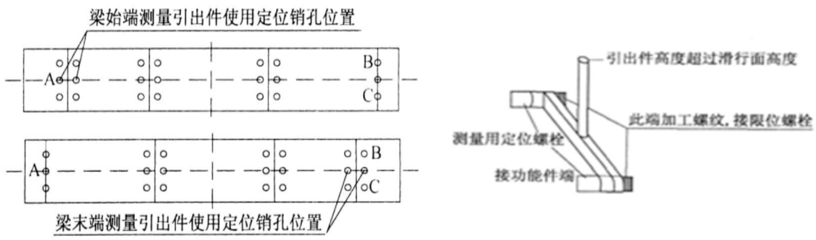

Figure 2. Locations of Dowel holes, Extension part

Dowel hole located within the side of the function module, and the space coordinates of center are provided by the design units. As the set of assembled reflector prism for CPIII cannot be mounted directly on the dowel hole, so we need to use locating bolts and extension parts which are specially made for positioning measurement. By using the space coordinates of the lateral side of the center point of the dowel hole and the space geometric relationship of extension parts of the dowel hole, the space coordinates of observation points of the extension parts can be calculated.

While monitoring measurements, we installed the set of assembled reflector prism for CPIII on the extension parts, thus it can be measured according to the control network for monitoring function modules' deformations.

5.2 The distribution of fixed points on the function modules

The length of maglev guideway beam is about 24m. To ensure the accuracy of function modules, the fixed points must be laid on each beam (SHAO, 2008).

Referring to the densified CPIII control network, fixed points are installed on the dowel hole on both sides of the lateral boundary in guideway beams. Points can be divided into A, B two categories, and these two kinds of points are arranged on each guideway beam **(Figure 3)**. A point: this kind of point is located on one side of guideway beam and the same side (All are on the left side or right side) of adjacent guideway beam. So the control network for monitoring function modules' deformations is composed of A points, and the spacing between two adjacent the points is generally 24m. B point: a pair of points on another lateral side of guideway beam. B points are used as relative measurement fixed point and are not included in the control network.

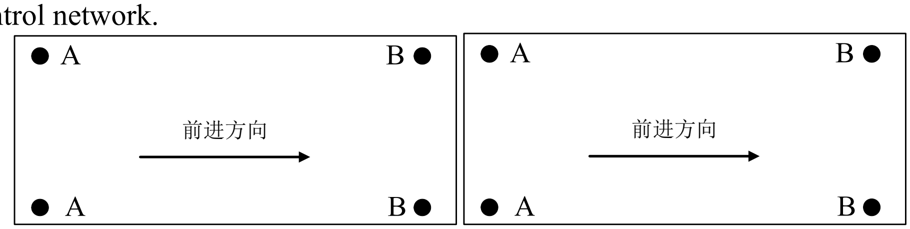

Figure 3. The distribution of fixed points

5.3 Measuring methods of the control network for monitoring function modules' deformations

According to the characteristics of maglev track beam, the measurement can be divided into two parts.

1) By referring to the measurement method of track control network (CPIII) and using the measuring methods of the control network for monitoring function modules'

deformations, the absolute position of fixed points on lateral boundary of guideway beams are accurately measured.

2) Through the relative measurement, the relative position of A points to B points on a adjacent guideway beam is accurately measured, so the absolute positions of the guideway beam and the whole line are accurately measured.

6 Measurement of fixed point and processing of data

Control network for monitoring function modules' deformations and track control network (CPIII) have similar method of measurement, calculation and instrument such as Lycra TCA2003, Trimble TrimbleS6 etc (HE, 2004).

Data processing includes inspection of on-site data and adjustment of control network, and it is similar to the track control network (CPIII) data processing method.

7 Conclusions

According to the characteristics of magnet suspension path and function modules and the reference to the burial location of marks which were used on the track beam accurate adjustment, the bury positions of function modules' location marks , measuring methods and control network for monitoring function modules' deformations are specially designed.

This study can provide theoretical basis for the formulation of standardized measurement of the high speed maglev line.

8 Acknowledgement

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References

CHENG Shengyi, GUO Chunsheng, ZHU Pingjin. (2009). "The Tolerance Index of Densified Horizontal Control Network in Maglev Engineering." *Urban Mass Transit*

CHEN Dingxiang, CHENG Shengyi, GUO Chunsheng. (2009). "Improved Design for Extension Part of Route Adjusting Survey." *Urban Mass Transit*

HE Wentao. (2004). "The Accurate Alignment Technology of Magnet Suspension Path." *Bulletin of Surveying and Mapping.*

LI Fuwei, WANG Jun. (2012). "Precision Measurement Instrument in the Application of Accurte Measurements for High-Speed Railway Bridge Construction." *Anhui Architecture.*

LIU Renzhao, LIU Tingming. (2007). "Establishment of Engineering Control Network with High Accuracy." *Geospatial Information.*

SHAO Donghua, KANG Ming. (2008). "Magnetism of "863" Floats the Track Roof Beam of Test Line Orients the Analysis of Measurement Accurately." *Urban Geotechnical Investigation & Surveying.*

XIA Ji, YING Lijun. (2010). "Precision Engineering Survey of High Speed Railway." *Science & Technology Information*.

Research on Natural Ventilation Intelligent Control Technology of a Highway Tunnel

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Abstract: Tunnel Intelligent Transportation Systems is an important part of highway intelligent transportation. Ventilation control of superlong road tunnels is mainly automatic control supplemented by manual control, which aims at maintaining good visual environment inside the tunnel with minimum power consumption, controlling the air pollution status within the prescribed permissible range and dealing with fires in a prompt and effective way. This study focus on the control strategies and methods of the highway tunnel ventilation systems, including axial fan, jet fans and other controlled object, and obtain highway tunnel ventilation intelligent control technology.

Keywords: Highway tunnel; Natural ventilation; Axial fan; Jet fan; Intelligent control.

1 Introduction

Highway as the two main modes of transportation, has always been the main force to promote the national economic development in china. With the rapid development of highway construction, the tunnel construction has come into a boom. In the construction of the tunnel, China has explored spontaneously and innovated bravely which leads to a leaping development in self-tunnel construction ability and makes China the country with the fastest speed of tunnel-growing. According to incomplete statistics, the number of highway tunnels has reached 8522 up to the end of 2011, whose total length is 6.25 million meters.

Thus, China has become a country possess the most tunnels and underground works around the word with the fastest development speed facing the most complex Geological condition and structural form.

With the growing scale of tunnel construction, the ventilation equipment designed in the extra-long tunnel has great power causing huge energy consumption.

2 Energy-saving analysis with the natural wind

According to the calculation, the values of the wind have a great influence on the power of fans. Because the natural wind speed has a relationship with the square of wind speed. The wind resistance in the ventilation system increased by three times. The power needed for ventilation increases when the wind resistance increases. And the situation of the wind resistance with different wind value is as followed taking Nibashan tunnel as an example the traffic of which adopts the value in 2015.

Table 1. Proportion of natural wind at different wind speed

natural wind speed (m/s)	natural wind resistance (kPa)	other resistance (kPa)	total wind resistance (kPa)	proportion of natural wind
0	0.00	51.86	51.86	0.00%
5	116.59	51.86	168.45	69.21%

Absolutely, the natural wind has a great influence on the power of ventilation. The power used to overcome the natural wind usually takes a part of 20%-50%, and specifications always take the natural wind as a kind of resistance. Actually, the natural wind acts as resistance or driving force with the change in the value and direction. But in the common ventilation calculation, the natural wind is regarded as resistance with a speed of 2.5～3.0 m/s. If the natural wind can be divided into two cases the positive and the negative then used as the driving force at the right time, a great economic profit will occur.

3 Month control Strategy

In the design stage, we built 4 automatic weather monitoring stations, monitored the meteorological conditions of Nibashan tunnel for a long time, collected the meteorological data and obtained the natu-ral wind movements rules. The arrangement of the weather stations is shown in the following figure 1.

Figure 1. Location of the automatic weather station:

We collected totally 93,120 groups of meteorological data by monitoring the tunnel weather conditions for up to 485 days, obtaining the histogram of monitoring data, the rose diagram of wind speed and directions by analysis the data. Take the station 1 for example, as shown in figure 2, where represent the distribution of these factors above.

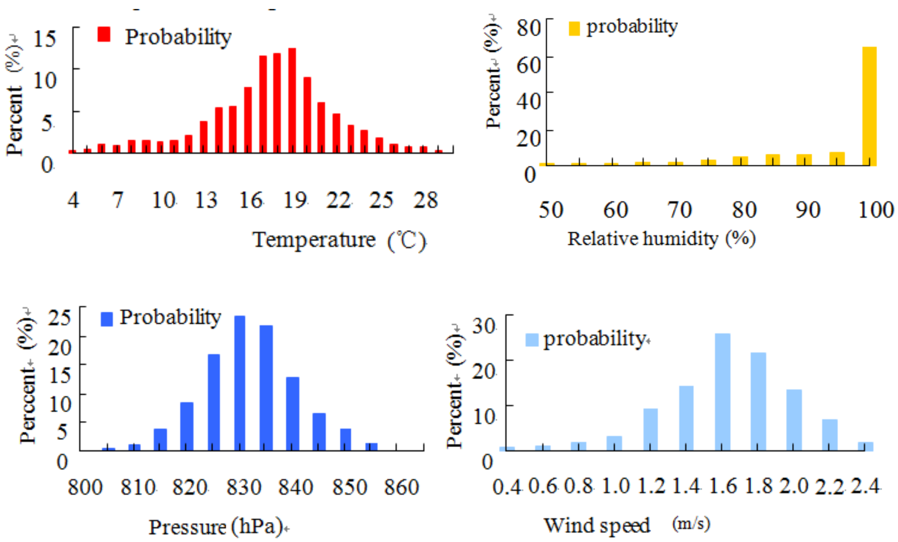

Figure 2. Meteorological data from the automatic weather station

Take Nibashan tunnel as an example the traffic of which adopts the value in 2015, calculate the arrangement situation of the fan on the condition that the natural wind is 2.5 m/s or the wind speed with a guarantee rate of 95%.The results are as followed:

Table 2. Power of the fan on the condition that the natural wind is 2.5 m/s or the wind speed with a guarantee rate of 95%.2.5m/s

working conditions		the first section (KW)		the second section (KW)			the third section (KW)		total power
		jet fan	axial flow fan	supply fan	jet fan	exhaust fan	jet fan	axial flow fan	KW
the fan required (2.5 m/s)	left tunnel	148	24	193	296	45	0	122	1601
	right tunnel	148	22	157	296	32	0	117	
	total	296	46	350	592	77	0	239	
the fan required (a guarantee rate of 95%)	left tunnel	148	24	193	370	45	148	122	1748
	right tunnel	74	22	157	296	32	0	117	
	total	222	46	350	666	77	148	239	

Table 3. Modes and the energy saving benefit in different period of time

period of time	left tunnel		right tunnel		power in total	
	jet fan (KW)	axial flow fan (KW)	jet fan (KW)	axial flow fan (KW)	total power (KW)	energy saving (%)
daytime in January	555	315	259	413	1542	3.7
nighttime in January	518	315	370	413	1616	0.0
daytime in December	555	315	259	413	1542	3.7
nighttime in December	185	315	370	413	1283	19.9

4 Detail control Strategy

Do the energy analysis by the control strategy of one hour then get the modes in different period of time and the corresponding energy efficiency by calculating. The following chart gives the data result in Nibashan tunnel.

The average condition can be obtained after take the average power calculated in different working conditions and at different time. And all the average conditions and the working condition with the speed of 2.5m/s are as shown below.

Table 4. Energy saving benefit in different period of time

working conditions	power of jet fans (KW)		energy saving
	left tunnel	right tunnel	
2.5 m/s	444	740	0
1 hour	128.7	543.5	43.2%

The chart above shows that energy-saving effect is great by rationally using the natural wind. And the effect would be more obvious if one hour control strategy was adopted. But the one hour control strategy would make the fan status changes too frequently which will reduce the life of fans. So what kind of control strategy to adopt needs a comprehensive consideration.

The natural wind probability distribution of each section in the main tunnel is shown in figure 3. It is shown that the main wind direction of section 1 is negative, the average value is about 2.4 m/s, the section 2 is positive, the average value is about 2.4 m/s, the section 3 is positive, the average value is about 1.2 m/s.

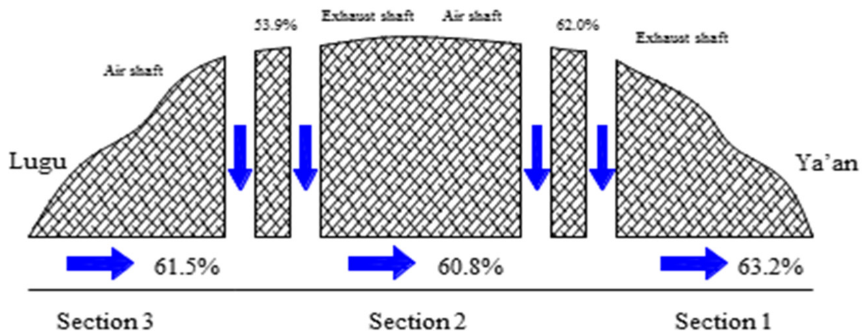

Figure 3. The annual probability distribution of Niba mountain (left line)

The original ventilation cost 21037140 yuan a year (1.5 yuan / kWh), and the cost will be 18231741 yuan a year after the monthly control optimization saving 2.8054 million yuan, The annual energy saving is 13.3%; the annual energy saving can be as much as 20.5% when six hours control strategy is adopted. What's more, the annual energy saving can be as much as 50.5% when real-time control strategy is adopted, the annual energy consumption can be 10624355 yuan saving electricity bill by 10.6244 million yuan.

5 Conclusions

The calculation shows that even the fan number designed according to the wind speed with a guarantee rate is more than that calculated with a wind speed of 2-3m/s recommended in the specifications, the actual number of fans turned on is less than that in the traditional conditions and better. Because Optimized design of the ventilation works. Reasons in detail are below:

(1) Wind speed adopted in the calculation is 2～3 m/s, but the natural wind of the tunnel located at climate boundaries usually is as much as 4～6 m/s, So the wind speed with a guarantee ratio is much more rational ensuring a better ventilation.

(2) The single hole tunnel can change the ventilation mode according to the speed and direction of the natural wind under the pattern of energy-saving. Thus, the tunnel can use the natural wind in different degrees, which will contribute to energy –saving.

(3) The conventional ventilation design takes both of the holes as the most unfavorable working condition in the double line tunnel. After adopting the energy-saving design one line will be in favorable condition and the other one will be in adverse condition.

Acknowledgement

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References

Documentation and history center of railway ministry. China railway yearbook 2011. Beijing: *China Railway Publishing house*. 2012.

GUO Chun, WANG Mingnian, Tang Zhaozhi. (2011). "A Study on Surge and Stall under the Interaction of Parallel Axial Flow Fan in Tunnel" *J. Noise and Vibration Worldwide*, 42(11): 9-14

GUO Chun, WANG Mingnian, Yu Li. (2012). "Control and Behavior Prediction of Personnel Evacuation in Underground Ventilation Equipment Room on Fire" *J. Applied Mechanics and Materials*, (121-126): 2582-2586

GUO Chun, WANG Mingnian, ZHAO Haidong. (2007). "Research into Fire Disaster Prevention and Rescue of Super-long Railway Tunnel" *J. China Safety Science Journal*, 17(9): 153-158

GUO Chun, WANG Mingnian, ZHOU Renqiang. (2008). "Fire Accident Relief and Disaster Prevention Response Technology of Fortes Road Tunnel" *The 3rd International Symposium on Modern Mining & Safety Technology*

Wang Mengshu. An overview of development of railways, tunnels and underground works in China. *Tunnel Construction,* 2010;30: 351-364.

Wang Mengshu. China has the largest amount of tunnels and underground works in the world with most complicated geological conditions, and has a foreseeable quickest development in the future. *Railway Standard Design*, 2003; 1: 1- 4.

Mechanism Analysis of the Box-Type Anti-Slide Pile with Vertical End-Curve-Arrangement Prestressed Tendons in Landslide Control

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Abstract: In this paper, a comparison analysis using FEM calculation was carried out regarding three kinds of anti-slide pile, i.e. the common one, the box-type reinforced concrete one and the box-type one with vertical prestressed tendons, showing that the displacement and positive bending moment of the pile with vertical prestressed tendons are smaller than that of the rest ones under 2000 kN landslide thrust, with slight increases of negative bending moment on both ends, indicating that it has obvious advantages in resisting displacement and bending during landslide control; on this basis, the layout patterns of the prestressed tendons were optimized by comparing the 5 types of layout option, and negative bending moment and shearing force of the box-type pile with vertical end-curve-arrangement prestressed tendons were found to be smaller than that of the rest ones, while the maximum positive bending moment and positive shearing force on the sliding surface remaining the same, proving that it is more scientific, reasonable and appropriate for landslide control; a loading simulation was conducted, showing that the prestress shall be applied appropriately. Combined with the inherent structure characteristics and internal vertical end-curve-arrangement prestressed tendons, the landslide stability is improved for box-type pile.

Keywords: Landslide control; Box-type; Vertical end-curve-arrangement prestressed tendon; Anti-slide pile.

1 Introduction

Many measures can be adopted for landslide control, such as anchor bolt in fixing frame, retaining wall and anti-slide pile, etc, and the anti-slide pile is used herein for the retaining and landslide control in case of large residual sliding force. Due to the large design section size, big concrete volume, large reinforcement amount and deep embedded pile body in bedrock, the construction of common pile is very expensive and difficult. Additionally, the concrete strength may be affected by the fact that the hydration heat in large volume concrete casting is hardly released. With the accumulations of theoretical research and engineering practice, especially the research on calculation theory, many research achievements were obtained for anti-slide pile at home and abroad, e.g. a pile with prestressed anchor cable (externally prestressed) was introduced with anchor cable applied on the top. The pile with prestressed anchor cable changes the stress pattern of the common one, namely, making the stress state of cantilever pile from passive to positive, thus bringing obvious reductions of shearing force and bending moment on the lower part and a more reasonable stress state and distribution of entire pile body comparing with the common one. And under the anchoring force, the entire pile body is endowed with a function of actively reinforcing the landslide mass.

As for externally prestressed anti-slide pile, its slide resistance is to be achieved by anchoring the pile in the stable bedrock via a prestressed anchor cable set on the top, and the anchor cable is subject to the elastic tensioning with applying of the prestress and the slide-thrust. However, with the change of working condition, like climate, groundwater, and rock-soil properties in anchorage zone, the force applied on pile and anchor varies dynamically, which reduces the bond strength between rock-soil and anchor cable. Besides, its anti-sliding effect will be reduced when the free-section of prestressed anchor cable is overlong due to the gentle sliding surface or thick slip mass, or when the prestress loss exsists during the linear tension transfer under the earthquake action. Considering the disadvantages of box-type structure in releasing hydration heat of mass concrete in casting, a box-type pile with vertical end-curve-arrangement prestressed tendons inside, is herein proposed to overcome the bond strength reduction of anchor cable and to improve the mechanical properties of pile, such as bending tensile strength, for further ensuring the anti-sliding effect.

2 Calculation Principle and Method

2.1 Basic Assumptions

It assumed that the compressive stress is applied inside the tensile area of pile by prestressed tendons, being counteracted by tensile stress induced by landslide to an appropriate degree.

2.2 Mechanical Model

(1) Based on the calculation of thrust distribution on the pile and considering that most of the landslide mass is the loose mass made up of gravel soil, it is more reasonable to adopt a trapezoid-distribution.

(2) The stiffness of pile, compared with that of soil, can be seen as infinity; the soil layer underneath the sliding surface can be seen as an elastic medium; generally, the lateral subgrade coefficient of soil layer increases with increasing depth.

(3) The stress load on the box-type pile with vertical prestressed tendon is basically the same as that on the cantilever pile except for the generation and changes of internal stress.

(4) The box-structure takes full advantage of high-strength material and large anti-bending inertia moment to improve the flexural behavior.

(5) The layout of prestressed tendon shall be consistent with the stress change inside the pile as much as possible.

(6) Only 24% of the total area is hollow, and the area of shear reinforcement shall be properly increased in the parts subjected to great shearing force.

3 Stress Calculation and Analysis

3.1 Finite Element Model

A finite element model for stress analysis is established by MIDAS/CIVIL, with 20 elements, 21 nodes and boundary conditions, of which an elastic interlink is made for the 7 elements underneath the sliding surface. As a box-type structure with prestressed tendon, whose wall thickness is 0.5 m and length is 20 m, the pile's section dimension is 1.8m*2.2 m and its internal dimension is 0.8m*1.2m. In this analysis, C35 concrete is to be used for its small shrinkage and creep under the action of prestress, steel strand of 1860 MPa is to be adopted as the prestressed tendon bonded with concrete and constructed by post-tensioning method, and HRB335 steel bar is to be selected for shearing resistance. Besides, as an elastic medium, common soil is to be used as the foundation of anti-slide pile with nodes for elastic supporting. During the simulation of working process, it is to choose trapezoidal pattern (2:5) for the distribution of external load (i.e. landslide thrust).

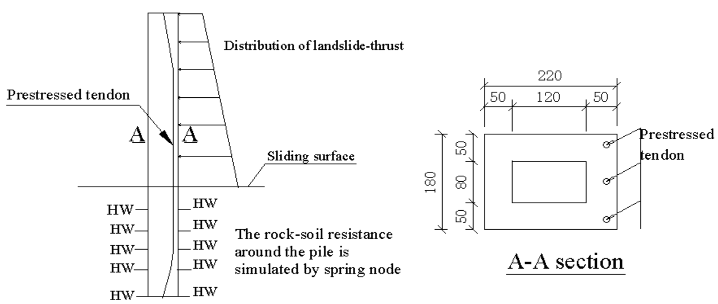

Fig.1 Structure of box-type anti-slide pile with vertical end-curve-arrangement prestressed tendon

3.2 Mechanical Calculation and Analysis under Various Conditions

To show the characteristics of pile with prestressed tendon, it is to compare the deformations of three kinds of anti-slide pile, i.e. the common one, the box-type reinforced concrete one and the box-type one with vertical prestressed tendon under the same load and boundary conditions. And to show the characteristics of prestressed tendon, it is to calculate its displacement and internal force changes, like changes of displacement, bending moment and shearing force and to do the mechanical analysis for curve-arrangement prestressed tendon after further optimization of prestressed tendon.

3.2.1 Comparison of nodal displacement and internal force change

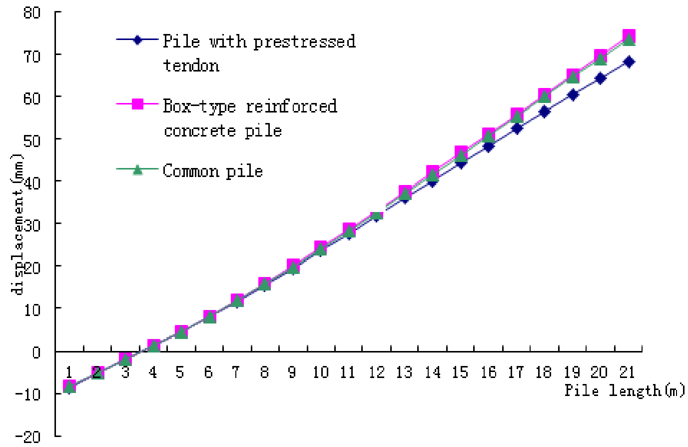

Fig. 2 Displacements of three kinds of pile under the action of thrust

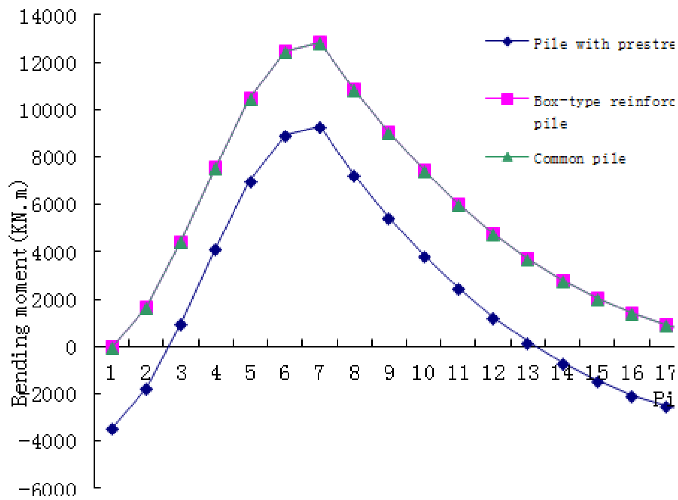

Fig. 3 Bending moments of three kinds of pile under the action of thrust

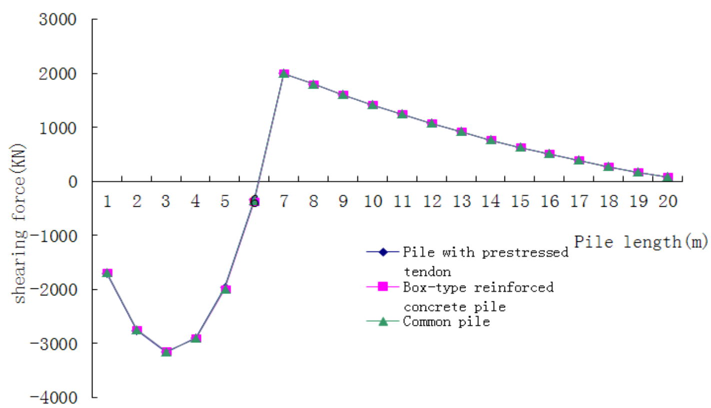

Fig. 4 Shearing force of three kinds of pile under the action of thrust

As shown in Fig.2, under 2000kN thrust, the displacements of three piles at the anchorage part of bottom are almost the same; their points with 0 displacement are all located at the 3.5m above the bottom, being considered as the pivot point for rotation. However, the closer to the pile top, the larger the displacement is. In general, the displacement of the box-type pile with prestressed tendon is the smallest, with 7.91% and 8.93% less than that of the common one and the box-type reinforced concrete one.

As seen in Fig.3, under 2000 kN thrust, the bending moment variation on common pile agrees with that on box-type reinforced concrete one and both of their bending moments are positive while the bending moment variation on pile with prestressed tendon is characterized by positive-negative alternating. On the whole, the maximum bending moments of the three piles are located at the same position, i.e. at the 7m above the bottom. But the maximum bending moments of the common pile and the box-type reinforced concrete one are 12857.25 kN.m, an excess of 38.44% compared with the 9787.28 kN.m of the pile with prestressed tendon, indicating that the bending moment of the pile with prestressed tendon is the smallest.

From Fig.4, it can be seen that the shearing forces and relevant variations of the three piles are almost the same under 2000 kN landslide thrust, namely, their maximum positive shearing forces are all about 2000 kN and located at the 7 m above the bottom (i.e. the sliding surface), and the maximum negative shearing force are all about 3150.93 kN and located at the 3 m above the bottom.

The results show that under the same load, the box-type pile with prestressed tendons has the smallest displacement and bending moment and nearly the same shearing force as that of the others, proving that it is more stable and owns a higher bending resistance compared with them.

3.2.2 Force comparison of piles with straight-arrangement tendon and curve-arrangement one

The prestressed tendon in concrete structure is subject to the tensioning or compressing depended on the internal force variation. It is necessary to adopt prestressed tendon arranged in curve form on both ends being applied 1500 kN landslide thrust, since the end bending moment trended to be 0 is reasonable. And the calculation of internal force of prestressed tendon is as shown in Fig.5 and Fig.6. In these figures, *Straight-arrangement Prestressed Tendon* refers to prestressed tendon arranged in straight form; *Top-curve-arrangement Prestressed Tendon* refers to prestressed tendon arranged in curve form near the top of pile; *End-curve-arrangement* refers to prestressed tendon arranged in curve form on both ends of pile. On these bases, *No.1 Adjusted Arragement Prestressed Tendon* represents the prestressed tendon with curve-form arrangement 12m above the bottom to the top; *No.2 Adjusted Arrangement Prestressed Tendon* represents prestressed tendon with curve-form arrangement 7m above the bottom (the position of maximum bending moment) to the top. The internal force variation shall be analyzed under the 5 working conditions.

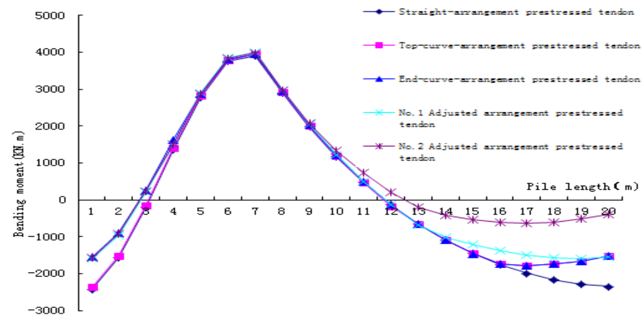

Fig. 5 Bending moment variation under various prestressed tendon arrangement

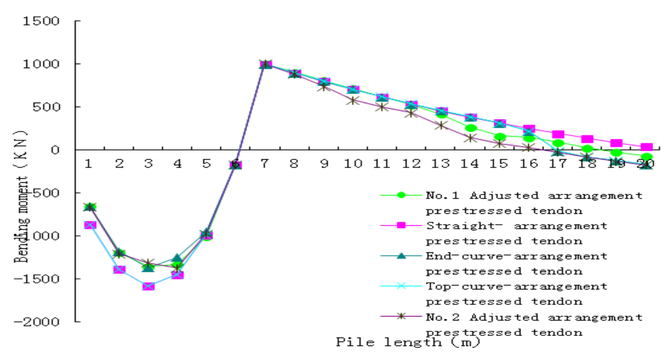

Fig6 Shearing force variation under various prestressed tendon arrangement

As shown in Fig.5, the maximum bending moments under the 5 conditions are nearly equal and all are located at the 7 m above the bottom. However, the closer the curved point of prestressed tendon is to the 7 m above the bottom, the smaller the negative bending moments are on both ends. And as shown in Fig.6, their maximum shearing forces are all located at the 7 m above the bottom. But the closer the curved point of prestressed tendon is to the 7 m above the bottom, the smaller the shearing forces are on both ends. Especially at the 3 m above the bottom of anchorage part, the shearing force varies considerably, which may reduce the shearing resistance of pile. Thereby, it indicates that the position of the maximum bending moment of pile with prestressed tendon is consistent with that of the common one, both on the sliding surface.

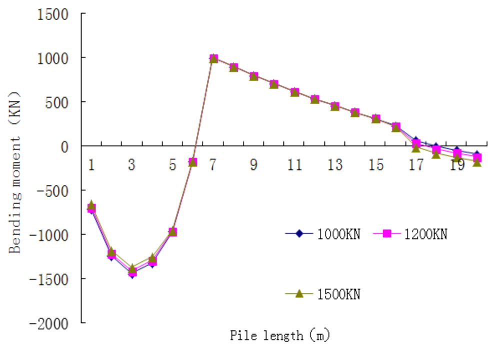

Fig. 7 Bending moment variation caused by prestress applied

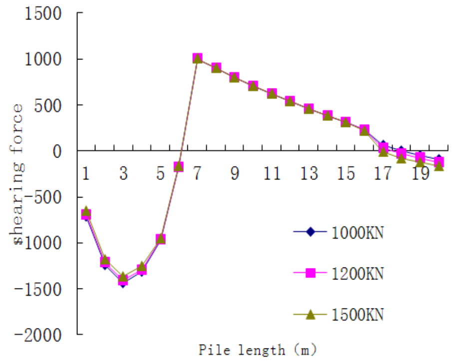

Fig. 8 Shearing force variation caused by prestress applied

Loading on prestressed tendon will cause a change of internal force, i.e. with an increase of loading, the positive bending moment of pile decreases gradually while the negative bending moments on both ends increase, as the analysis shown in Fig.7; with an increase of loading, the shearing force on the anchorage part of pile decreases while the negative shearing force near the top increases slightly, as shown in Fig.8. The results show that loading on prestressed tendon has effects on the bending moment, but no effect on the shearing force; prestress shall be applied appropriately.

3.2.3 Increasement of Grade and Area of Shear Reinforcement under the Maximum Shearing Force

Since the strength of C35 concrete to be adopted is higher than that of C25 concrete, it only needs to increase the stirrup quantity at the position of great shearing force for meeting the requirement of shearing resistance considering that the hollow area of box-type pile takes up only 24% of the total area and has slight effect on the shear-bearing capacity of anti-slide pile

4 Conclusion

The following conclusions are drawn from the mechanism analysis of box-type anti-slide pile with vertical end-curve-arrangement prestressed tendons:

(1) Based on the comparison using finite element modeling, the box-type pile with prestressed tendons conforms to relevant mechanics principle and plays an important role in reducing bending moment and pile displacement as well as improving the pile stability.

(2) Adopting the pile with prestressed tendons inside can resolve the following problems, such as the decreased bond strength between prestressed tendon and anchor cable induced by the rock-soil condition variation; the reduced anti-sliding effect under an overlong free-section of prestressed anchor cable induced by gentle sliding surface or thick slip mass or in a state of prestress loss caused by earthquake

during the linear tension transfer, etc.

(3) Using the unique hollow structure of box-type pile, the hydration heat produced by concrete casting can be effectively released to ensure the quality of concrete; the internal monitoring and maintenance for anti-slide pile can be implemented; the effective drainage inside the landslide mass can be achieved for improving its stability.

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References

Dai zihang. Anti slide pile and pile landslide thrust forward slip of. Chinese Journal of rock mechanics and engineering, the resistance distribution of 2002, 21 (4): 517 – 521

Hou Xiaoqiang, Cao Jianyu, Qian Puzhou,Sun Hong. Study on Mechanism of Box Vertical Pre-stressed Anti-slip Pile. Urban Roads Bridges & Flood Control, 2014,10 (1): 178-181

Hu Qingan, Xia Yongxu, Zhao Zisheng. Numerical simulation of anti slide pile. Journal of Chang'an University of Landslide Treatment Engineering: Architecture and Environmental Sciences, 2003, 2O (4): 8 12.

Shi Liang, Zhang Zhe, Li Xunchang, et al.316 national highway K25+040 ~ slide pile structure design. Journal of Earth Sciences and environment, anti landslide control in the +140 segment 2004, 26 (3): 44 47

Wei Ning, Fu Xudong, Zou Yong, et al. Finite element calculation of anti slide pile with prestressed anchor cable and its application. Journal of Wuhan University, 2004, 37 (5):73 ~ 76.

Remaining Life Prediction for Composite Airport Pavement

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Abstract: The remaining life is usually taken into account for pavement maintenance or reconstruction. To determine the optimal reconstruction time of a certain composite airport pavement, the authors used 3 kinds of methods to predict the remaining life, respectively based on a former Federal Aviation Administration (FAA) design standard called as Layered Elastic Design Layered Elastic Design Federal Aviation Administration (LEDFAA), Airport Pavement Design Method of China (APDMC) and Pavement Condition Index (PCI) regression model. According to the in-situ data of Heavy Weight Deflectometer (HWD), PCI and air traffic volume in the past several years, the pavement remaining life of the composite airport pavement was predicted using the above three methods. The prediction results and their comparison are presented as well.
Keywords: Airport engineering; Composite pavement; Remaining life; Prediction method; PCI.

1 Introduction

The remaining life of airport pavement is one concern for pavement maintenance or reconstruction. To predict the remaining life of existing pavement is considered as the inverse procedure of new pavement design, in addition, the structural and material parameters of existing pavement used for the prediction should be different from those of new constructed pavement. The current design procedures for airport cement concrete pavement involve LEDFAA and APDMC developed by FAA and Civil Aviation Administration of China (CAAC) respectively. To better predict complex wheel load interactions of the next generation of large civil aircraft such as the Boeing B-777 aircraft and Airbus A380, LEDFAA was introduced as the design program by the FAA in 1995. LEDFAA implements advanced design procedures based on layered elastic theory and handles new and overlay design of both flexible and rigid pavements. The LEDFAA thickness design standard for airport pavements design for fatigue failure expressed in terms of a "cumulative damage factor" (CDF) using Miner's rule. Also, the major material property of the pavement layers is now uniformly expressed as an elastic modulus instead of the previous CBR (California Bearing Ratio) for flexible pavements or k-value for rigid pavements (Federal Aviation Administration,1995). APDMC is similar to the conventional FAA design procedures. In APDMC, the concept of design aircraft is developed for calculating the cumulative equivalent loads of many types of common aircraft gears, and thickness design standard is defined as fatigue damage due to repeated stress at bottom of the concrete pavement(Civil Aviation Administration of China, 2000). Ling Jian-ming (Ling, J. M., Zheng, Y. F., 2001) *et al.* (2001) and Wang Wei (Wang, W., 2004) (2004) had applied APDMC method to develop the prediction method of remaining life for cement concrete pavement of airport. Moreover, PCI recession model was also considered an approach to predict the remaining life. PCI is based on a visual survey of the number and types of distresses in a pavement. The result of the analysis is a numerical value between 0 and 100, with 100 representing the best possible condition and 0 representing the worst possible condition. PCI surveying processes and calculation methods have been standardized by ASTM for airport pavement. PCI regression model is established by in-situ PCI survey data in past several years and can be used to predict PCI in the future years(Ollerman, F. A., and Varma, A. ,1998).

As seen from literature, the present prediction methods are mainly developed for unique cement concrete pavement. However, The remaining life of composite pavement need attention as well. This paper discusses the alternatives to estimate the composite pavement with an example of a certain composite airport.

The research object is a certain composite airport pavement which has experienced several times of overlayed. The initial pavement consisted of 15cm PCC slab and 25cm block stone base course, and the nowadays runway pavement presents to be relatively complex composite structure. Figure 1 shows the thickness and the materials of typical runway pavement and subgrade layers which were constructed in different stages.

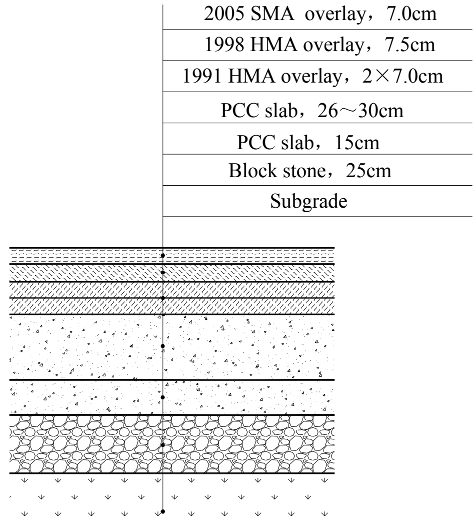

Figure 1. Cross-Section of the typical pavement of the composite pavement

To determine the optimal time for the next reconstruction of the pavement, the remaining life of the existing pavement should be accomplished as an import basis for decision-making. Three alternatives categorized as structural and functional methods are applied to predict the remaining life of the pavement which include LEDFAA pavement design procedure, APDMC pavement design method and PCI regression model.

2 Three methods to predict the composite pavement life

2.1 Appropriate Combination of Pavement Layers

To better account for the performance of various structural layers and decreasing the error level in the modulus back-calculation, the runway pavement is appropriately combined to five layers according to the pavement condition: 1998 and 2005 HMA overlays as one layer, 1991 HMA overlay, PCC slab, block stone and subgrade. The simplified pavement structure is shown in Figure 2.

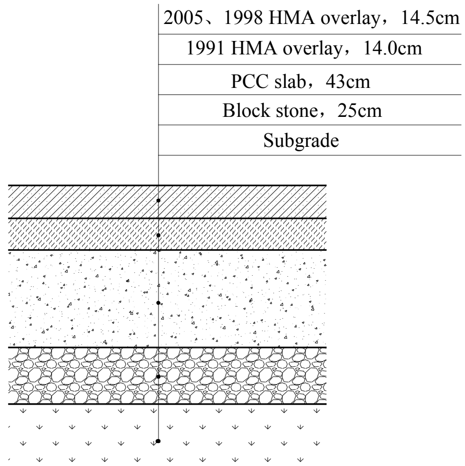

Figure 2. Simplified pavement structure

2.2 Pavement parameters determination

Since the existing pavement has been provided service for many years, the pavement materials have consumed a certain degree of structural life subject to a wide variety of loadings and climatic effects (Civil Aviation Administration of China, 2000). For this reason, the thickness of pavement layers must be appropriately discounted based on field testing results of pavement layers' condition, and elastic moduli of pavement layers and subgrade should also be back-calculated by HWD test. The FAA's back-calculation program, BAKFAA, is used to analyze deflection data to characterize the pavement and obtain the material properties of each pavement and subgrade layer.

Figure 3 shows the comparison of the calculated deflections and measured deflections, and table 1 shows the calculation parameters for predicting the remaining structural life of runway pavement conducted by LEDFAA pavement design procedure.

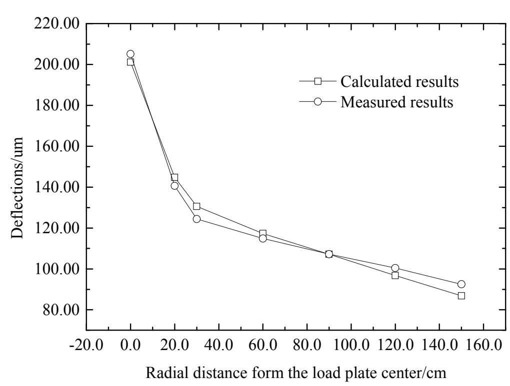

Figure 3. The comparison of the calculated deflections and measured deflections

Table 1. Calculation parameters for predicting the remaining structural life

Structural layer	Discounted thickness/cm	Back-calculated moduli/MPa	Poisson's ratio	Flexural strength/MPa
2005、1998 HMA overlay	13.0	1385	0.35	—
1991 HMA overlay	10.5	981	0.35	—
PCC slab	30.1	27600	0.15	5.5
block stone	25.0	280	0.35	—
subgrade	—	25	0.40	—

2.3 LEDFAA to Predict the Remaining Structural Life

LEDFAA program is applied to predict the remaining structural life of the runway due to present air traffic volume as shown in table 2. The integrated life of the overlaid pavement has two parts (Navneet, G., Edward, G., and Roy, M.,1998): (1) the number of years needed to overlay to the minimum value at the end of the life and (2) the number of years needed to cause reflection cracks to propagate through the asphalt overlay (the propagation rate is assumed to be one year per inch of overlay thickness). The inverse procedure of design method for asphalt overlay on PCC pavement is applied, theoretically, pavement structure life is an unknown variable while the thickness and the moduli of pavement layers and subgrade are deterministic. Based on above calculation parameters, the predicted pavement structural life is 9.6 years.

Table 2. The prediction annual air traffic volume

Aircraft Name	Prediction annual departures	Aircraft Name	Prediction annual departures
A320	31697	B767-200	5994
A300-600	5886	B777-200	3024
A330	1242	B737-800	1134
A340-500/600	216	MD-82/88	4734
B737-700	87766	MD-90-30	8928
B757	16056	CRJ-200	8046
B747-200	1602	Y-8	2412

2.4 Airport Pavement Design Regulation of China (APDMC) to Predict the Remaining Structural Life

2.4.1 Prediction Method

According to the loading response of the typical structure of the existing runway pavement, the PCC slab of the composite pavement is the main layer for contributing stress, so fatigue cracking at the bottom of the PCC layer is used as the critical index for predicting the remaining structural life. Based on the inverse procedure of specifications for cement concrete pavement design for civil transport airport of China, a model is established to predict the remaining structural life of the existing runway pavement:

$$f_{rm} = f_{cm}(0.885 - 0.063\lg N_e) \quad (1)$$

where:

f_{cm}= the concrete flexural strength, determined by field testing;

f_{rm}= the working horizontal stress at the bottom of concrete layer, determined by stress analysis of the composite pavement under design aircraft;

N_e= the remaining number of coverages to failure model for design aircraft.

2.4.2 Prediction Parameters

(1) Air Traffic Volume

"A300-600" is selected as the design aircraft on the basis that most of aircrafts operated on runway belong to type "D". The conversion to equivalent annual departures of the design aircraft is followed by the formula $N_s = \sum_{i=1}^{n} (\delta_i N_i)^{\sqrt{P_i / P_s}}$ and the results are 40912, then the equivalent annual coverages of the design aircraft followed by the formula $Y_s = 0.75 n_w W_t N_s / 100T$ are 3481.

(2) Stress Analysis

Bisar Program based on the elastic layer theory is used to analyze the stress on the bottom of slab on the response to one main loading gear of aircraft A300-600. Figure 4 shows assembly position for pavement stress analysis.

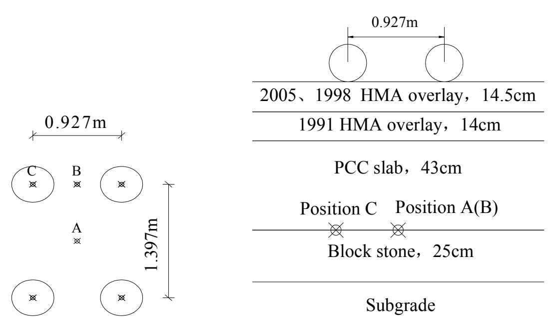

Figure 4. Assembly Position for Pavement Stress Analysis

2.4.3 Prediction results by APDMC

Table 3 shows the procedure of determining the remaining structural life based on APDMC。

Table 3. Procedure for determining the remaining structural life based on APDMC

Design aircraft		A300-600
The equivalent annual departures of the design aircraft N_s		40912
The length of tire print L_t/cm		53.88
The width of tire print W_t/cm		32.33
The passing width of pavement T/m		11.4
The equivalent annual coverages of the design aircraft Y_s		3481
The largest horizontal tensile stress on the bottom of slab/MPa	Position A	3.327
	Position B	3.122
	Position C	3.362
Concrete flexural strength/MPa		5.5
The remaining number of coverages of the design aircraft N_e/ Position C		22125
The remaining structural life t/years		6.4

The predicted runway structural life based on APDMC is 6.4 years due to the failure model of fatigue cracking on the bottom of slab. The predicted remaining structural life has a difference of 3.2 years between the prediction method of LEDFAA pavement design procedure and APDMC. The reason for causing the difference is that the failure model defined in individual method is different, and the control index conducted by LEDFAA program is that Structural Condition Index(SCI) drops to 80 and the reflection cracks propagate through the asphalt overlay while APDMC due to the appearance of fatigue cracking on the bottom of slab.

2.5 PCI Regression Curve to Predict the Remaining Functional Life

In-situ PCI survey data in past several years is provided to establish PCI regression model for the future years. FAA pavement evaluation method specifies that the critical value of PCI is between 55 and 70. For runway, and the value of 65 is adopted. The PCI regression model is established based on in-situ PCI survey data. The value of PCI for regressive curve is presented in Table 4.

Table 4. The Value of PCI for Regressive Curve

n(the service years)	0	2	3	4	5	6
PCI	100	91.5	88.0	80.7	74.6	68.6

Based on the calculation data, the curve was fit as quadratic equation, cubic equation, logarithm equation and exponential equation. The results show that the equation with the general form as $PCI = a \cdot e^{bn^2+cn}$ can fit the data preferably. The reasons are herein: (1) high coefficient of relativity; (2) PCI approximates to 100 in the initial years; (3) the trend of curve is consistent with the characteristic of PCI decreasing.

The regressive equation is determined with the form as $PCI = 99.97e^{-0.0055n^2-0.0301n}$ of which the coefficient of relativity is 0.9974. Following the regressive equation , it will take 6.5 years for PCI to drop from the value of 100 to 65.

3 Conclusions

The predicted pavement structural life based on LEDFAA and APDMC are 9.6 years and 6.4 years respectively. These differences are caused by different failure models defined in individual method. The LEDFAA thickness design standard is that Structural Condition Index (SCI) decreases to a critical value 80 and reflection cracks propagate through the overlay. The APDMC thickness design standard is slab fatigue damage due to repeated stress at bottom of the concrete pavement. In addition, the remaining structural life predicted by APDMC is much sensitive to the working horizontal stress (f_{rm}). A slight increase in f_{rm} has great impact on pavement structural life. Therefore, the remain life estimated by LEDFAA would be longer than that by APDMC, for it will take several years for fatigue cracks occurred in the slab bottom to propagate through the overlay. As a result, APDMC appears to be more suitable for unique concrete pavement than an old concrete pavement with a couple of asphalt concrete overlays. LEDFAA would be more reliable to predict the remaining life of composite pavement structure.

The predicted pavement functional life based on PCI regression model is 6.5 years which is approximately consistent with the result predicted based on APDMC. PCI regression model is established by realistic PCI survey data in past several years. Therefore, predicted by PCI regression model is also a feasible approach to estimate the remaining life for composite pavement if there are successive PCI data in past years available.

Acknowledgements

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References

Civil Aviation Administration of China. (2000).*Specifications for Airport Cement Concrete Pavement Design (MH/T5004 -2010)*. Civil Aviation Administration of China, Beijing.

Federal Aviation Administration (1995). Airport Pavement Design for the Boeing 777 Airplane, U.S. Department of Transportation,Washington, D.C.

Ling, J. M., and Zheng, Y. F. (2001). "On prediction method of remaining life for cement concrete pavement of airport". Journal of Tongji University: Natural Science Edition, 29(4):484-488.

Navneet, G., Edward, G., and Roy, M. (1998). "Opertional Life of Airport Pavement". U.S. Department of Transportation ,Washington, D.C.

Ollerman, F. A., and Varma, A. (1998). "Development and visualization of airport pavement management information: lessons learned". The 77th Annual meeting of the TRB, Washington, D C,.

Wang, W. (2004) . "Improved method for computing residual service life of civil airport pavement". Journal of Civil Aviation University of China, 22(3):37-41.

An Evaluation of Characteristics of Efficiency and Flexibility of the Eurasian Continental Bridge

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Abstract: This paper offers an integrative approach to evaluate factors contributing to efficiency and flexibility of the Russian section of the Eurasian Continental Bridge and examines characteristics that should be focused on to improve both. A survey approach was used to evaluate the efficiency and flexibility characteristics of the Eurasian Continental Bridge. Multistage stratified random sampling approach was adopted to sample respondents. The evaluation was based on analysis of railway transport characteristics in the Russian section of the Continental Bridge. Findings were that the characteristics related to information system, physical distribution, logistics processes and transport service delivery have significant impacts on efficiency and flexibility of the continental bridge. Main Conclusion from the analysis was that to improve efficiency and flexibility levels practitioners and policy makers should focus on the characteristics. The findings of this research will be valuable in realizing the most efficient, flexible and cost-effective railway transport improvements.

Keywords: Eurasian continental bridge; Efficiency; Flexibility; Railway; Transport.

1 Introduction

Eurasian Continental Bridge is rail transport route Pacific seaports in Russia and China to seaports in Europe. The land bridge was developed with the aim of improving international trade, globalization and regional integration between the West and East (Figure 1). Effective use of land bridge services could be the cornerstone of reconstruction of the world economy.

The main concerns about the land bridge by La-Roche (1997) are that: i) only a small proportion of traffic between Europe and Asia is by railways; ii) ways through which container volume transported by intermodal land bridge services between Europe and Asia could be increased; iii) ways of attaining efficiency, cost reduction and time saving in the railway transport; and iv) ways by which the land bridge countries can overcome political, economic and ideological differences and start to collaborate in order to achieve efficiency, cost reduction and time saving.

Previous research on Eurasian Continental Bridge mainly focused on regional collaboration in infrastructural development. Transport flexibility has been identified as an important aspect of overall supply chain flexibility. Flexibility encompasses infrastructure, physical movement of goods and communication. Flexibility of transport along railway line like the Eurasian Continental Bridge is vital in addressing uncertainties in the supply chains depending on it.

The Russian section of the Eurasian Continental Bridge runs from Vladivostok and Nakhodka through Chita, Oms and Moscow. Figure 1 shows the Eurasian Continental Bridge; blue line in the map shows Moscow – Vladivostok line. The Eurasian Continental Bridge connects Moscow to Vladivostok, a distance of 9,289 km with track gauge of 1.520 m. The Trans-Manchurian line connects Moscow to Beijing through Manzhouli border station which is 6,638 km from Moscow. The continental bridge also consists of Trans-Mongolian line to Beijing through Russia/Mongolian border station at Sükhbaatar, a distance of 5,921 from Moscow.

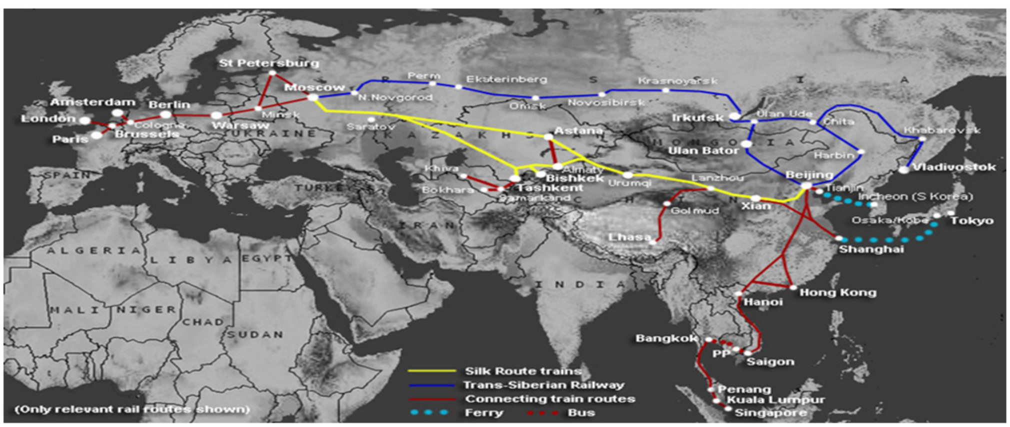

Figure 1. Eurasian continental bridge

This paper aims to address the concerns of La-Roche of attaining efficiency and flexibility in the land bridge as a step towards making the land bridge become cornerstone of reconstruction of world economy. It attempts to fill research gaps in the areas of railway efficiency and flexibility by adopting an integrative approach combining two. The research evaluates the current efficiency level of the Russian section of the land bridge as recommended by Ilie (2010) and Rodrigue (2012) among other researchers.

2 Literature Review

Several researchers have studied efficiency and flexibility of in transport systems. Performance based aspects of efficiency like cost efficiency, cost and service effectiveness (Tennenbaum, 2001; Fielding, Babitsky & Brenner, 1985; Rodrigue, 2012). Other researchers focused capacity and volume aspects of efficiency (Schiller Institute, 2001; Ilie, 2010).

Efficiency has been the main focus of previous railway research (Padila & Eguia, 2010). Zhu (2001) used simulation approach to analyze carrying capacity utilization of railway (European Commission, 2006; Vrugt & Robinson, 2007; Zitzler & Thiele, 1999). Some researchers used survey methods (Bussieck, Winter & Zimmermann, 1997; Cordeu, Toth & Vigo, 1998) but were not specific to Eurasian Continental Bridge. A number of researchers studied economic efficiency of railway transport (McCullough, 2005; Oum & Yu, 1994). Economic efficiency is divided into productive and allocative efficiencies (Oum & Yu, 1994). Determinants of railway efficiency have also been identified in literature. US Department of Defense (2005) noted that efficiency is impacted on by train characteristics, transit time, labor relations and time to clear customs. Federal Railway Administration Research Board (2006) identified key determinants of railway efficiency as human resource, information systems and railway logistics processes.

Research on flexibility has dwelt on both internal and external transport flexibilities. Gosling, Purvis and Naim (2009) classified internal transport flexibility into three: physical movement of goods, infrastructure related flexibility and capacity associated categories. Flexibility of physical movement of good encompasses mode, fleet and vehicle flexibility (Christopher & Juttner, 2000). Infrastructure related transport flexibility includes node, link and temporal flexibility (Gosling, Purvis & Naim, 2009; Christopher & Juttner, 2000). Node flexibility in international railway transport refers to ability of the concerned governments and other stakeholders to plan, approve, implement or remove transport nodes in a railway network. Link flexibility is the ability to establish or remove transport links between nodes. Temporal flexibility is defined as the ability to sequence transport infrastructural investments and the extent to which its use requires user coordination (Noteboom, Keters & Debruyne, 2013; Peppers & Rogers, 1996).

3 Research Methods

3.1 Objectives

There are two objectives:

To analyze efficiency and flexibility characteristics of the Eurasian Continental Bridge; To propose a model of flexibility and efficiency of the Eurasian Continental Bridge.

3.2 Methodology

This research adopted a survey approach to evaluate the efficiency and flexibility levels of the Eurasian Continental Bridge. It used multistage stratified random sampling method to sample respondents from the government ministry of transport, freight companies and Russian Railways. Table 1 shows sample of respondents.

Data collection was done using structured closed ended questionnaires. Determinants of flexibility were identified as: physical movement of goods;

infrastructure; capacity; speed; mobility; service delivery and ownership. Tables 2 and 3 summarize attributes of efficiency and flexibility, respectively. All the characteristics of efficiency and flexibility were rated using Likert Scale with 1= strongly disagree; 2=disagree; 3=agree; 4=strongly agree; 5=very strongly agree.

Table 1. Sample of Respondents

	Target Respondents	Number of participants	Percentage
Ministry of Transport	30	21	70%
Russian Railways	50	43	86%
Freight Companies (15 companies)	150	122	81.3%
Total	**230**	**186**	**80.87%**

Table 2. Efficiency attributes of the continental bridge

Question 1: To what extent do you agree that the following characteristics contribute to efficiency of the Eurasian Continental Bridge?				
Code	Category	Characteristics	Code	Rating
TC	Train characteristics	Train energy efficiency	TC1	
		Reliability of trains and wagons	TC2	
		Train capacity	TC3	
		Train speeds	TC4	
TF	Time factor	Transit speed and gauge characteristics	TF1	
		Automated fast train driving	TF2	
		Timely scheduling and planning	TF3	
		Time to clear customs	TF4	
HR	Human resource	Nature of Human Resource Utilization	HR1	
		Labor relations	HR2	
		Human Resource development	HR3	
IS	Information systems	Level and nature of data collection	IS1	
		Level of transport decision support system	IS2	
		Efficiency of wayside and onboard detection systems	IS3	
		Improved visibility of goods in transit	IS4	
		Data accuracy and timeliness	IS5	
LP	Railway logistics processes	Reliability of railway infrastructure	LP1	
		Ability to improve railway hardware management system	LP2	
		Reliability of railway physical infrastructure	LP3	
		Ability to increase throughput	LP4	
		Ability to reduce train idling	LP5	

Table 3. Flexibility attributes of the continental bridge

Question 2: To what extent do you agree that the following characteristics contribute to flexibility of the Eurasian Continental Bridge?				
Code	Determinant Category	Characteristics ability to:	Code	Rating
PD	Physical Distribution	1.Plan, approve, implement or remove transport nodes by concerned governments and other stakeholders	PD1	
		2.Adjust transport speeds in response to customer demand	PD2	
		3.Redeploy transport asset	PD3	
		4.Avoid under-utilization of organizational transport resources	PD4	
IN	Infrastructure	1.Improve railway infrastructure	IN1	
		2.Effect nodal (station) improvements	IN2	
		3.Have adequate warehousing facilities	IN3	
CP	Capacity	1.Have various transit options	CP1	
		2.Manage different types of information by transport service provider	CP2	
		3.Accommodate different routes	CP3	
		4.Improve carriage capacity to meet traffic demands	CP4	
SD	Service delivery	1.Implement quick response	SD1	
		2.Empower workforce	SD2	
		3.Have flexible planning system	SD3	
		4.Deliver quickly and effectively	SD4	
		5.Have an effective motivation system	SD5	
		6.Tailor service to customer demands	SD6	

Reliability and regression analysis was used in this research. Reliability analysis was done using SPSS software to obtain Cronbach's alpha. Regression analysis involved calculation of coefficient of determination R^2 between groups of correlated characteristics as shown in Tables 4 and 5. Test for multi-collinearity was done using Variance Inflation Factor (VIF) statistics of which VIF values of less than 10 indicate that there is no multi-collinearity (Hair, et al, 2009).

Table 4. Regression analysis of efficiency characteristics

Latent variable	R-square	Dependent variable	A-nova	Independent variable	Beta Coeff.	VIF
TC	0.561	IS	F=815.16, p=0.00	TC1	0.552	2.14
				TC2	0.613	2.14

				TC3	0.715	2.14
				TC4	0.846	2.14
TF				TF1	0.697	2.14
				TF2	0.584	2.14
				TF3	0.610	2.14
				TF4	0.732	2.14
HR				HR1	0.634	2.14
				HR2	0.695	2.14
				HR3	0.727	2.14
IS	0.627	LP	F=624.45, p=0.000	IS1	0.525	2.28
				IS2	0.653	2.28
				IS3	0.703	2.28
				IS4	0.741	2.28
				IS5	0.551	2.28

Table 5. Regression analysis of flexibility characteristics

Latent variable	R-square	Dependent variable	Anova	Independent variable	Beta Coeff.	VIF
PD	0.643	SD	F=716.15, p=0.000	PD1	0.651	1.39
				PD2	0.516	1.39
				PD3	0.675	1.39
				PD4	0.743	1.39
IN	0.745	PD	F=607.23, p=0.000	IN1	0.598	2.33
				IN2	0.774	2.33
				IN3	0.641	2.33
CP				CP1	0.655	2.33
				CP2	0.593	2.33
				CP3	0.677	2.33
				CP4	0.626	2.33

3.3 Research Hypotheses

H1: The characteristic studied is significant to efficiency of the Eurasian Continental Bridge. H2: The characteristic studied is significant to flexibility of the Eurasian Continental Bridge.

4 Discussions of Results

4.1 Results of Reliability Analysis

Tables 6 and 7 show calculated Cronbach Alphas for all the characteristics of efficiency and flexibility of Eurasian Continental Bridge are well ahead of the cut off rate of 0.70 which proves good reliability. It means that all the factors used to evaluate the efficiency and flexibility of the land bridge were found to be reliable so factors would produce consistent results irrespective of time period.

Table 6. Reliability and regression analysis results of efficiency characteristics

Latent variable	Independent variable	Cronbach's Alpha	Dependent variable	Independent variable	Cronbach's Alpha
TC	TC1	0.85	IS	IS1	0.72
	TC2	0.71		IS2	0.77
	TC3	0.81		IS3	0.80
	TC4	0.87		IS4	0.74
TF	TF1	0.79		IS5	0.75
	TF2	0.88	LP	LP1	0.70
	TF3	0.95		LP2	0.78
	TF4	0.70		LP3	0.71
HR	HR1	0.83		LP4	0.70
	HR2	0.91		LP5	0.83
	HR3	0.82			

4.2 Results of Regression Analysis

Infrastructure and capacity characteristics create significant positive impact on physical distribution of the land bridge as regression coefficients are significant (IN β – 0.928 and CP β – 0.725). The value of R2 shows 74.5% variations in physical distribution. The Variance Inflation Factor (VIF) statistics shows the value of 2.33 for both independent factors, which is very far from cut off rate of 10. Therefore there is no concern of multi-collinearity among independent factors. Physical distribution creates significant positive impact on service delivery (PD β – 0.724).

Table 7. Reliability and regression analysis results of flexibilitiy characteristics

Latent variable	Independent variable	Cronbach's Alpha	Dependent variable	Independent variable	Cronbach's Alpha
PD	PD1	0.76	CP	CP1	0.70
	PD2	0.70		CP2	0.90
	PD3	0.81		CP3	0.73
	PD4	0.75		CP4	0.77
IN	IN1	0.86	SD	SD1	0.81
	IN2	0.88		SD3	0.76
	IN3	0.79		SD4	0.72
				SD5	0.89
				SD6	0.82

The value of R2 shows 64.3% variations in Service Delivery. Train Characteristics, Time Factor and Human Resource factors create significant positive impact on Information System (TC β – 0.683, TF β – 0.749 and HR β – 0.786, respectively). The value of R2 shows 56.1% variations in Information Systems. Information System create significant positive impact on Logistics Processes as regression coefficients are significant (IS β – 0.941). The value of R2 shows 62.7% variations in Logistics Processes. The VIF statistics shows the value of 2.28 for both independent factors, which is very far from cut off rate of 10. So there is no concern of multi-collinearity among independent factors.

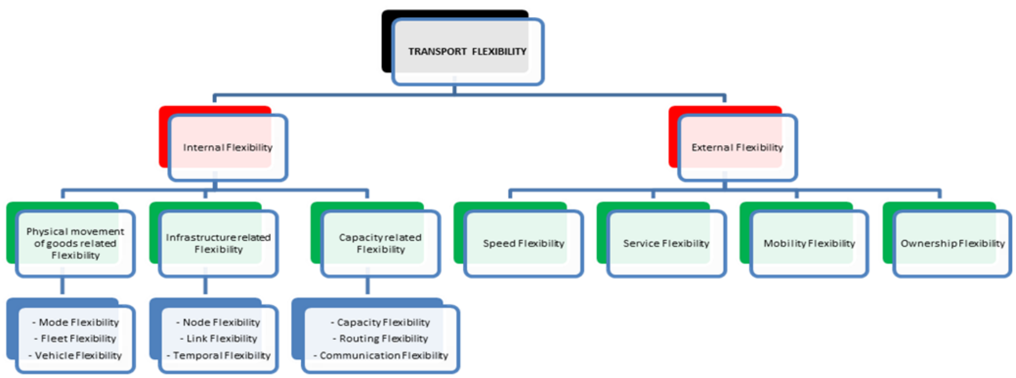

Figure 2. Transport flexibility

4.3 Implications of Research Findings

Infrastructure and capacity are key factors in flexibility of Eurasian Continental Bridge. Key factors influencing efficiency are train characteristics, time factor and human resource. However, physical distribution flexibility and service delivery flexibility cannot be achieved also without flexibility in infrastructural and capacity development. The role of physical distribution flexibility and service flexibility are very important in case of urgently required or fast transit goods. It requires timely and cost effective distribution of varieties goods to distant lands in Middle East and Europe across Russia.

Efficient logistics processes are important in meeting strict lead times. In order order to satisfy varieties of customer transport requirements in the Eurasian Continental Bridge bound supply chains, customized and timely transport and logistics services should be offered through effective and flexible service delivery and efficient logistics processes (Figure 3).

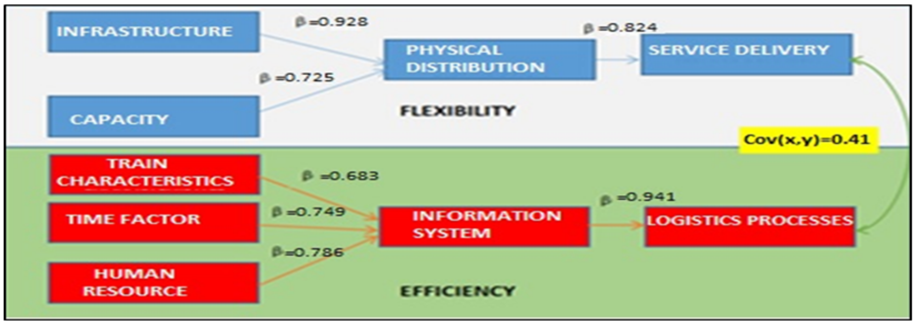

Figure 3. Relationship between efficiency and flexibility characteristics

5 Conclusions

The following conclusions can be drawn from the findings of this research:

(1) Main characteristics influencing efficiency and flexibility of the Eurasian Continental Bridge are train characteristics, time factor and human resource;

(2) Infrastructure and capacity characteristics create significant positive impact on physical distribution along the land bridge. This implies that improvement of infrastructure and capacity can positively improve physical distribution thereby increasing efficiency and flexibility.

(3) Train characteristics, time factor and human resource factors have significant positive impact on the use of railway information system. Trains should be made such as to allow for proper installation and use of onboard railway information system. Improvement of human resource capacity and train speeds (time factor) of the land bridge can lead to efficiency and flexibility improvement.

(4) Railway information systems have positive significant impacts on logistics processes of the land bridge. Most modern logistics processes need information system to ensure fast information processing to boost both flexibility and efficiency.

It is concluded that to improve efficiency and flexibility levels practitioners and policy makers should focus on the characteristics studied in this research.

References

Alejandro GC & César RT (2009). "Total productivity changes at the principal container ports" CEPAL Review, Mexico, 99:173 – 185.

Bussieck MR, Winter T & Zimmermann UT (1997). "Discrete optimization in public rail transport", Math Program,79:415 – 444.

Christopher M & Jüttner U (2000). "Developing strategic partnerships in the supply chain: a practitioner perspective. European Journal of Purchasing and Supply Management", 6(2):117 – 127.

Cordeau JF, Toth P & Vigo DA (1998) "Survey of optimization models for train routing and scheduling", TRANSPORT SCI, 32:380 – 404.

European Commission (2006) “Algorithms for robust and online railway optimization: Improving the validity and reliability of large-scale systems.” http://arrival.cti.gr

Federal Railroad Administration Research Board (2006). Washington DC, A Workshop April 5 – 6.

Feitelson E & Salomon I (2000). “The implications of differential network flexibility for spatial structures structures”, Transport Res A – Pol, 34(6):459 – 479.

Fielding GJ & Babitsky TT, Brenner ME (1985) Performance evaluation for bus transit, Transport Res A – Pol, 1: 73 – 82.

Gosling J, Purvis L & Naim MM (2009) “Supply chain flexibility as a determinant of supplier selection”, Int. J Prod Econ. doi:10.1016/j.ijpe.2009.08.029

Hair JF, Anderson RE, Tatham RL & Black WC (1999) “Multivariate Analysis”, Prentice Hall, Madrid.

Ilie E (2010) “New Eurasia Land Bridge provides connection between China and Europe, Railway Pro”, http://www.railwaypro.com/wp/?p=2153.

Kachi H (2007) “Mitsui talking to Russian railways operator on trans-Siberian freight services”. http://www.marketwatch.com/story/mitsui-talking-to-russian-railway-operator-on-trans-siberian-freight-service

La-Rouche L (1997) “From productive triangle to Eurasian Land-Bridge”, FDR-PAC Conference, Washington, D.C.

McCullough G (2005). “US railroad efficiency: A brief economic overview”. Department of Economics, University of Minnesota, USA.

Morlok EK & Chang DJ (2004). “Measuring capacity flexibility of a transportation system”. Transport Res A – Pol, 38(6):405 – 420.

Naim MM, Potter AT, Mason RJ & Bateman N (2006). “The role of transport flexibility in logistics provision”. Int. J Logist Manag17:297 – 311.

Naylor JB, Naim MM & Berry D (1999) “Leagility: integrating the lean and agile manufacturing paradigms in the total supply chain”. Int. J Prod Econ, 62(1,2):107 – 118.

Noteboom T, Keters D & Debruyne B (2013) “Volatility and uncertainties in seaports: tools and strategies towards greater flexibility, resilience and agility of port authorities and port companies”. Institute of Transport and Maritime Management, ANTWERP.

Oke A (2005) A framework for analyzing manufacturing flexibility. Int J Oper Prod Man, 25:973 – 996.

Oum TH & Yu, C (1994) “Economic efficiency of railways and implications for public policy: A comparative study of OECD Country’s railways”, J. Transp. Econ. Pol. 28(2):121 – 138.

Padilla MJ & Eguia RE (2010) “Relative efficiency of seaports in Mindanao”, 11th National Convention of Statistics (NCS), Davao City, October, 4-5, p 1 – 16.

Peppers D & Rogers M (1996) "The one to one future: Building relationships one customer at a time". New York: Doubleday.

Prater E, Biehl M & Smith MA (2001) "International supply chain agility Tradeoffs between flexibility and uncertainty". Int. J Oper Prod Man , 21(5/6):823 – 839.

Rodrigue JP (2012) "Geography of transport system", chapter 7. http://people.hofstra.edu/geotrans/eng/ch7en/conc7en/ ch7c1en.html

Schiller Institute (2001) "Chronology: from productive triangle to Eurasian Land Bridge", www.schillerinstitute.org/russia/ruseal_chronology.html

Tejas ND & Shah TR, Kulkarni MG (2014) "An analysis of logistics flexibility model among different product categories". J Info Res Admin Manag, 3(1):70 – 77.

Tennenbaum J (2001) "The New Eurasian Land Bridge infrastructure takes shape", Schiller Institute.

Tolley R & Turton, BJ (2014) "Transport Systems, Policy and Planning: A Geographical Approach". Taylor and Francis, New York.

United Nations (2010) "Conference on trade and development". ISBN 978-92-1-112810-9

US Department of Defense (2005). "Dictionary of military and associated Terms". http://www.dtic.mil/doctrine/dod_dictionary

Vrugt JA & Robinson, BA (2007) "Improved evolutionary optimization from genetically adaptive multi- method search". USA (PNAS), 104:708–711.

Zhu X (2001) "Computer-based simulation analysis of railway carrying capacity utilization, Info-tech and Info-net". ICII 2001 - Beijing 2001, International Conferences, 29th October to 1st November, 2001, 4:107 – 112.

Zitzler E & Thiele L (1999) "Multi-objective evolutionary algorithms: a comparative case study and the strength Pareto approach". IEEE T Evolut Comput, 3:257–271.

Durability Assessment of an RC Railway Bridge Pier under a Chloride-Induced Corrosion Environment

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Abstract: Reinforcement corrosion caused by chloride is one of the major reasons of reinforced concrete durability failure, and chloride in RC railway bridge is mainly derived from marine environment. Therefore, a resistance degradation model of axial compressed structure calculated on bearing capacity limited state is established against the background of the marine environment, considering the deterioration of reinforcement and concrete. Consequently, durability assessment of a coastal railway bridge pier is made by way of the reliability calculation program.
Keywords: Marine environment; Chloride corrosion; Deterioration; Durability.

1 Introduction

Professor P.K. Metha (Luo Fuwu, 1996) identified reinforcement corrosion as the first factor affecting durability of concrete structures. Furthermore, a large number of practice has proved chloride is the major cause of reinforcing bars corrosion. Statistical data showed that durability failure of concrete structures caused by chloride has brought about huge economic loss around the world. Therefore, concrete durability has already become a world's major problem. Reinforcement corrosion caused by chloride is different from the one under ordinary atmospheric environment. Its corrosion mechanism is macro cell corrosion and corrosion form is local pitting corrosion. Chloride corrosion caused the decrease of effective section area of reinforcement, which would result in degradation of reinforcement yield stress and concrete strength. For accurately predicting reliability and durability of the structure, many researchers (Mark G. Stewart, David V. Rosowsky, 1998) (Mark G. Stewart, 2004) (Peng J., Mark G. Stewart, 2008) (Vu K, Mark G. Stewart, 2005) proposed the pitting model of steel reinforcementand deterioration and time-dependent reliability model of concrete structures corrosion-induced cracking. In regard to railway bridge, chloride induced reinforcement corrosion is mainly derived from marine environment. Therefore, based on time-dependent reliability theory, durability assessment of a coastal railway bridge pier is implemented using Monte Carlo Method and considering reinforcement and concrete deterioration.

2 Reinforcing steel subjected to chloride-induced corrosion

2.1Time to initiation of reinforcing steel corrosion

In an atmospheric marine zone, the chloride content at a distance x from the concrete surface and at time t is(Mark G.Stewart,1998)

$$C(x,t) = 2W\left\{ \sqrt{\frac{t}{\pi D}}\exp\left(-\frac{x^2}{4Dt}\right) - \frac{x}{2D}\left[1-erf\left(\frac{x}{2\sqrt{Dt}}\right)\right]\right\} \tag{1}$$

where W is the diffusion flux on the concrete surface, D is the apparent diffusion coefficient.

The time to initiation of rebar corrosion is

$$T_i = \frac{(d_i - d_0/2)^2}{4D}[erf^{-1}(\frac{C_{cr}-C_0}{C_i - C_0})]^{-2} \tag{2}$$

where d_i is the distance from concrete surface to rebar centre, d_0 is the diameter of initiation rebar, C_0 is the surface chloride content, C_{cr} is the critical threshold chloride concentration, C_i is the initiation chloride content.

Above all, this paper proposes the chloride content $C(x,t)$ of reinforcing steel surface is expressed by numerical solution at time t (10~50 $years$) and at distance x (30~ 50 mm) from concrete surface, see Table 1.

Table 1. The chloride content of rebar surface with numerical solution

x \ t	10	20	30	40	50
30	0.296	0.638	0.930	1.187	1.419
40	0.174	0.456	0.717	0.954	1.171
50	0.096	0.317	0.542	0.756	0.957

The chloride content of reinforcing steel surface at time t can be confirmed shown in Table 1, according to the time to initiation of rebar corrosion is

$$T_i = \begin{cases} t, & C(c,t) = C_r \\ t+1, & C(c,t) < C_r < C(c,t+1) \end{cases} \tag{3}$$

2.2The deterioration model of reinforcing steel

2.2.1 Pitting model

The pit configuration is used to predict the cross-section area of the pit, as shown in Figure.1.

The maximum pit depth (Mark G. Stewart, 2008) along a reinforcing bar with surface area A is

$$P(t) = 0.0116 \times i_{corr} \times R \times t \quad (4)$$

Where, $R = P_{\max} / P_{av}$, $P_{\max}$ is the maximum pitting depth, P_{av} is the uniform corrosion depth, i_{corr} is the corrosion rate measured as a current density.

The pitting width a and cross-sectional area A_{pit} can be expressed as

$$A_{pit}(t) = \begin{cases} A_1 + A_2, & p(t) \leqslant \frac{D_0}{\sqrt{2}} \\ \frac{\pi D_0^2}{4} - A_1 + A_2, & \frac{D_0}{\sqrt{2}} < p(t) \leqslant D_0 \\ \frac{\pi D_0^2}{4}, & p(t) \geqslant D_0 \end{cases} \quad (5)$$

where D_0 is the initial diameter of reinforcing rebar.

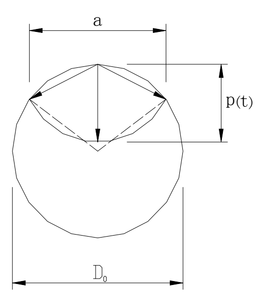


Figure 1. Pit configuration of reinforcing bar

2.2.2 Strength Loss Model

Reinforcement corrosion brought about not only the loss of bar section area, but also the mechanical and the bond properties deterioration of reinforcement. In this paper, mechanical property deterioration is only considered. It is recommended that the nominal yield strength standard value of reinforcement at time t can be expressed as (Niu ditao, 2002)

$$f_s = \begin{cases} f_y & t < T_i \\ f_y[1 - 1.077\eta_s) & t \geqslant T_i \end{cases} \quad (6)$$

where f_y is yield strength of non-corroded reinforcement, η_s is loss ratio of reinforcement section area. It is suggested that when $\eta_s \leqslant 15\%$, nominal yield strength of reinforcement is calculated as formula (6); when $\eta_s > 15\%$, it will be processed as hot rolled steel bar without yield point.

3 Concrete deterioration caused by chloride

Concrete strength still obeys normal distribution through statistical analysis of concrete strength of buildings used many years, only average value and standard deviation has changed. $\mu_f(t)$ and $\sigma_f(t)$ are average value and standard deviation of concrete strength after t years respectively, expressed as

$$\mu_f(t) = \xi(t)\mu_0 \quad , \sigma_f(t) = \eta(t)\sigma_0 \tag{7}$$

where μ_0 and σ_0 are average value and standard deviation of concrete strength at t =0 (i.e. 28 days), respectively.

Through statistical regression of actual measurement and test, the time-dependent models of average concrete strength and standard deviation of concrete strength are obtained, respectively. (Niu ditao, 1995)

$$\xi(t) = e^{-0.0347(\ln t - 0.3468)^2}, \eta(t) = 0.0143t + 1.0624 \tag{8}$$

Once $\xi(t)$ and $\eta(t)$ are determined, the time variation of average value and standard deviation of concrete strength can be completely determined by Formula (7).

4 Limit State Equation

Concrete structural resistance after the reinforcement is corroded will gradually decrease over time. A time-dependent function of structure at one limit state by stochastic process can be express as

$$Z(t) = R(t) - S(t) \tag{9}$$

where t is in-service time of structure, $R(t)$ is stochastic process of structural resistance, $S(t)$ is stochastic process of structural load effect.

The principle of durability failure of concrete structure under marine environment generally adopts the principle of bearing capacity. Based the analysis of reliability theory, the principle of bearing life can be described as: as to the functions representing the limit state of bearing capacity, when cumulative failure probability of structure reaches a certain value, it is called durability failure at the limit state.

4.1 Resistance Model

Taking circular section reinforced concrete eccentric compression member with longitudinal steel reinforcements uniformly provided along the periphery for example, its normal section compressive bearing capacity and resistance function can be expressed as

$$R = K_P N_u = K_P[\alpha f_{cd} A(1-\frac{\sin 2\pi\alpha}{2\pi\alpha}) + (\alpha-\alpha_t) f_{scd} A_s] \quad (10)$$

where A is sectional area of member, A_s is total sectional area of longitudinal reinforcements, f_{cd} and f_{std} are design value of compressive strength of concrete and longitudinal reinforcements, respectively, r is radius of circular section, r_s is radius of circumference where the centroid of longitudinal reinforcements is situated, α is the value for ratio of the central angle of concrete sectional area in compression zone to 2π , α_t is relative area of longitudinal tensile reinforcements, K_P is statistical parameter of resistance of structural member. Generally, for axial compression or small eccentric compression member, the average value and standard value will take 1.37, variation coefficient is 0.15.

4.2 Load Model

Bridge load includes dead load and live load. As to dead load, it is assumed that the mean of nominal values (G/G_n) of concrete bridge is taken as 1.02, and variation coefficient is 0.02. As to live load, the live load of train is the main load on railway bridges. The railway lines in China tend to the lines with passenger and freight traffic. Taking freight train as statistical object, statistical contents includes vehicle overload coefficient K_i , vehicle dead-weight variation correction coefficient K_g artificial recording deviation coefficient of vehicle load K_w. Taking K_i, K_g and K_w as parameters, its probability distribution function is fit using Beta distribution

$$F_{(x)} = \frac{(x-a)^{q-1}(b-x)^{r-1}}{\beta(b-a)^{q+r-1}}, a \le x \le b \quad (11)$$

Statistical analysis results are shown in Code for Railway Bridge (2005). Probability distribution of railway train live load Q1~N (1.0179, 0.0657^2) can be obtained by average value and standard deviation of these three parameters. Taking one of railway standard train live load as standard load, the distribution and parameter reflect the variability of railway train load.

4.3 Monte Carlo Simulation

Monte Carlo Method is also known as Random Simulation. The advantage of Monte Carlo Method for the research of structural reliability is to avoid mathematical difficulties in the analysis of structural reliability. This is to eliminate the need to consider complexity of limit state curved surface. The method is a way to seek the approximate solution of mathematical problem or physical problem adopting sampling statistics theory. Although calculating amount is large, it is considered to be a more accurate method in the current structural reliability calculation. In order to better simulate real process of resistance deterioration, and to obtain the more accurate structural failure probability, Monte Carlo Method is adopted in the process of durability analysis of one cross-sea bridges under chloride environment illustrated later in this paper.

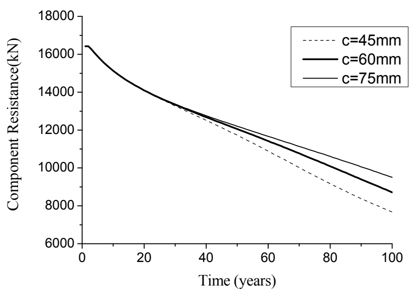
5 Illustrative example

A coastal railway bridge is located in off-shore salty soil area which belong to the strong chloride erosion environment, and the bridge pier corrosion is most serious than any other members. Calculating parameters: diameter of bridge pier d_{pier} is 1500 mm; uniformly providing 28 pieces of longitudinal reinforcements with diameter d_{rebar} of 25 mm, design value of tensile strength of longitudinal reinforcements f_y =340MPa, design value of compressive strength of concrete f_{cd} =23 MPa, water cement ratio W/C =0.4, for thickness of cover c, taking 40 ~60 mm respectively; distribution type of structural resistance is lognormal distribution, its variation coefficient V_R =0.15, axial pressure under permanent load bearing on bridge pier is S_G, axial pressure under live load is S_Q. Statistical data of parameters used in calculation are shown as Table 2.

Table 2. Statistical parameters for chloride diffusion and loading variables

Parameter	Mean	Coefficient of Variation	Distribution
D	$2.0E\text{-}8\ cm^2/s$	0.75	Lognormal
W	$7.5E\text{-}15\ kg/cm^2 s$	0.6	Lognormal
C_0	$2.95\ kg/m^3$	0.5	Lognormal
C_r	$0.9\ kg/m^3$	0.19	Uniform (0.6—1.2)
S_G	$4488\ kN$	0.021	Normal
S_Q	$960\ kN$	0.064	Normal

Due to eccentric compression model of pier used in this example, it should consider the combined action of reinforcement deterioration and concrete deterioration when establishing reinforcement deterioration model. This paper put out the curve of structural resistance and cumulative failure probability as the time applying Monte Carlo Method.



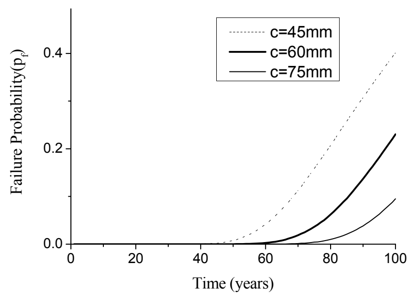


Figure 2. Mean component resistance **Figure 3. Time-dependent failure probability**

As known from the calculation, when cover thicknesses are taken as 45 *mm*, 60 *mm* and 75 *mm* respectively, its corresponding failure time are36 *years*, 45 *years* and 50 *years*, respectively. It is evident from Fig. 3 that reduced cover leads to an increase in failure probabilities, which conforms to the rule of reinforcement deterioration model. The larger cover thickness is, the longer initial corrosion time is, and the lower the reinforcement corrosion velocity is. Therefore, increasing properly concrete cover thickness is helpful to improve structural durability.

6 Conclusions

Corrosion initiation reduces the cross-sectional area of the reinforcing bars, leading to a loss in structural strength. Against the background of the reinforcing steel pitting induced-chloride under marine environment, a time-dependent probability deterioration model of resistance was developed considering deterioration of reinforcing steel and concrete. Based on time-dependent reliability theory, durability assessment of a coastal railway bridge pier is implemented using Monte Carlo Method. By comparing different concrete cover thicknesses, properly increasing the cover thickness is an effective measure which could improve structural durability under chloride-induced corrosion environment.

7 Recommendations for Future Research

The deterioration mechanism of corroded reinforcing model is important to study structural durability. Further work is clearly needed in refining these models and their associated parameters, and in the inclusion of other factors affecting corrosion initiation. Meanwhile the bond performance and seismic behavior of structure after the corrosion initiate are needed to further investigate.

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References

Luo Fuwu (1996). The analysis and prevent of the accident structural defects, Beijing, Tsinghua Press.

Mark G. Stewart, David V. Rosowsky. (1998). "Time-dependent reliability of deteriorating reinforced concrete bridge decks." Structural Safety, 20, 91-109.

Mark G. Stewart. (2004). "Spatial variability of pitting corrosion and its influence on structural fragility and reliability of RC beams in flexure." Structural Safety, 26, 453-470.

Niu Ditao (1995). "Changing models of concrete strength along with time in marine environment." JOURNAL OF XI'AN UNIVERSITY OF ARCHITECTURE&TECHNOLOGY, 27(1), 49-52.

Niu Ditao, Lu Mei, Wang Qinglin. (2002). "Study on the calculation method ofnormal section flexural bearing capacity for corrosive reinforcement concrete beam." Building Structure. 32(10), 14-17.

Peng J, Stewart M G (2008). Climate change, deterioration and time-dependent reliability of concrete structures. Proceeding of 20th Australasian Conference on the Mechanics of Structures and Materials, Toowoomba, Queensland, 559-565.

PRC Ministry of Railway. (2005). "Code for design on reinforced and prestressed concrete structure of railway bridge."

Vu K, Stewart M G (2005). Predicting the likelihood and extent of RC corrosion-induced cracking. Journal of Structural Engineering, 131(11):1681-1689

Numerical Analysis of a Geogrid-Reinforced High Embankment

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Abstract: High embankment with geogrid can restrict the deformation and improve the strength and stability of soil. In order to study the characteristics of geogrid reinforced high embankment, the stability based on geogrid reinforced high embankment project of Hebei province and compare reinforced embankment under different conditions by using the $FLAC^{3D}$ and analyze the mechanism of reinforced embankment were studied in this paper. The results show that the maximum deformation happened in the center of high embankment, and relatively small deformation appear at the edge of high embankment. The interface friction angle the greater the better, it can make the better friction between geogrid and soil, and could reduce vertical additional stress within a certain depth. Geogrid can improve the redistribution and decrease horizontal stress and vertical stress of reinforced embankment. Plastic zone appears the slope angle at top and bottom of the slope. Stretching damage of plastic region of embankment is located in the bottom of the embankment, tensile failure occurs in the slope of top of the embankment, shear failure and tensile failure appears at the bottom of the embankment.

Keywords: Geogrid; Reinforced soil; High embankment; Numerical analysis.

1 Introduction

FLAC program based on Lagrangian finite difference method is a common geotechnical engineering analysis software internationally with powerful computing capabilities and extensive simulation capabilities. The advent of $FLAC^{3D}$ based on three dimensional fast Lagrangian analysis program provided a powerful simulation tool for geotechnical engineering research, especially elasto-plastic analysis, large deformation analysis and simulate construction process, etc. $FLAC^{3D}$ has been widely application, for example: Hegde (2014), Hambleton (2013), TAO Hui (2014), Tafreshi (2013), ZHANG Hong (2009).

CHEN Xiangjun and TANG Jinsong (2002) have studied on the stability and deformation analysis of Maya slope using $FLAC^{3D}$. YU Zehong (2005) have studied on numerical analysis of reinforced embankment. The study shows that the performances of the shear zones of reinforced slope are correlated directly with the reinforcement effect, changes of shear zone morphology reflected the stability mechanics of reinforced embankment. WANG Mingyuan (2009) have carried out the numerical simulation on the pullout process of reinforced soil interface. The study shows that it is rational and feasible by setting boundary element to simulate interaction between reinforcement and soil. WANG Jiaquan and other people (2010) have carried out the field test on treat the old and new high embankments by using geocell associated with a mountainous expressway widening project. They analyzed the variation rules of the lateral displacement, settlement and soil pressure of high embankment and the effect of geocell treatment. Kevin and Jonathan (2006) analyzed the ultimate bearing capacity of foundation based on limit equilibrium theory. They compared two design methods for embankment reinforced with geogrids.

This paper simulated numerically reinforced embankment in mountainous area in Hebei by using the $FLAC^{3D}$ software. It discussed the reinforced effect of high embankment from the ground surface settlement, vertical displacement, horizontal displacement, plastic state distribution, and provides the reference for the future design and construction.

2 The establishment of numerical model

2.1 Project overview

The project is located in Hebei a mountainous area , the geological condition is the fully weathered light yellow gneiss, rock fragmentation and local irregular granular, basement is largely strong-fully weathered bedrock. The high embankment are mainly the stone. The embankment height varied with different slope ratios: when the slope height of embankment is less than or equal to 8 m, the slope ratio takes 1:1.5. It needs to set platform with 2 m width at 8 m; when the slope height of embankment is more than 8 m and less than 20 m, the slope ratio takes 1:1.75. It also needs to set platform with 2 m width at 20 m. When the slope height of embankment is more than 20 m, the slope ratio takes 1:2.0.

2.2 The basic assumption

Without considering horizontal tectonic and the influence of groundwater, surface water seepage and earthquake, the initial stress field of model takes self-weight stress field. Without considering the influence of temperature change of the structure, and the effect of soil consolidation and pore water pressure. This model makes the convergence of numerical calculation as a criterion of instability, it mainly considered the stress and the deformation under different conditions during the construction of high embankment.

2.3 The geometric model

The actual problem is simplified in this paper. Considering the symmetry of the embankment, this paper established on the left half of calculation model and divided network by using Mohr-Coulomb nonlinear constitutive model in $FLAC^{3D}$ and associated flow rule. Interface between geogrid and FLAC^{3D} solid element generates the friction. The model set without thickness geogrid unit between geogrid and soil.

The constraints of model boundary are fixed at the bottom of the model, and are normal at the left and the right sides of model, are free boundary at the upper of model. Horizontal direction is as X axis and vertical direction is as Y axis. The initial stress field of model takes self-weight stress field, network is divided into 2340 nodes and 1660 units. Sketch map and network division of analysis model are shown in Figure 1.

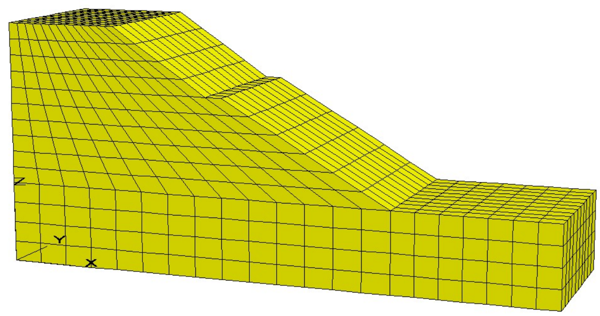


Figure 1. Sketch map and network division of analysis model

The geometric parameters of embankment model are as follows: half of the top of embankment width is 14 m, the embankment height is 20 m. On the basis of the survey data, the mechanical parameters of rock and soil mass are shown in Table 1. The model selected the EG3030 bidirectional plastic geogrid from the indoor test, physical and mechanical indexes are shown in Table 2.

3 Analysis of numerical calculation results of reinforced embankment

In order to analyze the reinforced influence of deformation and stability of embankment, this paper studies the reinforced effect of embankment by laying geogrid compared with not laying geogrid.

To control the excessive vertical settlement of embankment, the reinforced location choose to be at concentrated area in the vertical settlement of embankment, that is to say in the middle and lower of embankment. Position of geogrid is shown in Figure 2.

Table 1. The mechanical parameters of rock and soil mass

Structure layer	Bulk modulus K /MPa	Elastic modulus G /MPa	Density ρ /kN·m^{-3}	Cohesion c /kPa	Friction angle φ /°
Filling	12	3.0	2020	20	34
The upper layer of foundation	12	6.0	2260	25	22

The lower layer of foundation	15.8	7.3	2330	40	25

Table 2. Physical and mechanical indexes of geogrid

Bulk modulus K /GPa	Poisson ration υ	Geogrid thickness t /mm	The coupling spring stiffness k /N·m^{-3}	Coupling spring cohesion kPa
26	0.33	5	2.3*10^{6}	0

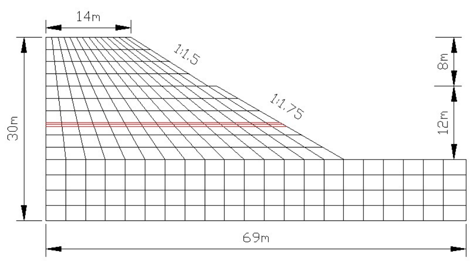


Figure 2. Sketch map of position of geogrid

3.1 Displacement analysis of reinforced embankment

The contour of displacement of reinforced embankment is shown in Figure 3. It can be seen that the whole deformation of embankment is mainly vertical settlement, the maximum deformation appeared at the top center of embankment from this figure. Centered on the top center of embankment, transverse radius is larger than 14 m, the vertical radius is approximately 10 m oval formed within the scope of a centralized settlement area, the region has the maximum deformation. The contour of displacement map of reinforced embankment is shown in Figure 4.

According to the analysis of the friction characteristics of reinforced soil interface, the results showed that the friction angle of reinforced soil interface is the bigger the better, so that reinforcement and soil produce better friction effect which can decrease vertical additional stress in certain depth of soil and stress distribution is more uniform in the cross section.

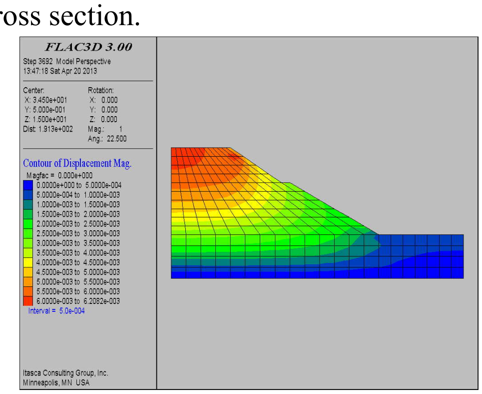
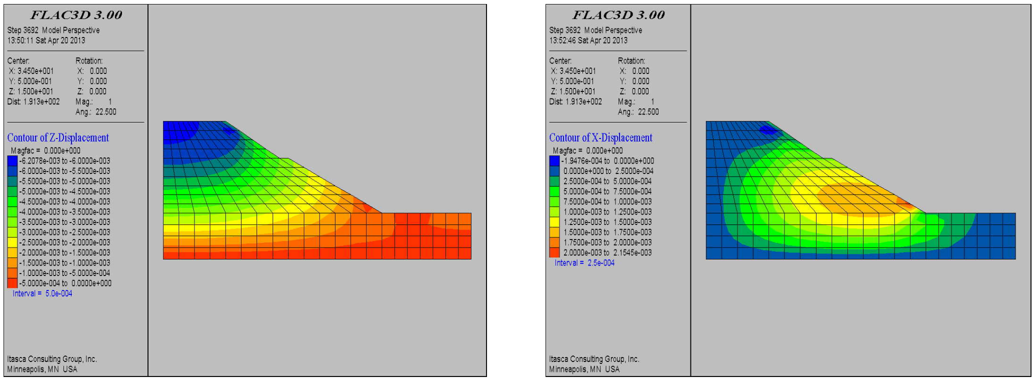


Figure 3. The contour of displacement of reinforced embankment



(a) The contour of vertical settlement (b) The contour of horizontal settlement

Figure 4. The contour of displacement map of reinforced embankment

Although the reinforcement has little effect on decreasing the vertical settlement of embankment from Figure 5, it was effective to lessen the differential settlement of embankment. Through constraining the lateral displacement of embankment, and decreasing the level of slope stress and the inhibition of the plastic zone development, thus the embankment is more stable.

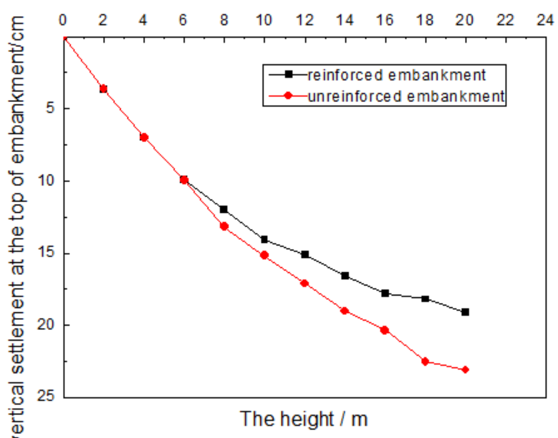


Figure 5. Relational graph between the height and vertical settlement

According to Figure 6 which is relational graph between the height and horizontal displacement at the foot of embankment, the result shows that lateral displacement at the foot of un-reinforced embankment is 9.23 cm, the horizontal displacement decreases to 8.12 cm after reinforcement, and decrease of 13.7%. These show that reinforcement can restricted lateral displacement to a certain extent when laying geogrid in the embankment.

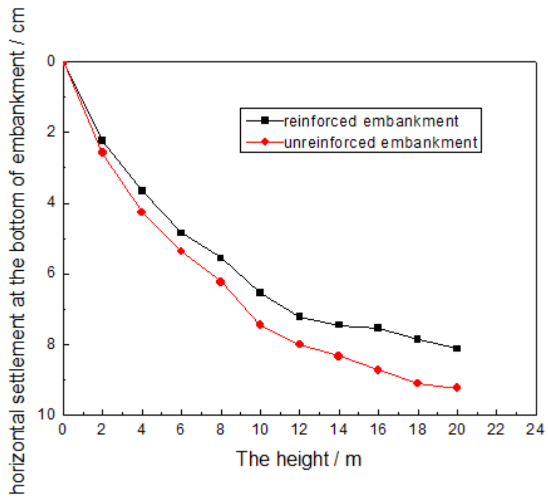


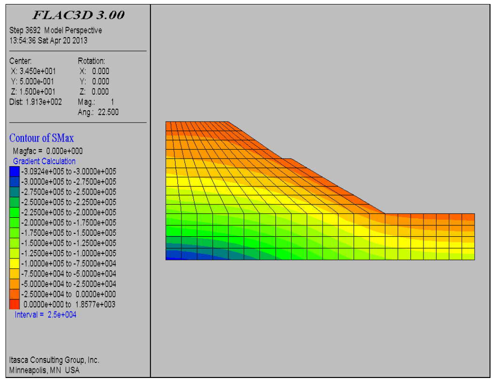
Figure 6. Relational graph between the height and horizontal settlement

The soil has high compressive strength and shear strength, but the tensile strength is lower, so after laying geogrid at the tensile direction in the soil, the friction bite force between geogrid and soil enhances lateral restraint of soil and limits lateral deformation of soil. Lateral displacement is an important reason to lead to the occurrence of settlement deformation under the external loads. It can improve the slope stability through reinforcement to restrict lateral displacement of embankment.

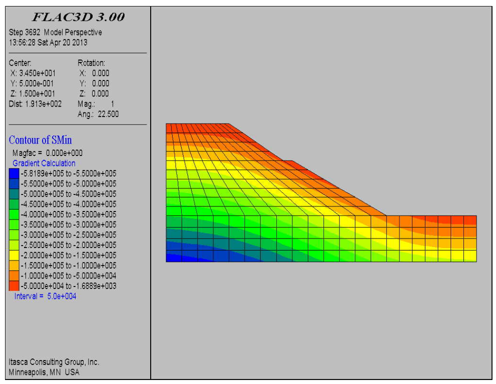
3.2 Stress analysis of reinforced embankment

It can be seen from Figure 7 of the contour of the main stress of reinforced embankment that the maximum principal stress increases with increasing fill depth, the main stress can reach the maximum at the bottom of embankment, the stress concentration area appears in the slope toe and the upper part of the embankment, and the main stress decreases gradually from inside to outside. The principal stress of slope reaches the minimum. The maximum of the minimum principal stress still appear in the bottom of embankment from the contour of the minimum principal stress.

The calculation result shows that the reinforced effect of embankment is not obviously, the whole deformation situations before and after reinforced embankment are the same by comparing the contour of displacement of reinforced embankment before and after. Comparison the contour of the maximum principal stress and the contour of the minimum principal stress of reinforced embankment, the study found that the maximum principal stress increases with soil depth, and reaches the maximum at the bottom of embankment. This suggests that the friction effect between geogrid and soil decrease the principal stress of embankment.



a. The contour of the maximum principal stress



b. The contour of the minimum principal stress

Figure 7. The contour of main stress of reinforce embankment

3.3 Plastic zone analysis of reinforced embankment

Plastic zone distribution is greater, this suggests that plastic yielding area of slope is larger. The case of the plastic zone illustrates distribution and development trend of the slide of slope. Once plastic zone through, the whole sliding surface is formed basically, the damage appeared along the sliding surface. The contour of the plastic zone of reinforced embankment is shown in Figure 8, the contour of shear strain increment of reinforced embankment is shown in Figure 9.

It can be seen from Figure 8 of the plastic state distribution, the tensile failure of plastic zone of embankment slope is located at the foot of embankment slope, tensile failure appeared at the top of embankment, and shear failure and tensile failure appears at the bottom of slope toe of embankment, the plastic zone is not through in a whole range of embankment, which can determine the embankment slope currently in stable.

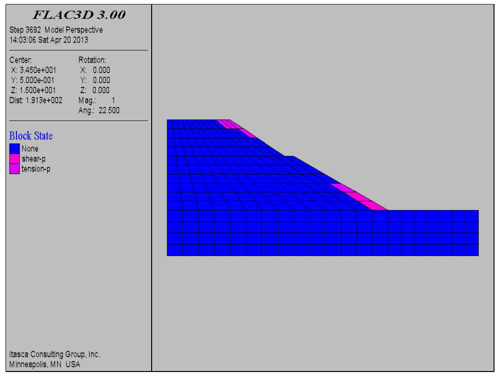


Figure 8. The contour of the plastic zone of reinforced embankment

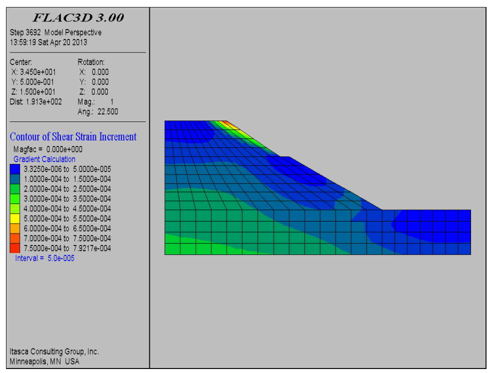


Figure 9. The contour of shear strain increment of reinforced embankment

When designing the geogrid position, it puts geogrid in plastic zone of embankment which can meet the engineering requirements, not necessarily laid in the whole embankment. The contour of shear strain increment has not yet run through from Figure 9, it suggests that the sliding force which provided by slope not enough to create shear failure of slope and slope is in the steady state. Shear strain increment of in the lower of embankment is very small, some close zero. These parts usually does not exist the potential sliding surface, and does not occur large deformation and the failure. Shear strain increment is larger at the top of slope of embankment, the shear failure zone appear easily in the region which exist a potential slip surface and happened easily the deformation damage. Shear strain increment is very small at lower part of embankment, it indicates that this region is in the shear condition which can provide better skid-resistance to keep the stability of embankment.

From the contour of plastic state distribution and the contour of shear strain increment of reinforced embankment, the result shows that the plastic zone and the contour of the maximum shear strain of reinforced embankment expand to embankment inner, the scope of the plastic zone gradually expand, but the maximum shear strain decreases. The location of slip surface of reinforced embankment moves downwards, it illustrates the resistance deformation ability of reinforced embankment are enhanced, the friction between geogrid and soil plays a role in a certain extent.

4 Conclusions

(1) Embankment deformation dominates by vertical, the maximum horizontal deformation appears in the toe of embankment slope. Through the numerical simulation of reinforced embankment, the study shows that with laying geogrid in embankment, it inhibites vertical deformation and horizontal deformation and enhances the overall stability of embankment, especially the stability of the embankment slope.

(2) The friction angle of reinforced soil interface is bigger, so that better friction effect produced between geogrid and soil, it decreases the vertical additional stress of soil in certain depth of embankment and stress distribution is more uniform in the cross section. Although the reinforcement has little effect on decreasing the vertical settlement of embankment, it is effective to decrease the differential settlement of embankment. Geogrid could inhibit the horizontal displacement of embankment, and lesson the stress of slope and inhibit the plastic zone development, thus tend to a more stability of embankment.

(3) With laying the geogrid in embankment, the stress of reinforced embankment will redistribute, the vertical stress and horizontal stress are decreased. Through the friction between geogrid and soil, the shear strength of reinforced embankment is enhanced, and the stress state is improved, so that reinforced embankment could stand greater load, anti-deformation ability and anti-crack ability are enhanced.

(4) The plastic zone of embankment appears at the slope angle in the top of embankment and in the toe of embankment slope, the tensile failure of plastic zone of embankment slope is located at the foot of embankment slope. Tensile failure appears in the top of embankment and shear failure and tensile failure appear in the bottom of slope toe of embankment.

Acknowledgement

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References

CHEN Xiangjun, TANG Jinsong. (2002). Stability and Deformation Analysis of Maya Slope Using FLAC^{3D}. *Journal of Shijiazhuang Railway Institute*, 15(3): 76-79.

Hegde, A., and Sitharam, T. G. (2014). 3-Dimensional numerical modelling of geocell reinforced sand beds. *Geotextiles and Geomembranes*, 1-11.

Hambleton, J. P., and Sloan, S. W. (2013). A perturbation method for optimization of rigid block mechanisms in the kinematic method of limit analysis. *Computers and Geotechnics*, 48: 260-271.

Kevin, L. C., and Jonathan, F. (2006). A comparison of two design methods for unpaved roads reinforced with geogrids. *Canada Geotechnical Journal*, 43(12): 1389–1394.

TAO Hui, CHEN Yumin, XIAO Yang, et al. (2014). Development and verification of 3D bounding surface model for rockfill materials in $FLAC^{3D}$. *Rock and Soil Mechanics*, 35(6): 1801-1808.

Tafreshi, S. N. M., and Khalaj, O., and Dawson, S. R. (2013). Pilot-scale load tests of a combined multilayered geocell and rubber-reinforced foundation. *Geosynthetics International*, 20(3): 143-161.

WANG Mingyuan. (2009). Research on the Behaviors at Interface Between Geogrids and Expansive Soils and the reinforced Mechanism. *Zhejiang University*.

WANG Jiaquan, ZHOU Jian, CONG Lin, et al. (2010). Analysis between numerical and field tests of high fill reinforced widening embankment. *Chinese Journal of Rock Mechanics and Engineering*, 29(Supp1): 2943-2950.

YU Zehong. (2005). Analysis for Deformation and Shear Zones of Reinforced Embankment. *Hunan University*.

ZHANG Hong, SUN Guanhua, LIU Defu. (2009). A practical procedure for searching critical slip surfaces of slopes based on the strength reduction technique. *Computers and Geotechnics*, 36(1-2): 1-5.

Ambient Temperature and Vehicle Loading Effects on Asphalt Concrete Pavement Rutting Development

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Abstract: In order to investigate ambient temperature and vehicle loading influence on asphalt pavement rutting development, ABAQUS is utilized to build pavement structure three-dimension model. Based on the actual temperature data, heat transfer theory, creep model and 3-D finite element method, the temperature filed variation law in pavement is calculated. And asphalt pavement rutting developments under different vehicle loadings in different ambient temperatures are analyzed. The results indicate that pavement rutting develops nonlinearly as ambient temperature varies; the rutting developing rate under high temperature condition is much higher than under low temperature condition; there is a linear correlation between rutting depth and vehicle loading under the same loading times; the rutting proportion developed in hottest season is much higher than any other seasons.
Keywords: Road engineering; Asphalt concrete pavement; Rutting development; Environment temperature; Vehicle loading.

1 Introduction

Finite element analysis method is utilized to study asphalt concrete pavement rutting development by many researchers. However, daily and seasonal periodical variations of ambient atmospheric temperature were ignored in traditional researches. As a temperature sensitive material, asphalt concrete rutting calculation results influenced by temperautre field very significant. Thus two-step analysis method is utilized in this paper. Fist, pavement temperature fields under different ambient temperatures are obtained by heat transfer analysis utilizing ABAQUS. Based on temperature field calculation results, rutting development laws under different ambient temperature and vehicle loading are analyzed.

2 Temperature Field Analysis Theory

Because of solar radiation, the atmospheric temperature varies greatly between day and night, and presents a periodical variation on a yearly cycle. Effect of solar radiation can be described as boundary condition which varies periodically.

The main factors which influence asphalt concrete temperature are daily maximum temperature $T_a^{\max}$, daily minimum temperature $T_a^{\min}$, total amount of daily solar radiation Q, effective duration of sunshine c, and daily average wind speed v_w.

2.1 Solar radiation

According to the research achievements of Barber, Yan zuo-ren etc, daily variation of solar radiation $q(t)$ can be simulated by using follow equations:

$$q(t)=\begin{cases}0 & 0\le t<12-c/2\\ q_0\cos m\omega(t-12) & 12-c/2\le t\le 12+c/2\\ 0 & 12+c/2<t\le 24\end{cases} \qquad (1)$$

Where: q_0 is maximum radiation in a day where $q_0=0.131mQ$, $m=12/c$; Q is total amount of daily solar radiation; c is effective duration of sunshine, with the unit of hour; ω is angular frequency, and $\omega=2\pi/24$, the unit is rad.

2.2 Heat exchange of atmospheric temperature and convection

Variation of ambient atmospheric temperature can be simulated by using a line combination of two sine functions. The simulation results accurately predict this variation.

$$T_a=\overline{T_a}+T_m[0.96\sin\omega(t-t_0)+0.14\sin 2\omega(t-t_0)] \qquad (2)$$

Where: $\overline{T_a}$ is daily average atmospheric temperature, $\overline{T_a}=(T_a^{\max}+T_a^{\min})/2$, the unit is ℃; T_m is amplitude of daily atmospheric temperature, $T_m=(T_a^{\max}-T_a^{\min})/2$, $T_a^{\max}$ and $T_a^{\min}$ are maximum temperature and minimum temperature respectively; and t_0 is initial phase, t_0 usually takes the value of 9 in normal conditions.

$$h_c=3.7v_w+9.4 \qquad (3)$$

Where: h_c is the heat convection coefficient, the unit is $W/(\mathrm{m}^2\cdot ℃)$, and v_w is the daily average wind speed, m/s.

2.3 Effective radiation of pavement

Effective radiation of pavement relates to pavement surface layer, atmospheric temperature, cloud cover, humidity levels, and so on.

This paper presents effective radiation of pavement by using the following equation:

$$q_F = \varepsilon\sigma[(T_1|_{Z=0} - T_Z)^4 - (T_a - T_Z)^4] \quad (4)$$

Where: q_F is ground effective radiation, $W/(m^2 \cdot ℃)$; ε is emissivity; where asphalt concrete pavement usually takes the value of 0.81; σ is the Stefan-Boltzmann constant; $T_1|_{Z=0}$ is the pavement surface temperature, ℃ ; T_a is the atmospheric temperature; and T_Z expresses the absolute zero temperature.

2.4 Creeping parameters of asphalt concrete

Creepage and plasticity of asphalt concrete cannot be treated respectively becuase the tests can only observe the combined effect of these two phenomenon in recently. Creeping model in ABAQUS is utilized to simulate asphalt concrete creepage in this paper. Material properties in high temperature is described as followed.

The deformation of material ε_c is expressed as the function of temperature *T*, stress σ and time *t*:

$$\varepsilon_c = f(T, \sigma, t) \quad (5)$$

The expression of Bailey-Norton law which used widely in material deformation analysis is shown as:

$$\dot{\varepsilon}_c = A\sigma^m t^n \quad (6)$$

Where: $\dot{\varepsilon}_c$ —strain rate (the strain variation in unit time);
σ —axle deviator stress (the difference between axle and confining pressure);
t —the loading cumulative acting time;
A, *m*, *n* —material related parameters, rely on the temperature and stress, can be determined by material tests.

3 Analysis Results

3.1 Influence of ambient temperature

Figure 1 and Figure 2 show the rutting developments in different month under standard loading and double times overloading.

According to the results shown in Figure 5 and Figure 6, it can be found that rutting develops most rapidly during July which is the hottest month in one year. The rutting depth under standard vehicle loading is about 735mm. in January, February and March, the rutting develops least, and the rutting depth under standard vehicle loading is about 0.54mm. The largest rutting depth is about fourteen times larger than the least rutting depth. Therefore, the rutting disease in high atmospheric temperature is much more serious than in low temperature. The anti-rutting performance of asphalt concrete should be paid mainly attention, and it is very coincidence to the actual engineering experience.

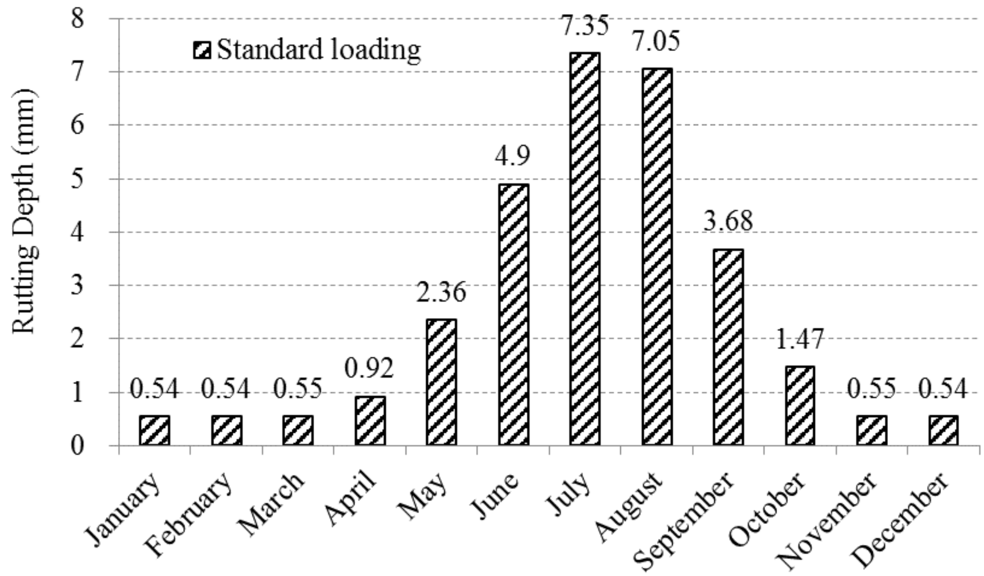

Figure 1. Rutting Developments under Standard Loading

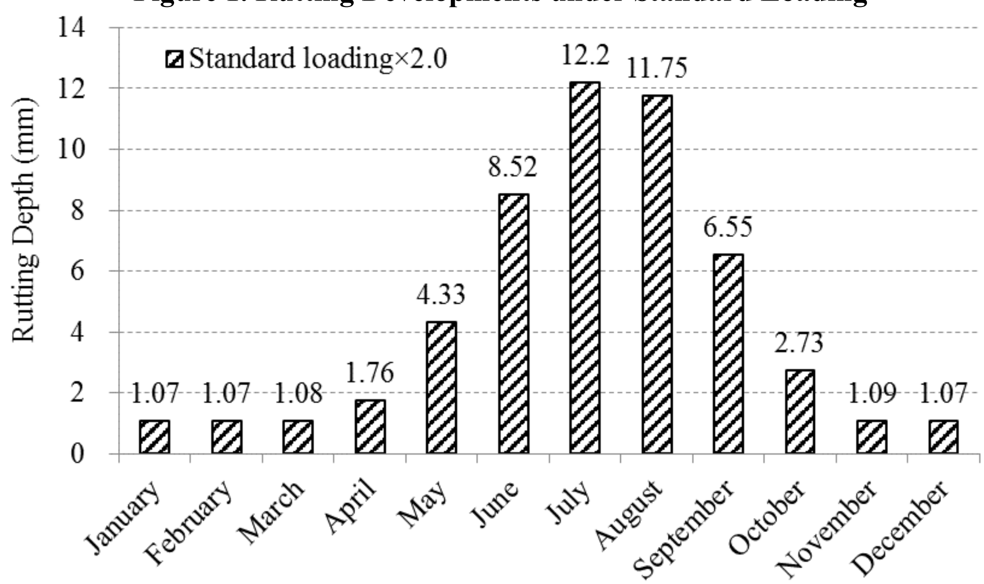

Figure 2. Rutting Developments under Double Times Overloading

In sum, the rutting disease is more serious while the ambient temperature rising, there is no linear relation but non-linear relation with transient variation between them. Therefore, the actual engineering material designation should focus on the asphalt concrete anti-rutting performance under high temperature.

3.2 Influence of vehicle loading

In order to evaluate the vehicle loading influence on rutting development, rutting developments under different loading in coldest month: January and hottest month: July are shown in Figure 3 and Figure 4.

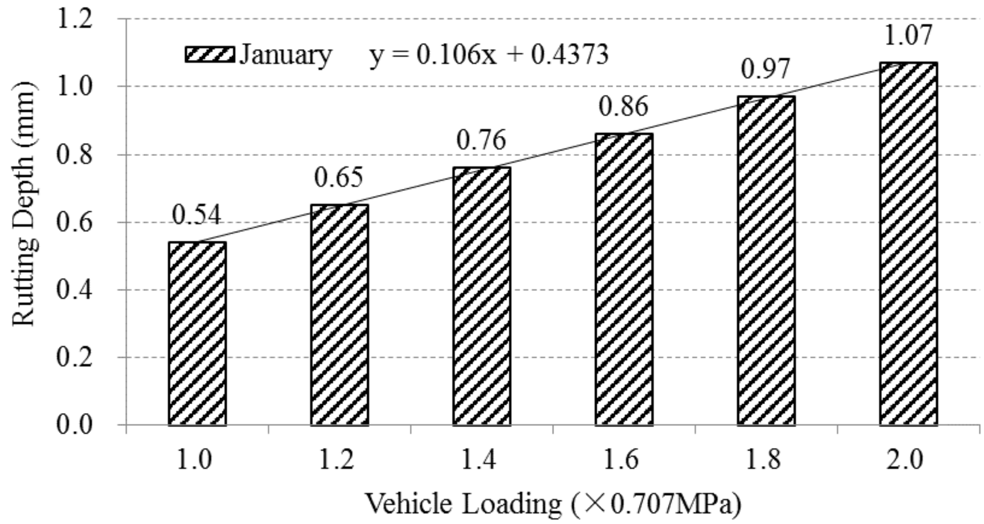

Figure 3. Rutting Developments under Different Loading in January

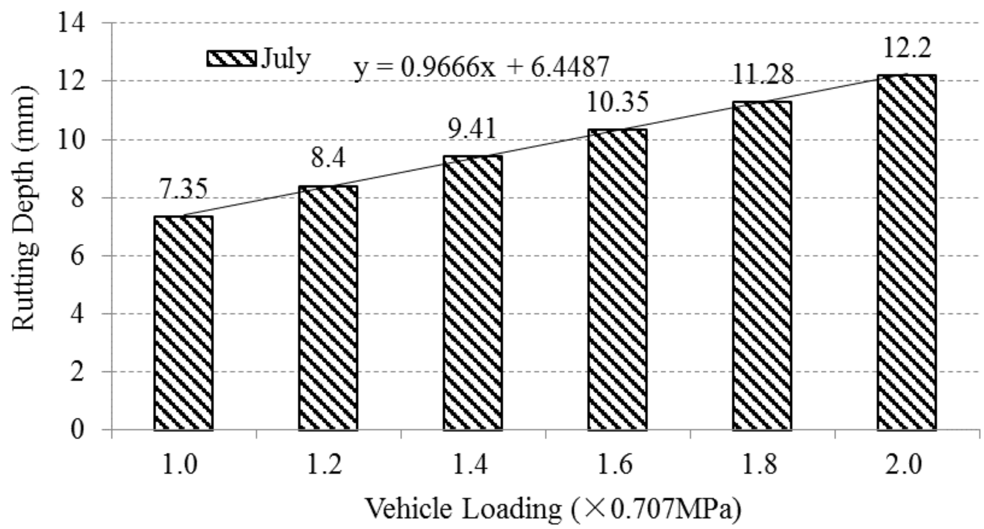

Figure 4. Rutting Developments under Different Loading in July

According to the results shown in Figure 3 and Figure 4, no matter in high temperature or low temperature seasons, rutting depths increase linearly related to vehicle loading.

3.3 Rutting Development Proportion in High Temperature Seasons

From the analysis results mentioned above, pavement rutting develops with different rates in different months because of the temperature difference. In one year, rutting develops much faster in hot seasons than in cold seasons. There are three months that maximum ambient temperatures are exceeding 30℃, they are June, July and August. And maximum ambient temperature in one more month is almost 30℃:

September. Make a statistic to rutting development proportion in these three or four months. The results are shown in Figure 5.

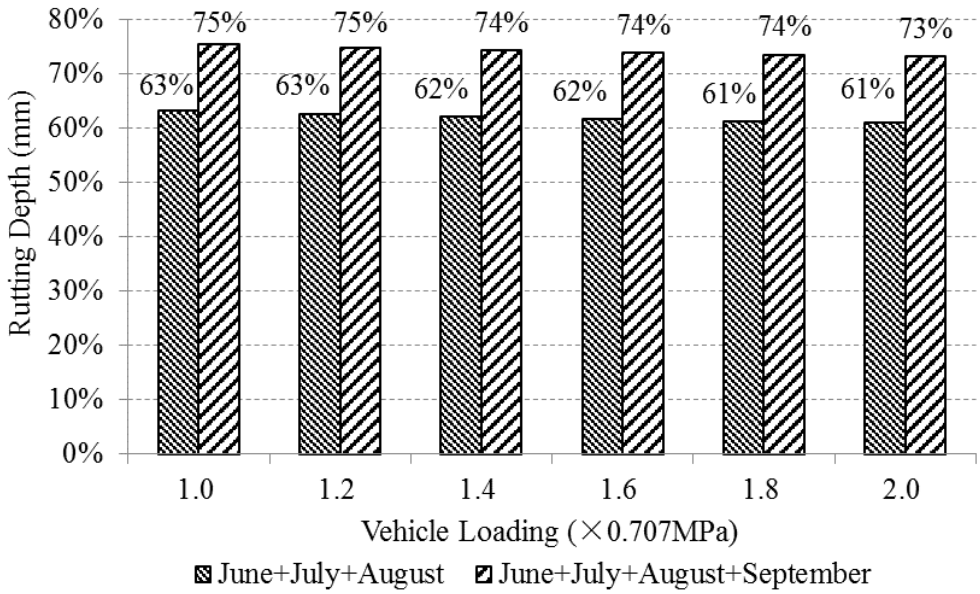

Figure 5. Rutting Development Proportion in High Temperature Seasons

According to the results shown in Figure 5, it can be found that the rutting development proportion of three hottest months in one year is about 61%~63%; the proportion of four hottest months is about 73%~75%. Pavement rutting in hot months is much more serious than in cold months.

All mentioned above, the rutting growing linearly while the vehicle loading increasing. Therefore, the overloading of vehicle can accelerate the the asphalt concrete rutting disease growing rapidly and shorten the pavement normal service lifetime. It is very necessary to control the overloading phenomenon to avoid the rutting disease developing rapidly. The rutting growing rate is much less in high temperature seasons than in low temperature seasons, but the absolute value of rutting depth is still bigger, the effect of overloading under high temperature condition is more serious, it should be paid more attention in actual engineering.

4 Conclusions

This paper utilize finite element method, based on heat transfer theory, and analyzed the asphalt pavement structural temperature field. ABAQUS creeping model is utilized to simulate and analyze the rutting development of asphalt concrete under vehicle loading. The main conclusions are followed:

(1) Rutting growing rate under high temperature is much more bigger than under low temperature condition, material anti-rutting performance must be considered first;

(2) Rutting development and temperature variation are basically following same law, but there is non-linearly relation between them. Rutting develops rapidly once asphalt concrete temperature achieving a certain level.

(3) In any ambient temperature condition, rutting growing rate is linearly related to the vehicle loading. The absolute rutting depth under high temperature is much larger than under low temperature. Thus, the overloading action on asphalt concrete pavement under high temperature can accelerate the rutting developing procecuere much more.

Rutting proportion develops under high temperature is much higher, rutting disease is much more serious in June, July, August, September in which moths the ambient temperatures are very high.

In summary, both the condition of high temperature and overloading can lead more serious rutting disease. Therefore, asphalt concrete anti-rutting performance under high temperature must be considered and paid enough attention. Traffic vehicle overloading phenomenon must be restricted as less as possible to avoid rutting development acceleration. By these ways, normal service capability of asphalt concrete pavement can be protected and the service life can be extended.

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Reference

Cui Juan (2006). Research on Prediction of Rutting Depth of Asphalt Pavement on Steel Deck Bridge .Nanjing: Southeast University.

Li, Q. Lee, H. L. and Hwang, E. Y., "Characterization of Permanent Deformation of Asphalt Mixtures Based on Shear Properties," Transport. Res. Rec., No. 2181, 2010, pp. 1–10.

Dai Zheng (2004). Mechanics Analysis of Asphalt Pavement Structure. Nanjing: Southeast University.

Feng Jiliang, Xu Aihua, Xi Xiaobo (2004). Visco-elastic Method for prediction of asphalt pavement rutting. Journal of highway and transportation research and development.

Li, Q. Ni, F. and Li, G., "Conversion Method of Axle Load for Asphalt Pavements

Based on the Rutting Equivalent," J. Transport. Eng. Inform, Vol. 11, No. 4, 2013, pp. 63–70.

Liao Gongyun, Huang Xiaoming (2008). Application of Finite Element Software ABAQUS on Road Engineering. Nanjing: Southeast University Press.

Peng Miaojuan, Xu Zhihong (2004). Method of rutting prediction in asphalt pavements. Journal of Tongji University (Natural Science).

Sides A, Uzan J, Perl M (1985). A comprehensive viscoelastic plastic characterization of sand asphalt compressive and tensile cyclic loading. Test evaluate.

Yan Zuoren (1982). Temperature Field Analysis in Layered Pavement: Shanghai: Tongji University.

Li, Q. Lee, H. L. and Lee, S. Y., "Permanent Deformation Model Based on Shear Properties of Asphalt Mixtures: Development and Calibration," Transport. Res. Rec., No. 2210, 2011, pp. 81–89.

Xue Wei (2006). Data Analysis Based on SPSS. China Renmin University Press.

Zhang Jiupeng, Huang Xiaoming, Wang Xiaolei (2007). Analysis of asphalt pavement rut based on elastic-viscoplastic theory. Journal of highway and transportation research and development.

Huang, B. Chen, X. Shu, X. Masad, E. and Mahmoud, E., "Effects of Coarse Aggregate Angularity and Asphalt Binder on Laboratory-measured Permanent Deformation Properties of HMA," Int. J. Pavement. Eng., Vol. 10, No. 1, 2009, pp. 19–28.

Li, Q. Li, G. and Wang, H., "Effects of Loading Modes on Dynamic Modulus for Asphalt Mixtures," J. Build. Mater. (in press)

Monismith, C. L. Hicks, R. G. Finn, F. N. Sousa, J. Harvey, J. Weissman, S. Deacon, J. Coplantz, J. and Paulsen, G., SHRP-A-415: Permanent Deformation Response of Asphalt Aggregate Mixes, National Research Council, Washington, D. C., 1994.

Hajj, E. Siddharthan, R. Sebaaly, P. and Weitzel, D., "Laboratory-based Unified Permanent Deformation Model for Hot-Mix Asphalt Mixtures," J. Test. Eval., Vol. 35, No. 3, 2007, pp. 272–280.

Chehab, G. R. Kim, Y. R. Schapery, R. A. Witczak, M. W. and Bonaquist, R., "Time-Temperature Superposition Principle for Asphalt Concrete with Growing Damage in Tension State," J. Assoc. Asph. Paving. Technol., Vol. 71, 2002, pp. 559–593.

Urban Road Speed Humps Setting Technology

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Abstract: Set the speed control humps scientifically, both from the reminder and to decelerate purpose, effective protection of urban road traffic safety. The paper describes the function of speed humps' reducing accidents. Basing on the comprehensive analysis of domestic and foreign studies of speed humps, it further analyzes the influencing factors of deceleration zone's speed limit effect and a preliminary method of setting humanized speed humps is proposed. Finally, the paper chooses a selection from student apartment area 1 to area 2 in Qishan campus of Fuzhou University as an example to analyze decelerating effect of speed humps on all types of vehicles and conclude the relationship between the speed limit effect of deceleration and vehicle speed, some suggestions of setting speed humps are put forward.

Keywords: Speed humps; Speed limit effects; Traffic safety; Experimental analysis.

1 Background

In recent years, with the fast development of urban traffic and rapid growth in vehicle ownership, urban roads are under increasingly heavy traffic burden, road traffic safety problems have frequently happened. The speeding phenomenon are existing although repeated banning, this not only caused deaths and huge property loss, but also has serious impact on the entire economic and social development. Especially in the speeding deaths and property loss is most serious, speeding is still a typical traffic accident inducement. To solve the speeding problem, in addition to depending on legislation, promoting safety awareness, setting the sign and marking to remind drivers, it is more important to set some mandatory facilities to constrain driving speed. As a typical speed limit facility, speed humps is widely used.

Speed humps is an enhanced road traffic safety facilities on smooth roads, set the deceleration zone in moving vehicles, non-motor, both from the reminder and to decelerate purpose, effective protection of urban road traffic safety. Speed humps has advantages of simple construction, low cost of building and maintaining and quick effect, in recent years it has made great recognition in the domestic industry.

Scientific settings to slow down, we can reduce noise with environmental pollution, improve efficiency with speed reducer, effectively improve road traffic safety conditions, on the other hand, it may be ineffective or even become human barricades which cause second accident. Furthermore, the negative effects such as energy consumption, noise pollution caused by lack of humanistic consideration on the model, set position and range of speed humps can not be ignored.

2 Research Status at Home and Abroad

Foreign research on speed humps is deeper, they optimize control mode mainly based on the influence on driver behaviors, model and algorithm of speed humps, and on the basis of theoretical study on stochastic point process, further analysis and research on control problem have been done. Foreign experts have made a profound summary on the relationship between speed humps and drivers, systematically and vividly drew the effect of speed humps on the driver's driving behavior, they also got a conclude that vehicle’s through speed humps will result road vibration and even cause property damage, so the setting location need to be considered seriously to avoid the vibration nuisance. Some scholars came to a conclusion, that is, a longer speed humps can not necessarily achieve better slow effect, and we can know the best setting position based on the comparison on the horizontal section of speed humps.

With the introduction of foreign advanced technology research and ideas, domestic scholars also do a large number of studies, it mainly analysis the impact on the traffic flow, control effect on vehicle speed, effect on vehicle vibration, etc. Meng Jianping, Zhang Jiefang and others developed advanced methods, hat is, whether need to set a speed humps can be relatively accurate calculated by predicting traffic flow, to make the traffic safety and efficiency achieve the double priority. Wang Chao, Sun Xiaoduan, Shi Yang put forward the method to evaluate slow effect of speed control facility, this is a positive reference for the future related researches and decisions.

3 Influencing Factors of Speed Limit Effect

Due to the driver, vehicle factors and its own material, designed grade, passage length, it can generate impact force when vehicles have collision with speed humps and it will make people feel uncomfortable when under a excessive high speed, forcing the driver to get through speed humps at a low speed.

An ideal road speed humps must ensure that the vehicle is always under control, as well as those important safety components will not produce the dangerous situation, such as fracture, which means it should have high driving and structure safety. The driving safety of vehicles never be allowed to continue reducing with the increase of the speed, it should be kept at a stable level as it reduced to a certain degree, or even there is some increase with the increase of the speed.

3.1 Driver's Speed Selection

Road speed humps to slow down the speed are realized by influencing the drivers' driving psychology. When a vehicle get through the deceleration zone at a high speed, severe vibration from tire will be passed to the driver through the body and seat, producing strong physiological stimulation (including vibration stimulation and visual stimulation) and mental stimulation. Physiological stimulation will produce a strong discomfort, mental stimulation will deepen the unsafe concerns, further reducing the drivers' sense of security on the road environment. In general, the more uncomfortable, the less safe people feel, namely the smaller sense of security.

Therefore, to a large extent, the vehicle's speed depends on the driver's expected speed and the expected speed is decided according to the driving safety and comfort. A high sense of security and good ride comfort make the expected speed higher, On the other hand, the driver's expected speed will be lower. When a vehicle get through the speed humps, it will greatly reduce the driver's expectations of driving safety and comfort. Without any outside pressure, the driver will take the initiative to make the vehicle at low speed under the guidance of expected speed in order to achieve the expected requirements when the vehicle is close to the road speed humps .

Some speed limit effect is not obvious instead under the case of high entering speed because the nonrigid turbulence is quickly absorbed the impact before the vehicle responding to it. For those roads with higher traffic speed, the width of road speed humps should be further increased according to the relationship between limited speed and speed humps' design width, the specific design size should be determined after a lot of experimental research.

3.2 Model and Layout of Speed Humps

The height and width size of the rubber speed humps is very important for traffic safety. If the height is too high, the through vehicle will get a greater impact from the speed humps and its damping effect is not obvious, especially for two-wheel motorcycles, it can cause the vehicle out of control, leading to traffic accidents. If the height is too low or the width is too wide, the slow effect is not obvious. Considering the above factors, urban road rubber speed humps must have a certain hardness to ensure the safety of the through vehicle, however, the hardness cannot be too high in case that greater impact effect and increased noise be caused .

When different types of vehicles get through road speed humps of different structure size, car body acceleration and car axle acceleration varies with the speed of the car. Researches show that : the design width of speed humps is proportional to the control speed while the design height is inversely proportional to the control speed. For roads of which speed less than 40 km/h, width of 400~500mm and height of 40~50mm can achieve good speed control effect, while for roads of which speed less than 60 km/h, width of 500~600mm and height of 30~40mm can achieve good speed control effect. The width of the existing urban road speed humps is generally narrow as 300~500mm and the height size design is more casual, this not only severely affects the speed control effect, but also brings new hidden trouble to the urban road traffic safety.

The setting distance should also be considered when we set speed humps for urban roads, it increases with the increase of the design speed when at constant slope. If conditions permitted, the combination of antiskid pavement and vibrate speed humps can be considered to improve the slow effect.

4 Experimental Analysis on the Speed Limit Effect of Speed Humps

The height and width of road speed humps are the most two key design parameters of the vehicle speed limit, which directly affect the the speed control effectiveness and use safety of the road speed humps, but different types of vehicles will bring out different speed limit effect.

To analyze speed limit effect of speed humps, a real vehicle test from the angle of speed humps' speed limit effect on different types of vehicles has been conducted. Because of the various types of vehicles, the survey just chose buses, minivans and cars as the sample vehicles, selected a certain number of samples of each model and detected their speeds, eliminating some too high or too low speed data, to analyze speed humps' different speed limit effect on different types and speeds of vehicles.

4.1. Test Object

The research selected a section of Fujian Medical School in Fuzhou university town which has speed humps to control vehicle speed. Because the section is long, straight and flat, some other influencing factors can be eliminated, considering that the speed changes is just caused by the speed control facilities, which can reflect the slow effect of speed humps.

We eliminated some too high speed to ensure the data accuracy as we just study speed humps' whole efficiency on vehicles. Due to the constraints, we just investigated a speed humps. The experimental instrument that used are BUSHNELL VELOCITY of radar and a speed humps of which the width is 38cm and the height is 5cm. The survey time is on the daytime of working days, sample size and location information are shown in table 1.

Table 1. Sample Size and Location Information

Type of Speed Humps	Number of Buses	Number of Minivans	Number of Cars
Width:38cm;Height:5cm	43vel	27vel	30vel

4.2 Experimental Instrument

The two main measuring tools: BUSHNELL VELOCITY of radar(measuring speed), a fiber tape of Changcheng brand(measuring width and height).

The Doppler Effect principle that speed measuring radar use: When the goal towards radar antenna, reflection signal frequency will be higher than the transmitter frequency, On the other hand, when the target far away from the antenna, reflection signal frequency will be lower than the transmitter frequency. We can calculate the relative speed between the target and radar by the change value of frequency.

4.3 Test Method

Firstly, use a tape to measure the specifications of speed humps(the width is 38cm,the height is 5cm). Observation location is 20m ahead of the object speed humps, then use BUSHNELL VELOCITY radar to measure the vehicle speeds before and after speed humps, lastly, measure and record the data according to the method of data collection.

4.4 Test data analysis

The test data is collected from a city road of which limited speed is 30 km/h, it uses speed humps to control vehicle speed. Because the section is long, straight and flat, some other influencing factors can be eliminated, considering that the speed changes is just caused by the speed control facilities, which can reflect the slow effect of speed humps, as table 2.

Table 2. Statistical Result of Bus/minivan/car Speed（km/h）

Bus/minivan/car	Entering Speed (Bus/minivan/car)	Out of Speed (Bus/minivan/car)
Average speed	36.7/30.3/37.7	33/24.8/34.4
$V15$	26/25/23	21/21/22
$V50$	37/29/39	31/22/36
$V85$	48/33/48	46/27/45
Minimum Value	22/25/22	18/21/20
Maximum Value	53/37/61	50/29/61
Variance	77.3/19.8/95.3	95.3/9.9/89.5
Standard Deviation	8.8/4.4/9.8	9.8/3.2/9.5

As can be seen from the statistical results, vehicle speed is relatively high before the speed humps, the 85th Percentile Speed of the three types are all over the limited speed of 30km/h, after the speed humps, their speeds have a certain decline, 4.17% for buses, 18.18% for minivans and 6.25% for cars. The mean velocity and run speed of the vehicles are basically down to the limited speed. It can be seen that the current speed humps play a good role through the data comparison.

In order to better reflect the effect of speed humps, weeding out useless data, we divided the entering speed into a few section: <30km/h, 30~40km/h, 40～50km/h, 50～60km/h. We used the velocity decrement which is equal to the speed reducing values divided by the entering speed to inspect the slow effect, as table 3.

Table 3. Entering speed（<30/30～40/40～50/50～60km/h）

	Entering Speed (<30/30～40/40～50/50～60km/h)	Out of Speed (<30/30～40/40～50/50～60km/h)	Deceleration value (<30/30～40/40～50/50～60km/h)
Average speed	25.8/34.2/45/51.2	21.6/30.2/41.9/49	4.2/4/3.1/2.2
$V15$	22/30/41/50	19/26/37/48	3/4/4/2
$V50$	26/33/45/50	21/29/42/49	5/4/3/1
$V85$	29/38/50/53	23/35/48/50	6/3/2/3
Minimum Value	22/30/40/50	18/22/36/48	Slow Effect
Maximum Value	29/40/50/55	26/40/49/50/50	
Variance	7.26/13.79/13.15/3.19	4.65/13.94/20.18/0.75	17.5%/11.3%/6.8%/4%
Standard Deviation	2.69/3.71/3.63/1.79	2.16/3.73/4.49/0.87	

4.5 Experimental Conclusions

It can be seen by contrasting and analyzing the results:

(1) Speed humps can't slow down all vehicles of different speed to a roughly same speed, but only have a corresponding slow effect on vehicles of different speed.

(2) When the entering speed is lower than 30 km/h, the slowing down phenomenon is most obvious, the slow effect will gradually become worse due to the increase of speed. The speed reduction theory is that the higher the vehicle speed, the more uncomfortable the driver feel with the vibration,which will make the driver reduce speed. This phenomenon seems to conflict with the theory, but we cannot rule out the driver's improving speed by sacrificing the ride comfort.

(3)When the entering speed is higher than 40 km/h, it still can't meet the limited speed of 30 km/h after slowing down. Assuming that the limited speed is reasonable, from the data, the proportion of this part of vehicles is very large, so the speed humps still can not solve the speeding problem most effectively.

5 Conclusions and Suggestions

The paper has a deeper understanding of speed humps' characteristics basing on observing and comparative analyzing the vehicle speed which get through the speed humps, it also presents a good method to evaluate the slow effect of speed humps. The following can be found from the research:

The slow effect of speed humps on three types of vehicles is as follows:minivan (18.15%), bus (10.08%) and car (8.75%).

The slow effect of this speed humps becomes less obvious instead with the increase of vehicle speed.

The speeding problem still cannot be solved most effectively just by speed humps.

References

CHENG Guo-zhu, PEI Yu-long. (2008). Analysis on Characteristic of 85th Percentile Speed and Suggestion on Speed Limit of Freeway. *Highway Engineering*.

GUO Dong-hua, MA Jun, DU Ling-ling. (2008). Study and Establishment of Trade Standard of "Pavement Rubber Bump".

Hamid Ansari Ardeh, Masoud Shariatpanahi, Mansour Nikkhah Bahrami. (2008). Multiobjective. Shape optimization of speed humps. *Struct Multidisc Optim* 37: 203-214.

LIU Zhi-qiang, WANG Zhao-hua, QIAN Wei-dong. (2005). Analysis of Traffic Accidents Based on Speed. *China Safety Science Journal*.

MENG Jian-ping. (2005). Study on the Effect of Speed Humps on Traffic Flow in the Cellular Automation Model.The Proceedings of the 7th National Academic Conference and the 19th National Seminar on Hydrodynamics (Volume one).

TANG Zheng-zheng. (2005). Speed Limit,Speed and Safety. *Journal of Highway and*

Transportation Research and Development, 22(3).

WANG Chao, SUN Xiao-duan, SHI Yang. (2009). Research on Vibrate Decelerate Belt and its Speeding Controlling Effectiveness.*Western China Communications Science&Technology*.

Watts GR.Krylov VV. (2000). Ground-borne vibration generated by vehiclecrossing road humps and speed control cushions. Applied Acoustics, 1000 Vol.59, No.3.

YUAN Yong-an. (2005). Speed and Safety.*Traffic Management*.

ZHANG Suo, LI Jie, LI Lian-sheng. (2006). Study on Speed of Vehicle for Road Traffic Accident. *Road Traffic and Safety*.

ZHANG Wei, WEI Lang, YU Qiang. (2008). Effect of Road Hump on Driving Comfort and Safety of Vehicles. *Journal of Chang'an University(Natural science edition)*.

Zhang, G., Avery, R. and Wang, Y.(2007), 'Video-based vehicle detection and classification system for real-time traffic data collection using uncalibrated video cameras',Transportation Research Record: Journal of the Transportation Research Board 1993, 138–147.

An Improved Method of Evaluating Technical Conditions of a Concrete Bridge

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Abstract: Bridge detection and evaluation are designed for bridge maintenance and repair decision service. Current bridge technical condition evaluation method can't response the main performance decay process of the structural members. Through the analysis on 398 reinforced concrete bridges' detection data, a bridge performance decay model is established. Based on the existing bridge evaluation specifications, an optimum method of classified evaluation of technical condition between structure and nonstructural members, together with classified detection method of bridge structure based on structural design principles, was set up. It can provide important basis for the structural and non-structural repairing on bridge maintenance. At the same time, it's helpful for establishing the correlation between the structural defects and the decay of the structural bearing capacity.
Keywords: Bridge inspection; Evaluation of technical condition; Load-carrying capacity; Structural design; Service life.

1 Introduction

In 2013, China's National Highway Bridges amounted to 735,300 in number, 39,778,000 meters at length (Ministry of Transport). Reinforced concrete bridges accounted for the majority of all the bridges. In order to ensure operation safety, bridge inspection and evaluation is becoming increasingly important. The purpose of the evaluation of bridge technical condition is to get the bridge's defects through a comprehensive inspection, evaluate the technical condition of the bridge, provide basis for decision making on bridge maintenance and repair. The study on getting Bridge Evaluation Method improved is helpful for bridge maintenance management.

2 Literature review

Currently, Bridge technical condition evaluation method based on appearance defect detection is commonly used both in domestic and abroad (LIU Guojin,2009; Kawamura K,2003; ZHU Yan,2012; GAO Zhibo,2013; CHEN Dongliang,2013; Melham H.G,1996; Rene B.Testw,2002). Based on the right to check on the current status of the bridge components, a key indicator of experts for fuzzy classification and index weights are given, then grading and weighted summation, evaluation findings at last. Many countries have developed their own hierarchical ordering of evaluation criteria, but the basic method is of the same. The evaluation method is wildly used in many country's technical standards such as "China highway bridge technical condition assessment standard", "China urban bridge maintenance technical specification", "German Bridge Disease and evaluate the technical condition of the new technology", "British road bridge monitoring priority standard," "American highway bridge defect classification standard".

3 Bridge evaluation results using current method

3.1Statistical Analysis of Bridge evaluation results

Statistical analysis of assessment data of 398 highway RC bridges is carried out. The relationship between bridge age (distribution range of 4 to 62 years) and technical condition scores of the whole bridge, deck, superstructure and substructure is built up, which helps fitting out performance decay models (shown in Formula1).

$$f(x) = p_1 x^3 + p_2 x^2 + p_3 x + p_4 \quad (1)$$

Through time-to-space conversion method (SUN Lijun, 2009), the fitting curves and parameters of bridge, deck, superstructure and substructure were brought out. As shown in Figure 1-4 and Table 1.

Table 2. Fitting Analysis of the condition decay model of reinforced concrete bridges

Fitting curve BCI	Decay model parameters				Minimum point		Maxima point		Fitting parameters	
	P_1	P_2	P_3	P_4	age/year	Minimum	age/year	Maxima	R^2	RMSE
bridge	-0.000876	0.07763	-1.985	98.24	18.7	82.5	40.4	87.0	0.05507	10
deck	-0.0004608	0.03603	-0.7153	83.5	13.3	79.3	38.8	83.1	0.01341	14.16
superstructure	-0.000963	0.09213	-2.708	105.7	23.0	80.4	40.8	83.2	0.042	17.17
substructure	-0.0009673	0.08095	-1.812	97.64	15.5	85.4	40.3	92.8	0.06485	11.43

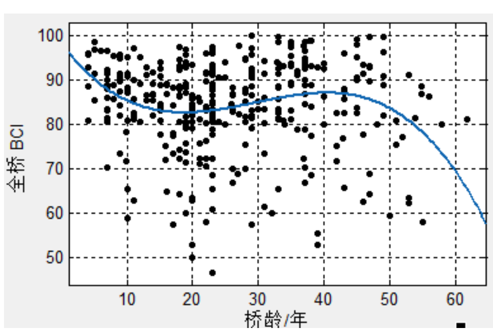


Figure 1. Fitting curve of bridge

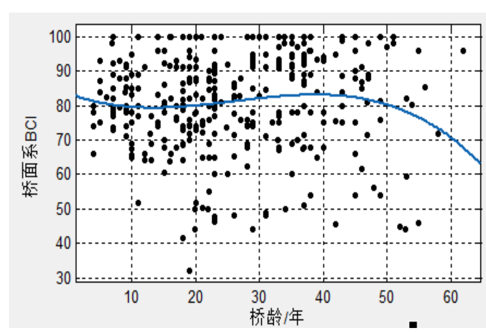
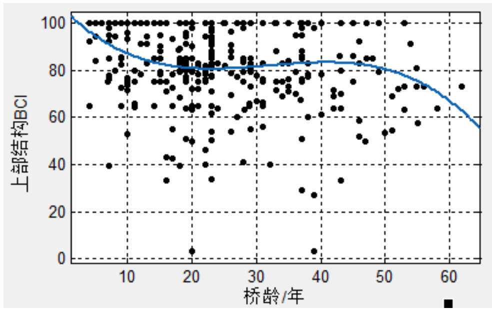


Figure 2. Fitting curve of bridge decking



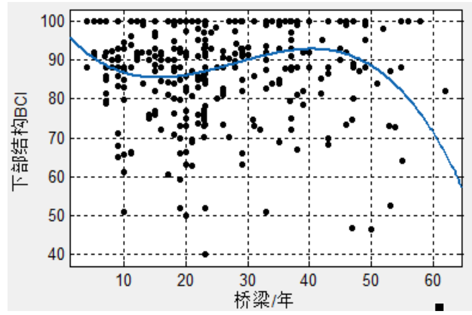


Figure 3. Fitting curve of superstructure Figure 4. Fitting curve of substructure

Fig.1-4 shows, when bridge age distributing from 1 to 19 years, the bridge performance curve shows a clear downward trend under the effects of traffic loads and environmental factors; when bridge age 20 to 40 years, part of the bridges go into the medium and large repair phase, bridge performance curve shows upward trend slightly; when bridge age more than 50 years, the bridge performance curve appears accelerated decline.

Tab.2 shows, when the bridge age is18.7 years, BCI of Bridge reaches its lowest point of 82.5.Then it gradually increases, getting to the highest point 87 at the year 40.4. BCI of Deck System declines fastest, it reaches its lowest point of 79.3 at the minimum age of 13.3 years. Fitting Curves objectively reflect the actual RC bridge performance decay law in the recent r 50 years.

3.2 Problems in current evaluation methods

(1)The current specification use comprehensive technical condition index Dr or BCI, in which includes diseases of structural and non-structural components. Therefore，it cannot objectively reflect the safety performance and the development process of structural disease of the bridge structure.

(2)The deck system’s life and the bridge structure’s life are not synchronized (TAN Jinhua, 2004). The life of the former is much shorter, which results in frequent maintenances. Apparently, this will cause fluctuations of BCI (or Dr) Index.

(3)BCI (or Dr) Index can’t give clear guidance for the decision making of maintenance scope and scale. Therefore, the current evaluation methods are fit for network-level bridge management, but not fit for the project level management.

4 Improvement of bridge evaluation method

4.1 Separate evaluation of structure and bridge deck system

First, evaluate bridge structure and deck system separately. Then, evaluate bridge deck system in the whole length, using index BDCI; evaluate bridge span structure, using index SSCI; evaluate bridge superstructure, using index SPCI; evaluate bridge substructure, using index SBCI.

4.2 Evaluation of bridge structure

Bridge structure can be divided into a total of six levels, including full-bridge, plot (according to the type of interchange ramp or structural division), span (or Continuous beam), of the upper and lower structure, parts, components, shown in Figure 5. Scoring rules and evaluation standards are referring to the current specification. The score of Span structure (SSCI) is the weighted average of the score of superstructure (SPCI) and the score of substructure (SBCI). (As shown in Formula 2)

$$SSCI_i = \mathrm{a}_p \times SPCI_i + a_b \times SBCI_i \qquad (2)$$

Generally, $\mathrm{a}_p = a_b = 0.5$

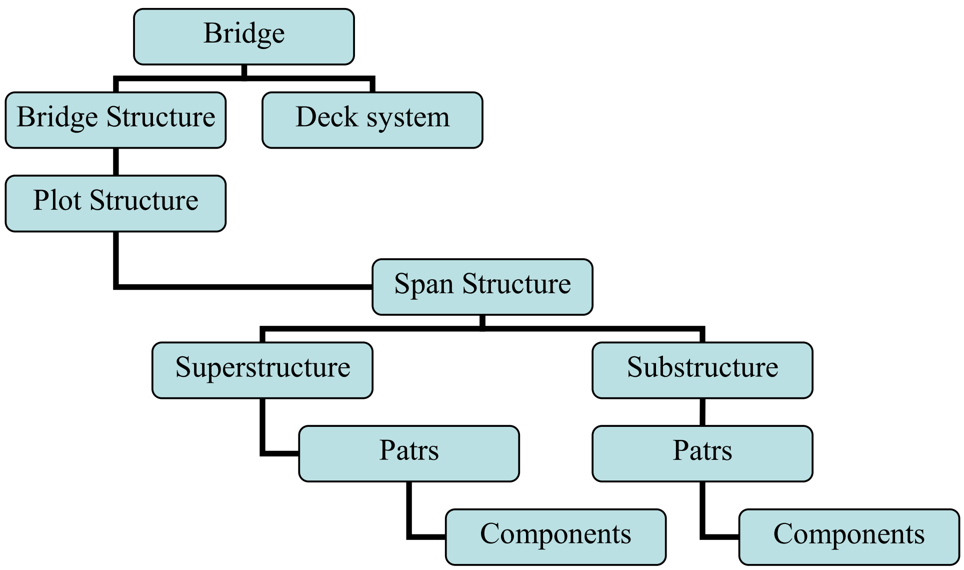


Figure 6. Hierarchical division of bridge structure

5 Applications

5.1 Project summary

A highway bridge was built in 1991, the bridge length 66m, span combination of 4×16m, bridge width 2×1m+7m=9m. The bridge is simply supported reinforced concrete with 4 spans of T-beam; double-column pier substructure, lightweight reinforced concrete abutments; cement concrete bridge deck. Bridge inspection and evaluation was carried out in May 2012.

5.2 Results of the several evaluation methods

Three methods were used in the evaluation of the bridge, including "China highway bridge technical condition assessment standard", "China urban bridge maintenance technical specification" and improved Method. The result is shown in Tab.

Table 3. Comparative analysis of bridge condition evaluation between the present specifications and the optimum method

Bridge Evaluation method	Bridge layer	Bridge evaluation scores					Evaluation index	Evaluation results
		1st span	2nd span	3rd span	4th span	Bridge BCI		
Highway bridge standard	Superstructure	46.6	64.2	69.2	66.3	61.6	Dr=72.6	Bridge in Class 3
	Substructure	84.2	85.2	85.2	85.2	85.0		
	Deck	69.7	69.7	69.7	69.7	69.7		
	Assessment					72.6		
Improved method	Superstructure	46.6	64.2	69.2	66.3	61.6	SSCI1=46.6 SSCI2=64.2 SSCI3=69.2 SSCI1=66.3	1 span in class4, 3 spans in class 3
	Substructure	84.2	85.2	85.2	85.2	85.0		
	Deck	46.6	64.2	69.2	66.3			
	Assessment	Class 4	Class 3	Class 3	Class 3			
Urban bridge standard	Superstructure	51.9	65.9	67.8	65.9	62.9	BCI=74.6	Bridge in Class C
	Substructure	93.5	93.5	93.5	91.5	93.0		
	Deck	61.2	61.2	61.2	61.2	61.2		
	Assessment					74.6		
Improved method	Superstructure	51.9	65.9	67.8	66.2	64.5	SSCI1=51.9 SSCI2=65.9 SSCI3=67.8 SSCI1=66.2	2 spans in class D, 2 spans in class C
	Substructure	93.5	93.5	93.5	91.5	93.0		
	Deck	51.9	65.9	67.8	66.2	78.7		
	Assessment	Class D	Class D	Class C	Class C			

6 Conclusions

(1) Through Statistical analysis of assessment data of 398 highway RC bridges, bridge performance decay models were fitted out. The models show that when bridge ages distributing from 1 to 19 years, the bridge performance curve shows a clear downward trend under the effects of traffic loads and environmental factors; when bridge ages distributing from 20 to 40 years, part of the bridges go into the medium and large repair phase, bridge performance curve shows upward trend slightly; when bridge ages are more than 50 years, the bridge performance curve appears accelerated decline.

(2) In the improved evaluation method, bridge structure and deck system are evaluated separately, bridge span index (SSCI) becomes the Evaluation Criteria. The evaluation results can clearly reflect the technical state of each span structure, which is very helpful for grasping the structure condition and locating the repair cite.

(3) The improved evaluation method focuses on the structural members without the disturbing of non-structural members, which can help building the correlation between structural diseases and structure decay properties gradually.

References

CHEN Dongliang (2013). “Comparative study on the methods of bridge technical condition evaluation”. Chongqing Jiaotong University, Master's thesis, 6，4-23.

GAO Zhibo (2013). “Discussion on the method of structural members scoring on the Standards for Technical Condition Evaluation of Highway Bridges”. Journal of SiChuan institute of technology (natural science edition), Vol. 26(1), 44-46.

Kawamura K， Miyamoto A. (2003). “Condition state evaluation of existing reinforced concrete bridges using neuro-fuzzy hybrid system” . Computers & Structures, (81), 1931-1940

LIU Guojin (2009). “Discussion on the method of bridge technical condition evaluation on the Standard of Highway Bridge and Culvert Maintence” .Journal of northern transport, 68-70.

Melham H.G. (2014). “Bridge condition rating using an eigenvector of priority settings”. Microcomputers in Civil Engineering. 50(5), 923-934.

Ministry of Transport of the People's Republic of China(2013). Statistics of traffic and transportation industry in 2013, [EB/OL], 2014.05.13.. http://www.moc.gov.cn/zfxxgk/bnssj/zhghs/201405/t20140513_1618277.html

Rene B.Testw, Bojidar S.Yanwv (2002). “Bridge Maintenance Level Assessment”. Computer -Aided Civil and Infrastructure Engineering. (17): 358-367.

SUN Lijun. (2009). “Transportation Infrastructure Management System: Theory and Pratice”. BeiJing: China Communications Press. 367-376.

TAN Jinhua, CHEN Huaizhen (2004). “Comparison and application of methods for bridge survey and condition evaluation”. Journal of bridge construction, (6):73-76.

ZHU Yan, ZHU Yi (2012). “Study on the method of the evaluation of rail bridge technical condition in ShangHai”. Journal of Shanxi Architecture, 38(37): 171-174.

Development of Capacity Models for Twelve-Lane Freeways in China

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Abstract: Recently, a number of four or six-lane freeways have been widened to account for the increasing traffic demand. However, there is no specific study about capacity models of multi-lane freeways with more than eight lanes. Based on the data from Shen-Shan Segment of Jing-Ha Freeway, this paper aimed to develop different capacity models of 12-lane freeways for two different cross section layout modes, including, the integral mode and the passenger-freight separated mode. VISSIM simulation studies were conducted to obtain different speed-flow curves, based on which, the calibrated parameters were developed for different capacity models.. The research results can help transportation professionals determine proper cross section layout and organizational modes in reconstruction and expansion projects of multilane freeways. They can also be used to calculate capacities of 12-lane freeways.

Keywords: Multilane freeways; Freeway; Capacity; Cross section mode.

1 Introduction

With the development of Chinese economy in recent years, transportation demand increased rapidly. To account for the increasing traffic demand, numerous freeways are changed into 8 or more than 8-lane freeways by reconstruction and expansion. It is the future trend to construct multilane freeways in pivotal transport corridors. For safe and well-ordered traffic, lane management is common to be operated on freeways with more than 8 lanes overseas to restrain disorder driving between lanes. Previous studies of multilane freeways in China have not developed adequately and are deficient in capacity calculating theories for freeways with more than 8 lanes.

Gene Daigle and Michelle (1998) conducted a simulation study to get accurate capacities in different lane management methods for reconstruction, but the study is not suitable for freeways in China. Calculating theories in China so far have taken the method for motor/non-motor vehicles mixed traffic mode, established on lane management of 4-lane freeways without consideration of lane changing impact (CHEN K. et al.,2003). Han et al. (2007) analysed driving states and levels of service of multilane freeways under different traffic organizations from Hu-Ning Freeway reconstruction and expansion project, and developed an improved calculating model for traffic volume calculation. Based on road segment and ramp flow conservation and traffic volume constraint, Tan et al. (2002) proposed a multilane freeway dynamic discrete traffic flow model in which the lane changing and origin-destination (OD) of vehicles are considered.

In domestic studies of multilane freeway capacity, parameters, modes and capacity analysis systems suited to China's national conditions are deficient. Technical Standard of highway engineering ('Standard' for short) uses the capacity from several foreign research achievements, which cannot show actual operating characteristics of Chinese road traffic. Thus, considering analysis above, this paper choose a 12-lane freeway from Shen-Shan Freeway as analysis object and does analysis and modeling of capacity under different traffic organizations.

2 Traffic Organizational Modes of Multilane Freeways

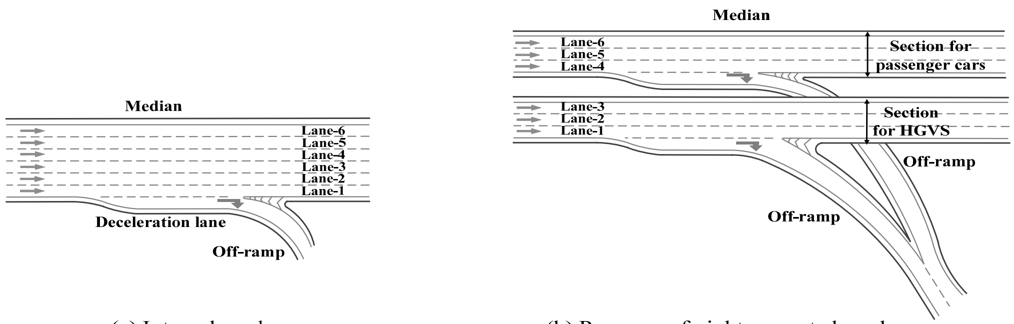
To meet requirements of different vehicle categories, vehicle safety and convenient access and improve operation efficiency and driving security of multilane freeways effectively, two traffic organizational modes of cross sections are generally used in multilane freeways: integral mode and passenger-freight separated mode (Traffic planning and design institute of Liaoning province ,2014).

(1) Integral mode

Integral mode is usually used by freeways with 6 to 8 lanes, as well as 10-lane and 12-lane freeways when roadside land is limited. Figure 1 (a) illustrate the integral cross section of Shen-Shan Segment of Jing-Ha Freeway, which was broadened to 6 lanes in each direction. All lanes serve both passenger and freight vehicles. This mode is usually used when roadside land is limited.

(2) Passenger-freight separated mode

When there are more lanes in cross sections, separated modes are usually used in each direction. There are two types of separated modes. One type is that inner and outer parts are separated totally, which is called passenger-freight separated mode. In this mode, lanes of outer parts only allow freight vehicles to use while lanes of inner parts only serve passenger vehicles. In this case, Ramps of interchanges need to connect relatively with lanes of inner and outer parts. A 12-lane freeway in passenger-freight separated mode actually serves as a 6-lane passenger freeway and a 6-lane freight freeway. Inner and outer part have individual ramps. Figure 1 (b) illustrate the passenger-freight separated cross section of Shen-Shan Segment of Jing-Ha Freeway, which was broadened to 6 lanes in each direction.



(a) Integral mode (b) Passenger-freight separated mode

Figure 1. Aerial view of each mode

3 Calculating Methods for Capacity of Different Traffic Organizational Modes

3.1 The calculating method for capacity of integral mode

According to Standard (JTG B01-2014), freeways should be designed to provide for a minimum of level of service of Third class. Maximum Service Volume (*MSV*) of each level of service are shown in Table 1. C_D is defined as the design capacity of each lane. Considering a driver population and its characteristics, the design capacity of each lane is converted to C_D*f_p, where f_p.is the adjustment factor for driver population.

Table 1. Level of service criteria for freeways

Level of Service	***v/c* ratio**	**designing speed (km/h)**		
		120	**100**	**80**
		Maximum Service Volume (*MSV*) (*pcu/h/ln*)		
First-class	$v/c \le 0.35$	750	730	700
Second-class	$0.35 < v/c \le 0.55$	1200	1150	1100
Third-class	$0.55 < v/c \le 0.75$	1650	1600	1500
Fourth-class	$0.75 < v/c \le 0.90$	1980	1850	1800
Fifth-class	$0.90 < v/c \le 1.00$	2200	2100	2000
Sixth-class	$v/c > 1.00$	0~2200	0~2100	0~2000

Note: The *v/c* ratio is the ratio of the *MSV* to the based capacity of the facility. The based capacity is maximum hour volume of the corresponding level of service.

Lanes under the integral mode are available for both heavy and light vehicles. Because of the differences in automobile dynamic performance and criteria for design speeds, the decrease to the capacity caused by heavy-vehicle mixing rate need to be considered during the calculating. So the adjustment factor for the presence of heavy vehicles is introduced as f_{HV}. The non-divided road cross section is used in the 6-lane freeway and the ramps only connect to the outer lane, which causes frequent lane changes between inner and outer lanes. Lane change disturbs the driving of vehicles on the outer lane and reduce the capacity. The adjustment factor for the outer lane is introduced as f_{OL} therefore. Vehicles on the inner lanes normally travel with higher speed and more freedom, so they have to travel in long headway to ensure safe driving. Thus, the traffic volume of inner and median lanes should decrease. The adjustment for inner and median lanes is denoted as f_{IL}. (Roger P. Roess et al.,2011; HCM 2010) According to the analysis above, the actual capacity of a 12-lane freeway may be expressed as :

$$CAP = C_d * N * f_P * f_{HV} * f_{OL} * f_{IL} \qquad \text{Eq. (1)}$$

where： N = number of lanes (in one direction) of the freeway

f_p = adjustment factor for driver population

f_{HV} = adjustment factor for presence of heavy vehicles

f_{OL} = adjustment factor for outer lane

f_{IL} = adjustment factor for inner and median lanes

3.2 The calculating method for capacity of passenger-freight separated mode

The operation of passenger and freight vehicles don't disturb each other, so the heavy-vehicle mixing rate doesn't need to be considered in this mode. The actual capacity of a 12-lane freeway may be expressed as the algebraic sum of the capacity of a passenger freeway and a freight freeway:

$$CAP = C_D^p * N^p * f_P^p * f_{OL}^p * f_{IL}^p + C_D^f * N^f * f_P^f * f_{OL}^f * f_{IL}^f \qquad \text{Eq. (2)}$$

where: factors with superscript 'p' denote parameters of the passenger freeway while factors with superscript 'f' denote parameters of the freight freeway. Concrete meanings of related parameters are the same with above.

4 Simulation Analysis of Adjustment System

4.1 Calibration of VISSIM simulation models

VISSIM is one of the commonly used traffic simulation platforms to simulate the operation of traffic flow in freeways and output multiple simulation operation parameters of traffic flow. VISSIM is a microscopic simulation tool that was originally developed in Germany at the University of Karlsruhe in the early 1970s. One of the major benefits of VISSIM is that it allows users to model detailed geometric configurations such as medians, driveways, and turning bays, as well as drivers' behavioral characteristics encountered in the transportation system (LIU P. et al., 2012; HUANG F. et al., 2013). On the basis of results from the field research in Shen-Shan Segment of Jing-Ha Freeway, Speed- flow curve was plotted and illustrated as Figure 2. With curves in

Figure 2 as calibrated target of simulation platform, this study made adjustments of distributions of desired speed under free flow condition of cars and heavy vehicles which take high ratios in traffic composition. The method to test capacities was utilized to verify simulation models. Through inputting traffic flows over capacities, capacity was ascertained as 2196 veh/h, critical speed as 75.1 km/h and calibration error as 0.2% when cars are only served while capacity was ascertained as 1064 veh/h, critical speed as 44.1 km/h and calibration error as 3% when heavy vehicles are only served. Simulation was verified at a 95% confidence level. Adjusted plans of driving behavior parameters for different heavy-vehicle mixing rates is listed in Table 2.

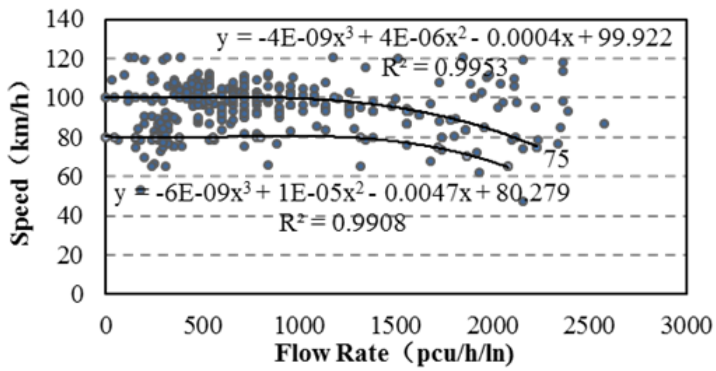


Figure 2. Actual flow-speed curve in Shen-Shan Segments of Jing-Ha Freeway

Table 2. Parameter adjustment of car following model in driving behaviors

Plan	a	b	c	d	e	f	g	h
Adjusted parameters	Percentage of HGV（%）							
	0	5	10	20	30	40	60	100
CC0	1.50	1.58	1.65	1.80	1.95	2.10	2.40	3.00
CC1	1.50	1.53	1.55	1.60	1.65	1.70	1.80	2.00
CC8	3.50	3.43	3.35	3.20	3.05	2.90	2.60	2.00
CC9	1.50	1.45	1.40	1.30	1.20	1.10	0.90	0.50

4.2 Calibration of adjustment factors

Through the simulation platform with adjusted parameters, simulations were conducted for 4-lane, 6-lane and 12-lane freeways under integral mode and passenger-freight separated mode respectively to calibrate adjustment factors under each mode.

4.2.1 Adjustment factor for outer lanes f_{OL}

Based on the analysis of field research and simulation results, in interchange areas of multilane freeways, capacities of two outer lanes decrease because of vehicles changing lanes to access ramps. Simulation schemes utilized single variable control method when calibrating f_{OL} and eliminates impacts of heavy-vehicle mixing rate, switching lanes and cross-section layout and traffic organizational modes. Integral mode was utilized and the ability obtained from Simulation Scheme A was adopted as based capacity. In simulation scheme A, freeways were 2 lanes in one direction and traffic compositions were only cars and parameters of driving behaviors adopted Plan a in Table 2. f_{OL} of integral mode for 12-lane freeways was calibrated by ratio of capacity obtained from simulation scheme B to based capacity. In Simulation Scheme B, freeways were 6 lanes in one direction and traffic compositions were only cars and parameters of driving behaviors adopted Plan a in Table 2. f_{OL}^{p} and f_{OL}^{f} of passenger-freight separated mode for 12-lane freeways were calibrated by ratio of capacity obtained from simulation scheme C and D to based capacity. In Simulation Scheme C, freeways were 3 lanes in one direction and traffic compositions were only passenger vehicles and parameters of driving behaviors adopted Plan a in Table 2. In Simulation Scheme D, freeways were 3 lanes in one direction and traffic compositions were only freight vehicles and parameters of driving behaviors adopted parameters from Plan h in Table 2. Simulation schemes to calibrate f_{OL} were Simulation Scheme A-D, as illustrated in Table 3. Speed-flow curves obtained by simulation were shown in Figure 3 and results of calibration were illustrated in Table 3.

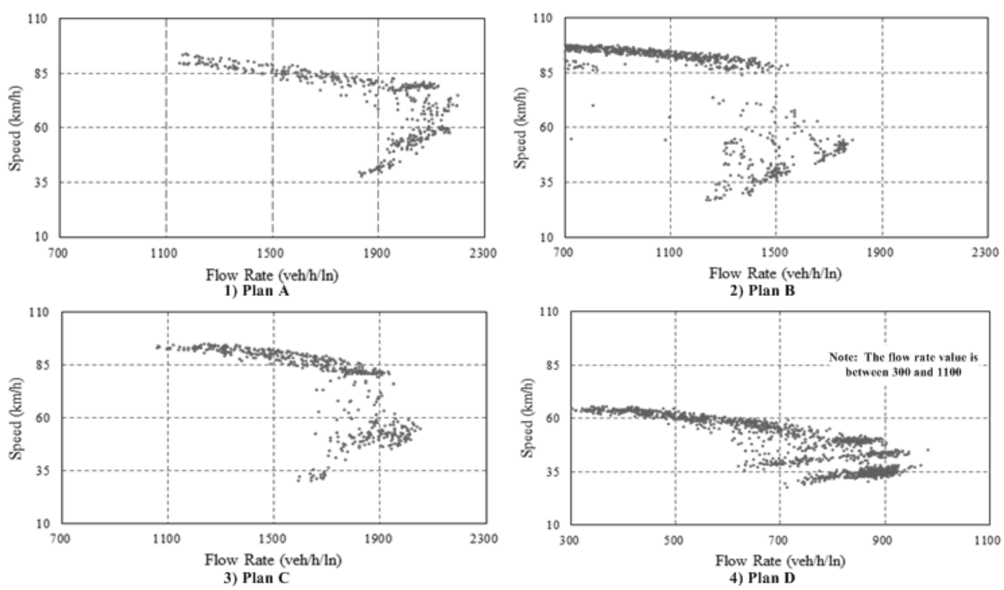


Figure 3. Speed-flow curve of the two outer lanes in scheme A、B、C and D

Table 3. Calibration values of f_{OL}

f_{OL}	Lanes in one direction		
	2	3	6
Integral	1.0	0.94	0.82

Passenger-freight separated	passenger	——	0.94	——
	freight		0.92	

4.2.2 Adjustment factor for inner lanes f_{IL}

Simulation Schemes adopted for calibration of adjustment factor for inner lanes are identical with those adopted for calibration of adjustment factor for outer lanes. The value of f_{IL} is the ratio of capacity of two inner lanes to based capacity. Speed-flow curves obtained by simulation were shown in Figure 4 and results of calibration were illustrated in Table 4.

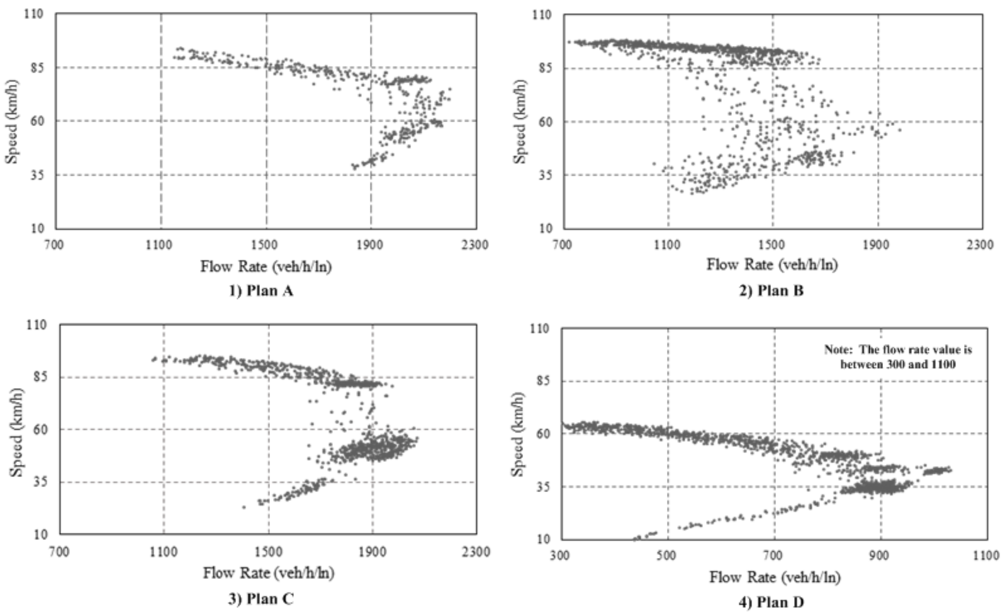


Figure 4. Speed-flow curve of the two inner lanes in scheme A、B、C and D

Table 4. Calibration values of f_{IL}

f_{IL}		Lanes in one direction		
		2	3	6
Integral		1.0	0.96	0.90
Passenger-freight separated	passenger	——	0.96	——
	freight		0.97	

Table 5. Calibrated values of f_{HV}

Simulation Scheme	A	E	F	G	H	I	J	K
Heavy vehicle mixing rate(%)	0	5	10	20	30	40	60	100
f_{HV}	1.00	0.96	0.93	0.84	0.71	0.65	0.61	0.48

4.2.3 Adjustment factor for presence of heavy vehicles f_{HV}

Simulation schemes utilized single variable control method when calibrating f_{HV}

and eliminates impacts of outer lanes, inner lanes, switching lanes and cross-section layout and traffic organizational modes. Simulation schemes were formulated by adjusting the ratio of cars to heavy vehicles of 2-lane freeways in integral mode, as shown in Table 6. The value of f_{HV} is the ratio of capacity of each scheme to based scheme. Speed-flow curves obtained by simulation were shown in Figure 5 and results of calibration were illustrated in Table 5.

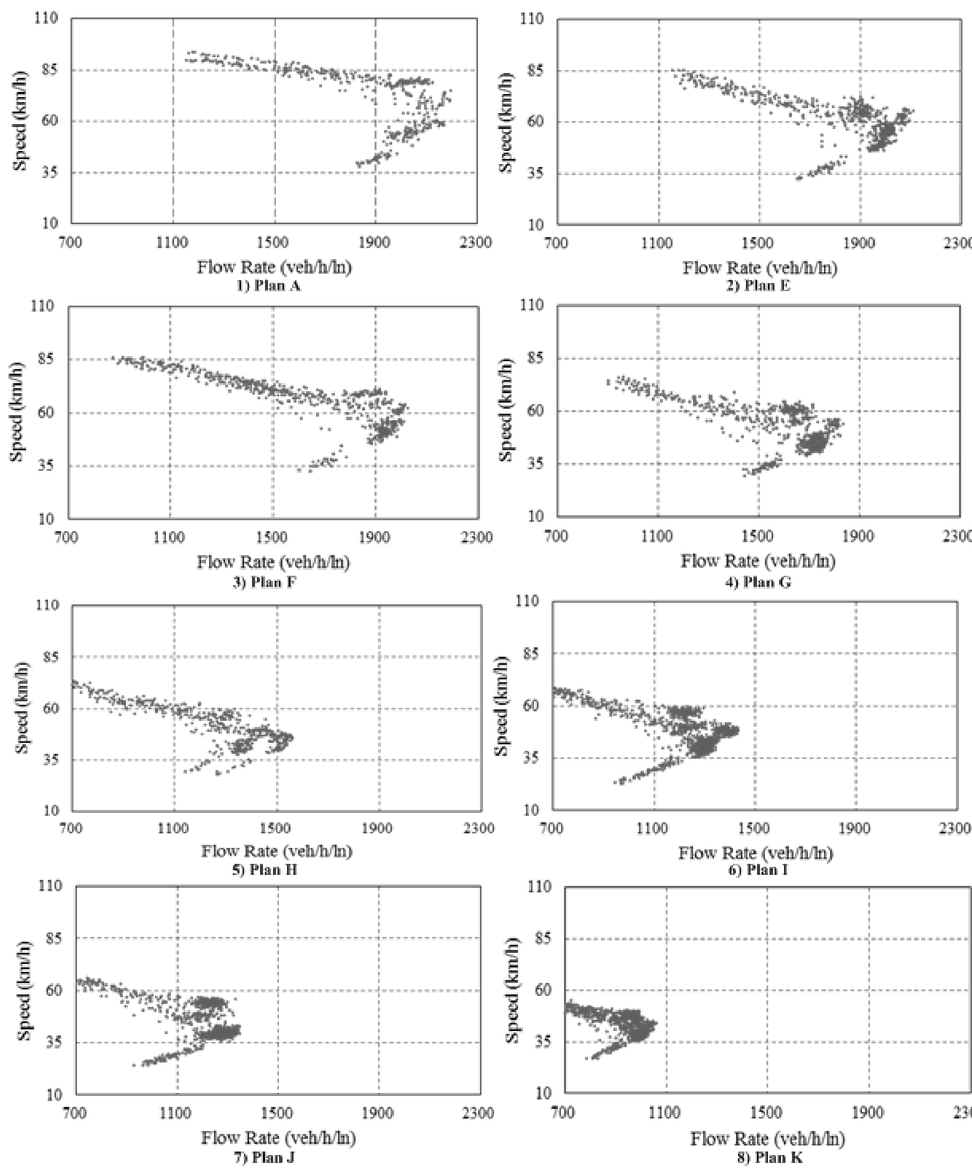


Figure 5. Speed-flow curve of the two lanes in Scheme A and E to K

Table 6. Simulation schemes in this research

Scheme	Lane in one	Traffic composition	Driving behavior

	direction		plan (see Table 2)
A	2	all cars	a
B	6	all cars	a
C	3	all cars	a
D	3	all HGVs	h
E	2	95%cars & 5%HGVs	b
F	2	90%cars & 10%HGVs	c
G	2	80%cars & 20%HGVs	d
H	2	70%cars & 30%HGVs	e
I	2	60%cars & 40%HGVs	f
J	2	40%cars & 60%HGVs	g
K	2	all HGVs	h

5 Comparison among Capacities of Different Traffic Organizational Modes

Based on field data from Shen-Shan Segment of Jing-Ha Freeway, the heavy-vehicle mixing rate is approximately 40%. If this freeway is extended to 12-lane freeway, capabilities of it are not equal to each other when various cross-section layout and traffic organizational modes are adopted. For integral mode, capacity is 2200 2200pcu/h/ln at a designed speed of 120km/h and lanes in one direction is 6. The adjustment factor for driver population is 0.981. Adjustment factors for outer and inner lanes are selected as follows:

f_{OL} = 0.82 (Table 3, integral, 6 lanes in one direction)

f_{IL} = 0.90 (Table 4, integral, 6 lanes in one direction)

Using Eq. (1), CAP = 6021pcu/h. For freeways in passenger-freight separated mode, CAP = 8732 pcu/h through the same calculation. Detailed comparison between two modes are illustrated in Table 7.

Table 7. Comparison of capacities of Shen-Shan Segment of Jing-Ha Freeway in each cross-section layout and traffic organizational mode

Modes	Calculating Equation	Values of factors	Capacity (pcu/h)
Integral	Eq. (1)	$C_D = 2200$, $N = 6$, $f_P = 0.981$, $f_{HV} = 0.63$, $f_{OL} = 0.82$, $f_{IL} = 0.90$	6021
passenger-freight separated	Eq. (2)	$C_D^p = 2200$, $C_D^f = 1100$, $N^p = 3$, $N^f = 3$, $f_P^p = 0.981$, $f_P^f = 0.981$, $f_{OL}^p = 0.94$, $f_{OL}^f = 0.92$, $f_{IL}^p = 0.96$, $f_{IL}^f = 0.97$	8732

6 Conclusion

This paper developed models about capacities of 12-lane freeways in two cross section layout and organizational modes, which are integral mode and passenger-freight separated mode. Simulation of traffic flow operation was conducted by VISSIM simulation platform. Different speed-flow curves were obtained and related parameters were calibrated. This research utilized field data from Shen-Shan Segment of Jing-Ha Freeway. Thus, ratios of volumes in off-ramp and on-ramp to volume in arterial are fixed. As a matter of fact, the phenomenon of changing lanes would be more prominent with these higher ratios and calibrated values of related factors would be different. However, the research idea of this paper applies to researches about capacities of freeways with various lanes and different ratios of volumes in access ramps to volume in arterial. Subsequent researches will be about the extent of impacts of those ratios.

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References

CHEN K., YAN M., B. J. (2003). “Capacity analysis”. Beijing: *China communication press.*

Gene Daigle, Michelle Thomas (1998). “Field Applications of Corsim: I-40 Freeway Design Eva Proceedings of the 1998 Winter Simulation Conference”.

HAN B. R., MA J. X., LIN L. (2007). A calculation model for average adaptable daily in multilane expressway. *Journal of Nanjing Forestry University (Natural Sciences Edition)*, 2007, Vol. 31, No. 1, Pages: 63-66.

Highway Capacity Manual-2010. *Transportation Research Board of the national academies*, page14-1 to 14-5.

HUANG F., LIU P. et al. (2013). “Identifying if VISSIM simulation model and SSAM provide reasonable estimates for field measured traffic conflicts at signalized intersections”. *Accident Analysis and Prevention,* Vol. 50, Pages: 1014-1024.

JTG B01-2014, “Highway Engineering Standard Specifications”.

LIU P., QU X. et al. (2012). “Development of a VISSIM Simulation Model for U-turns at Unsignalized Intersections”. *Journal of transportation engineering*, Vol. 138, No. 11, Pages: 1333-1339.

Roger P. Roess et al. (2011). “Traffic engineering-4th edition”. Upper Saddle River :*Pearson Higher Education*, 285-314.

TAN M. C., TANG S. A., XU J. M. (2002). “Dynamic discrete traffic model of freeway with multiple lanes". *China Journal of Highway and Transport*, Vol. 15, No. 2, Pages: 91-94.

Traffic planning and design institute of Liaoning province (2014). "Capacity and safety studies of multilane freeway". Shenyang.

Analysis of the Macro Factors Influencing Dalian Road Traffic Safety Based on the Gray Correlation Method

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Abstract: Traffic safety is a perpetual theme in the development of automobile traffic, with the rapid increase of vehicle population, road traffic accidents, particularly the high incidence of serious accidents; safety problems have become increasingly prominent. The factors influencing Dalian road traffic accidents are analyzed under the current Dalian road transport safety situation. Gray correlation method was adopted to quantify the factors causing traffic accidents. The main factors include the population, number of driving, number of passengers, freight volume and passenger transport circulation. The correlation order among the factors was determined to provide data for the management.

Keywords: Macro factors; Dalian road traffic safety; Gray correlation method.

With the rapid development of economy and changing urban structure, vehicle population especially private cars continue rapid growth, combined with low sense of law and not law-abiding behavior of a little number of transport travelers, and various other uncivilized behavior seriously affect traffic safety. Therefore, the gray correlation analysis on macro factors affecting Dalian road traffic safety plays an increasingly important role in improving road safety level and reducing traffic accidents.

1 Macro factors analysis of influencing Dalian road traffic safety

(1) Population(Yuzhuo Men, 2012)

If the population of a region rises (including the floating population), the population travel times and the probability of traffic accident also will increase.

(2) Economy

The increase of economic strength will expand the range of people's activities and influence the regional population flow. The change undoubtedly makes the possibility of the occurrence of road traffic accidents increase.

(3) Traffic mileage

The speed of increasing in the road mileage is far less than the car ownership, which will cause the emergence of vicious spiral in road traffic accidents.

(4) Passenger and freight volume

The increased passenger and freight volume will undoubtedly affect road traffic risk level.

(5) Travel times

The increased travel times will make travelers and vehicles contact frequently, resulting in an increased number of road traffic accidents.

(6) Drivers number

If we ignore the driver's quality and ability, and simply focus on drivers number. It is undoubtedly associated with road accident frequency.

(7) Motor vehicles number

The rising number of motor vehicles increase the vehicle collision chance.

2 Gray correlation analysis

Steps of gray correlation analysis is summarized as follows：

(1) Analysis sequence (Sifeng Liu, 2014)

On the basis of qualitative analysis on the question，determine the dependent variable factors and multiple independent variable factors. The dependent variable data set constitute a reference sequence X_0', independent variables constitute comparative sequence X_i'（i=1，2, 3. . . n） the following matrix is listed as follows:

$$(X_0, X_1, \cdots, X_n) = \begin{pmatrix} x_0(1) & x_1(1) & \cdots & x_n(1) \\ x_0(2) & x_1(2) & \cdots & x_n(2) \\ \vdots & \vdots & & \vdots \\ x_0(N) & x_1(N) & \cdots & x_n(N) \end{pmatrix}_{N\times(n+1)} \quad (1)$$

(2) Dimensionless initialization of variables sequence

The initial value method of dimensionless data processing is listed as follows:

$$x_i(k) = \frac{x_i'(k)}{x_i'(1)} i = 0,1,\cdots,n; k = 1,2,\cdots,N \quad (2)$$

(3) Difference sequence, the maximum difference and minimum difference

Calculate the absolute difference in the first column (reference sequence) and the remaining columns (comparative sequence), and form the following absolute difference matrix:

$$\begin{pmatrix} \Delta_{01}(1) & \Delta_{02}(1) & \cdots & \Delta_{0n}(1) \\ \Delta_{01}(2) & \Delta_{02}(2) & \cdots & \Delta_{0n}(2) \\ \vdots & \vdots & & \vdots \\ \Delta_{01}(N) & \Delta_{02}(N) & \cdots & \Delta_{0n}(N) \end{pmatrix}_{N\times n}$$

$$\Delta_{0i}(k) = \left| x_0(k) - x_i(k) \right| i = 0,1,\cdots,n; k = 1,2,\cdots,N \quad (3)$$

The maximum and smallest numbers in the absolute difference matrix is the maximum difference and minimum difference:

$$\max_{\substack{1\le i\le n\\1\le k\le N}}\left\{\Delta_{0i}(k)\right\}\triangleq\Delta(\max) \tag{4}$$

$$\min_{\substack{1\le i\le n\\1\le k\le N}}\left\{\Delta_{0i}(k)\right\}\triangleq\Delta(\min) \tag{5}$$

(4) Calculating the correlation coefficient

Transform the data of absolute difference matrix as follows:

$$\xi_{0i}(k)=\frac{\Delta(\min)+\rho\Delta(\max)}{\Delta_{0i}(k)+\rho\Delta(\max)} \tag{6}$$

Get the correlation coefficient matrix:

$$\begin{pmatrix} \xi_{01}(1) & \xi_{02}(1) & \cdots & \xi_{0n}(1) \\ \xi_{01}(2) & \xi_{02}(2) & \cdots & \xi_{0n}(2) \\ \vdots & \vdots & & \vdots \\ \xi_{01}(N) & \xi_{02}(N) & \cdots & \xi_{0n}(N) \end{pmatrix}_{N\times n} \tag{7}$$

(5) Calculating the correlation degree

The correlation degree of comparative sequence Xi and reference sequence X0 is reflected by N correlation coefficient (equation7), the correlation degree is listed as followed：

$$r_{0i}=\frac{1}{N}\sum_{k=1}^{N}\xi_{0i}(k) \tag{8}$$

(6) Correlation degree analysis

The higher the value of correlation degree, the better the correlation may be. The change of comparative sequence and reference sequence is relative identification.

3. Applications of gray correlation method analyze in Dalian road traffic safety

(1) The dependent variable of 2003-2012 year for Dalian road traffic safety is shown in table 1, and the independent variable is shown in table 2(Dalian Municipal Bureau of Statistics,2013)：

Table 1. The dependent variable of 2003-2012 year

Year	The number of traffic accidents Y_0 /piece	The number of deaths Y_1/piece	The number of injuries Y_2 /piece	Economic losses Y_3/ million yuan

2003	3868	590	698	2616.6862
2004	3866	543	1031	2171.8495
2005	2250	317	1405	1294.4983
2006	1713	293	1326	995.7430
2007	1369	294	1226	857.3191
2008	1142	278	955	893.0310
2009	1129	248	823	711.8550
2010	1122	244	821	665.1000
2011	1036	243	816	663.5000
2012	1029	239	951	766.4000

Table 2. The independent variable of 2003-2012 year

Year	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
2003	5.602	163260	0.11	8.52	230	126590	4613	20.1	0.229	0.591
2004	5.616	185040	0.12	10.80	230	162230	4863	21.6	0.261	0.650
2005	5.653	215220	0.12	11.03	260	192330	5401	21.8	0.317	0.723
2006	5.721	256970	0.13	12.33	290	250320	10588	22.4	0.398	0.796
2007	5.782	313070	0.15	13.53	310	409960	10315	26.6	0.454	0.903
2008	5.834	380440	0.17	15.52	350	458630	11533	28.6	0.505	1.041
2009	5.848	434950	0.17	16.32	290	513130	11367	29.6	0.584	1.152
2010	5.864	515820	0.13	15.72	320	593840	11402	22.0	0.699	1.265
2011	5.885	615060	0.14	17.49	360	682120	11538	23.3	0.826	1.392
2012	5.903	700280	0.14	18.79	400	778950	11853	24.4	0.943	1.550

x_1 —Population / million people

x_2 —GDP / million yuan

x_3 —assenger volume / billion people

x_4 —Passenger turnover volume/billion people·km^{-1}

x_5 —Freight volume / million tons

x_6 —Freight turnover quantity / million tons· km^{-1}

x_7 —Traffic mileage / km

x_8 —Travel times / times

x_9 —Motor vehicles number / million

x_{10} —Drivers number / million people

(2) According to the Formula 2, the variables are initialized as showed in table 3 and table 4.

Table 3. Initiation treatment of reference sequence

Y_0	Y_1	Y_2	Y_3
1.00	1.00	1.00	1.00
1.00	0.92	1.48	0.83
0.58	0.54	2.01	0.50
0.44	0.50	1.90	0.38
0.35	0.50	1.76	0.33
0.30	0.47	1.37	0.34
0.29	0.42	1.18	0.27
0.29	0.41	1.18	0.25
0.27	0.41	1.17	0.25
0.27	0.41	1.36	0.29

Table 4. Initiation treatment of comparative sequence

x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.00	1.13	1.08	1.27	1.02	1.28	1.05	1.08	1.14	1.10
1.01	1.32	1.09	1.29	1.12	1.52	1.17	1.08	1.39	1.22
1.02	1.57	1.14	1.45	1.26	1.98	2.30	1.12	1.74	1.35
1.03	1.92	1.37	1.59	1.37	3.24	2.24	1.32	1.99	1.56
1.04	2.33	1.48	1.82	1.53	3.62	2.50	1.42	2.21	1.76
1.04	2.66	1.54	1.92	1.26	4.05	2.46	1.47	2.55	1.95
1.05	3.16	1.15	1.85	1.42	4.69	2.47	1.10	3.06	2.14
1.05	3.77	1.22	2.05	1.58	5.39	2.50	1.16	3.61	2.35
1.05	4.29	1.28	2.21	1.76	6.15	2.57	1.21	4.12	2.62

(3) Difference sequence, the maximum difference and minimum difference According to the formula 3, absolute difference matrix is as shown in table 5.

Table 5. Δ_{0i} of differential serial numbers

0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.003	0.134	0.078	0.268	0.021	0.282	0.055	0.075	0.141	0.099
0.427	0.737	0.512	0.713	0.54	0.938	0.589	0.502	0.805	0.641
0.578	1.131	0.697	1.004	0.813	1.535	1.852	0.673	1.299	0.903
0.678	1.564	1.012	1.234	1.019	2.885	1.882	0.969	1.631	1.206
0.746	2.035	1.184	1.526	1.231	3.328	2.205	1.126	1.915	1.465
0.752	2.372	1.246	1.624	0.969	3.762	2.172	1.181	2.262	1.656

0.757	2.869	0.856	1.555	1.130	4.401	2.182	0.805	2.767	1.850
0.783	3.500	0.951	1.785	1.315	5.121	2.233	0.892	3.346	2.086
0.788	4.023	1.012	1.940	1.491	5.887	2.303	0.947	3.858	2.355

(4) According to the formula 4 and formula 5, Y_0 maximum differential and the minimum difference are showed as follows:

$$\max_{i=1}^{10}\min_{k=1}^{10}\left|Y_0(k)-X_i(k)\right|=5.887$$

$$\max_{i=1}^{10}\min_{k=1}^{10}\left|Y_0(k)-X_i(k)\right|=0.000$$

(5) Calculate the correlation coefficient

According to the formula 6, ρ =0.5,calculate the correlation coefficient of Y_0, which is listed in table 6.

Table 6. correlation coefficient of Y_0

ε_{01}	ε_{02}	ε_{03}	ε_{04}	ε_{05}	ε_{06}	ε_{07}	ε_{08}	ε_{09}	ε_{10}
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.999	0.956	0.974	0.916	0.993	0.913	0.982	0.975	0.954	0.968
0.873	0.800	0.852	0.805	0.845	0.758	0.833	0.854	0.785	0.821
0.836	0.722	0.809	0.746	0.784	0.657	0.614	0.814	0.694	0.765
0.813	0.653	0.744	0.705	0.743	0.505	0.610	0.752	0.644	0.709
0.798	0.591	0.713	0.659	0.705	0.469	0.572	0.723	0.606	0.668
0.797	0.554	0.703	0.644	0.752	0.439	0.575	0.714	0.566	0.640
0.795	0.506	0.775	0.654	0.723	0.401	0.574	0.785	0.515	0.614
0.790	0.457	0.756	0.623	0.691	0.365	0.569	0.767	0.468	0.585
0.789	0.423	0.744	0.603	0.664	0.333	0.561	0.757	0.433	0.556

(6) Calculate the correlation degree

According to the formula 7, the correlation between each influence factor and Y_0 is shown in table 7. In the same way, calculate the factors correlations between each influence factor on Y_1, Y_2, and Y_3.

Table 7. Correlation degree among Y_0

The macro factors	Correlation degree	Rank
x_1	0.849	1
x_2	0.666	9
x_3	0.807	3

x_4	0.735	5
x_5	0.790	4
x_6	0.584	10
x_7	0.689	7
x_8	0.814	2
x_9	0.666	8
x_{10}	0.733	6

(7) Grey correlation matrix obtained of Y_0 is listed as follows in table 8:

Table 8. Grey correlation matrix

x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
0.849	0.666	0.807	0.735	0.790	0.584	0.689	0.814	0.666	0.733
0.863	0.668	0.818	0.742	0.799	0.583	0.692	0.825	0.668	0.738
1.246	0.848	1.134	0.969	1.091	0.701	0.873	1.152	0.840	0.972
0.834	0.636	0.788	0.716	0.770	0.554	0.669	0.796	0.637	0.708

4 Result analysis

According to the gray correlation matrix, the result analysis is listed as follows:

For the reference sequence Y_0 (The number of traffic accidents), $x_1 > x_8 > x_3 > x_5 > x_4 > x_{10} > x_7 > x_9 > x_2 > x_6$, x_1 (population) is the optimal factor, x_8 (travel times) are the secondary factors, x_3 (passenger volume) is the worst factor.

For the reference sequence Y_1 (The number of traffic deaths), $x_1 > x_8 > x_3 > x_5 > x_4 > x_{10} > x_7 > x_9 > x_2 > x_6$, x_1 (population) is the optimal factor, x_8 (travel times) are the secondary factors, x_3 (passenger volume) is the worst factor.

For the reference sequence Y_2 (The number of traffic injuries), $x_1 > x_8 > x_3 > x_5 > x_{10} > x_4 > x_7 > x_9 > x_2 > x_6$, x_1 (population) is the optimal factor, x_8 (travel times) are the secondary factors, x_3 (passenger volume) is the worst factor.

For the reference sequence Y_3 (Economic losses),

$x_1 > x_8 > x_3 > x_5 > x_4 > x_{10} > x_7 > x_9 > x_2 > x_6$, x_1 (population) is the optimal factor, x_8 (travel times) are the secondary factors, x_3 (passenger volume) is the worst factor.

For the independent variable factors, the result analysis is listed as follows:

$$\sum_{j=0}^{3} X_{j1} > \sum_{j=0}^{3} X_{j8} > \sum_{j=0}^{3} X_{j3} > \sum_{j=0}^{3} X_{j5} > \sum_{j=0}^{3} X_{j4} > \sum_{j=0}^{3} X_{j10} > \sum_{j=0}^{3} X_{j7} > \sum_{j=0}^{3} X_{j2} > \sum_{j=0}^{3} X_{j9} > \sum_{j=0}^{3} X_{j6}$$

$x_1 > x_8 > x_3 > x_5 > x_4 > x_{10} > x_7 > x_2 > x_9 > x_6$, x_1 (population) is the optimal factor, x_8 (travel times) are the secondary factors, x_3 (passenger volume) is the worst factor.

For the dependent variable factors, the result analysis is listed as follows:

$Y_2 > Y_1 > Y_0 > Y_3$, Y_2 （The number of traffic injuries） is the optimal factor.

To sum up, the factors of population, travel times, passenger volume and freight volume are the main macro factors influencing Dalian road traffic safety.

We should strengthen the force of propaganda campaign for birth control to control population growth there, and improve the travels quality. At the same time, enhance exploration and promote basic research in the forecasts and analysis of passenger and freight demands in Dalian.

References

Dalian Municipal Bureau of Statistics. "Dalian Statistical Yearbook from 2004 to 2013." *Beijing: China Statistics Press, 2013*

Sifeng Liu."Grey systems theory and its application." *Beijing: Science Press, 2014*

Yuzhuo Men, Haibo Yu and Xiansheng Liu(2012)."Grey correlational prediction model of macroscopic influencing factors contributing to urban traffic accident." *Machinery design & manufacture*，12(12)

Impact Analysis of Concrete Shrinkage and Creep on a Prestressed Concrete Box Girder Bridge

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Abstract: This article builds a model of the actual engineering using Midas/Civil, and makes an analysis of the impact on the deformation and stress of the bridge of concrete shrinkage and creep. Midas/Civil software uses the shrinkage and creep formulas in the "highway reinforced concrete and prestressed concrete bridge and culvert design specifications (JTG D62-2004). First, through changing the two parameters of relative humidity and creep coefficient of the model in the shrinkage and creep formulas specified in JTG D62-2004 specification, it analyses the effects of the shrinkage and creep on bridge deformation. Second, in and without the consideration of shrinkage and creep, it makes simulation analysis of the internal forces of the bridge to determine the degree of the influence of shrinkage and creep on bridge stress. By contrasting the parameters under different conditions, it obtains that the linear influence of the different relative humidities on the bridge is 25% in maximum. The concrete shrinkage and creep may also exert a relative great impact on the internal forces of the whole bridge. The stress of the upper flange decreases 1.9 MPa at most and the lower decreases 3.81 MPa at most. Through making an analysis on the impact of changing parameters and considering the shrinkage and creep on the actual engineering model linear and internal force, the author obtained the conclusion of the rule in the influence on a continuous girder bridge under the action of concrete shrinkage and creep, which provides a direction for the design and construction of continuous girder bridge using prestressed concrete.
Keywords: Loss of prestress; Shrinkage and creep; Relative humidity; The deflection; Cantilever construction.

1 Introduction

Shrinkage and creep is one of the basic characteristics of concrete materials, it not only has a great impact on the bridge structure, but a long lasting time of complex and various changing process. The prestressed concrete continuous girder bridge is widely used since it has the characteristic of good entirety, construction simple, large structure stiffness, and good vibration resistance. But with the bridge span increases gradually, many bridges across in the problems of large deflection and cracking in different degrees, these issues are related with construction methods, temperature changes and concrete shrinkage and creep. Wherein, the material shrinkage and creep is one of the most important reasons. The alignment of main beam in appearance and stress safety are related to the concrete shrinkage and creep. In our country, the shrinkage and creep in concrete box girder bridge is a very important and difficult problem, especially the concrete continuous beam that was built in the early 90s, has a lot of problems during its construction and operation period. Excessive midspan deflection during the process of operation causes the craze problem and so on, which related to many factors and the shrinkage and creep is the main reason. Now as the component is more and more thin, the strength of the material is increased. The influence of shrinkage and creep to concrete member is more and more obvious. Due to the insufficient consideration on effect of concrete shrinkage and creep, this leads to the bridges across cracking and excessive downwarping. Shrinkage and creep on the prestressed concrete box girder bridge deflection has a greater influence. To ensure the prestress concrete continuous box girder bridge of completed bridge geometric shape and its running process are in long-term deflection, it has positive and realistic significance to analysis and research the concrete shrinkage and creep.

2 The generating mechanism of shrinkage and creep of concrete and the influencing factors

2.1 The generating mechanism of contraction

The shrinkage deformation of concrete is happened under the condition of unloaded, the deformation of concrete member slowly deformed over time. The shrinkage strain under the condition of unloaded-time curves in Figure 1. Shrinkage of concrete contains three types which are the spontaneous, drying shrinkage and carbonization contraction. Spontaneous contractions means the contraction without of the water transfer, which is the cement volume participate in the hydration reaction is greater than the volume of cement hydrates, so it’s a kind of inherent shrinkage. Drying shrinkage refers to the disappearance of the adsorption of water inside the concrete, concrete volume contraction, this is the main part of the concrete shrinkage strain. Carbonization contraction refers to the concrete cement hydrates and CO_2 in the chemical reaction. The reason of shrinkage of concrete is the precipitation of calcium carbonate and calcium hydroxide dissolved.

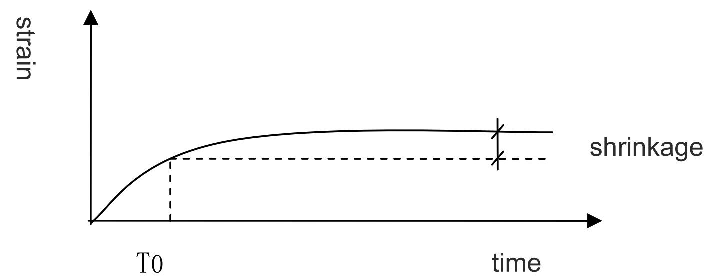

Figure 1. The contraction of unloaded component

2.2 The mechanism of creep

The concrete creep is load on the concrete specimen, the specimen firstly occurs instantaneous elastic deformation, and then, slowly increases the deformation furtherover time. Creep of concrete is concrete in the long-term effects under constant load; the compressive strain phenomenon continues to grow over time. Concrete creep can recover when initially loaded, viscoelastic theory to explain this phenomenon; continue to load reaches a certain degree, creep and strain is not a linear change, creep will tend to be stable. Concrete creep – time Figure 2.

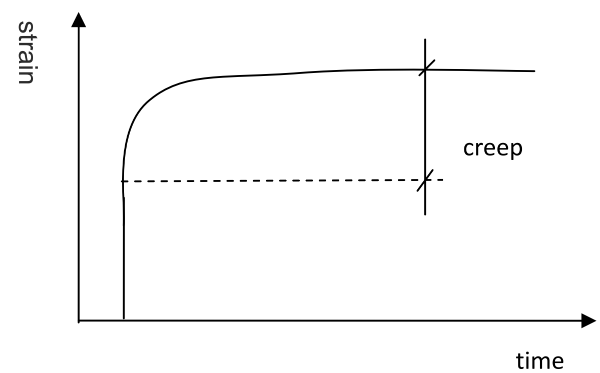

Figure 2. The creep of concr

2.3 Factors of impact on concrete shrinkage and creep

Impacts on the concrete shrinkage and creep have both internal factors and external factors. The main factors that affect the concrete shrinkage and creep are shown in Table 1.

Table 1.The main factors impact on shrinkage and creep

the main factors	internal factors	external factors
1	the types of cement	The environment temperature
2	curing conditions	stress
3	water cement ratio	Load duration time

Internal factors are the kinds of cement, curing condition, water cement ratio, etc.

(1) The types of cement

In general, load the same situation, cement strength quickly, shrinkage and creep will be lower. As a result, shrinkage and creep of concrete strength cement according to the low thermal cement, Portland cement and drought decline in turn.

(2) Curing conditions

There are three kinds of curing conditions: The curing time, curing environment humidity and temperature. Curing conditions have more influence on the concrete shrinkage and creep. Effective control of temperature and humidity can control the degree of hydration, so as to increase the strength development of concrete fast, decrease the influence of concrete shrinkage and creep.

(3) Water cement ratio

Water cement ratio is proportional to the values of shrinkage and creep of concrete. In a certain range, the greater the water cement ratio of concrete, the greater shrinkage and creep value.

External factors are temperature, applied stress, load, duration, etc.

(1) The surrounding environment temperature

Workplace surrounding environment temperature also has a great influence on the shrinkage and creep of concrete. Under the other conditions being the same, the hydration reaction is accelerated with the temperature increase, thus the contraction speed is also accelerated. Before a certain critical point of temperature, the temperature is increased, as well as the creep is also increased.

(2) Stress

As practice has shown, the concrete creep and stress has a direct connection, stress increases, concrete creep also increases. In the project, continuous load of concrete member is bad.

(3) Load duration time

Creep in concrete will last a long time, with the growth of time, the creep rate is decreased. Initial loading, due to the hydration thermal response, low concrete strength, and creep change is big.

3 The theoretical calculation of the concrete shrinkage and creep

The "highway reinforced concrete and prestressed concrete bridge and culvert design specifications" (JTG D62-2004) has specified the calculation formula of shrinkage and creep.

General expression of the concrete shrinkage strain:

$$\varepsilon_{cso} = \left[160 + 10\beta_{sc}\left(9 - f_{cm} / f_{cmo}\right)\right] \cdot 10^{-6} \cdot 1.55\left[1 - \left(RH / RH_0\right)^3\right] \tag{1}$$

$$\beta_s\left(t - t_s\right) = \left[\frac{\left(t - t_s\right)/t_1}{350\left(h/h_0\right)^2 + \left(t - t_s\right)/t_1}\right]^{0.5} \tag{2}$$

$$\varepsilon\left(t, t_s\right) = \varepsilon_{cso} \cdot \beta_s\left(t - t_s\right) \tag{3}$$

Type: ε_{cso} ,nominal contraction coefficient; RH, annual average relative humidity (%); $\varepsilon(t,t_s)$,age at the beginning of the contraction for t_s,calculating considering the age of t shrinkage strain; h, component theoretical thickness h=2A/u, A, component cross-sectional area; u, peripheral length of components in contact with the atmosphere; RH0=100%；h0=100mm;

Starting from the time t0 effect of concrete under uniaxial stress to the unit, in t time to produce the total strain, commonly referred to as creep function. Creep coefficient calculation formula:

$$\phi(t,t_0) = \phi_0 \cdot \beta_c(t-t_0) \tag{4}$$

$$\phi_0 = \left[1 + \frac{1 - RH/RH_0}{0.46(h/h_0)^{1/3}}\right] \cdot \frac{5.3}{(f_{cm}/f_{cmo})^{0.5}} \cdot \frac{1}{0.1 + (t_0/t_1)^{0.2}} \tag{5}$$

$$\beta_c(t-t_0) = \left[\frac{(t-t_0)/t_1}{\beta_H + (t-t_0)/t_1}\right]^{0.3} \tag{6}$$

Type: t_0 ,age of concrete(d) in loading; $\phi(t,t_0)$,loading age is t0, calculating considering the age of t of the concrete creep coefficient.

Based on the analysis of internal and external factors of influencing on the concrete shrinkage and creep, the author builds model with actual engineering, by changing the theoretical calculation of the parameters such as relative humidity and creep coefficient are calculated respectively, studying the effect of changing parameters on the linear and stress.

4 Engineering background

Bridge(48m+80m+48m) is a variable cross-section prestressed continuous box girder, using construction technique of cantilever casting method. Wherein, the 0 # 8 m, 1 # ~ 2 # 3.5 m, 3 # ~ 9 # 4.0 m, straight line segments(the side span cast-in-place section) 7.5 m, side span closure segment 1.5m, the middle span closure segment 2.0m. Continuous beam cross section is using the form of single box single room direct plate. Midspan bridge pier beam height H=6.4m, midspan and side span fulcrum girder high H = 3.6m. Beam height longitudinal changes by parabola. Midspan fold length is 2m, side span folded length 1.5m, cast-in-situ length 7.5 m. Box girder top width of 7.2m(Including sidewalks on both sides), box width 4.6m, To meet the needs of continuous beam support installation, midspan fulcrum Box girder width widened to 5.6m, side across fulcrum is not widened. Box girder roof thickness is 35cm, the baseplate thickness is gradually changed from 105cm to 40cm; the plate thickness from 105cm to 40cm. The whole beam support position and midspan set total of 7 transverse partitions, the diaphragm plate thickness of the fulcrum is 200 cm, the diaphragm plate thickness of the side support is 145cm, the diaphragm plate thickness of midspan is 100cm. The author uses Midas/Civil finite element program to analyze and calculate, and uses document design specification. The finite element model is shown in Figure 3.

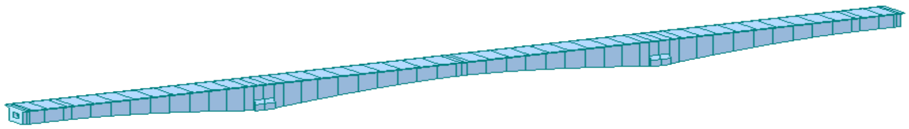

Figure 3. Bridge finite element model

5 The influence of shrinkage creep on the prestressed concrete box girder bridge

Concrete is a kind of material with a time effect. The shrinkage will happen after pouring the concrete, and the creep will happen under the load. So, shrinkage and creep on the prestressed concrete bridge has great effect on stress and linear. When continuous girder bridge closure that it happens system transformation, the concrete shrinkage and creep will cause the change of structural internal force, thus result in stress variation of reinforcement; eventually lead to the reinforced prestressed loss. As a result, it is necessary to research shrinkage and creep for continuous girder bridge linear, stress and the steel beam loss of prestress.

5.1 The concrete shrinkage and creep analysis of the influence on deflection

During the simulation analysis was carried out to the bridge, calculating the model by using theregulations of shrinkage and creep which specified in "China JTG D62-2004". On the parameters of the model were compared under different conditions, analysis of the influence of concrete shrinkage and creep on the bridge deflection.

(1) The control of relative humidity on the influence of concrete shrinkage and creep analysis. Shrinkage and creep are very sensitive to environment humidity change, therefore the humidity parameter in three cases analysis: Case 1: Relative humidity is 80%; Case 2: Relative humidity is 60%; Case 3: Relative humidity is 40%. Long-term deflection is produced by different humidity as shown in Figure 4(abscissa is half bridge unit location).

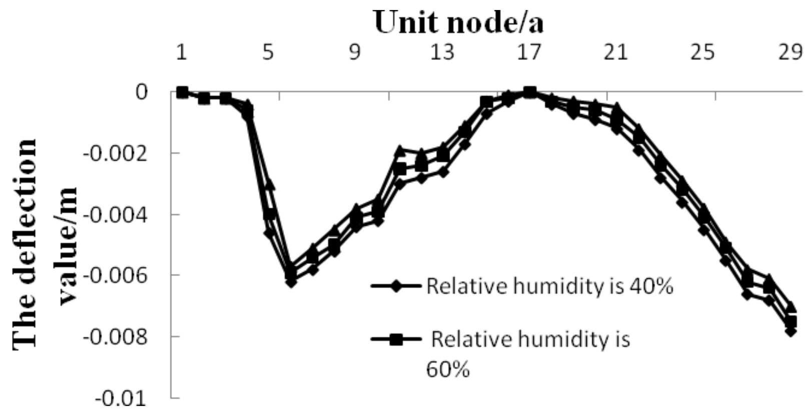

Figure 4 The influence of different relative humidity on the deflection

From Figure 4 we can see that relative humidity is 80% and the maximum difference of relative humidity 60% is 0.001 m, relative humidity 60% and the maximum difference of relative humidity 40% is 0.0006 m, relative humidity 80% and the maximum difference of relative humidity 40% is 0.0016 m. Relative humidity affects the concrete shrinkage and creep, the lower the relative humidity, the larger the shrinkage increases, while the shrinkage promotes the creep, especially in midspan affected by humidity is more obvious. Therefore, the lower the relative humidity, the larger the bridge deflection is. During curing the proper increase of relative humidity can reduce long-term deflection of the bridge. Relative humidity increases, the long-term deflection of bridge is reduced, an appropriate increase in humidity can reduce the impact of creep on the long-term deflection of the bridge.

(2) The influence analysis of creep coefficient on bridge deflection. Condition 1: Creep coefficient is 1.6; Condition 2: creep coefficient is 2.0; Condition 3: creep coefficient is 2.4. Bridge deflection values shown in Table 2.

Table 2 Bridge deflection value

node	Condition 1 (m)	Condition 2 (m)	Condition 3 (m)	1、2 difference (m)	2、3difference（m）
1	0.000	0.000	0.000	0.000	0.000
2	−0.001	−0.002	−0.002	−0.001	0.000
3	−0.004	−0.009	−0.013	−0.005	−0.004
4	−0.015	−0.018	−0.029	−0.003	−0.011
5	−0.023	−0.035	−0.046	−0.012	−0.011
6	−0.037	−0.046	−0.055	−0.009	−0.009
7	−0.049	−0.055	−0.060	−0.006	−0.005
8	−0.046	−0.050	−0.061	−0.004	−0.011
9	−0.034	−0.037	−0.044	−0.003	−0.007
10	−0.031	−0.035	−0.042	−0.004	−0.007
11	−0.024	−0.027	−0.030	−0.003	−0.003

12	−0.023	−0.025	−0.028	−0.002	−0.003
13	−0.021	−0.024	−0.026	−0.003	−0.002
14	−0.009	−0.015	−0.021	−0.006	−0.006
15	−0.003	−0.007	−0.011	−0.004	−0.004
16	−0.001	−0.001	−0.003	−0.000	−0.002
17	−0.000	−0.000	−0.000	−0.000	−0.000
18	−0.001	−0.002	−0.004	−0.001	−0.002
19	−0.002	−0.005	−0.007	−0.003	−0.002
20	−0.005	−0.007	−0.011	−0.002	−0.004
21	−0.008	−0.011	−0.014	−0.003	−0.003
22	−0.012	−0.016	−0.025	−0.004	−0.009
23	−0.021	−0.025	−0.031	−0.004	−0.006
24	−0.028	−0.032	−0.038	−0.004	−0.006
25	−0.035	−0.041	−0.049	−0.006	−0.008
26	−0.047	−0.052	−0.055	−0.005	−0.003
27	−0.053	−0.058	−0.067	−0.005	−0.009
28	−0.059	−0.065	−0.068	−0.006	−0.003
29	−0.058	−0.062	−0.065	−0.004	−0.003

The analysis results are shown in table 2, maximum difference of condition 1 and conditions 2 is 0.012 m, maximum difference of condition 2 and conditions 3 is 0.011 m. Under the situation of other conditions being same, creep has a greater impact on the long-term deflection of the bridge. Through changing the parameters of creep coefficient, the larger the coefficient, the larger the bridge deflection is. So, creep has a greater impact on deflection of the bridge. Creep coefficient is one of the most important factors that cause long-term deflection of bridge. Take measures to determine the creep coefficient is necessary for bridge linear.

5.2 The concrete shrinkage and creep analysis of the influence on stress

Shrinkage and creep function can be seen, shrinkage and creep function is a function which related to the time development. Bridge stage at different times of shrinkage and creep effects on the internal forces of the bridge is not the same, after three years completion of the bridge, the stress of the bridge is analyzed. Tensile stresses are positive, compressive stress is negative. Two cases to analyze calculation model: considering the shrinkage and creep， regardless of the shrinkage and creep。

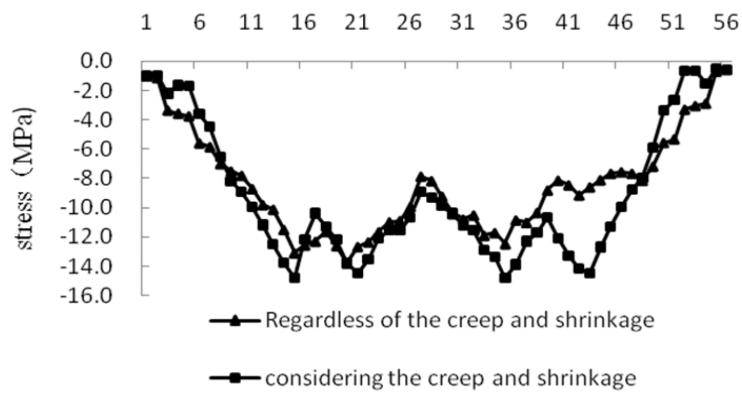

Figure 5. The bridge cross section upper flange stress diagram

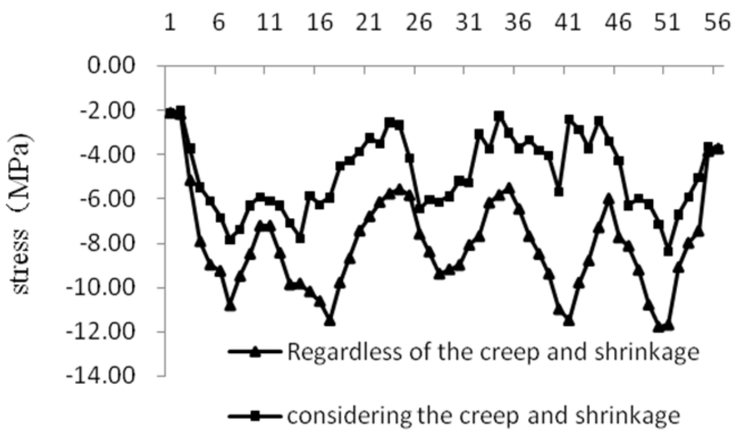

Figure 6 The bridge cross section bottom flange stress diagram

From Figure 5 we can see that after three years completion of the bridge, upper flange of cross section are compressive stress, the maximum compressive stress is -14.5MPa, which is in the range of allowable compressive stress of concrete. Considering compare with does not consider the shrinkage and creep side span piers's stress is decreased, the maximum difference of decrease is 1.9 MPa. Considering compare with does not consider the shrinkage and creep that upper flange of midspan cross-section stress increases obviously, the largest difference is 0.78 MPa. Near the bridge pier considering shrinkage and creep decrease bridge stress maximum 15.4%; near the midspan considering shrinkage and creep make stress maximum increased by 7.3%.

From Figure 6 we can see that after three years completion of the bridge, bottom flange of cross section are also compressive stress, under the effect of shrinkage and creep stress significantly decreased. The largest Midspan can maximum decrease 3.81 MPa. So, considering the shrinkage and creep of stress is advantaged for the lower flange of the longitudinal section.

In conclusion, after continuous girder bridge closed to become a statically indeterminate structure, under the effect of shrinkage and creep bridge structure produce time internal force, these Secondary internal forces cause bridge internal force redistribution, Therefore, shrinkage and creep on the internal forces of the statically indeterminate beam bridge structure have great influence.

6 Conclusions

By the analysis of the above:

(1)The influence of shrinkage and creep displacement of the bridge is very big, this article selects two parameters to analyze and demonstrate. There are some shrinkage creep parameters and correlation coefficient which needs a large number of the actual project data to further analyze.

(2)This paper using analysis of the influence of considering shrinkage and creep on the upper girder cross sectionand lower flange after three years completion of the bridge. The secondary internal force produced by shrinkage and creep causes the internal force redistribution between concrete and prestress steel beam. This has a great influence on stress and strain of upper or lower flange. Considering the shrinkage and creep has very important significance on bridge during its design and construction.

References

JTG D62-2004 Highway reinforced concrete and prestressed concrete bridge design code .

PIOTR GWOZDZIEWICZ. Long term service ability of concrete structures with regards to material behaviors and cyclic loading // Proceedings of the 2000 Structures Congress of Advanced Technology in Structural Engineering. Philadelphia Pennsylvania USA:ASCE，2000:1-8.

The A.M. neville. Li Guo pan et al(1983). The performance of concrete.China building industry press.

Zhang Jiyao, Wang Changjiang(2004). Cantilever casting prestressed concrete continuous beam bridge.Bei jing: People's Communications Press.

Zhou lv, Zhu lin, Li Xiwu(1984). The long span prestressed concrete railway continuous beam shrinkage creep calculation. Bridge Construction .

Z.P.Bazant, F.H.Wittmann(1982). Shrinkage and creep in concrete structures. John Wiley & Sons Ltd.

Both the Highway Tunnel Secondary Lining Crack Damage Causes and the Renovation

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Abstract: Lining crack is the main form of tunnel disease. Tunnel lining crack undermines the integrity of the tunnel structure and reduces the strength and stiffness of lining structure. Thus it influences the normal operation of tunnel. Through the detection of a highway tunnel lining appearance and by using the software Midas GTS to conduct numerical calculation for typical section of tunnel lining are used to analyze the influence factors of cracking of tunnel. At the same time through analyzing the cause of crack and combining the actual condition of the tunnel this paper puts forward the regulation scheme of pasting CFRP to expect it can have the essential reference for the similar project in the future.
Keywords: Tunnel; Crack; Cause; Lining.

1 Introduction

Our country has become a veritable tunnel superpower. We have accumulated rich experience in tunnel construction, but still have a gap with the world advanced level in engineering technology. And our country has a vast territory, so the engineering geological and hydrogeological condition of the mountains that the tunnel goes through is complex and natural conditions have large differences. This makes our country become one of the countries that have most serious tunnel disease. Most of the tunnels have different levels of disease, especially the crack diseases. For different tunnels, the cause of the crack is not identical the same and the improvement measures are also different. This paper combines the actual tunnel engineering to analyze and discuss the main causes of crack of the tunnel according to the actual situation of the tunnel and puts forward specific improvement measures so as to achieve the desired effect.

2 Engineering General Situation

The primary tunnel is composed of the north line and south line and is designed as motor vehicles and non-motor vehicles mixed traffic. Wherein, Traffic capacity of motor vehicle is just two-way two-lane. And the clear width of the two holes both is 7m. The south hole of the tunnel is completed in 1983. The entrance and the exit stake no .are K0+204.72 and K0+647.97. The total length of the tunnel is 443.25m. The north hole of the tunnel is completed in 1993. The entrance and the exit stake no .are K0+190.21 and K0+661.69. The total length of the tunnel is 471.48m. And the height limit of the traffic is 4.5m. The total length of the two holes is 914.73m and the clear width of the two holes is 23-24m. The traffic height limit of the two tunnels both increases to 5.5m and the clear width of the two tunnels also increases to 12m.

The site of this tunnel belongs to the low mountain hilly terrain landform. The highest mountain (ridge) that the tunnel goes through is 176 m and the lowest is 96 m. In a small area of the ground the site is located in the tumor upwarping north part. The surrounding rock that the tunnel holes area goes through is mainly the breeze of the mixed granite rock and weathered rock, local weak weathered and rock integrity is good. Degree of surrounding rock which is influenced by geological structure is heavy and no large fault zone goes through the rock mass. In the middle of Tunnel hole area of the central hole there is rock fracture water and the water level is not stable. The water level of the mountain body in high area is higher above hole body around 30 m, so the water pressure should be considered in designing. PH of rock fissure water is 7.1 which belongs to calcium magnesium bicarbonate water. Rock body is weak permeable layer which has no corrosive to concrete and weak corrosive to steel. Seismic fortification intensity is 7 degrees and designing basic acceleration is 0.1 g. Site which belongs to class I lies to the favorable seismic area.

3 Detection of Crack Disease of Tunnel

Appearance test is a comprehensive inspection of the basic technical conditions of the tunnel. Appearance test can find lining crack diseases and other anomalies. Through the test, we can systematically master the basic technical condition of structure, evaluate function of the structures and determine the countermeasures to provide evidence for the work plan.

3.1 Type of lining crack

(1) Longitudinal crack damage Concrete lining of arch crown is generally the outer stretch lining cracking because of outer tension. Concrete of hance and side-wall are mainly opened because of inner tension that has the greatest harm.

(2) Circumferential crack is mainly caused by the different geological condition of surrounding rock, uneven load which is not improper handled and other factors. And it has little effect on the normal bearing of lining structure.

(3) Oblique crack its hazardous is second only to longitudinal crack damage that is caused by concrete which is influenced by many kinds of tensile stress.

3.2 Crack damage detection

In the south hole about 180 cracks are found. There are 52 cracks in the arch crown, 50 cracks in the hance and 78 cracks in the side-wall. All the cracks are mainly longitudinal crack and also have a part of circumferential crack and oblique crack. The widthest crack which lies in arch crown k0+557.57 (See Fig.1) is 1.3mm and is longitudinal. In the north hole about 151 cracks are found. There are 19 cracks in the arch crown, 22 cracks in the hance and 110 cracks in the side-wall. All the cracks are mainly longitudinal crack and circumferential crack and also have part of oblique crack. The widthest crack which lie in the left arch hance k0+420.49 (See Fig.2) is 1.1mm. Cracks are crossed in the longitudinal and circumferential. There are more longitudinal cracks than other kinds of cracks in north and south holes of tunnel, some of which are through cracks and falling cuts. It has caused potential safety concerns.

Fig 1. Longitudinal crack of secondary lining

Fig 2. Cross cracks of secondary lining

4 Crack Cause Analysis

4.1 Analysis of preliminary formation

(1) The surrounding rock integrity is good. Degree of surrounding rock which is influenced by geological structure is heavy and no large fault zone goes through the rock mass. There is no unfavourable condition for geology structure, so geology structure is not the reason that causes cracks.

(2) Thickness of the secondary lining is not enough, uneven distributed and void between the first lining and the secondary lining when the tunnel is constructed. These factors may be one of the reasons that tunnel lining appears cracks and spall.

(3) When the tunnel is designed, level of surrounding rock is divided incorrectly and type of lining is selected improperly, which causes the lining structure do not adapt with the actual load of the surrounding rock. This situation causes cracks. Objectively, because the mountain of the tunnel going through possesses complex engineering geology and hydrogeology conditions, so the depth and the number of

reconnaissance design work is limited. A number of tunnels only have geological drilling holes. In the design phase it is difficult to achieve complete and accurate geological data, in some areas the level of the surrounding rock is not accurately classified and type of lining is chose incorrectly. If in the construction it is not rectified or the right design is made the wrong change, the condition of lining structure not match the actual load of surrounding rock will occur. Not consistent load may be one of the reasons to causes of crack damage.

(4) When tunnel is constructed, the bad engineering quality is caused because of restricted technical conditions, undeserved method and mismanagement. Improper process cooperate, lining ring formation not in time, dangling on arch lining section is too long when horse's mouth digged in fall mouth slot and the deformation of arch support sinking and other reasons are all easy to causes the arch lining produce uneven subsidence, which leads to the early construction cracks in hance and arch crown lining. If vault is not sticked closely with surrounding rock hole, holes will occur. Under the action of "saddle" stress tensile cracks occurs in hance. To pursuit the construction progress and demould too early make low strength concrete early to bear loads, deformation of primary support has not reached a stable state, lining concrete bears too large loads or structure changed may also be a direct reason to cause lining crack damage.

According to the above preliminary analysis, the main reason of tunnel lining crack damage may be that lining concrete undertakes excessive load which causes bending crack damage, insufficient of the lining thickness and holes behind the lining.

4.2 Modeling build

Typical section which lies in zk0+215 is chose to perform plane analysis using midas GTS. The secondary lining of this section is chose to be calculation model. The cross section is 15m in depth and close to alternate place of open cut hole and dark cut hole. The thickness of the surface silty clay is 0.5m to 2.5m. Bedrock is mixed granite rock.

The area that the hole body goes through is mainly slightly weathered rock and local is weak weathered rock. The thickness of mountain body is a little thin and has already had a renovation expansion. So surrounding rock is disturbed a few times. The consequence is that surrounding rock is loose when it is excavated. For safety considerations, we assume that surrounding rock can not form a stable pressure arch. The initial support of tunnel and wall of secondary lining use bride unit. Then foundation uses only compression elastic connection to build the model. Solid pressure, linear girder unit load which is combined by ground springs and load, curve spring support and combined load are put to the girder unit. Then compression-only unit is only used to build ground springs to conduct boundary non-linear dynamic analysis. The calculation parameters are shown in table 1.

Table 1. Calculation parameters

project	gravity density /（kN · m^{-3}）	modulus of elasticity/Gpa	poisson ratio	coefficient of thermal expansion
initial support concrete:C30	25	30	0.2	1e-5
Secondary lining concrete:C30	25	30	0.2	1e-5

4.3 Secondary lining model analyse

If ground springs use compression only function which is in the elastic connection to conduct non-linear analysis, the loads is impossible become to a linear combination. Therefore exact result can not get according to the function of combination value of linear static force. So before the analysis using the function of the combined load to be a new group will see load combination transformation as a static load. Overall displacement, bending moment, axial force and shearing force diagram of secondary lining under the effect of load are shown in fig.3-fig.6. We can see from fig.4 that bending moment at arch crown and inverted arch is the biggest, about 812.449kN · m and the bending moment at two sides is the smallest.

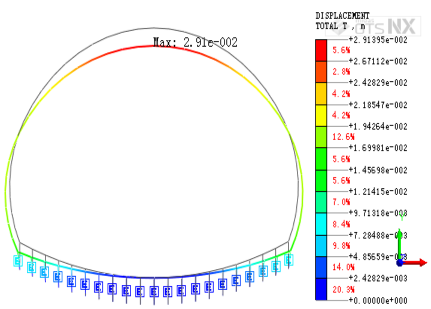

Fig 3. Overall displacement diagram of secondary lining under the effect of load (m)

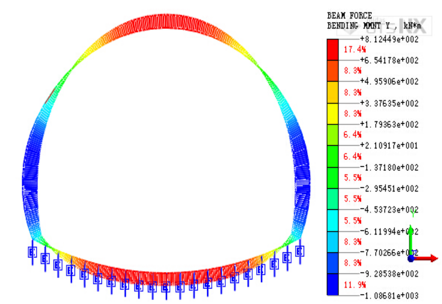

Fig 4. Overall bending moment diagram of secondary lining under the effect of load (kN · m)

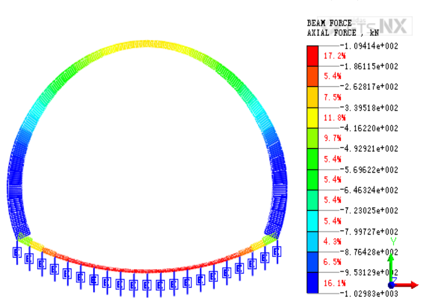

Fig 5. Overall axial force diagram of secondary lining under the effect of load (kN）

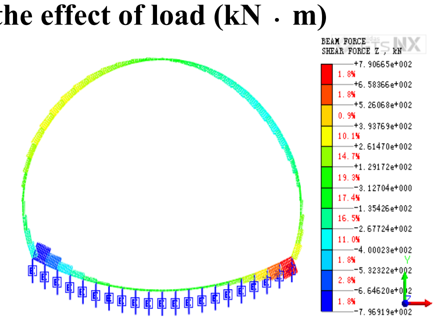

Fig 6. Overall shearing force diagram of secondary lining under the effect of load (kN)

When bearing capacity calculation for flexural members is conducted, the flowing assumptions should be made:（1）After bending deformation, component still keep the section plane. (2) Do not take the tensile strength of concrete into consideration. That is pull force is undertaken by the steel. (3) Concrete compressive stress-strain relationship should comply with the rules and regulations of the corresponding design curve. (4) Reinforcement stress taken is equal to the strain and modulus of elasticity of the product, but not greater than the strength design value.

It is known that strength grade of concrete is C30, HRB335 steel, 1m strip chose to calculate, size of section :b×h=1000×700,h_0=665mm, tensile bar: 4Φ22(1520mm^2), compression reinforcement: 4Φ22(1520mm^2), C30 concrete, fc=14.3N/mm^2，α_1=1.0; HRB335 steel, εb=0.55， fy=300N/$mm^{2.}$ Because the size of tensile bar and compression reinforcement is equal, so the height of compressive zone is x=h/2=350mm.

$$2as' = 70\text{mm} < x < \varepsilon bh0 = 0.55 \times 665 = 365.75mm$$

$$\begin{aligned} Mu &= \alpha 1fcbx(h0-0.5x) + fy'As'(h0-as') \\ &= 1\times14.3\times1000\times350\times(665-0.5\times350)+300\times1520 \\ &\times(665-35) = 2739.73\text{kN}\cdot\text{m} \end{aligned}$$

Mmax=812.449kN · m<Mu=2739.73. From this we can see the surplus of structure is larger, so it is safe.

5 Plan of Renovating Secondary Lining

According to overall analysis of secondary lining crack of tunnel, more reasonable, safer, more effective and more economic regulation measures are put forward. Because the highway tunnel lies in major urban traffic trunk road, in order to minimize effect on normal operation of the tunnel, regulation measures to the tunnel lining crack should try to be quick, convenient, economic and security.

5.1 Maintenance treatment measures

During the tunnel construction, there are holes behind the lining, especially at the arch crown of the tunnel. When a tunnel is renovated, we should test the place which has cracks using GRP. If holes are found, we should backfill the holes to improve the structure stress taking the measure of drilling grouting.

Nowadays the measures to renovate the tunnel cracks mainly include seam filling and grouting, pasting fiber cloth, adding steel arch, changing the arch, grouting hollow holes grouting behind the lining, pasting steel plate and other measure. Through compared with various aspects, seam filling and grouting and pasting fiber cloth are used as the renovation.

Different renovation measures are taken according to whether the crack is leakage of water.

(1) If the crack is dry (not leakage of water), according to the width of crack: more than 0.3mm and less than or equal to 0.3mm, these two situations are divided

and applying epoxy mastic directly, betting epoxy slurry and other measures are used respectively to deal with the problems.

(2) According to the width of crack: more than 0.3mm and less than or equal to 0.3mm,these two situations are divided for ring crack and applying two-component polyurethane binder directly, betting two-component polyurethane sealing slurry and other measure are used respectively to deal with the problems.

(3) For some places its Lining crack cracks more serious, including map cracking area near the arch and vault near longitudinal cracks distribution more populated areas, the measures of crack closed or potting first and then local paste CFRP are taken to renovate. If in some of these areas the width of the crack which is longitudinal stress is more than o.5mm, further measures that across the seam paste CFRP will be taken.

5.2 Construction technology process

5.2.1 Drilling grouting to void of secondary lining

According to the test report two rows of grouting side hole are drilled at the void behind the secondary lining. Middle holes should be drilled in the middle of the side holes. Grouting is started from the two side holes and water-cement radio is 1:1. The level of a single hole of finishing grouting is that the grouting pressure gradual rises to the design final pressure 0.5MPa, sustains more at least 10min. Grouting speed should less than one fourth of the initial admission speed and when the grout outflows from the middle hole, side holes finish grouting. Then press the grout from the middle holes. Because thickness of the arch crown is thin, grouting pressure should be controlled appropriately. And temporary support measures are also essential. At the same closely observe the lining deformation and development of surrounding cracks to ensure the safety of construction. Grout should be cement or cement mortar. Details can be seen from Fig.7 and Fig.8.

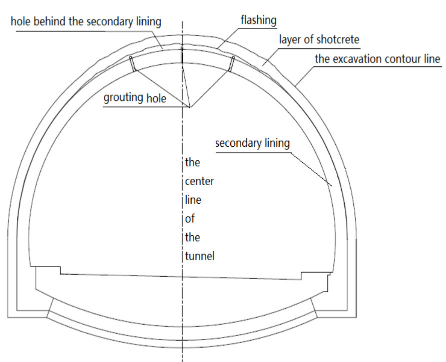

Fig 7. Grouting and air flow section

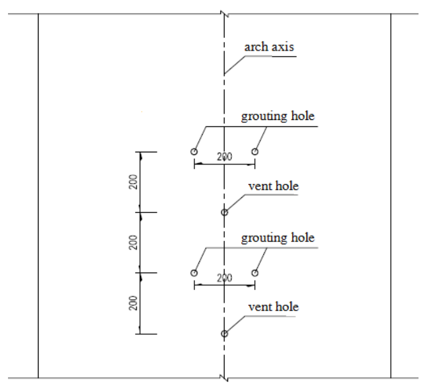

Fig 8. Grouting and air flow plan sketch

During drilling grouting holes, depth of drilling holes should be adjusted flexible according to the thickness of lining in the test report and physical truth. And try not to damage the flashing or existing waterproof system. If grouting in one time can not pack tightly, weakly expansive early-strength cement mortar should be used and grouting repeatedly several times after the concrete hardening. It is shown in Fig.9.

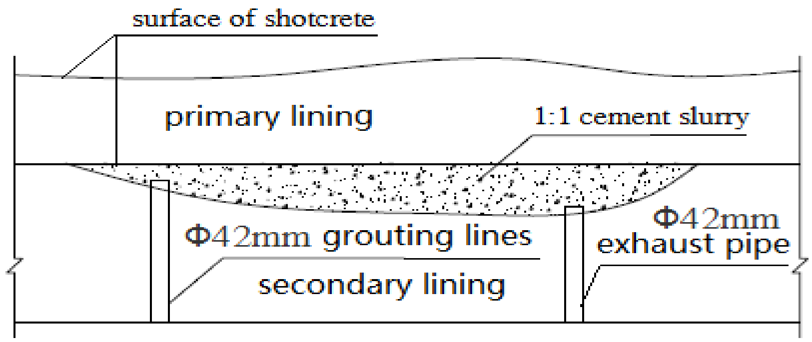

Fig 9. Installation of grouting holes and air flow holes

5.2.2 Crack renovation steps of lining

According to the different width of lining cracks, renovations measures which are based on different properties and different levels are taken to renovate cracks respectively. Various properties of crack renovation steps of lining are as follows.

(1)Daubing directly, namely closed treatment: base treatment, crack-cleaning, daubing, surface treatment.

(2) Grouting to seal joint, namely grouting processing: base treatment, crack-cleaning, crack pouring, maintenance, checking.

(3) Firstly, grouting uses low pressure; secondly, carbon fiber cloth is pasted. But Longitudinal and oblique cracks which are in the area of local crack treatment should be closed or glued. Detail process can be seen in "（1）" and "（2）". Carbon fiber cloth of 100cm in width should be pasted to reinforce the cracks which are in the area of local treatment and its width δ is more than 0.5mm. And carbon fiber cloth which is 30cm in width and its longitudinal spacing is 60cm should be pasted in the area of local crack treatment no less than 50cm.

6 Conclusions

Tunnel lining crack causes bad effect on stabilization of tunnel, traffic and personal safety, as well as facilities in the hole, even threatens and reduces the life of tunnel. What was worse, it will harm the normal operations of the tunnel. Studying the cause of tunnel lining is basement to us to solve the engineering problems. But the cause of tunnel crack includes construction, designing, geology and other aspects and the treatment plan is also different. Therefore only studying the cause of tunnel crack can we design technology appropriately and using better ways and processes to deal.

This paper preliminary analyse the various cause of tunnel crack. Then build model according to the midas GTS to analyses the bearing capacity, and the more accurately judge the main reason to cause lining crack. Taking the pasting carbon fiber cloth and grouting the holes behind as renovation measures, which makes the tunnel is completed renovation measures more safely, more rapidly and convenient. So it can be used as reference for similar maintenance and renovation projects.

References

DENG Boke.(2013) Control Technology on Cracking and Deformation of Primary Support in Soft and Weak Surrounding Rocks of Water-rich Section of Yanmenguan Tunnel. Railway Standard Design , (01).

GB 50367-2006 Design code for strengthening concrete structure[S].

GUAN Baoshu.(2009) Shotcrete Supporting Technology of Tunnel and Underground Engineering.Bei Jing: China Communications Press.

JTG F80-2004 Highway Engineering Quality Inspection Evaluation Standard .

LIU Xuezeng, BAO Haoshan, ZHOU Min.(2012) Experimental Study on the Effect of Longitudinal Crack on Reinforced Concrete Tunnel Lining. Journal of Shanghai Jiaotong University,46(3).

SUN Xuelian. The Design of Highway Tunnel Disease. West-China Exploration Engineering

SITU Xinli,ZHOU Youquan.(2007) Study of harmfulness on highway tunnel of holes Behind the Lining. Shanxi Architecture,33(31).

ZHU Gang, Wang Jinsha.(2012) Damage testing and solutions of lining crack of highway tunnel engineering. Engineering Construction,24(15).

ZHANG Shibing, ZHANG Jian.(2011) Detection and Elementary Analysis of Causes of Tunnel Lining Cracks. Bridge & Tunnel Engineering, (22).

Metrological Traceability Technology for the Pavement Frictional Coefficient Using the Law of Conservation of Energy

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Abstract: Pavement frictional coefficient using the law of conservation of energy is widely used in the evaluation of the pavement in China. To improve the reliability of evaluation, it is in urgent need of building the metrological traceability system of the pavement frictional coefficient. By deeply analyzing the operational principle and definition of Baizhi of the pavement frictional coefficient measuring instrument and considering the economy and portability needs, the project team proposed a two-level-deliver programme of metrological traceability. I level indoor standard is consist of a photoelectric encoder, a force sensors and a sampling control system, etc. Ⅱ level outdoor standard are lave and textured glass. The results show that the expanded uncertainty of I level standard is 0.42 (k=2), and the uncertainty of II level standard is 0.98 (k=2).The research will be effective support to the pendulum friction tester calibration.
Keywords: Road engineering; Pavement anti-slide performance; Friction coefficient; Energy loss; Metrological traceability.

1 Introduction

Antiskid performance is one of the key technologies which affects the traffic safety. The relevant factors include the abrasive performance of stone and the level of the bituminous pavement roughness shaped by the gap between bituminous pavement aggregates. And standards of transportation industry put forward different requirements for different levels of pavement. Pendulum friction tester was introduced from Britain since the 90's of last century and widely used in the final acceptance evaluation. While, as the main measuring instrument of antiskid performance evaluation, there are lots of knotty problems, such as the lack of technical supervision, the disparity of market price（1500~25000yuan）and cannot meet demand of stand. These problems debase the reality of the antiskid performance in China. Though industry standard JT/T 763-2009“Pendulum Friction Tester”has the requirements of product technology, the accurate results still cannot be guaranteed in actual detection work. JJG（Traffic）053-2009“Pendulum Friction Tester” has solved the problem of how to check-up the basic measurement parameters, but it doesn’t point out the traceability path clearly. Therefore, it is in urgent need of establishing the actual available traceability system to ensure the accuracy and reliability of measurement data.

2 Measuring Principle

2.1 Operational principle

Pendulum friction tester is consists of a pendulum, a slippery block, a sheet rubber, a dial and a upright column, etc. The sheet rubber is fastened to the slippery block. The distance between the swing center and the pendulum bob center is (410±5) mm. The slip distance of the measured object is (126±1) mm. The quality of the pendulum and connections is (1500±30) g. In the law of conservation of energy, the kinetic energy loss of the pendulum bob from the friction of the measured object is equal to friction energy of the sheet rubber overcome.

Measurement: Level and adjust the slip distance by up-down knob. Fasten the pendulum on the right cantilever and make the needle left parallel with the pendulum pole. Purl some water on the measured surface and press the release-push, then the pendulum bob free down and fall over the measured object surface. When the pendulum dropt, hand it. While reads and marks the measurement result. The same swing distance of the slippery block can ensure the same friction work and friction. Thus, the adjustment of the swing distance is a key step in the measurement.

2.2 Definition of Baizhi

Baizhi is the characterizes of pavement frictional coefficient which is expanded 100 times, measured by pendulum fiction tester under wet condition. It is denoted by BPN. According to the law of conservation of energy, the initial gravitational potential energy of the pendulum in the measurement converted into two parts: overcoming the friction work and the residual potential, as shown in figure 1.

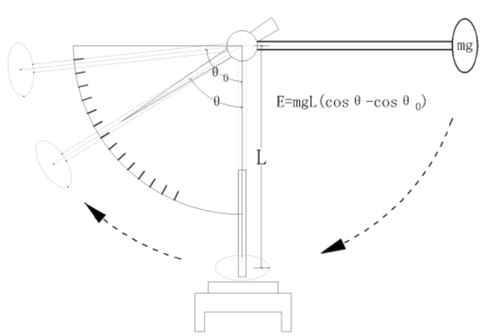

Figure 1. Diagrammatic sketch of the mechanical model of pendulum friction tester

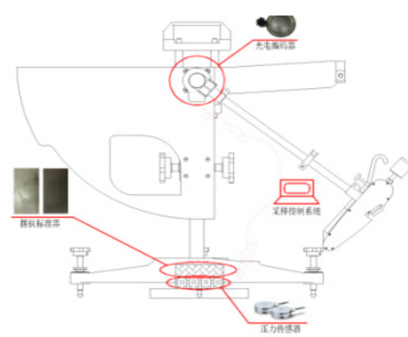

Figure 2. Structure diagram of I level standard

Energy conservation can be expressed as:

$$mgL(1-\cos\theta_0) = \mu\int_0^S N(x)dx + mgL(1-\cos\theta) \qquad (1)$$

The coefficient of friction is changing during the measurement process. The slippery block and the tested positive pressure integral calculation friction work between objects and the inverse, but it is hard to achieve. The actual project doesn't need real-time variation to characterize the antiskid performance, so the positive pressure is simplified as the maximum positive pressure *N* (Quantitative), as follows:

$$mgL(1-\cos\theta_0) = \mu NS + mgL(1-\cos\theta) \tag{2}$$

$mgL(1-\cos\theta_0)$ represents when the friction free, gravitational potential energy of the pendulum swing to the highest position in the air. μNS represents the pendulum to overcome the friction work. $mgL\cos\theta$ represents the potential energy of pendulum swing to the lowest position. $\mu_{BPN} = 100\cdot\mu$ represents Baizhi.

$$\mu_{BPN} = \frac{mgL(\cos\theta - \cos\theta_0)}{NS} \times 100 \tag{3}$$

with: μ_{BPN} - Baizhi;

S - the friction distance, mm;

N - the pressure between the measured project and the slippery block, N;

m - the quality of the pendulum, kg;

g - the local acceleration of gravity, g= 9.8m/s^2;

L - the distance between the center of gravity of the pendulum bob and the swing axis, m;

θ - the max deflection angle of the sheet rubber, rad;

θ_0 - the max deflection angle under with no friction, rad.

Visible, non-dimensional Baizhi is chosen to be the Characterization of value to evaluate the pavement surface resistance in highway industry. Its essence is the nature of friction coefficient but it is not the actual one. So it cannot be directly trace to the friction coefficient. Thus there is need for establishing a separate traceability system.

3 Metrological Traceability

3.1 Needs analysis

"Law on Metrology of the People's Republic of China" stipulates size tracing should follow the principle of economy and rationality, being carried out on the spot or in the vicinity. At present, there are more than two thousand test labs and nearly over a field laboratory in the transportation sector. Polished stone value and friction coefficient of pavement is the basic ability of test department. Pendulum friction tester is one of the enormous quantity wide instruments in the transportation sector. According to an incomplete statistics, there are a number of sets which mostly used in the field. The pendulum, needle, and the inside spring rigging of the pendulum friction tester is easily damaged in the transportation. It doesn't fit long-distance transportation. Therefore, studying the technical scheme of metrological traceability programme should consider the portability and efficiency requirements.

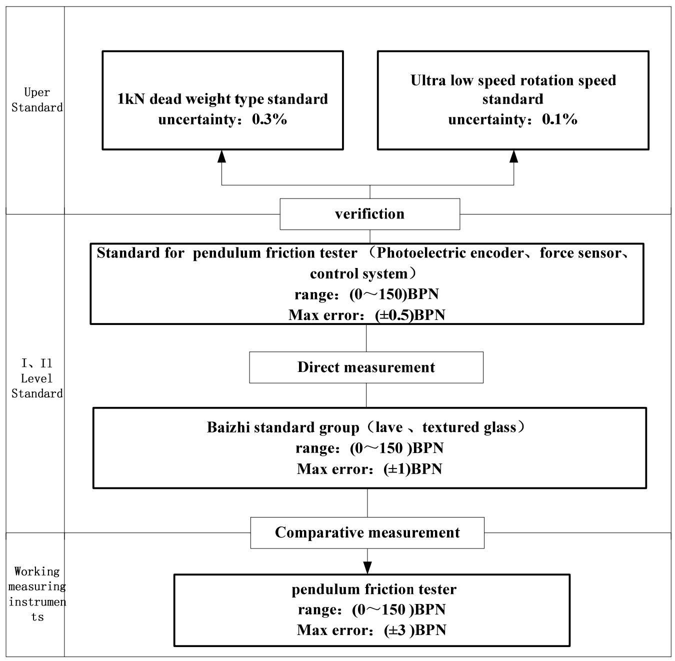

Figure 3. Hierarchy scheme of the pendulum friction tester

Combined with pavement antiskid performance evaluation of the actual engineering requirements, the paper designs a two-level-deliver programme of metrological traceability. Ⅰlevel indoor standard traced Baizhi to its definition with high accuracy requirement. Meanwhile, it also gives assignment to Ⅱlevel standard group which should be placed in the environment avoiding vibration and windage. Ⅱlevel outdoor standard is used to keep the assignment and actually verification which need accuracy requirement. The chosen of the standard block will be economic and portable. Now, the regulation for verification stipulates the accuracy is 2BPN, but it can't meet the demand in real. Besides, that high accuracy demand is unnecessary in engineering, so the paper confirm 3BPN, the hierarchy scheme is shown in fig.3.

3.2 Programme

The structure of I level standard is shown in fig.2. Formula (3) shows the potential energy loss to friction distance ratio is friction and friction to the max pressure ratio is Baizhi. So Ⅰ level standard needs to measure friction and pressure on the slippery and measured surface to gain Baizhi. In the law of conservation of energy, the friction can be achieved by calculating ratio of the potential loss energy and pressure. The potential loss energy can be obtained by measuring the rotational angle of the pendulum with photoelectric encoder. Friction distance can be received by using control system to measure the contact position of the sheet rubber and the measured object. The pressure can be calculated by the force sensor.

II level standard (hereinafter referred to as the standard group) need to be capable of covering (0~150) BPN measurement range. Whether be qualified can be judged through calculating the error of indication of the measurement results of pendulum friction tester and standard assignment. Taking into account the actual using premises, the standard group should be cheap, easy transfer, and field engineering calibration. Therefore, the paper chooses a group of lave and textured glass to be the standard group, its reproduction Baizhi interval distribution in different measurement range, with the character of stable, portable and economic.

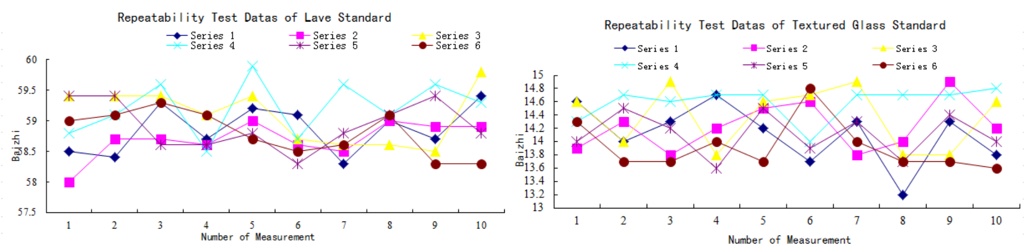

Figure 4. Measurement Repeatability Data Trend

As shown in fig.4, the abscissa is the number of the measurement and the ordinate is Baizhi. There are 6(Series 1-6) Ⅰ level standard to measure Ⅱ level standard group 10 times (we did the experiment with 3 pieces standard group, considering the limited space listed only one). Through the data trend in the figure, can we know that the Baizhi kept by the standard group is stable. The maximum standard deviation is chosen for evaluation of uncertainty, as seen in Table 1.

Table 1 standard group repeatability test sample data

number of measurements	1	2	3	4	5	6	7	8	9	10	average	standard deviation
textured glass	14.6	14	14.9	13.8	14.6	14.7	14.9	13.8	13.8	14.6	14.37	0.464399
lave	59.4	59.4	59.4	59.1	59.4	58.7	58.6	58.6	58.5	59.8	59.09	0.455705

4 Evaluation of Uncertainty

4.1 I level standard

The uncertainty of Ⅰ level standard is the uncertainty of surface friction coefficient (Baizhi). Based on its definition, the paper built the measurement model as shown in fig.3. Baizhi is the ratio of energy loss of the pendulum and the friction distance. Then, the branch of uncertainties of physical factors influence: 1) u_m that related with the quality of the pendulum bob; 2) u_g that related with the local acceleration of gravity; 3) u_L that related with the distance between the center of gravity of the pendulum bob and the swing axis; 4) u_θ that related with the max deflection angle of the sheet rubber; 5) u_{θ_0} that related with the max deflection angle under with no friction; 6) u_N that related with the pressure between the measured project and the slippery block; 7) u_s that related with the friction distance. In view of the fact that each branch of uncertainties is independent, while differentiate every branch of uncertainties, we can get the torsion relative standard uncertainty.

$$u_r(\mu_{BPN}) = \frac{u(\mu_{BPN})}{\mu_{BPN}} = \sqrt{\left(\frac{u(\mathrm{m})}{m}\right)^2 + \left(\frac{u(g)}{g}\right)^2 + \left(\frac{u(\mathrm{L})}{L}\right)^2 + \left(\frac{u(\cos\theta)}{\cos\theta}\right)^2 + \left(\frac{u(\cos\theta_0)}{\cos\theta_0}\right)^2 + \left(Nu(\mathrm{N})\right)^2 + \left(Su(\mathrm{S})\right)^2} \quad (4)$$

$$即 u_r = \sqrt{u_{r,\mathrm{m}}^2 + u_{r,\mathrm{g}}^2 + u_{r,\mathrm{L}}^2 + u_{r,\theta}^2 + u_{r,\theta_0}^2 + u_{r,\mathrm{N}}^2 + u_{r,\mathrm{S}}^2} \quad (5)$$

Among: $u_{r,m}$—the relative standard uncertainty related with the quality of the pendulum bob which less than 1/10 of the maximum error; $u_{r,g}$—the relative standard uncertainty related with the local acceleration of gravity which less than 10%; $u_{r,L}$—the relative standard uncertainty related with the center of gravity of the pendulum bob and the swing axis which less than 1/10 of the maximum change; $u_{r,\theta}$—the relative standard uncertainty related with max deflection angle of the sheet rubber. The pendulum angle is measured by the photoelectric encoder whose scale division maximum change is ±30″; u_{r,θ_0}—the relative standard uncertainty related with that related with the max deflection angle under with no friction. The pendulum angle is measured by the photoelectric encoder whose scale division maximum change is ±30″; $u_{r,N}$—the relative standard uncertainty related with the pressure between the measured project and the slippery block. In the law of conservation of energy, the response frequency of the force sensor is 5 kHz, the max margin of error is about 0.3mm; $u_{r,S}$—the relative standard uncertainty related with the friction distance, the uncertainty of the force sensor is 1.0%.

In addition, a slight change in temperature, the deformation of mechanical and the sensor affected by temperature will call the branch of uncertainty u_T. While u_T is far less than above branches of the uncertainty that can be omitted. In summary, the s branch of uncertainties is shown in table 2.

Table 2 List of the uncertainty

No.	Symbol	Classif-ication	Distribution	Figure	Remarks
1	$u_{r,\mathrm{m}}$	B	equidistribution	$\Delta_m/2\sqrt{3}$	Δ_m —max error of the quality of the pendulum which is 3g
2	$u_{r,\mathrm{g}}$	B	equidistribution	0.1%	On the certification
3	$u_{r,\mathrm{L}}$	B	equidistribution	$\Delta_L/2\sqrt{3}$	Δ_L —max error of the distance between the center of gravity of the pendulum bob and the swing axis which is±1.5mm
4	$u_{r,\theta}$	B	equidistribution	$\Delta_\theta/2\sqrt{3}$	Δ_θ —the max error of the photoelectric encoder 30″
5	u_{r,θ_0}	B	equidistribution	$\Delta_{\theta_0}/2\sqrt{3}$	Δ_{θ_0} —the max error of the photoelectric encoder 30″
6	$u_{r,\mathrm{N}}$	B	equidistribution	1.0%	On the certification
7	$u_{r,\mathrm{S}}$	B	equidistribution	$\Delta_S/2\sqrt{3}$	Δ_S —max error of the distance measurement which is 0.3mm
8	u_T	—	—	0	0

The combined standard uncertainty of the standard is

$$u_{\mathrm{I}} = \sqrt{u_{r,\mathrm{m}}^2 + u_{r,\mathrm{g}}^2 + u_{r,\mathrm{L}}^2 + u_{r,\theta}^2 + u_{r,\theta_0}^2 + u_{r,\mathrm{N}}^2 + u_{r,\mathrm{S}}^2 + u_{r,T}^2} \approx 1.06\% \qquad (6)$$

Thus, the expanded uncertainty of Ⅰ level standard $U_{\mathrm{I}} = 2 \cdot u_{\mathrm{I}} = 2.1\%\,(k=2)$, the maximum permissible error of full range is 0.31 BPN. It fits the requirement of the calibration of Ⅱ level standard group.

4.2 Ⅱ level standard

The factors affect the uncertainty of the standard group mainly come from the upper level standard and the measurement repeatability. The combined uncertainty of Ⅰ level standard $u_1 = u_{\mathrm{I}} = 0.156\,\mathrm{BPN}$. Choosing the maximum standard deviation from table 1 as the related with the repeatability $u_1 = 0.464\,\mathrm{BPN}$. The combined standard uncertainty of the standard group $u_{\mathrm{II}} = \sqrt{u_1^2 + u_2^2} \approx 0.49\mathrm{BPN}$, and the expanded uncertainty $U_{\mathrm{II}} = 2u_{\mathrm{II}} = 0.98\mathrm{BPN}\,(k=2)$.

5 Conclusions

Evaluate the pavement surface resistance with the use of pendulum friction tester is an important mean of final acceptance. But the traceability system of pendulum friction tester is faulty in current China. Therefore, this paper proposes a pendulum friction tester program of traceability, using I level standard and the II level standard group transfer quantity. I indoor level standard keep the value stable. II level standard has the characteristic of stable, low cost, portability strong which can fit the demand of field pendulum friction tester metrological verification. The results show that the uncertainty of I level standard is 0.42(k=2), the uncertainty of II level standard is 0.98(k=2), which fits the requirement of calibration of the pendulum friction tester. The research will be the strong support to the metrology of the pendulum instrument. In the light of the rubber sheet plays an important role in the measurement of Baizhi, the team considered there is strong need to develop the technical standard of the rubber sheet.

Acknowledgement

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References

WANG Qi-lin,TIAN Jin-yue. Approach to Analysis and Testing Technology of Dynamic Road Friction Coefficient.HIGHWAY,2007,7:140-144.

JTG D50-2006,Specifications for Design of Highway Asphalt Pavement.

JTG F80/1-2004,Quality Inspection and Evaluation Standards for Highway Engineering.

ASTM E 303-93,Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester.

JT/T 763-2009,Pendulum friction tester.

HE Song,XIA Li-xiu. Friction Coefficient Measurement and Evaluation for Lane Surface of Expressway.Journal of Highway and Transport Research and Development,2002,1:8-11

JTG E60-2008,Field Test Methods of Subgrade and Pavement for Highway Engineering.

JJF1001-2011,General Terms in Metrology and Their Definitions.

NI Xiaoli.Research of metrological traceability of reference material,Measurement technique,2002.11:45-61

Properties of Natural Bitumen Gilsonite Modified Bitumen

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Abstract: This article introduces the characteristics of the gilsonite and the natural bitumen gilsonite .It also discusses the performances, effect, modified mechanism and using of the natural bitumen gilsonite modified bitumen. A series of tests of the natural bitumen gilsonite modified bitumen were made. These included asphalt technical property, rutting test a high temperature, marshall test. The result showed that the stability of natural bitumen gilsonite modified bitumen was markedly increased. The effects of the natural bitumen gilsonite modified bitumen were made in highway application.
Keywords: Natural bitumen gilsonite; Gilsonite; Modify; Application.

1 Introduction

With the focus of the economic construction transfer from the east to the Midwest in our country, the development of highway construction will be continued and be accelerated in our country. Most of the highway surface pavement adopts material asphalt concrete, asphalt concrete as a kind of road materials has some advantages such as convenience construction, low cost, the advantages of driving comfort, etc, but also it has inherent performance unstable faults. Therefore improve the performance of gilsonite in the road can make the gilsonite pavement have excellent performance under different weather conditions, and the effect of different vehicles, it is a task facing each road workers.

At present the methods of improving the performance of gilsonite materials can be achieved by mainly adopting different nature of the modifier in asphalt, this paper mainly introduces using natural bitumen as a modifier to improve the performance of gilsonite.

2 The characteristics of the gilsonite and natural bitumen comparative analysis

2.1 The characteristics of the gilsonite

Currently the gilsonite using in highway pavement basically all is petroleum asphalt, it is the product of crude oil after refining. Analysis of chemical composition of the asphalt material is very complicated by using chemical analysis method. To facilitate the work, usually will pitch into several chemical group for research of a similar nature, the so-called components. Gilsonite is generally divided into saturates, aromatics, colloid and asphaltene four components.

Asphaltene is solid matters, saturates and aromatics are liquid, colloidal is semi-solid material. In gilsonite solid asphaltene absorption semi-solid colloid can reverse micelle, it disperses in liquid saturates and aromatics, saturates is a gels among it, in the mixture saturates prevents the asphalt and colloid separation from the micelles, the gel structure can keep. Therefore the asphalt is not solid, not liquid, but a colloid. The gel due to its different components, so the characterization of colloid is different also.

When the asphalt content is rarely in the asphalt, less in tar micelle, asphalt micelle due to the effect of peptization of the colloid, completely dispersed in aromatic points and saturated medium, micelle attraction between minimal or no, this kind of asphalt is sensitive to temperature, type in the colloid theory belongs to the sol.

When asphalt content in asphalt appropriate, formed between asphalt micelle has a certain appeal, so the temperature is appropriate, elastic effect of asphalt performance is very obvious, but when the deformation increases to a certain value, and for the plastic deformation. This kind of circumstance belongs to the solubility of the colloid theory – gel structural.

The third kind of asphalt content a lot of asphaltene, micelle formation asphalt contact each other, form the space network structure, the asphalt has obvious elastic effect, it is called the gel structure. On the road performance, it is low temperature sensitivity, but low temperature deformation ability is poor.

Due to the crude oil refining asphalt composition and properties is different, and the methods of refining is also different, so content of various components in asphalt is different , properties of the asphalt is Larger differences.

2.2 The characteristics of the natural bitumen gilsonite

The natural bitumen is a kind of contains natural resin of the asphaltenes which it had be formed after long period of complicated changes under natural conditions, this kind of material is mostly by the oil in the rock fracture, after the earth's crust changes, which is caused by high temperature and high pressure, the role of oxygen in a series of chemical - physical reactions and generated, so it is with asphalt, lake asphalt have bigger difference in nature:

1) The natural bitumen's molecular weight is very big, from several thousand to more than ten thousand, so a high softening point, from 1300C ~ 2700C.

2) The purity of natural bitumen is higher, and very few impurities such as dirt in it.

3) The nitrogen content of natural bitumen as much as 2.5% ~ 7.5%, the nitrogen mainly exists as functional groups such as pyrolle and benzoyl ammonia nitrogen, so the natural bitumen have stronger invasive and high resistance of the free base oxide.

2.3 Comparison of characteristics

General asphalt in the outdoor exposure after a long time, due to the effect of ultraviolet radiation, in just a few years has strong oxidation, so that the asphalt aging metamorphism, but the natural bitumen asphalt has good resistance to weathering. The natural bitumen has mostly used in due to produce black paint, used in industries such as bicycle paint, and the black paint for outdoor conditions has a long application life(SHEN Jinan 1999,2001).

The natural bitumen has the strong affinity of stone, because natural bitumen contains high content of nitrogen, the equivalent of infiltration in the asphalt antistripping agent , so when we are in the asphalt mixture extraction experiment was carried out, the aggregate surface black trichloroethylene after several times of washing, still not to drop.

Shown in table 1 for DaQing crude oil of asphalt and north American natural bitumen and the comparison of domestic natural bitumen components.

Table 1. All kinds of asphalt components in contrast table

Parameter	Type			
	Nsphalt(Ⅰ)	Nsphalt(Ⅱ)	North America	Domestic
Saturates%	7.6	3.1	2.76	2.43
Aromatics%	33.0	43.5	2.76	3.99
Colloid%	55.3	51.6	60.91	63.79
Asphaltene%	4.0	1.8	30.65	29.30

3 The modification effects of natural bitumen of petroleum asphalt

North American natural gilsonite as DaGang asphalt modifier used in SMA pavement construction in 307 national road rebuilding project of HeBei province. North American natural modified domestic petroleum pitch contrast test results such as table 2.

Table 2. North American gilsonite modified domestic index detection

Modifier added amount %	Penetration 25℃	Ductility 15℃	Softening point /℃
0	99	21	43
2	78	18	44.5
3	70	15	45.5
4	63	13	46
5	59	11	46.5

Experimental results show that the north American natural gilsonite modified gilsonite has better efficacy, and modified asphalt and stone adhesive increased significantly. But look from the ductility index, DaGang asphalt itself can not meet the requirement of the indicators, therefore with north American natural gilsonite modified asphalt, indicators can not meet the required value(ZHOU Fuqiang,2006).

On the basis of indoor test, north American natural gilsonite as DaGang asphalt modifier pave the contrast test sections in 307 national road rebuilding project of HeBei province, asphalt mixture field sampling the rut dynamic stability test results shown in table 3.

Table 3. Dynamic stability test results

Gradation type	Dynamic stability time/MN	Asphalt type	Bitumen aggregate ratio %
AC-16I	480	DaGang asphalt	4.7
SMA-16	5040	DaGang asphalt	4.7
SMA-16	7000	North American Modified DaGang	6.3

Indoor test and outdoor experimental results have confirmed that the north American natural gilsonite modified domestic petroleum significantly effect. Is worth a special emphasis on the north American natural gilsonite fusible in domestic petroleum pitch, modification technology and modification equipment are relatively simple, it can even artificial added, so more its popularization and application provided favorable conditions(Hebei Traffic Science Research Institute 2009,Shijiazhuang City Transport 2011,YANG Yang 2007).

In addition, through the study found that the United States NA -u natural gilsonite modified pavement asphalt can significantly improve the adhesion of asphalt and stone, can greatly improve the asphalt surface thermal stability because of its high softening point, so using the modified asphalt, building roads can have very good resistance to deformation. Blending technology of asphalt performance is shown in table 4.

Table 4. NA-U modified Nandagang Asphalt technical performance tables

Parameter	Name of the asphalt	
	Nandagang asphalt	Mix 4% NA-U
Thixotropic Index 25℃,100g,5s	99	63
Brittle point /℃	-12	-9
Softening point /℃	43	46
Ductility 5cm/min,15℃	21	13

Rutting test results and the actual pavement rut has good correlation, this study adopts high temperature conditions evaluated the stability of the mixture. The stability testing is shown in table 5. As can be seen from the experimental data in the table: when natural bitumen gilsonite content of 4%, dynamic stability of the natural bitumen gilsonite modified asphalt is 2 times higher than asphalt (LI Zhongqiu 2004, ZHANG Dengliang 2003).

Table 5. Rutting test

Name of asphalt	Dynamic stability time/MN
Nandagang asphalt	1800
Mix 4% NA-U	4500

Lanzhou produces the natural gilsonite in china ,through experimental study by lanzhou Tianli company shows that using domestic natural gilsonite modified pavement asphalt is also very significant effect, modified asphalt properties as shown in table 6.

Table 6. Modified asphalt performance tables

Natural gilsonite content %	Thixotropic Index 25℃	Ductility 15℃	Softening point /℃
0	87	47.5	114
1.9	58	50.5	121
3.3	47	54	114
4.95	42	55.5	115

4 The reasons of natural bitumen modified petroleum asphalt

According to the introduction of the relevant information, natural gilsonite can improve performance of petroleum asphalt, basically has the following several reasons (JI Genzhong 2002, SHEN Jinan 2000):

1) When natural bitumen added to the asphalt, the interaction of thermal and molecular solvents, large molecular weight micelle rupture, micellar active substances can be adsorbed and combined by small molecules of asphalt, structure formation with natural bitumen as the core internal restructuring, such reprogramming will determine the modification by adding the size of natural gilsonite molecular and the activity of sulfur, nitrogen ,oxygen in internal asphalt.

2) After joining the natural bitumen in asphalt, due to the high activity of natural bitumen molecular weight, thus adsorption colloid and asphaltene of original asphalt, the size of the micelle combined with the most densely populated in the asphalt's gel, the dense combination strengthened the forces between them, prompting base asphalt from sol to gel type ,cohesiveness enhanced obviously, and restructuring is stable, modification effect is not decline over time.

3) Natural bitumen of high nitrogen, infiltrating force strong, can combine well with stone and have the effect of antistripping agent commonly used stoned.

4) Because the natural bitumen is formed by oil in the long geological evolution, so it is the same as the basis of asphalt composition, when use it to modified road asphalt, it put itself stability, oxidation resistance and other excellent properties of passing into asphalt and asphalt matrix does not produce, modified asphalt performance is

very stable, with the other adding agent, such as resin, rubber, compared with incomparable superiority (MA Jingkun 2004, ZHANG Junchao2006).

5 Conclusion

Natural bitumen good modification effect petroleum asphalt has been gradually to be known and accepted by internal and external highway, especially in some higher requirements of engineering, such as long span steel box girder of asphalt pavement, the application effect is good, there are other kinds of modified asphalt can not replace the effect.

Through our research to the following conclusions:

1) Using natural bitumen gilsonite modified asphalt can make its Penetration slash, softening point, the high temperature performance is improved.

2) Marshall stability, dynamic stability and high temperature performance of bituminous mixture is improved after natural bitumen gilsonite modified asphalt, but the low temperature performance basic remain unchanged.

3) The natural bitumen gilsonite modified asphalt technology is simple, low prices, has great popularization value in the highway.

References

SHEN Jinan (1999). “Modified Asphalt and SMA pavement.” The People's Communication Publishing Company, BeiJing.

Hebei Traffic Science Research Institute(2009). “SMA performance and indicators research report”.

Shijiazhuang City Transport(2011). “ North America Gilsonite modified Dagang asphalt research report”.

YANG Yang , HE Zhaoyi(2007). “Study on performance of natural bitumen gilsonite modified asphalt and the mixture”, HANXI ARCHITECTURE, 33(17), 11-12.

SHEN Jinan(2000). “ Trinidad lake natural asphalt and its application prospect”. Foreign highway, 20(2), 28-30.

SHEN Jinan(2001). “Road asphalt and asphalt mixture”, The People's Communication Publishing Company, Beijing.

JI Genzhong(2002). “The development of domestic natural bitumen agent”. Highway traffic science and technology, (6) , 20-21.

LI Zhongqiu , MA J ingkun(2004). “ In-door experiment on Sasobit modifying additive”. Journal of highway and transportation research and development, 21(10) , 27-28.

ZHANG Dengliang(2003), “Asphalt pavement engineering handbook”, The People's Communication Publishing Company, Beijing.

MA Jingkun , LI Zhongqiu(2004). “Road use performance of natural modified asphalt". Journal of highway and transportation research and development, 21(9), 26-27.

ZHANG Junchao(2006). "Application of modified asphalt in Hebei section of Beijing-Shanghai expressway", Communication standardization issue, (6) , 137.

ZHOU Fuqiang , ZHOU Bigong(2006). "Influence of fiber contents on compressive resilient modulus of asphalt concrete", Highway, (12) , 141-142.

Analysis and Treatment of Mountain Roads' Dangerous Sections

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Abstract: In order to study the unique accident characteristics of mountain roads to guarantee safety. Through careful investigation and information search on mountain roads and on the basis of a large number of data and cases of actual accidents, this paper summarized the main features of accidents in mountainous areas. According to the core idea of intrinsic safety, more attention should be paid to the design stage of road construction in mountain areas. Using both qualitative and quantitative methods, this paper sums up the main factors that influence the safety of mountain roads, they are road geometry, road condition and unique road environment in mountain areas. On the basis of the three factors, this paper proposes the principles and methods of dangerous section of governance. Through various analysis and comparison, this paper provides a more reasonable method of identifying black spots. The research results show that: the main reason of road accidents is a continuous curve and stadia, the tunnel without lighting equipment and water seepage inside the tunnel after earthquake are the factors that lead to accident, and the existence of the hidden dangers of accidents are mainly caused by the loosening mountain rocks and the lack of Kanawha rail.
Keywords: Traffic safety; Mountain roads; Accidents; Governance.

1 Introduction

In our country, more and more highways are being constructed in mountain areas in these years. From the situation of road safety, although the absolute number of mountain highway accident is relatively low, but the severity of traffic accidents is very high, the mortality rate of ten thousand vehicle significantly higher than the national average level. In addition, mountain accidents has the characteristics of more major accidents, the accident at night more high mortality, the more rear end collision accident, and more single accidents.

According to the characteristics of mountainous highway accidents, foreign scholars from system of accident characteristics of mountainous highway, studied in detail and found out the standard of a series of mountain highway safety facilities (Hu, Xiang, Babe). China started late, the research has been focused on the road linear design (Zheng), the causes of mountain accident analysis (Wang, Tang), and the strengthening of protection facilities (Wang, 2009).

Unlike the plain areas, restricted by terrain, the steep and sharp downhill linear of mountain road is common and difficult to avoid. The majority of mountain highway will use limit or near limit geometrical index, though do exceed the standard requirements, but in the highway complex environmental condition of mountainous area, easy to cause the driver to the spirit of high tension. So this paper, the characteristics of mountain highway road hazard analysis and control, in order to improve its safety level, with certain practical significance.

2 A method of identifying dangerous sections

On road traffic system, accident-prone points or sections is called an accident black spot (black-spots).There are many conventional methods to identify accident black spots, such as the number of accidents, expert empirical method, quality control method, the accident rate method, but for a long and small traffic road, the analysis of accident black spots does not apply. When an equivalent number of accidents as an indicator, identify accident black spots of mountain road based on non-fixed-length segments is more reasonable. The so-called non-fixed-length segment is divided into segments not refer to sections of equal length, but according to the actual location of the accident to be segmented. Simply put, that is, when the accident location adjacent points are in close proximity, we have consolidated their position and the corresponding extension of the accident segment length; when the position adjacent to the accident spot is more than a certain distance, we will split off them.

Specific steps of this method (Fan):

(1) Collecting data. Find a complete and accurate data of a road traffic accident in the traffic police department, including the absolute number of accidents, location of the accident, injuries, deaths and other data;

(2) Determine the shortest length of the segment and can be classified as the same accident accident point adjacent segments of the maximum distance. The length of the shortest in general can be set to 50m; which can be classified as the same accident point adjacent segments maximum distance and road survey involved years are of a great relationship, the shorter highway mileage is 200m,the longer is 400m.

(3) Statistical analysis. On the statistical data collected: the site of the accident as classification based statistical number, the number of injuries and deaths from the accident within each segment.

(4) Determine the parameter values. All parameters needed for the investigation, the final decision. The number of accidents due to the use of equivalent method, the formula and the required parameters are as follows:

$$A_{EQ} = A + k_1 D + k_2 W \quad (1)$$

Type: A_{EQ} is the equivalent number of accidents; A is the actual number of accidents; D is the number of deaths; W is the number of injured people; k_1 and k_2 are the weights of the number of deaths and injuries, these two parameters are needed to determine the specific sections of specific analysis, there is no value or standard.

(5)Calculation. After the determination of the conditions are thoroughly investigated, according to the formula, calculate the equivalent number of accidents each segment A_{EQ}, and then follow the equivalent number of accidents in the size of the sort, the larger point A_{EQ} is that the value of accident black spots.

3 The example analysis

According to the method of identifying dangerous sections, choose State Road 213 for analysis. 213 State Road (or "State Road 213", "G213 line") is one of China's national highway from north to south, starting on Lanzhou, Gansu, ending in Yunnan Mohan, the entire 2827 km. G213 line through Gansu, Sichuan and Yunnan three provinces, including Wenchuan -Dujiangyan segments on the network was named one of China's top ten killer road, the main reason is that the segment is very muddy, back and forth a driveway, carts, bad car more, one side is the mountain, the other side is the Minjiang River, the speed limit of 40 km. After the Wenchuan earthquake, the road is life channel, after renovation, road conditions have improved, but the rain prone to mudslides and landslides, the risk is still high. Based road hazard identification methods to get more significant incidents sections, and elaborated their dangerous characteristics.

3.1 Analysis of dangerous sections

The main danger point's situation is as follows:

In common State Road and State Road 213 and State Road 317 at 50km + 600m, there is a continuous curve, shown in Figure 1, due to poor mountain, trees, houses of shelter, driver sight distance on corners is bad, road width is narrow, very prone to crash out of the vehicle and vehicle road accident.

Figure 1. Continuous curve

In common 213 State Road and State Road 317 and State Road 52km + 200m, at the side of a mountain road, after the 512 earthquake, because of loose rock mountains, flying rocks often smashed the protective net after falling, rain is a factor of landslides, there is a big traffic hazards. The other side of the road is a fast flowing river, only a layer of guardrail can intercept the vehicle, if the vehicle out of control out of the way, it will lead to serious injury or death. As shown in Figure 2.

Figure 2. Roadside flying rocks

In common State Road 213 State Road 317 and State Road 52km + 900m (grass tunnel exit), there is a sharp bend, because the 5.12 earthquake, the old State Road 213 in the segment bridges were destroyed, making the new line is designed to a small radius corners, change bend road located beside the tunnel exit. No lighting in the tunnel, is the high point of the accident, there is a fork in the road near profiled, because of the green belt to block the line of sight, and it is easy to cause traffic accidents.

In common State Road 213 State Road 317 and State Road 53km, grass tunnels, power plant dam built on the tunnel, the tunnel seepage long since March 2011 and there is no lighting, water potholed roads, slippery roads inside the tunnel , poor road conditions, it is easy to cause traffic accidents too.

In common State Road and State Road 213 and State Road 317 at 53km + 800m (grass on the 2nd North Bridge, Railway Tenth), a slight landslides during the rainy season often block the road that leads to fewer cases of traffic accidents. As shown in Figure 3:

Figure 3. Minor mudslides segment

3.2 Countermeasures

The main cause of the accident is a continuous curve and line of sight is bad. There are three control points:①Set a reasonable speed. You should give the reasonable speed limit for the driver to have a sufficient emergency response and processing times, however, in our country, some drivers do not mind the speed limit, we can set the speed at the starting point of a continuous curve and capture facilities, make drivers force to slow down.②Set obvious warning signs at both ends of a continuous curve, reminding front of a continuous curve and accident-prone. Warning signs should be ergonomic, concisely, to the drawings, Fig should be simple and easy to read and understand. The warning signs should be eye-catching color, and night must have strong reflection effect, and warning sign distance continuous curves start distance should be reasonable.③Remove the roadside obstacles, give the driver enough corner vision. For the mountain, can clear the effect of the prominent part of the driver's field of vision, to form a concave cavity; the trees should be cut off or cut the height, to not affect the driver's field of vision.

The hidden dangers of accidents is mainly the problem of mountain rocks loose and Kanawha barrier caused by. There are two control points:①The mountain of rock debris is more, can send special vehicle to clean up, remove the clastic stone. At the same time increase the conservation efforts have protective net, once the damage is to be replaced as soon as possible.②The buffer is set in the Kanawha side, can be accumulated on the clastic Hill Road in Kanawha end of the guardrail, debris have very good effect for alleviating the vehicle kinetic energy, when the vehicle decelerates rapidly broke through the barriers, so as not to fall into the river.

For small radius section and tunnel lighting bad situation.①The small radius bend vehicle centrifugal force is larger, and increases with the increasing speed, so limiting vehicle speed is the best treatment, set up warning signs in the reasonable position of curve ends, to remind the driver in front of a small radius, and set a reasonable speed limit;②A great relationship between the frequent accidents in the tunnel with no lighting equipment. The longer time of dark adaptation of human, adequate lighting effects can effectively help the body fight the dark adaptation, the tunnel speed also have reasonable limits;③the fork in the road of the aliens, plus not to the driver to provide adequate vision, natural accident prone. At a distance of alien three fork reasonable position setting briefly graphics to illustrate three fork shape, clear or green trim facilities so that it does not affect the driver's field of vision.

The present situation of grass slope tunnel and earthquake also has a certain relationship. The seepage in the tunnel and the uneven road surface, leading to accumulation of water inside the tunnel, and there is no lighting facilities, poor road conditions, traffic accidents easily occur. The main control scheme are: ①The reinforcement of tunnel. The use of cement will lead paint, but with the seepage of the accumulation of time, cement is likely to fall off, the actual implementation may be difficult.②The construction of the lighting facilities. Part of the funds for the lighting facilities settings, select waterproof device, ensuring enough lighting.③On the tunnel road renovation, adding drainage ditch. The key is the refurbishment of longitudinal slope of 2%~3% set, so that infiltration of water can naturally along the drain outflow, but not the whole wet pavement; repair of hollows, reduce pavement roughness degree.

Debris flow treatment focuses on prevention and cure is not in. In view of mud rock flow occurred, the priority is to place built after debris flow blocking stone dam, to prevent debris flow down the spread of. Secondly it should start from the source, to reduce the debris on the reinforcement of mountain, rainwater drainage, not to the debris flow formation provide conditions, planting trees and grass is the most economical way.

4 Conclusions

(1) Combining with accident data carries on the analysis to the present situation of mountain highway safety, according to current research status at home and abroad, get the necessity to carry on the research of highway in mountainous area of the dangerous section of the road.

(2) Give a reasonable identification method of the mountain road accident black spots: Based on the equivalent number of accidents as an indicator of mountain highway segmentation method of non-fixed length. Investigate mountainous highway concrete road, select State Road 213 and State Road 317 public sections of several accident black spots, carries on the risk analysis, and puts forward the more reasonable countermeasures in theory.

(3) The main factors affecting the mountain road safety is linear, road and environment, combining accident principle, using the knowledge to present reasonable corrective principles and methods, to provide a theoretical basis for the safe management of mountain roads.

5 Recommendations for Future Research

The next step of research is the establishment of mountain highway safety audit index system.

References

Hu, J. B. (2003). “Situation and New Developments for Studying on Improving Road Safety in High Motorized Countries.” *Northeastern Highway,* 26(3):121-123.

Xiang W., Cao M., and Yang, J. C. (2005). Plan and Design of Highway Traffic Signs, 156. Transport Standardization.

Babe, G.B. (1990). Road Conditions and Traffic Safety. Shanghai: Tongji University press.

Zheng K., and Feng G.Y. (2002). “The Technical Analysis of Road State in Traffic Accidents Frequently Occurred Site.” *Journal of Changsha Institute of traffic*, 16(l), 64-65.

Wang Y. Y. (2008). Research on the Accident Causations of Mountainous Road. Beijing University of Technology.

Tang G. L. (2004). Study on The Connection of The Mountain Roads Conditions and Accident Action Mechanism and The Accident Counter-Measures. Southwest Jiao Tong University.

Wang Y. J. (2009). The Optimization of Mountain Highway Traffic Signs and Deceleration Vibration Marking. Chang'an University.
Fan X. (2006). Mountain Highway Safety Evaluation. Chang'an University.

Multiple Attribute Group Decision Making by Analytical Hierarchy Process in Pavement Preventive Maintenance

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Abstract: Based on the connotation of decision problem of expressway pavement preventive maintenance, multi-target multi-attribute pavement preventive maintenance decision is divided into four layers as the target layer, criteria layer, indicator layer and measure layer. Considering the cost of preventive maintenance measures, traffic characteristics, technical factors, construction factors as the evaluation value of the target layer, and using the group decision model to reduce the subjective factors, we can get the best preventive maintenance decision measures. Finally, the article illustrates how to develop a reasonable conservation measure by using the case studies.
Keywords: Road projects; Preventive maintenance; Conservation measures decision; Technique for order preference by similarity to an ideal solution (TOPSIS); Complex multi-attribute decision making.

1 Introduction

Traditional maintenance decision sometimes cannot be better to prolong and keep the usability of expressway. Preventive maintenance management system is developed in abroad, like The United States, Japan and so on .British use modern management techniques to play the efficiency of the original road, in order that the road can be better to serve the socio-economic development, peoples travel demand and environmental need. Cuelho E, Mokwa R and Akin M (2006) through the decision tree method, WeiCJ and Tigh S(2004) through decision matrix method choose preventive maintenance measures, But the transplant performance is not good enough. Some advanced methods have been used for maintenance decision, such as expert system, neural network. Neural network and expert system have been widely used in the selection program of foreign maintenance measures, and show tremendous superiority, however the two methods at present in our country are not widely used. In domestic, based on the interaction between the each factor of the maintenance system, ZengFeng (2013) use the analytic network process to analyze preventive maintenance measures. It will bring great difference to appraise a same problem due to many experts having different viewpoint on each index and exiting deviation, although researchers have done a large amount of research on the preventive maintenance decision. Therefore, how to assemble the experts' opinion in the decision-making process is a key link in the maintenance decision. Based on level analysis, the article analyze the problem of the expressway pavement preventive maintenance decision, use the TOPSIS (technique for order preference by similarity to an ideal solution) to aggregate groups of experts decisions to reduce the subjective factors, and then get the optimal preventive maintenance measures to guide decision-makers to adopt reasonable preventive maintenance measures in order to enhance the comprehensive service level of freeway.

2 Construction of the index system for preventive maintenance decisions

2.1 The process of preventive maintenance measures implemented

Expressway preventive maintenance measures firstly must be on the basis of the basic characteristics of the road to analyze the expressway, and then judge whether it can carry out preventive maintenance. When it satisfies the preventive maintenance conditions and then we should make the comprehensive evaluation of each program measures cost, technical features, constructional difficulties and measures for the driving effect, aggregate groups of experts' decision, and then determine the best maintenance measures program so as to achieve the corresponding goal. The process of preventive maintenance decision is following in Fig1.

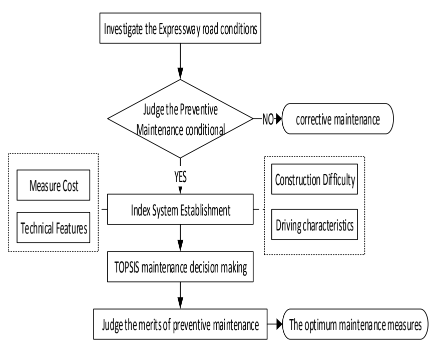

Figure 1. Implementation process of preventive conservation measures

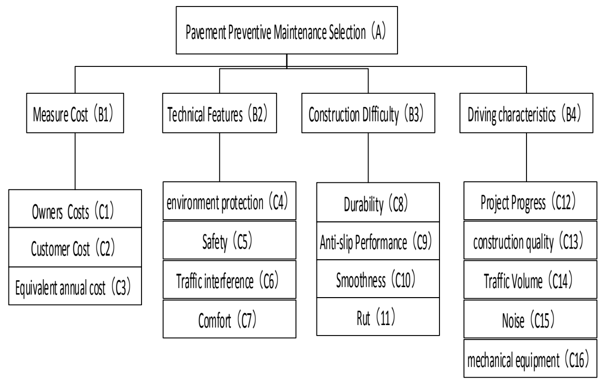

Figure 2. Preventive Maintenance indicator system structure diagram

2.2 The confirm of the system of preventive maintenance decision index

When selecting the best preventive maintenance measures, we should consider many factors, for instance, preventive maintenance measure costs, and the construction difficulty of measures itself, the security of measures and so on. On this basic the impact on the vehicle must be considered. According to the related literature, using a set of evaluation system to evaluate the entire situation is unreasonable and we should base on management departments and owner's specific requirements for specific analysis.

The constructed evaluation index system of preventive measures in figure 2 is divided into four levels: measures cost factors, factors of affecting traffic characteristics, the technology itself of measures and construction factors. Among them, the sub-indexes of measure costs factors belong to the quantitative index; the other indexes can be denoted respectively the influence degree of the measures by using index 0-1 in the process of calculation.

3 Based on the analytic hierarchy process to determine the index weight

As the preventive maintenance decision of our road has the characteristics of multi-factor, multi-level and multi-objective, and the method of AHP ranks vector to represent the relative importance of different factors. So the preventive maintenance measures can be divided into four basic steps when we use this method.

(1) Build the hierarchical structure model of multi-objective decision-making. Hierarchical structure model include target layer *A*, criterion layer *B*, layer criteria *C* and measures *Q*.

(2) Construct judgment matrix and single-level sorting. Experts use the Delphi method and the 1-9 scaling method combining the actual problems to construct the both judgment matrix of the factors of each layer

(3) Single-level sort. Let *B* layer number is n, using the sum-product method to normalize each column of the judgment matrix *A* of *A*-*Bi,* and then get the

normalized matrix $\left(\overline{a_{ij}}\right)_{n\times n}$

$$\overline{a}_{ij} = a_{ij} / \sum_{i=1}^{n} a_{ij} \, (j = 1, 2, \cdots, n) \tag{1}$$

The summation of each row of normalization judgment matrix,

$$W_i = \sum_{j=1}^{n} \overline{a_{ij}} (i = 1, 2, \cdots, n) \tag{2}$$

Let $W = (W_1, W_2, \cdots, W_n)^T$,and normalize it, and then the relative weight of the target layer A relative to the criterion layer B is

$$W^{(1)} = \left(W_1^{(1)}, W_2^{(1)}, \ldots W_n^{(1)}\right)^T \tag{3}$$

Similarly, the relative weight of the sub-criterion layer C relative to the criterion B is:

$$W_i^{(2)} = (W_{1i}^{(2)}, W_{2i}^{(2)}, \cdots, W_{mi}^{(2)})^T (i = 1, 2, \cdots, n) \tag{4}$$

Among it, the *m* is the criterion layer in *Bi* criterion layers.

The relative weight of the sub-criterion layer C relative to the criterion D is:

$$W^{(2)} = \left(W_1^{(2)}, W_2^{(2)}, \ldots W_n^{(2)}\right)^T \tag{5}$$

(4) Consistency test. Consistency index *CI* and random consistency index *CR*:

$$CI = \left(\lambda_{\max} - n\right) / \left(n - 1\right), \quad CR = CI / RI \tag{6}$$

Among (6) *CI* is consistency index; $\lambda_{\max}$ is the biggest eigenvalue of the judgment matrix; n is the order of judgment matrix; *RI* is the average random consistency index.

The average random consistency index as follow（in table 1）

.

Table 1. Consistency index table

Order	1	2	3	4	5	6	7	8	9
RI	0	0	0.52	0.89	1.12	1.36	1.41	1.46	1.49

When CR<0.1, we consider that the consistency of the judgment matrix is acceptable, then continue the solution. Otherwise we must adjust the judgment matrix until it satisfies the requirement of consistency.

(5) The total level of sorting. The total level of sorting is the criterion layer relative to the target layer, and the comprehensive weight is:

$$W^{(0)} = W^{(2)} \cdot W^{(1)} \tag{7}$$

4 The method of TOPSIS to select preventive maintenance decision measures

In reality, experts may have different opinion on the identity of each index and also have deviation on it, then to evaluate the same problem may have difference. Therefore, how to assemble the experts' opinion in the decision-making process is a key link in the maintenance decision. Choose TOPSIS method to select maintenance decision. The basic idea is to first select a positive ideal and negative ideal solution, and then find a scheme that is most close to the positive ideal solution and is most far away from the negative ideal solution as the optimal scheme. The TOPSIS introduce the relative closeness coefficient to weigh two distances, and judge the quality of solution.

(1)Q preventive maintenance measures and m indexes determine the judgment matrix $G=(g_{ij})_{Q\times m}$, then normalize the judgement matrix, finally obtain the normalized judgment matrix $U=(u_{ij})_{Q\times m}$.

(2)Construct weighted standardization decision matrix:

$$S = (s_{ij})_{Q\times m}, \quad s_{ij} = w_{ij} \cdot u_{ij} \,(j = 1, 2, \cdots, m) \tag{8}$$

(3)Determine the evaluation of the positive ideal solution $V+$ and negative ideal solution $V-$,

$$V^{+} = \left\{ (\max_{i} s_{ij}), (\min_{i} s_{ij}) \right\} \begin{pmatrix} i = 1, 2, \cdots, p \\ j = 1, 2, \cdots, m \end{pmatrix}, \quad V^{-} = \left\{ (\min_{i} s_{ij}), (\max_{i} s_{ij}) \right\} \begin{pmatrix} i = 1, 2, \cdots, p \\ j = 1, 2, \cdots, m \end{pmatrix} \tag{9}$$

(4)Determine the relative closeness coefficient of the positive and negative ideal solution of the preventive maintenance measures

$$R_i = D_i^- / (D_i^+ + D_i^-) \tag{10}$$

$$D_i^+ = \sqrt{\sum_{j=1}^{m}(s_{ij} - V^+)^2}\,(i = 1, 2, \cdots, m),\ \ D_i^- = \sqrt{\sum_{j=1}^{m}(s_{ij} - V^-)^2}\,(i = 1, 2, \cdots, m) \tag{11}$$

The bigger of R_i in (10) the better of the scheme of preventive maintenance measures, namely the corresponding measure is more appropriate.

5 Application of group decision-making level

5.1 Case description

A section of an expressway single-track length is 10km, two-way six-lane in Hubei, opened in August 2009. A comprehensive survey conducted in May 2013 shows that the expressway is good road conditions and part of the road is short of anti-sliding and local sections have cracks. Management hopes through appropriate conservation measures to improve pavement anti-sliding performance, at the same time can repair the pavement crack, improve the pavement smoothness level, reduce maintenance costs, shorten the construction period, and reduce the degree of disturbance to traffic.

5.2 Calculation and analysis of the case

The main restricting factors of decision goal which is divided into the construction difficulty, cost, technical measures, measures of driving and so on as the traffic analysis index, according to the index of dominance and subordination, the article has the whole structure of index system is divided into 4 levels and establish the decision model as shown in Figure 2, according to figure 1 preventive process. According to the figure 1 process have 3 options, micro surfacing, composite seal, and thin overlay.

(1)Calculate the comprehensive weights On the basis of Delphi method and 1-9 scaling method and formula (1) ~ (7) to be the weight coefficient of the TOPSIS evaluation.

$W^{(0)} = (0.074, 0.148, 0.078, 0.034, 0.071, 0.062, 0.033, 0.044, 0.026, 0.052, 0.078,$
$0.076, 0.072, 0.063, 0.04, 0.049)$

(2)Evaluate the index quantification to the 3 kinds of preventive maintenance measures according to Figure 2, as follow (Table2).

Table 2. Candidate Evaluation Table preventive conservation measures

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}
Q_1	14	6	10.3	0.82	0.88	0.91	0.85	0.8	0.9	0.94	0.84	2	1	0.74	0.73	0.87
Q_2	10	6	8.25	0.69	0.76	0.63	0.91	0.7	0.6	0.94	0.79	1	1	0.83	0.81	0.97
Q_3	8	8	5	0.82	0.73	0.91	0.84	0.9	0.9	0.94	0.84	3	1	0.76	0.62	0.79

(3)Calculate the weighted norms of decision matrix $S=(s_{ij})_{Q\times m}$ According to the formula (8), (3 kinds of preventive measures such as table 3).

Table 3. Three kinds of preventive measures decision table specification

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
Q_1	0.0323	0.0444	0.0341	0.0119	0.0263	0.0230	0.0107	0.0146
Q_2	0.0231	0.0444	0.0273	0.0100	0.0227	0.0159	0.0115	0.0128
Q_3	0.0185	0.0592	0.0165	0.0119	0.0218	0.0230	0.0106	0.0165
	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}
Q_1	0.0097	0.0173	0.026	0.025	0.024	0.020	0.0135	0.0162
Q_2	0.0065	0.0173	0.024	0.012	0.024	0.022	0.015	0.0180
Q_3	0.0097	0.0173	0.026	0.038	0.024	0.020	0.0114	0.0147

(4) Calculate V^+ and V^- according to the formula (9).

$$V^+=(0.0323,0.059,0.0341,0.0119,0.026,0.023,0.011,0.0165,0.0997,0.0173,0.0265,\\ 0.038,0.024,0.0224,0.0150,.018072)$$

$$V^-=(0.0185,0.0444,0.0165,0.0100,0.0218,0.159,0.0106,0.0128,0.0065,0.0173,\\ 0.249,0.0126,0.024,0.020,0.011,0.0147)$$

(5)Determine the distance from every index of 3 preventive maintenance measures to positive and negative ideal solution according to the formula (10) ~ (11), and then calculate the relative closeness of the supplier and the ideal solution. (The results in table 4).

Table 4. Candidate evaluation results of preventive conservation measures

	Q_1	Q_2	Q_3
D_i^+	0.0921	0.0988	0.092
D_i^-	0.262	0.266	0.263
R_i	0.259	0.270	0.261

Management hopes through appropriate conservation measures to improve pavement anti-sliding performance, repair the pavement crack, improve the pavement smoothness level, reduce maintenance costs, shorten the construction period, and reduce the degree of disturbance to traffic. The preventive measures and the ranking is a composite layer (R_2=0.270)>thin overlay (R_3=0.261)> micro surfacing (R_1=0.259). So the Optimal for Expressway Preventive Maintenance Measure is the composite seal.

6 Conclusions

Preventive maintenance decision has the character of multiple attributes, multi object properties, and proper preventive maintenance treatment selection is complex system engineering. It is scientific and applicable to combine the AHP and TOPSIS to analyze the pavement preventive maintenance decision, providing an effective method for the selection of the proper preventive maintenance measures, guiding the scientific maintenance to improve the social and economic benefits of expressway.

References

CHEN Lixiang, Cao Guo(2012). "Model based on multiplayer Network AHP commercial banking network security evaluation model".*Computer Applications.*32 (2): 480-484

Cuelho E, Mokwa R, Akin M(2006). "Preventive maintenance treatment of flexible pavements: A synthesis of expressway". Bozeman: Western Transportation Institute. 2006

Shatnawi S,Marsh R, Hicks R G,etal(2006)."Pavement preservation strategy selection in California" .The 11th AASHTO-TRB Maintenance Management Conference, Charleston South Carolina: Transportation Research Board. 29-35.

Tsai Y J, Wu Y, Pitts E(2006).". Implementing enhanced Georgia department of transportation pavement preservation program". The 85th Transportation Research Board Annual Meeting, Washington DC: Transportation Research Board.

Wei C J,Tighe S(2004)."Development of preventive maintenance decision trees based on cost effectiveness-An Ontario case study". The 83rd Transportation Research Board Annual Meeting, Washington DC: Transportation Research Board :1-11.

ZENG Feng,ZHANG Xiaoning（2013）."Pavement preventive maintenance decision-making by analytic network process" Systems Engineering-Theory&Practice. 33(3):666-681

Microstructure of Modified Asphalt of PPA in Conjunction with SBS

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Abstract: The traditional polymer modified asphalt is stirred and sheared using the specialized equipment in order to making modifier is evenly dispersed in the asphalt. This belongs to physically blending modification. So there are some problems of poor compatibility and insufficient heat storage stability between asphalt and modifier. However, PPA modified asphalt belongs to the chemical modification which can effectively make up for the inadequacy of traditional polymer modified asphalt and improve the road performance. Microstructure of modified asphalt of PPA in conjunction with SBS is deeply researched base on these four tests in this paper. These tests include four constituents、fluorescence microscopy、infrared spectroscopy and DSC. Modification mechanism of PPA modified asphalt is explored from different angles. The internal reasons are analyzed and discussed that PPA can effectively improve the high temperature performance, ageing resistance and thermal storage stability performance by using the principle of the micro chemistry. The optimum dosage of PPA is 0.75~1.5%.
Keywords: Poly-phosphoric acid; Microstructure; Modified asphalt; Modification mechanism.

1 Introduction

Polyphosphoric acid (PPA) can effectively improve the high temperature performance，fatigue resistance and aging-resisting performance of asphalt. But it is making less contribution at the low temperature performance of asphalt. The modified asphalt of PPA in conjunction with SBS can enhance not only the high temperature performance and low temperature performance but also the thermal storage stability. It is more suitable for the application in northern China. However, modified asphalt of PPA belongs to the chemical modification and SBS modified asphalt belong to physical modification. The internal microscopic structure change of asphalt of PPA in conjunction with SBS is researched base on these four tests in this paper. These tests include four constituents、fluorescence microscopy、infrared spectroscopy and DSC. Internal factors of modified asphalt are in-depth analyzed after blending two kind of asphalt modifier of PPA and SBS in order to explore modification mechanism of asphalt of PPA in conjunction with SBS.

2 Four Constituents

Four constituents analysis utilize the principle that material dissolve in alternative in different organic solvent and absorb in the alternative in different adsorbent. So the asphalt can be separated four chemical similar characteristics constituents such as asphaltene、saturated fraction、aromatic fraction and colloid. It is analyzed four constituents of asphalt by solvent sediments and chromatographic columns in this experiment. As is well known, polymer is dispersed many granules by swelling and high speed shearing when polymer is joined in asphalt. It is physical miscible process and polar of the swelling polymer is similar to colloid. It is considered that the SBS has little influence on performance of asphalt because polymer is used as part of colloid. So it is major studied on that PPA influence on each component of asphalt in this paper. The proportion of PPA is 0%、0.5%、1%、1.5% and 2% . The test results are shown in fig1.

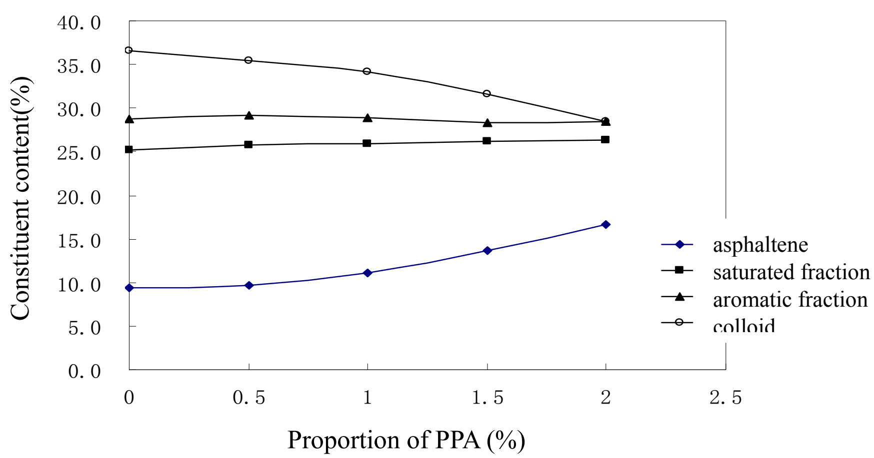

Fig1. The relationship between different proportion of PPA and asphalt

The content of asphaltene obviously increase and the content of colloid obviously decrease When the proportion of PPA increase from 0% to 2% from fig1. The content of asphaltene increase from 9.4% to 16.7% and the content of colloid decrease from 36.6% to 28.5%. The content of saturated fraction and aromatic fraction has no significant change. Changes in constituents of asphalt can affect changes of colloidal structure according to modern colloidal theories. The contents of asphaltene increases will lead to the contents of colloidal core increase. Colloidal core can absorb surrounding oil which results in the formation larger micelle. The number of micelle increase means the distance of micelle decrease and part of micelle even come into contact with each other. So the viscosity of asphalt increases because the forces of between micelles increase. As the same time, the forces of between micelles increase with the volume of micelles which lead to form the intensive space network structure. That is helpful to enhance the storage stability of asphalt.

PPA contributes to the colloidal structure of asphalt conversion from sol to sol-gel structure. The content of asphaltene increase and colloid decrease which lead to asphalt stiffness increase, the softening point and viscosity increase and penetration reduce. So PPA can effectively improve the high temperature performance and storage stability of asphalt.

3 Infrared absorption spectroscopy

Infrared absorption spectroscopy belongs to the category of molecular absorption spectra which is usually used to analyze chemical structure of substances. The principle is what polar molecules absorb infrared ray correspond of vibration energy levels. Parts of wavelengths radiation are absorbed into sample when the sample is irradiated by different wavelengths infrared ray. Some wavelengths of radiation are absorbed by the sample, then weaken, thus formed the infrared absorption spectrum. We can analyze group and molecule structure of the material from the position、the number、the relative intensity and the shape of absorption peak of the infrared absorption spectrum.

First the asphalt is dissolved in 5 percent carbon tetrachloride solution. Then this solution is smeared on flake of potassium bromide in order to form a thin film coating. Finally we can analyze the sample which carbon tetrachloride solution is volatilized using the spotlight. We consider that the coating thickness of asphalt is not being the same on the potassium bromide[1]. It's only comparison of the spectral curve of different samples is pointless because the different coating thickness will affect the strength of the absorption peak. So we can compare changes of different asphalt absorption peaks using the area ratio method.

It is chosen the proportion of SBS is 0%、3% and 4% and the proportion of PPA is 0%、0.5%、1 %、1.5% and 2% under each SBS dosage. We can know that absorption peak of asphalt is mainly located in 1030 cm^{-1} from spectrum of asphalt. So we calculate percentage of absorption peak area in 1030 cm^{-1} by the sum of absorption peaks area within 600 cm^{-1}-2000 cm^{-1} as the reference area. It is showed by the index of $I_{s=o}$ and the test results are shown in Fig2. At the same time we can know that the absorption peak of SBS modified asphalt mainly located in 6965 cm^{-1} and 97 cm^{-1}. It is showed by indexes of $I_{C=C}$ and I_{C-H}. The test results are shown in fig3 and fig4.

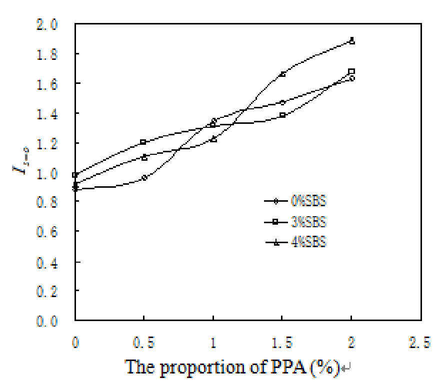

Fig2. The relationship between the index of $I_{s=o}$ and different proportion PPA

We know that the index of $I_{s=o}$ increase with the proportion of PPA increases in the different dosage of SBS from fig2. It is due to the index of $I_{s=o}$ corresponds Pressure sulfonic functional group what belong to polar group. Its can Interact with asphalt to form Larger and more closely new group. So it leads to increase the viscosity of asphalt. At the same time, the dosage of SBS has little effect on the index of $I_{s=o}$.

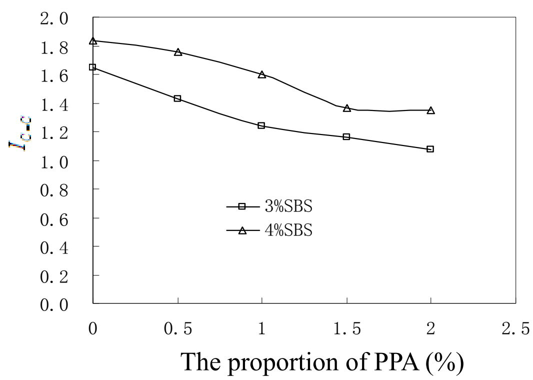

Fig3. The relationship between the index of $I_{C=C}$ and different proportion PPA

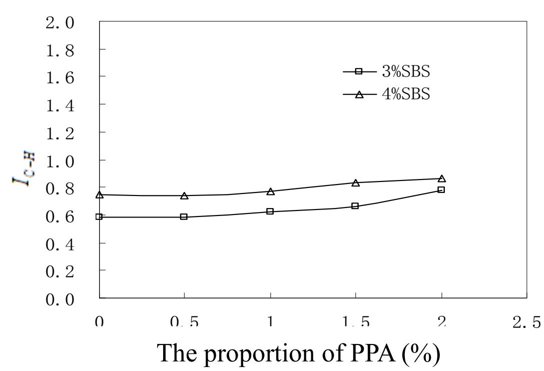

Fig4. The relationship between the index of I_{C-H} and different proportion PPA

We know that the index of $I_{C=C}$ gradually decrease with the proportion of PPA increases but I_{C-H} basically unchanged from fig3 and fig4. The index of $I_{C=C}$ decrease indicates that more $-C=C-$ double bond of butadiene block have been disconnected when the PPA is added. Asphalt activity increasing can increases the crosslinking effect between SBS and the grafting function between SBS and asphalt. Crosslinking of SBS contributes to form a network structure that asphalt be wrapped in the network structure and prevent separation between SBS and asphalt. There are products present in the interface of SBS and asphalt by the grafting function between SBS and asphalt[2]. It is can be prevent the aggregation of SBS and inhibit the separation of SBS and asphalt. Obviously, PPA is added to the SBS modified asphalt that it's can enhance network structure to improve high temperature storage performance of SBS modified asphalt.

4 Fluorescence microscope

Fluorescence microscope is an effective tool for analysis of phase structure of polymer modified asphalt. Polymer phase will produce a fluorescent of the modified asphalt while asphalt phase does not inspire any light when they are inspired by Shortwave light of ultraviolet ray. Fluorescence microscope using this principle can clearly distinguish the polymer phase and asphalt. Fluorescence microscopy can real observe phase structure of the modified asphalt and won't destroy the morphology of polymer phase and asphalt phase because of using the reflected light field.

It is chosen the proportion of SBS is 3% and 4%，the proportion of PPA is 0% 、0.5%、1 %、1.5% and 2% under each SBS dosage. The test results are shown in fig5.

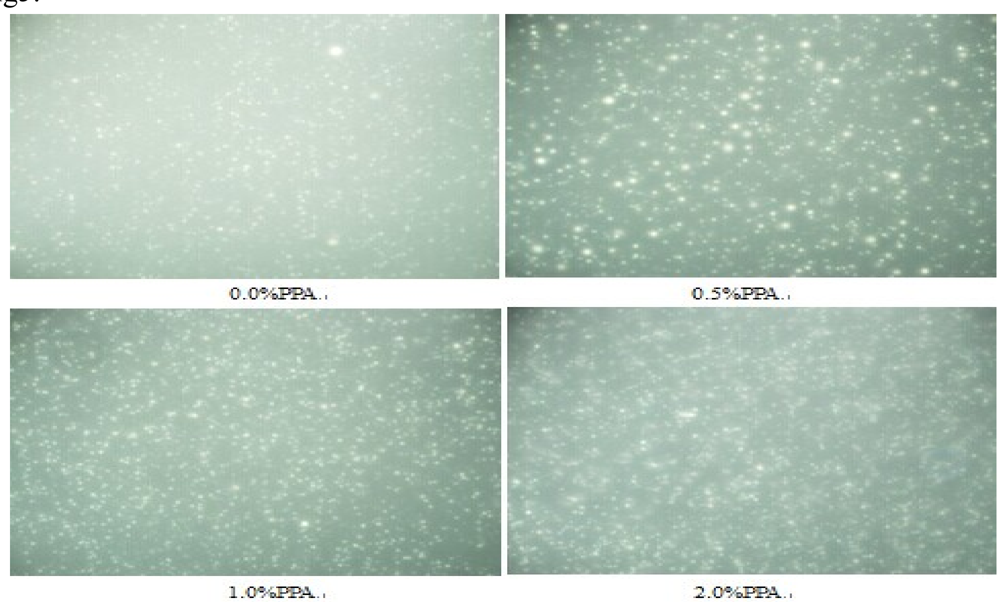

Fig5. 4% SBS+PPA（different proportion）

Particle size of SBS has larger difference having a lot of big size particles and uneven distribution when the PPA is not added from fig5. SBS particle mutual independent suspend in the asphalt and does not form network structure. Particle size of SBS is less and there is an increased in the number of particle with the increasing of proportion of PPA that the distribution is more even. Big size particles of SBS cannot be basically detect when the proportion of PPA more than 1%. Its show that PPA can effectively prompt SBS to disperse into tiny particles in the process of making modified asphalt. It is can effectively shorten the particle spacing because of the number of SBS particle increases and uniform distribution and make the synergy improved. The synergy was occurred by the long-term effect of many particles through interface layer[3]. That is can enhance network structure of modified asphalt and improve the high temperature storage performance.

At the same time, the smaller the SBS particle is, the easier light component of asphalt will penetrate. It is conducive to penetrating through macromolecule network of SBS which can promote infiltration and adsorption between asphalt and SBS and swelling of SBS particle. Obviously PPA can effectively reduce the cost of the asphalt and improve its storage stability using the modified asphalt of PPA in conjunction with SBS.

5 Differential scanning calorimetry（DSC）

DSC analyzes the power difference and temperature curve between sample and reference under a certain temperature. So the glass transition temperature of material can be found in order to evaluate its low temperature performance. The glass transition temperature of asphalt is a reversible change from viscous flow state or rubber state to a relatively rigid of glassy state. The glass transition temperature of asphalt is the temperature of glass transition when the asphalt starting to happen.

Asphalt is a complex structure that it is made of high polymer and low polymer and some small molecule. Asphalt is the state of solid and liquid aggregation at different temperature. The change of the aggregation state determines the changes of asphalt performance which mainly reflect the transformation from plastic to brittle. The optimum glass transition temperature should be lower than its service temperature in order to ensure the low temperature performance of asphalt. So asphalt has a good ability of deformation resistance during the whole service. The lower the glass transition temperature is, the better the low temperature performance will be.

It is chosen the proportion of SBS is 0%、3% and 4% and the proportion of PPA is 0%、0.5%、1 %、1.5% and 2% under each SBS dosage. The test results are shown in fig6.

We can see that the glass transition temperature has little change during the process of the proportion of PPA is gradually added from 0% to 2% under different SBS dosage. So PPA has little impact on low temperature performance of asphalt. Meanwhile we can also see that the glass transition temperature of modified asphalt is decreased with the increase of SBS dosage[4]. This is mainly due to the glass transition temperature of SBS is lower than asphalt in low temperature (the glass transition temperature of SBS is usually - 80 □ or so). Therefore, the increase of SBS dosage is helpful to improve the low temperature performance of asphalt.

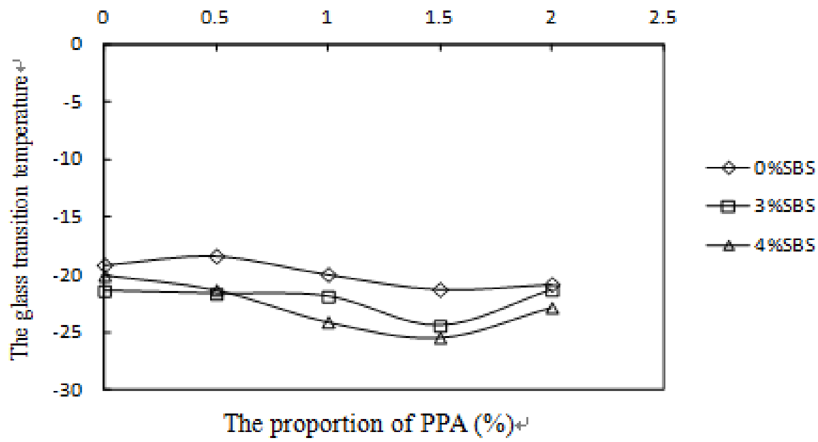

Fig6. The influence of PPA proportion on the glass transition temperature

6 Conclusions

(1) PPA is added in the asphalt which results in asphaltene and saturated fraction content increase but the aromatic fraction and colloid content have no obvious change. That is can improve softening point and viscosity and reduce the temperature sensitivity. So PPA can effectively improve the high temperature performance of asphalt.

(2) PPA contributes to the colloidal structure of asphalt conversion from sol to sol-gel structure. It is can increase the crosslinking effect between SBS and the grafting function between SBS and asphalt in order to enhance the network structure of asphalt. That is helpful to improve high temperature storage performance of SBS modified asphalt.

(3) PPA has little impact on low temperature performance of asphalt but the increase of SBS dosage is helpful to improve the low temperature performance of asphalt.

References

Li Yuan，Study on modification mechanism and pavement performance of SBS compound modified asphalt，2013.6.

Wang Yunpu, Zhang Feng, Study of 90# road asphalt modified by poly-phosphoric acid and SBR，2007.09.

Wang Qinsheng, Yang Shuren, analysis on reaction mechanism of PPA modified asphalt and its properties，2011.2.

Zhang Henglong, Shi Caijun, Yu Jianying, Shen Junan, Modification and its mechanism of different asphalt by polyphosoric acid，2013.4.

Zhang Feng, Wang Yunpu, Properties of asphalts modified with polyphosphoric acid and styrene-butadiene rubber, 2009.01.

Effect of Elongated and Flaky Particles Content on the Durability of Concrete

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Abstract: Considering the durability of concrete, properties of raw materials have a marked effect, especially the properties of coarse aggregate which takes most position in concrete. In this paper, effects of elongated and flaky particles content on the durability of concrete were studied. 6.8%, 16% and 25.2% were chose as the dosages of elongated and flaky particles. The workability, compressive strength, drying shrinkage and impermeability were studied. The results revealed that all properties which were mentioned above were weakened with the increasing of elongated and flaky particles content. According to the results of this research the content of elongated and flaky particles should be fewer than 16%, while the workability and maximum packing density can be achieved.
Keywords: Concrete; Coarse aggregate; Durability; Elongated and flaky particles.

1 Introduction

Concrete is wildly used all over the world due to its excellent properties. Properties of concrete are determined by raw materials, such as cement, fine aggregate, coarse aggregate and chemical admixtures. Coarse aggregate takes almost 40% in concrete, so it has marked effect on concrete properties. Elongated and flaky particles content of coarse aggregate is an important property factor, and it is considered as a harmful factor (Sengupta, 2009) (Zeng, 2011). The effects of elongated and flaky particles content on workability and compressive strength were studied by many researchers (Zhang, 2013) (Liu, 2012), but its effect on durability has not been studied so widely. As the developing of construction industry, the durability of concrete attracts more and more attention. So it is necessary to study the relationship between durability and elongated and flaky particles content. In this paper, effects of elongated and flaky particles content on the durability of concrete were researched.

2 Materials and experimental methods

Cement of P·O 32.5, P·O 42.5 and class Ⅰ fly ash were used in all mixtures, and the properties of cement and fly ash were given in Table 1 and Table 2. Cement of P·O 32.5 was used in C30 concrete, and Cement of P·O 42.5 was used in C60 concrete. Fine aggregate used was river sand with the special gravity of 2.63g/cm^3

and the fineness module of 2.6. Coarse aggregate was crushed limestone rock with the elongated and flaky particles content of 6.8%, 16% and 25.2%. Air content and workability were adjusted by adding appropriate amounts of SJ-2 saponin air entraining agent and UNF-5 naphthalene formaldehyde sulphonated superplasticizer. The proportion of concrete mixture was given in Table 3. In order to study the effects of paste aggregate ratio on the durability of concrete, two paste aggregate ratios were chosen, and *P*/*A* stands for the ratio of paste to aggregate.

Table 1. The properties of cement

Type	Water requirement (%)	Time of initial setting [min]	Time of final setting [min]	Flexural strength [MPa] 3d	Flexural strength [MPa] 28d	Compressive strength [MPa] 3d	Compressive strength [MPa] 28d
P·O 32.5	27.8	207	334	4.7	7.5	22.1	45.8
P·O 42.5	28.0	195	320	5.9	8.5	24.7	53.7

Table 2. The properties of fly ash

Fineness, amount retained, (80μm) sieve [%]	Water requirement [%]	Loss on ignition [%]	Content of SO_3 [%]	Strength activity index [%]
4.9	94.7	2.8	0.25	83.3

Table 3. Mixture proportions of concrete

P/*A*	Group	*W*/*C*	Water [kg/m^3]	Cement [kg/m^3]	Fly ash [kg/m^3]	Sand [kg/m^3]	Coarse aggregate [kg/m^3]	SJ-2 [‰]	UNF-5 [%]
32.5/67.5	C30	0.53	172	326	75	606	1068	0.35	0.49
	C60	0.38	146	380	87	597	1068	0.21	1.6
35/65	C30	0.53	186	351	80	578	1028	0.36	0.49
	C60	0.38	157	409	94	569	1028	0.21	1.4

The specimens of concrete with the sizes of 100mm×100mm×100mm and φ100mm×300mm were cast and demoulded 24h after casting. Mechanical properties and chloride diffusion coefficient were tested after curing in standard condition (20±2℃ and 95% RH) for 28 days, and the dry shrinkage properties were tested after curing for 3 days.

3 Results and discussions

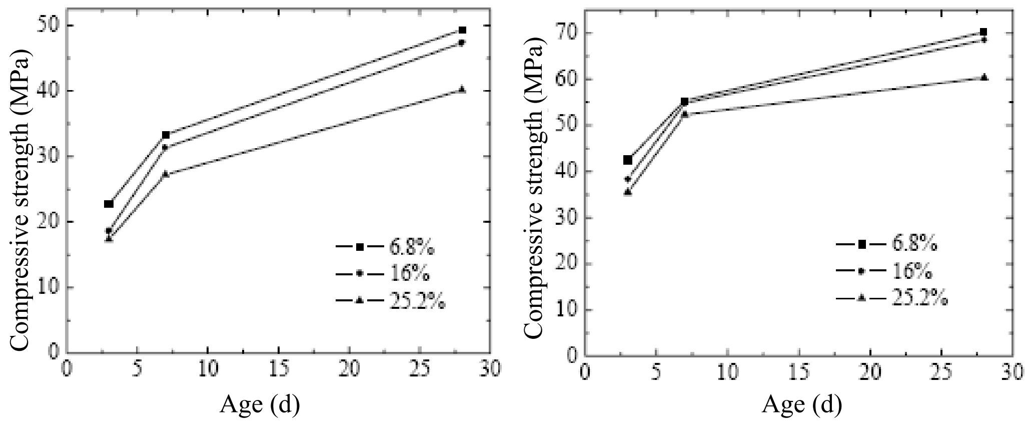
3.1 Effect of elongated and flaky particles content on the workability of concrete

Table4. Relationship between elongated and flaky particles content and slump

P/*A*	Group	Elongated and flaky particles content (%) 6.8	16.0	25.2
32.5/67.5	C30	90	81	55
	C60	93	85	52
35/65	C30	85	75	56
	C60	94	81	55

Table 4 indicated that when the content of elongated and flaky parties increased the slump of both C30 concrete and C60 concrete decreased, and concrete with higher strength has higher decreasing amplitude. Meanwhile, when the contents changed from 16.0% to 25.2%, the slump of concrete sharply dropped. With different *P*/*A*, the tendency of the variation is similar. The higher surface area of elongated and flaky parties is the main reason for the decrease of slump, and the second one is the augment of bite force between elongated and flaky parties, which could cause a less fluidity.

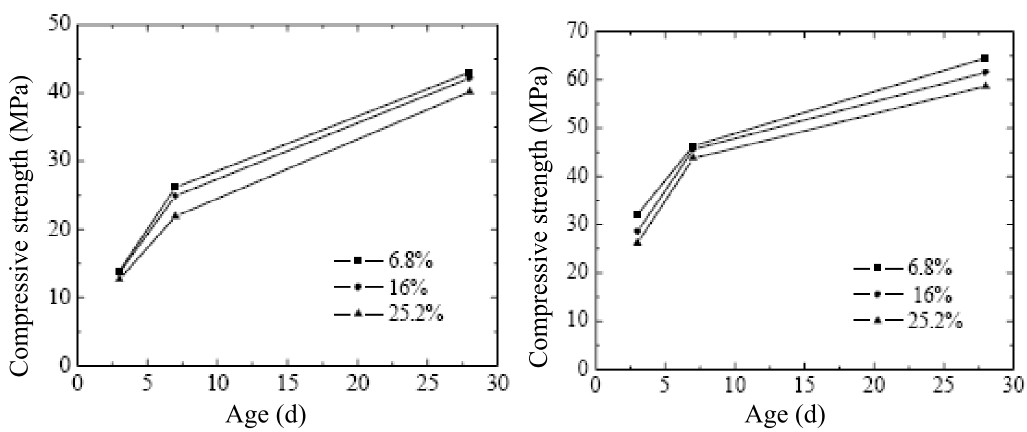
3.2 Effect of elongated and flaky particles content on compressive strength of concrete



a) C30 b) C60

Figure1. Relationship between elongated and flaky particles content and compressive strength

（*P*/*A*=32.5/67.5）



a) C30 b) C60

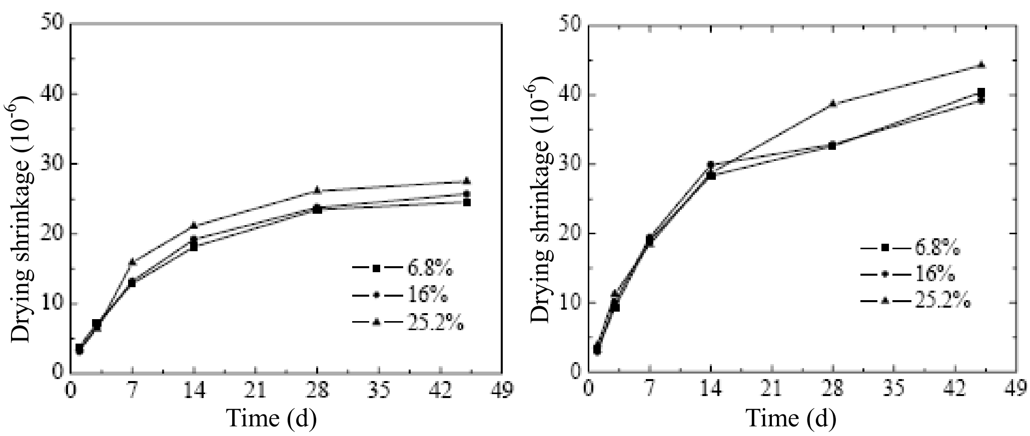
Figure 2. Relationship between elongated and flaky particles content and compressive strength

（*P*/*A*=35/65）

Compressive strengths of concrete with different strength grades and *P*/*A* were shown in figure 1 and figure 2. From these two figures, it is can be seen that the compressive strengths of concrete dropped with the increasing of elongated and flaky particles contents. But when *P*/*A* changed from 32.5/67.5 to 35/65, the decreasing amplitude of compressive strengths was declined. When the *P*/*A* is lower, surface of aggregate can not be packed by the paste, so the surface would have more defects and the intersurface is much weaker. On the other hand, the elongated and flaky particles trend to be horizontal, it will cause the increase of water binder ratios under the particles and more cracks in the intersurface. The two effects make more defects formed in concrete, so the compressive strength decreased when the contents of elongated and flaky particles rise. When the *P*/*A* is 35/65, there would be more paste, so the surface of aggregate can be packed much better and has fewer defects.

The decrement of compressive strength became larger during the increasing of elongated and flaky particles content, especially when the *P*/*A* is lower. When the contents of elongated and flaky particles were 6.8% and 16%, the compressive strengths were equal to each other. But when it was 25.2%, the compressive strength declined sharply. This indicated that the effect of elongated and flaky particles on compressive strength is nonlinear, and the similar results have also been found by other researchers (Wu, 2001) (Zhang, 2013).

3.3 Effect of elongated and flaky particles content on dry shrinkage of concrete



a) C30 b) C60

Figure 3. Relationship between elongated and flaky particles content and drying shrinkage

（P/A=32.5/67.5）

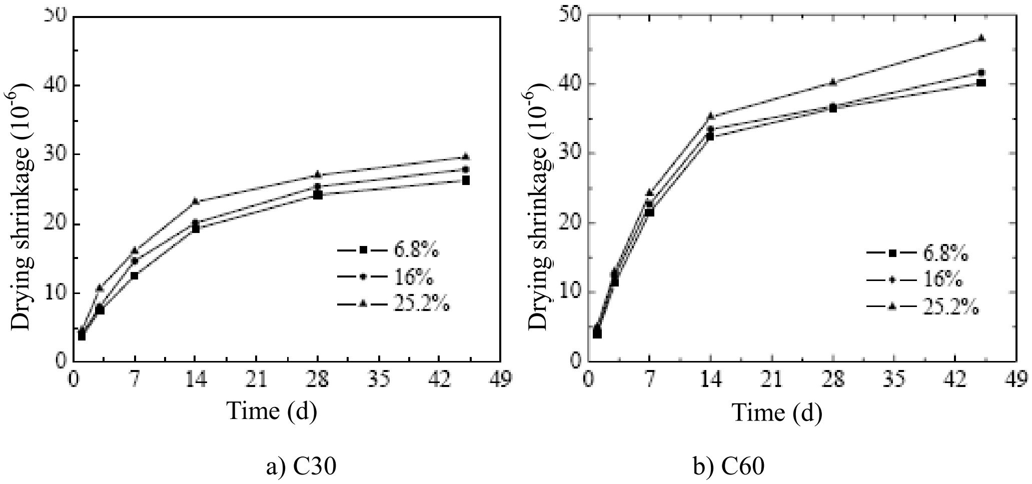


Figure 4. Relationship between elongated and flaky particles content and drying shrinkage（P/A=35/65）

The effects of elongated and flaky particles contents on drying shrinkage of concrete with different strength grades and *P*/*A* were shown in figure 3 and figure 4. From the two figures, it is can be found when the paste quantity increased, the drying shrinkages became larger, and it is marked when the concrete has higher strength grade. When the contents of elongated and flaky particles changed from 6.8% to 25.2%, the increment of drying shrinkage of both C30 and C60 concrete were over 10%. At the same time, with the increasing of elongated and flaky particles content, the growth rate of drying shrinkage of different ages of C30 concrete was stable, but for C60 concrete, the growth rate of drying shrinkage of early age was smaller than later age.

3.4 Effect of elongated and flaky particles content on chloride diffusion coefficient of concrete

Table 5. Relationship between elongated and flaky particles content and chloride diffusion coefficient

($\times 10^{-12} m^2/s$)

Group	*P*/*A*	Elongated and flaky particles content (%)		
		6.8	16.0	25.2
C30	32.5/67.5	2.74	3.27	3.71
	35/65	4.52	5.14	5.46
C60	32.5/67.5	2.22	2.52	2.95
	35/65	2.53	3.01	3.09

The effect of elongated and flaky particles content on chloride diffusion coefficient was displayed in table 5. Chloride diffusion coefficient increased as the increasing of elongated and flaky particles content, because of the inferior compactness. Meanwhile, chloride diffusion coefficient increased with the increasing of *P*/*A* and decreased with the increasing of compressive strength. The impermeability is determined by the size and character of porosity. The quantity of porosity increased with the increasing of elongated and flaky particles content, so the chloride diffusion coefficient also increased with the increasing of elongated and flaky particles content. When water binder ratio was constant, there would be more paste and less aggregate in concrete as the increasing of *P*/*A*, and more porosity appeared, so chloride diffusion coefficient increased with the increasing of *P*/*A*. When *P*/*A* was constant, concrete with higher strength had lower porosity because of the lower content of free water, so the chloride diffusion coefficient of C60 concrete was lower.

4 Conclusions

In this study, test results showed the workability, the compressive strength, the drying shrinkage and impermeability of concrete decreased with the increasing of elongated and flaky particles content. Therefore, in order to achieve the durability, the content of elongated and flaky particles should be controlled. According to the results of this research and the content of elongated and flaky particles should be fewer than 16%, while the workability and maximum packing density can be achieved.

Reference

Liu Fenghan, Chen Xiaoling. (2012).Cement concrete with coarse aggregate of elongated particles content test. Sichuan Building Science. 38(5):163-165.

Sengupta Anirwan, Santhanam Manu.(2009). Influence of aggregate characteristics on uniformity of SCC. Indian Concrete Journal. 83(6):50-60.

Wu Libin, Sun Zhenping, Jiang Zhengwu, Wang Xinyou. (2001)The influence of aggregate to mechanical performances concrete. Concrete. 1:43-46.

Zeng Chongsheng, Gui Miaomiao, Liu Junxiu, Peng Junzhi.(2011) Quantitative analysis of the impact of acicular content of coarse aggregate on passing ability of self-compacting concrete. Concrete. 11:34-38.

Zhang Shuliang.(2013) The influence of aggregate flakiness content and particle size on concrete performance. ShanXi Science &Technology of Communications. 4:11-14.

Zhang Yan.(2013)Effect of elongated and flaky particles content on the properties of concrete.Water Conservancy Science and Technology and Economy. 19(7):110-111.

Calculation Method for the Cable Zone Beams of a Single Cable Plane Low-Pylon Cable-Stayed Bridge with a Wide Box Girder

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Abstract: The researches for cable area beams of single cable plane low-pylon cable-stayed bridge were summarized; Based on plane frame theoretical mechanics, the simplified model for cable area beams of single cable plane low-pylon cable-stayed bridge with wide box girder is elaborated; and mechanical characteristics of the cable zone beams were studied by changing the structural properties. The Conclusions has some reference value.
Keywords: Low-pylon cable-stayed bridge; Single cable plane; Cable zone beam; Simplified calculation modalities; The mechanical characteristic.

1 Introduction

The applications of low-pylon cable-stayed bridge as a beam-cable composite system is becoming more and more, due to the advantages of cost and landscape. Therefore, the study of the characteristics for cable area beams of single cable plane low-pylon cable-stayed bridge with wide box girder has well theoretical and practical value.

Currently, scholars has researched on longitudinal stress distribution of wide box girder under the cable force (Han, 2010, Xie, 2006, Xu, 2012), mechanical characteristics of cable area beam with a large cable force (Zou, 2010), live load calculation method for cable area beam (Lu, 2012), key construction of Nanping Bridge (Lai,). And some results have been achieved. But there are less research results for cable area beams of single cable plane low-pylon cable-stayed bridge with wide box girder. AoJiang fifth bridge which is single cable plane low-pylon cable-stayed bridge with wide box girder is set as an example in this paper to raise a practical calculation method and analyze the relationship among of the cable zone beams stiffness, cable tension, transverse prestressing steel and box girder internal forces. Furthermore, a better understanding of structure properties of cable area beams of single cable plane low-pylon cable-stayed bridge is made.

2 Project Overview

AoJiang fifth bridge with two towers is single cable plane low tower cable-stayed bridge, using 85 m+150 m+85 m span and tower pier beam consolidation system. Full-bridge sites tower in the middle position with 40 pairs of cables, shown in Figure 1.

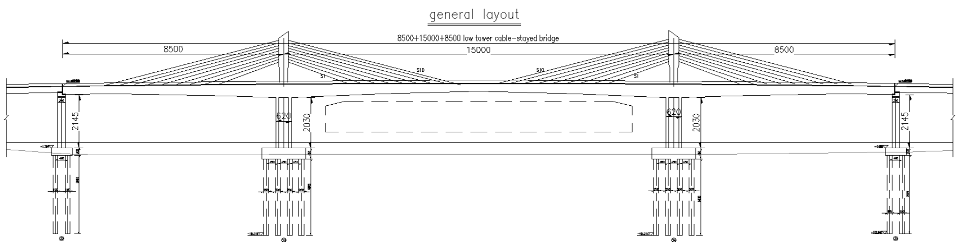

Figure 1. Bridge layout in general (unit cm)

Box girder full width is 38 m, with 4.75 m cantilever, cross slope by tilting box girder roof. A typical box girder cross-section is shown in Figure 2. Spacing of cable at beam is 3.75 m. Prestressed crossbeam thickness is 30 cm. Crossbeam arrangement is shown in Figure 3, and the steel arrangement of cable zone prestressed crossbeam is shown in Figure 4.

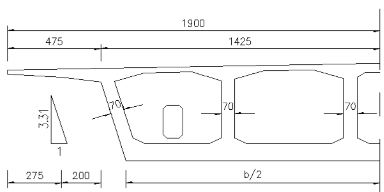

Figure 2. Typical section layout of girder (unit cm)

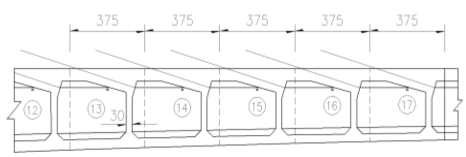

Figure 3. Crossbeam arrangement layout (unit cm)

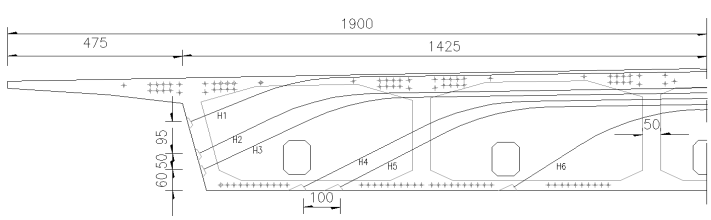

Figure 4. Cable zone crossbeam prestressed steel arrangement layout (unit cm)

3 Cable Area Crossbeam Simplified Calculate Mode

3.1 Load Mode

For spatial unevenness serious stress in the cable area beam calculations, the way load pass to the beam is the key of plane frame practical computing model.

Mechanical properties of low tower cable-stayed bridge is close to continuous beam. its dead and live load still pass from the midspan to the fulcrum. No.N segment, for example, bears No.N+1 segment load F_{N+1}, while the load F_N again passes to No.N-1 segment (Figure 5).

No.N segment the force balance analysis,

$$F_{N+1} + G_N - F_N - T_N \times \sin\theta_N = 0 \text{ (Vertical component)} \qquad (1)$$

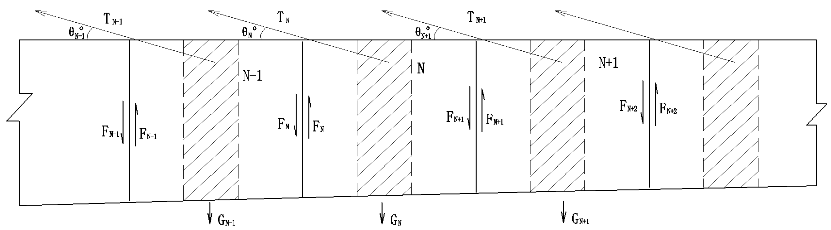

Figure 5. Beam segment force analysis (unit cm)

Figure 5 shows that the difference of load between longitudinal segment is bore by cable, and is allocated according to the stiffness of cable, beam and main beam. Considering the load delivered by cantilever is negligible (Xu, 2012), shear F_N can be considered that it's delivered to the beam by webs, roof and floor. So, the cable zone beams can be considered as continuous beams elastically supported by web, roof and floor. Then,

$$F_N = F_{N+1} + G_N - T_N \times \sin\theta_N \qquad (2)$$

According to equation (2), considering load delivered by the roof and floor is little. So, the cable zone beams can be simplified as continuous beams elastically supported by web. Stiffness of each elastic support in simplified model (Figure 6) support is directly related to the web thickness and the beam segment position.

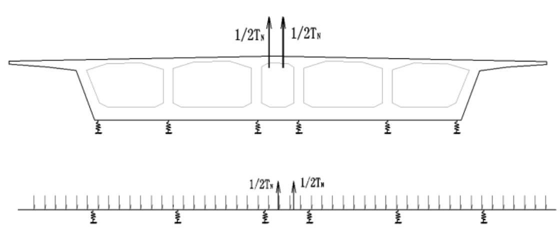

Figure 6. Crossbeam simplified calculation mode

3.2 Support Stiffness

Since the main beam web thickness is often designed fairly, so the main beam stiffness can be allocated according to the thickness of the web. Each support stiffness of the web: K/n (K is support stiffness, n is the number of the web).

Support stiffness is a unit displacement corresponding support force. For constant section beam, the expression is:

$$K = \frac{3EI}{L^3} \qquad (3)$$

Among, I is the moment of the beam, L is cantilever length, K is elastic support stiffness.

For variable cross-section beams, the equivalent stiffness method will be used in calculation (Zou, 1995).

$$E_x I_x = E_e I_e \qquad (4)$$

Among, $E_e I_e$ is the equivalent stiffness, $E_x I_x$ is variable stiffness.

3.3 Effective Width

Multi-elastic-supported continuous beams calculation of internal force and reinforcement needs the impact beam width to be considered (Code JTG D62-2004). the effective width $B_m = b + 2b_h + 12h_f^{'}$ (b_h supporting the length , b beam thickness, $h_f^{'}$ thickness of the roof or floor).

4 Calculation Results

Set the No.16 beam segment as an example, using the simplified calculation model, crossbeam calculation is carried out with the external cable force. Considering of dead load and live load, prestressing effect, crossbeam internal forces, anti-force calculation results are shown in Figure 7, Figure 8.

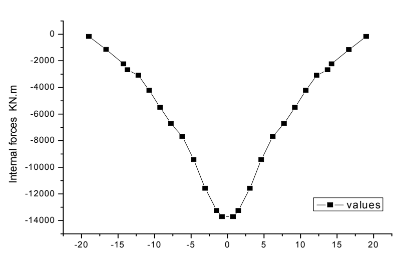

Figure 7. internal forces results

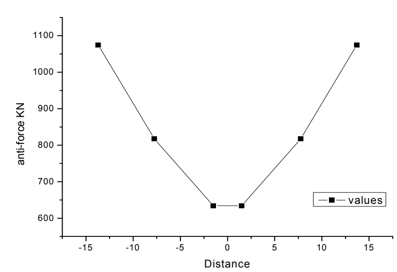

Figure 8. anti-force results

Figure 7 shows, beam moment doesn't change as the parabolic law due to the multi-point elastic support. Figure 8 shows the shear distribution is uneven between the box girder webs, shear greater edge web. Affected by beam stiffness, each web shear distribution has large differences (Han, 2012), which is consistent with the law of the solid elements calculation. So, elastic support continuous beam pattern can simulate the mechanical characteristics of the cable zone beams.

5 Parametric Analysis

Through changing the stiffness of the support beams, beam stiffness, prestress degrees and cable force, the effects of the stress state and internal forces of the stringer beams are analyzed.

(1) support stiffness

0.1, 0.5, 1.0, 2.0, 5.0 times support stiffness were taken for analysis, dead load results are shown in Figure 9 and Figure 10.

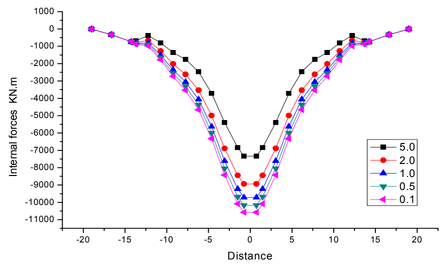

Figure9. internal forces results of various support stiffness

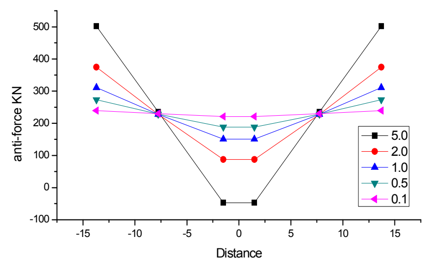

Figure 10. anti-force results of various support stiffness

Figure 9 shows as the support stiffness increases, the beam internal force distribution tends to be uniform; Figure 10 shows the difference between the webs force increases while the support stiffness increases; Results reflects the beam characteristics affect the internal forces and stringers internal force distribution and the mechanical characteristics of the different cable position.

(2) beam stiffness

0.1, 0.5, 1.0, 2,5 times beam stiffness were taken for analysis, dead load results are shown in Figure 11 and 12.

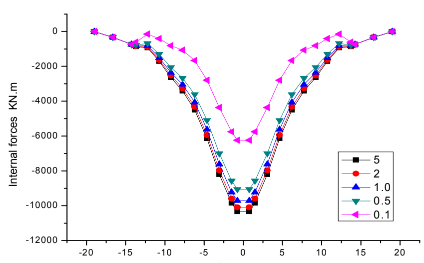

Figure 11. internal forces results of various beam stiffness

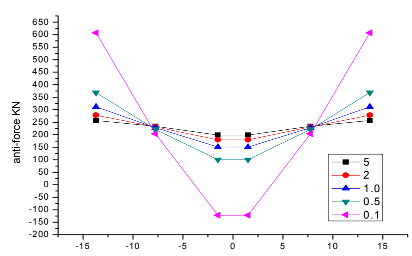

Figure 12. anti-force results of various beam stiffness

Seen from Figure 11 and Figure 12, as the beam stiffness increases, the internal force distribution between the beams increases; each web brace force tends to be uniform; the stress responds to characteristics of different cable beam position.

(3) prestressed degree

0.1, 0.5, 1.0, 2,5 times Prestressed beams degree were taken for analysis, dead load results are shown in Figure 13 and Figure 14.

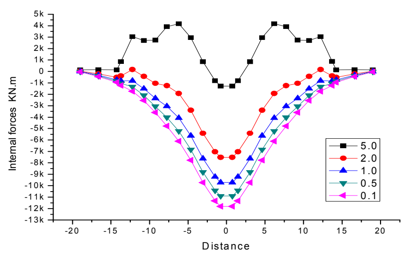

Figure 13. internal forces results of various prestressed degree

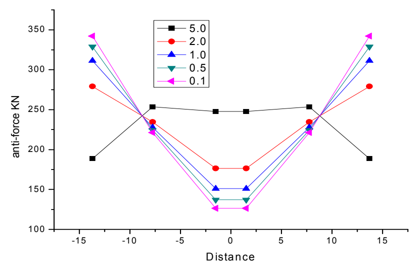

Figure 14. anti-force results of various prestressed degree

Seen from Figure 13 and Figure 14, as the increase of prestressing, beam internal force distribution tends to be uniform; each web brace force difference increases; the choice of the prestressed design has a greater impact on internal forces.

(4) cable force

0.1, 0.5, 1.0, 2, 5 times cable force were taken for analysis, dead load results are shown in Figure 15 and Figure 16.

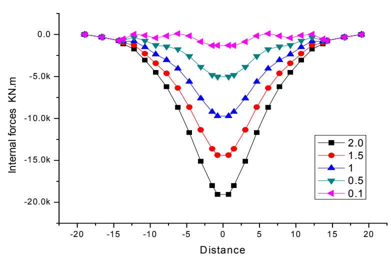

Figure 15. internal forces results of various cable force

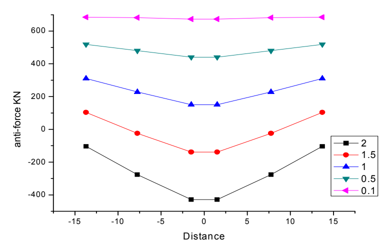

Figure 16. anti-force results of various cable force

Seen from Figure 15 and Figure 16, as the increase of cable force, beam internal forces difference increases; each web brace force difference increases, with a negative reaction; increased cable force is detrimental to the beam.

5 Conclusion

Here we may draw the following conclusions.

(1) Elastically supported continuous beam simplified model is an appropriate calculation method, and can be used for similar engineering design.

(2) Calculations of the elastically supported continuous beam simplified model

is determined by cable area crossbeam support stiffness and the various load applied to the crossbeam.

(3) The structural characteristics of crossbeam has a greater impact on internal force distribution of box girder.

References

Code for Design of highway Reinforced concrete and prestressed concrete bridges and culverts. JTG D62-2004.

Han, G. P. (2010). Distribution of stress for Prestressed concrete cable-stayed bridge with low pylon cantilever box girder.

Han, Q. H. (2012). Distribution of Shear Webs for Short Tower Cable Stayed Box Girder. *Shanxi Architecture.*

Lai, Y. P. and Liu, G. X. Hechuan Jialing River Nanping Bridge Structure Design. *19th National Bridge Academic Conference.*

Lu, Y. G. and Yang, D. C. (2012). Calculation methods discussion for Part cable-stayed bridge Crossbeam. *Engineering and construction.*

Xie, Y. Z. and Zhong, M. X. (2006). Distribution of Cable Tension in the box girder for cable-stayed bridge. *Central South Highway Engineering.*

Xu, Y. (2012). Analysis of cantilever length for Large cantilever wings box girder *Journal of China Three Gorges University (Natural Sciences).*

Zou, D. Y. (2010). Wuxi Qingming Road Qingning Extradoses Bridge Cable area beam design. *Urban Roads Bridges & Flood Control.*

Zou, J. X. (1995). deformation Calculatied of variable cross-section beam with equivalent stiffness method. *Hydraulic Calculation and Monitoring.*

A Theoretical Model of Rail Corrugation on a Slab Track

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Abstract: Researches on rail corrugation were briefly reviewed. A rail corrugation model for the whole vehicle and the slab track was developed. It considered a combination of the coupling dynamics model of a whole vehicle and track, the modified Kalker's non-Hertzian rolling contact model for wheel and rail, a material wear model and an accumulated wear model. It takes not only the effect of wheel/rail transient dynamic interaction on the formation and development of corrugation into account, but also the effect of the accumulated corrugation on the wheel/rail contact and coupling dynamics. That is, this model can take into account a feedback process between the long-term effects of the rail corrugation and the transient coupling dynamic of whole vehicle. This model can be used to study the formation mechanism of rail corrugation. And the initiation and development of the corrugations caused by various track defects, such as track gap, scratch, dent and random geometry irregularities, can be analyzed. A numerical example was presented to verify the procedure. The numerical results of the example are reasonable and indicate the development of corrugation in the initial stage after grinding.
Keywords: Rail corrugation; Mechanism; Vehicle-track coupled dynamics; Rolling contact; Material wear.

1 Introduction

Rail corrugation (periodic surface irregularities with distinct wavelengths) is a serious problem experienced by many railway networks worldwide. Its formation and development causes fierce vibrations of structures of the railway vehicle and track, as well as noise, and also reduces the life of structural parts. In addition, sometimes serious corrugations of rails can lead to derailment accidents. Thus, railway engineers have to adopt regular and expensive grinding to manage the problem. Such a treatment deals only with the symptoms. An investigation of the underlying causes is necessary in order to determine more fundamental remedies through the optimization of vehicle and track parameters. This emphasizes the need for an accurate simulation model of corrugation to understand the mechanism and give some measures for mitigation. This is exactly the purpose of this paper.

The phenomena of rail corrugation has been observed and studied for more than one hundred years. Much progress in recognizing the mechanism of initial formation and evolution of corrugation was made (Frederick, 1986; Ahlbeck, 1991; Tassilly, 1991; Groβ-Thebing, 1992; Kalousek, 1992; Grassie, 1993; Igeland, 1997; Diana, 1998; Nielsen, 1999; Gómez, 2001; Muller, 2001; Matsumoto, 2002; Sato, 2002; Suda, 2002; Wild, 2003; Wu, 2004; Jin, 2007; Sun, 2007; Baeza, 2008; Jin, 2008; Knothe, 2008; Collette, 2009; Grassie, 2009; Xie, 2010). The studies on corrugation mainly include three parts: (a) observation and measurement in file site (Ahlbeck, 1991; Tassilly, 1991; Kalousek, 1992; Bracciali 2006); (b) theoretical and numerical model (Tassilly, 1991; Diana, 1998; Wu, 2005; Sun, 2007; Daniel, 2008; Jin, 2008; Collette, 2009; Baeza, 2011; Kurzeck, 2011); and (c) experimental methods (Baumann, 1996; Diana, 1998; Suda, 2002; Wild, 2003; Jin, 2007; Bellette, 2011). Studies with theoretical and numerical methods primarily involve vehicle/track dynamics, rolling contact theory, material wear. Conventionally, a simple vehicle/track dynamics model, which ignores the flexible deformation of track structure, and approximate contact model were used in the long-term simulation of corrugation growth. In this paper, the coupling model of vehicle and track in (Jin, 2008). was further developed to study the dynamic response of vehicle and track and the corrugation on the slab track system. A corrugation model was put forward based on the vehicle/track dynamics model, a non-Hertzian rolling contact model, and a material model. This model takes not only the effect of wheel/rail transient dynamic interaction on the formation and development of corrugation into account, but also the effect of the accumulated corrugation on the wheel/rail contact and coupling dynamics. That is, it can take into account a feedback process between the long-term effects of the rail corrugation and the transient coupling dynamic of whole vehicle. It can also be used to study the formation mechanism of rail corrugation. And the initiation and development of the corrugations caused by various track defects, such as track gap, scratch, dent and random geometry irregularities, can be analyzed.

2 Calculation Model of Rail Corrugation

2.1 General description

The corrugation model is based on the vertical and lateral coupling dynamics of railway vehicle and track, Kalker's three-dimensional rolling contact theory with non-Hertzian form, and the frictional work wear model. It is roughly depicted in Fig. 1 which expresses a feed-back process between the transient coupling dynamics of the vehicle and track and the long-term wear process.

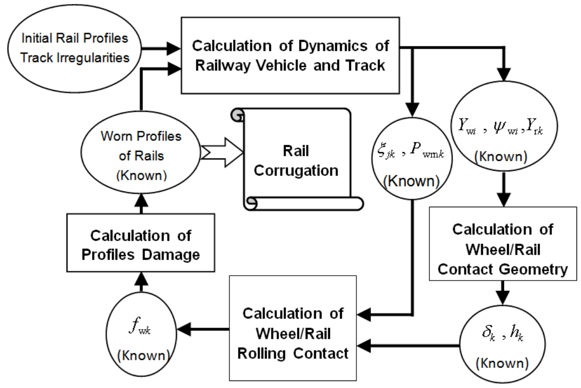


Figure 1. General description of rail corrugation model

In Fig. 1, Y_{wi} and ψ_{wi} are, respectively, the lateral displacement and the yaw angle of wheelset *i*, subscript *i* denotes the number of the wheelset considered in the calculation model, Y_{rk} is the lateral displacement of the rail head under wheel *k*, and subscript *k* is the number of the wheel in the model, δ_k and h_k are, respectively, the contact angle and the normal distance between wheel *k* and the rail. The ranges for *i* and *k* selected depend on the total numbers of the wheelsets and the wheels in the calculation model. ξ_{jk} and P_{wrnk} are, respectively, the creepages and the normal loads between the wheels and the rails, subscripts j = 1, 2, 3 indicate, respectively, the longitudinal, lateral and normal directions at the contact point of wheel and rail, subscripts *w* and *r* denote, respectively, wheel and rail, *n* indicates the vertical direction of the track. f_{wk} denotes the frictional work density in the contact area under wheel *k*. Carrying out the dynamic analysis obtains $Y_{wi,}$ ψ_{wi}, Y_{rk}, δ_k, ξ_{jk}, P_{wrnk}, Using $Y_{wi,}$ ψ_{wi}, Y_{rk}, and the spatial calculation method of the W/R contact geometry, h_k is calculated. ξ_{jk}, P_{wrnk}, h_k and δ_k are used in calculating the rolling contact behavior of the W/R (i.e. Wheel/Rail), in which the modified Kalker's model for three-dimensional elastic bodies in rolling contact is introduced to calculate the normal pressure, the tangent traction component, the sliding distance, the stick/slip areas, etc. The frictional work density is used to determine the wear depth of the running surface in the normal direction of the contact patch. Before the next loop calculation is performed, the profile of the rail is renewed using the wear depth at the present step. After the repeated loop calculations the accumulated material wear and its distribution on the rail head are obtained.

2.2 Model for coupling vehicle and track

The coupling dynamics model for a vehicle and a track is illustrated in Fig. 2. In the model, the vehicle considered is treated as a rigid multi-body system with 35 degrees of freedom. It is equipped with a pair of two-axle bogies with double suspension systems. The wheelset and the bogie are connected by the primary suspension, while the carriage is supported on the bogie through the secondary suspension. The track, which is treated as a dynamic flexible structure, is considered as a 2-layer model with rails, fixed slabs. Two layers of discrete springs and dampers represent the rail fastenings and subgrade. Each rail of the track is modeled with a Timoshenko beam resting on discrete rail pads. The slab is modeled as a three-dimensional flexible structure based on finite element method. The vehicle couples with the track through wheel/rail contact which includes a normal model and a tangent model. The normal model, which characterizes the relationship between the normal load and deformation of the wheel-rail, is described by a Hertzian nonlinear contact spring with a unilateral restraint. Shen-Hedrick-Elkins's model is adopted as the tangential model determining the relationship between the creepages and the total creep forces of the wheel/rail (Shen, 1983).

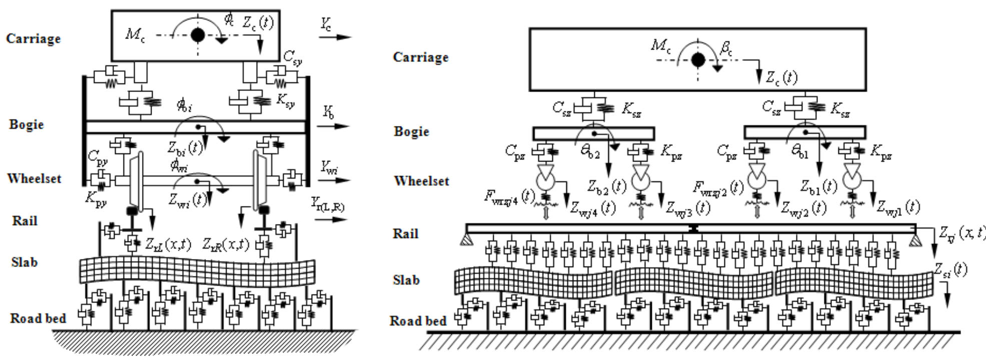


Figure 2. Coupling vehicle/track model: (a) Elevation; (b) Side elevation

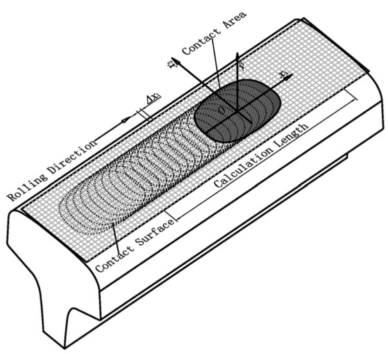
2.3 Rolling contact model for wheel and rail

The analysis on the detailed information in the wheel/rail contact patches, such as the distribution of the normal and tangential forces, the total slip and the frictional work, is carried out by means of Kalker's theory. In order to consider the effect on the normal gap of the cumulative wear depth $w^k{}_3$ obtained at the previous steps, the principle of complementary virtual work of wheel and rail in rolling contact was modified as follows:

$$\begin{cases} \min\limits_{p_{Jj}} C = \frac{1}{2} p_{Ii} A_{IiJj} p_{Jj} + \left[\left(h_J^k + w_{3J}^k - h_{\min}^k \right) - q \right] p_{J3} + \\ \qquad (W_{J\tau} - u'_{J\tau}) \, p_{J\tau} \\ s.t \quad p_{J3} \geq 0 \quad \left| p_{J\tau} \right| \leq b_J \quad \forall \mathbf{x} \in A_c \\ \qquad A_0 \sum_J^M p_{J3} = P \end{cases} \tag{1}$$

where h_J is the normal gap at the center of element *J,* and $h^k{}_{\min}$ is the minimum normal gap between the wheel and rail. The rectangular element area is equal to $A_0 = \Delta x_1 \times \Delta x_2$, A_0 is that 0.8×0.8=0.64 mm^2 for the case of non-flange contact (on straight line and inner rail), and 1.3×0.1=0.13 mm^2 for the case of flange contact (on outer rail). A_c is the potential contact area; M is the total number of elements, selected as 21 × 21 = 441 in the calculation. The denotations of other symbols in Eq. (1) can be found in (Jin, 2008)..

The modification reflects that at each calculation step, $w^k{}_3$ and h_J are updated since they are different at different contact points. Accordingly, the effect of the wear depth in the previous calculation step is taken into account in the present step, as sketched in Fig. 3, which depicts the contact area moves on the rail running surface and also indicates that the wear depth on each contact area is accumulated along the surface. It should be noted that Fig. 3 is just a schematic diagram indicating the calculation position of rail corrugation. An actual location where the corrugation occurs is determined through the vehicle-track dynamics analysis, i.e. the wheel/rail contact point obtained through the dynamic calculation. The calculation of the corrugation can be carried out on both the rails of the tangent and curved tracks, as shown in Fig. 4. For convenience, the wheels of the vehicle are numbered 1~8 respectively. The wheels on the left hand side are numbered with 1, 3, 5 and 7, and the wheels on the right hand side are numbered with 2, 4, 6 and 8, as schematically shown in Fig. 4. The corrugation calculation length is selected as 1.6m in this paper.



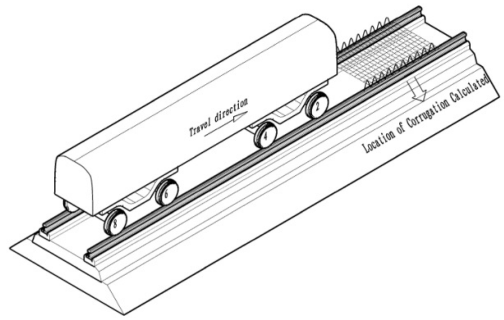


Figure 3 Rail running surface passed by contact area; Figure 4 Location of rail wear analysed on the track

2.4 Material wear model

The material wear model is a friction work model, in which the mass loss of unit area is proportional to frictional work of unit area.

$$\Delta m(x_{I1}, x_{I2}) = C_w f_w(x_{I1}, x_{I2}) \tag{2}$$

In Eq. (2), (x_{I1},x_{I2}) are the coordinates of the center of element I, the $\Delta m(x_{I1},x_{I2})$ and $f_w(x_{I1},x_{I2})$ are, respectively, the material mass loss of unit area and the friction work density at point (x_{I1},x_{I2}), the proportional coefficient C_w=1.0×10^{-9} kg.(N.m)$^{-1}$ (Igeland and Ilias 1997, Jin and Wen 2008).

3 Discussions of Results

In the coupling vehicle-track dynamics simulation, the vehicle speed is 50 km/h. The sleeper pitch is 0.625 m. The vertical stiffness and damping of fasteners system are 12.07 kN/mm and 1.4 kN·s/m, respectively, and the lateral stiffness and damping are 7.6 kN/mm and 0.98 kN·s/m, respectively. The measured roughness of the straight line after grinding is used as a vertical excitation in the dynamic simulation, and the lateral excitation is ignored. The calculation length of the track is 100 m. The integration step in solving differential equations of the vehicle-track is 7.2e-8 s. It takes a longer CPU time in the calculation of the whole feed-back process of corrugation evolution. The calculation length of the corrugation along the rail is 1.6 m. The rail irregularities in the corrugation calculation section are illustrated in Fig. 5, in which the roughness amplitude of the right rail is larger than the left rail. The rail irregularities after grinding indicate the residual corrugations.

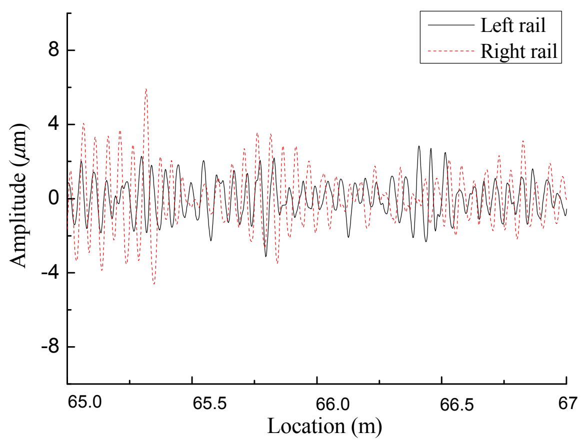


Figure 5. Measured roughness used in the corrugation calculation section

3.1 Dynamic characteristics of track

Through the dynamic simulation, the vertical, lateral and torsional displacements of the rail are obtained when the vehicle operates on the track with the residual corrugations after the grinding. Figs. 6 (a), (b) and (c), illustrate the linear spectra of the vertical, lateral and torsional displacement respectively. It can be observed that the track resonances in the three frequency bands, 160~300 Hz, 500~700 Hz and 900~980 Hz, can be easily excited when the vehicle passes the Cologne egg fasteners track with the residual corrugations. The resonant frequencies in the range of 160-300 Hz nearly match the dominant corrugation wavelength of 40~50 mm, and those in the range of 500~700 Hz match the wavelength of 25 mm. From Fig.6, it can be seen that the maximum amplitude of vertical, lateral and torsional displacement spectrum occurs around 300 Hz. Therefore, the resonances around 300 Hz play an important role in the formation and development of 40~50 mm corrugation on the Cologne egg fasteners track.

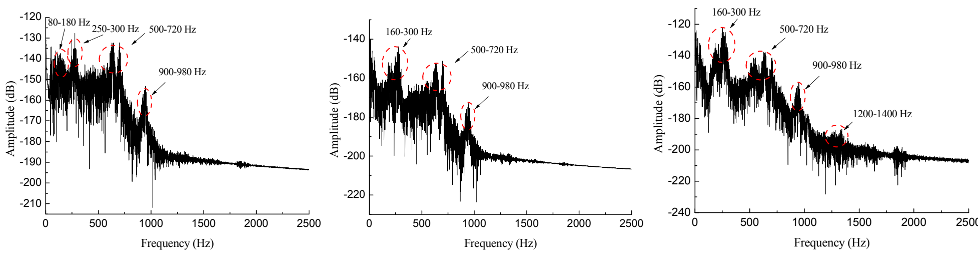
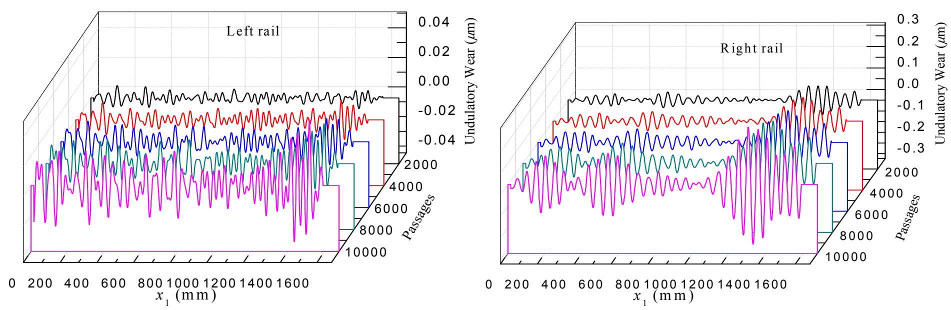


Figure 6. Receptance of the track: (a) Vertical; (b) Lateral ; (c) Torsional

3.2 Rail corrugation evolution

After the dynamic simulation, the non-Hertzian rolling contact code is used to calculate the frictional power and then the material wear model is employed to calculate the wear depth in the contact patch. The wear depth gradually accumulates on the rail running surface with the wheel passage increase.

Fig.7 illustrates the evolution of the profiles of the left and right rails, respectively, due to wear. Each line in these figures represents 2,000 wheel passages increase. Here it is noted that the wear depth does not contain the even wear on the running surface. Namely, the even wear is removed from the calculated results so as to compare the wavy surface after each increment of 2,000 passages.



(a) (b)

Figure 7. Rail profile evolution: (a) Left rail (b) Right rail

It is obvious that the corrugation develops quickly with the passage increase, especially with 2,000~10,000 passages. And it develops slowly after 10,000 passages. This is because the contact condition between the wheel and rail is changed with the passage increase due to the accumulated wear increase on the rail surface. Namely, the wheel gets in a pretty good conformal contact with the rail in a running-in period. Comparing (a) with (b), it can be found that the fluctuated amplitude of the right rail corrugation is approximately 10 times greater than that of the left rail after 20,000 passages. This is because the input irregularity on the right rail is severer than that on the left rail, as depicted in Fig. 5, which results in the greater fluctuant normal load and the larger frictional work between the right rail and the wheel. So the growth rate of the right rail corrugation is much faster than that of the left rail.

4 Conclusions

A numerical model of rail corrugation for the whole vehicle and the slab track and its procedure were put forward and discussed in detail. The model considered a combination of the coupling dynamics model of a whole vehicle and track, the modified Kalker's non-Hertzian rolling contact model for wheel and rail, a material wear model and an accumulated wear model. The procedure is utilized to predict the evolution of the residual corrugation after grinding. The mechanism was analyzed according to the dynamical response of the track. The numerical model can be used to estimate the effect of many concerned factors on corrugation. It plays an important role in the improvement of the vehicle and track dynamical characters to mitigate the initiation and development of rail corrugations.

5 Recommendations for Future Research

The numerical model can be further improved in wheel-rail contact model considering the effect of stick-slip curve, in the material wear model considering the effect of hardening and environment.

Acknowledgement

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References

Ahlbeck, D. R. and L. E. Daniels (1991). "Investigation of rail corrugations on the Baltimore Metro." *Wear* 144: 197-210.

Baeza, L., P. Vila, A. Roda and J. Fayos (2008). "Prediction of corrugation in rails using a non-stationary wheel-rail contact model." Wear 265(9-10): 1156-1162.

Baeza, L., P. Vila, G. Xie and S. D. Iwnicki (2011). "Prediction of rail corrugation using a rotating flexible wheelset coupled with a flexible track model and a non-Hertzian/non-steady contact model." Journal of Sound and Vibration 330(18-19): 4493-4507.

Baumann, G., H. J. Fecht and S. Liebelt (1996). "Formation of white-etching layers on rail treads." Wear 191(1-2): 133-140.

Bellette, P. A., P. A. Meehan and W. J. T. Daniel (2011). "Validation of a tangent track corrugation model with a two disk test rig." Wear 271(1-2): 268-277.

Bracciali, A. (2006). RAIL CORRUGATION GROWTH IN A METRO CURVE. 7th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems, Brisbane, Australia.

Collette, C., M. Horodinca and A. Preumont (2009). "Rotational vibration absorber for the mitigation of rail rutting corrugation." Vehicle System Dynamics 47(6): 641-659.

Daniel, W. J. T., R. J. Horwood, P. A. Meehan and N. Wheatley (2008). "Analysis of rail corrugation in cornering." Wear 265(9-10): 1183-1192.

Diana, G., F. Cheli, S. Bruni and A. Collina (1998). "Experimental and numerical investigation on subway short pitch corrugation." Vehicle System Dynamics 29(suppl): 234-245.

Frederick, C. (1986). A rail corrugation theory. 2nd international conference of Contact Mechanics and Wear of Rail System, University of Kingston, University of Waterloo Press.

Gómez, I. and E. G. Vadillo (2001). "An analytical approach to study a special case of booted sleeper track rail corrugation." Wear 251(1-12): 916-924.

Grassie, S. L. (2009). "Rail corrugation: characteristics, causes, and treatments." Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit 223(6): 581-596.

Grassie, S. L. and J. Kalousek (1993). "Rail corrugation : characteristics , causes and treatments." IMechE 207(F): 57-68.

Gro β -Thebing, A., K. Knothe and K. Hempelmann (1992). "Wheel-rail contact mechanics for short wavelengths rail irregularities." Vehicle System Dynamics 20(sup1): 210-224.

Igeland, A. and H. Ilias (1997). "Rail head corrugation growth predictions based on non-linear high frequency vehicle/track interaction." Wear 213(1-2): 90-97.

Jin, X. and Z. Wen (2007). "Rail corrugation formation studied with a full-scale test facility and numerical analysis." Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology 221(6): 675-698.

Jin, X. S. and Z. F. Wen (2008). "Effect of discrete track support by sleepers on rail corrugation at a curved track." Journal of Sound and Vibration 315(1-2): 279-300.

Kalousek, J. and K. L. Johnson (1992). "An investigation of short pitch wheel and rail corrugations on the Vancouver mass transit system." ARCHIVE: Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit 1989-1996 (vols 203-210) 206(26): 127-135.

Knothe, K. and A. Gross-Thebing (2008). "Short wavelength rail corrugation and non-steady-state contact mechanics." Vehicle System Dynamics 46(1-2): 49-66.

Kurzeck, B. (2011). "Combined friction induced oscillations of wheelset and track during the curving of metros and their influence on corrugation." Wear 271(1-2): 299-310.

Matsumoto, a. (2002). "Formation mechanism and countermeasures of rail corrugation on curved track." Wear 253(1-2): 178-184.

Muller, S. (2001). "A linear wheel-rail model to investigate stability and corrugation on straight track (vol 243, pg 122, 2000)." Wear 249(12): 1116-1127.

Nielsen, J. B. (1999). "Evolution of rail corrugation predicted with a non-linear wear model." Journal of Sound and Vibration 227(5): 915-933.

Sato, Y. (2002). "Review on rail corrugation studies." Wear 253(1-2): 130-139.

Shen, Z., J. Hedrick and J. E. M. o. T. Design (1983). "A comparison of alternative creep force models for rail vehicle dynamic analysis." Vehicle System Dynamics 12(1-3): 79-83.

Suda, Y. (2002). "Study on rail corrugation in sharp curves of commuter line." Wear 253(1-2): 193-198.

Sun, Y. Q. and S. Simson (2007). "Nonlinear three-dimensional wagon–track model for the investigation of rail corrugation initiation on curved track." Vehicle System Dynamics 45(2): 113-132.

Tassilly, E. and N. Vincent (1991). "A linear model for the corrugation of rails." Journal of Sound and Vibration 150(1): 25-45.

Tassilly, E. and N. Vincent (1991). "Rail corrugations: analytical model and field tests." Wear 144(1-2): 163-178.

Wild, E., L. Wang, B. Hasse, T. Wroblewski, G. Goerigk and A. Pyzalla (2003). "Microstructure alterations at the surface of a heavily corrugated rail with strong ripple formation." Wear 254(9): 876-883.

Wu, T. X. and D. J. Thompson (2004). "On the parametric excitation of the wheel/track system." Journal of Sound and Vibration 278(4-5): 725-747.

Wu, T. X. and D. J. Thompson (2005). "An investigation into rail corrugation due to micro-slip under multiple wheel/rail interactions." Wear 258(7-8): 1115-1125.

Xie, G. and S. Iwnicki (2010). "A rail roughness growth model for a wheelset with non-steady, non-Hertzian contact." Vehicle System Dynamics 48(10): 1135-1154.

Development Regulation of Rutting Deformation Based on an Accelerate Pavement Test

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Abstract: Based on the experimental data of different pavement structure through full scale accelerate pavement test (f-APT), the development regulation of rutting on different pavement structure is analyzed and compared, and the characteristics of rutting depth development trend and rut profile shape is summarized. Based on the test date of several semi-rigid base asphalt pavement structures, a rutting prediction model based on f-APT is achieved by multivariate regression, and the range of uplift coefficient is determined. The axle load and vehicle velocity conversion are also considered in the prediction model. The research result can provide a reference for optimizing the structural design and determining reasonable pavement structural scheme.

Keywords: Development regulation of rutting; Uplift coefficient; Prediction model; Accelerated pavement test.

1 Introduction

The main research methods on the development regulation of rutting deformation including wheel tracking test, accelerate pavement test and the study of long term performance of pavement. While the influence factors of rutting deformation are complex and interactional, the laboratory wheel tracking test cannot simulate the actual road environment and stress states accurately, and the study of long term performance of pavement takes too long and costs too much. By comparison, the full scale accelerated pavement test (f-APT) can simulate the actual environment and stress states of pavement more realistically, and obtain the decay law of pavement performance in a relatively short period of time. Taking account of this advantage, it is widely adopted in the research of pavement materials and structure design.

The domestic and overseas scholars adopted different analysis methods and proposed various rutting prediction models. These prediction models can be classified into three categories: mechanistic methods, mechanistic-empirical methods and empirical methods. Based on the experimental data of f-APT conducted by Liaoning Transportation Research Institute, the development regulation of rutting on different pavement structure is analyzed. By regression analysis of the experimental data, a rutting prediction model based on f-APT is achieved. The uplift coefficient of rutting is also determined, and the axle load and wheel speed conversion of equivalent rutting deformation based on f-APT is preliminary studied.

2 Test Condition and Structure Type

The rut-resistance f-APT test was conducted under two types of temperature condition, i.e. normal temperature condition and high temperature condition. The temperature was monitored by the temperature sensor installed at 2cm depth beneath the pavement surface. The range of normal temperature is 10~40℃, and the test result can revel the development regulation of rutting under normal temperature condition. To stimulate the high temperature condition, 45 and 55℃ were selected as the representative temperature. The temperature controlling is realized by the heating unit accessory to the facility. The axle load is 75kN. Several typical structures are chosen to analyze the development regulation of rutting. The structure types of test road are shown in Fig.1.

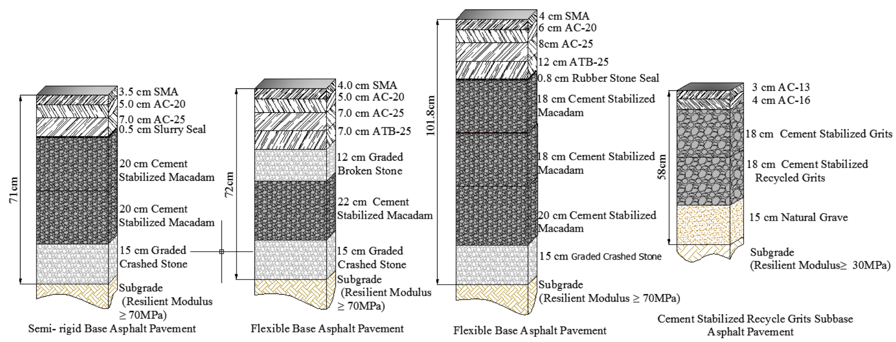
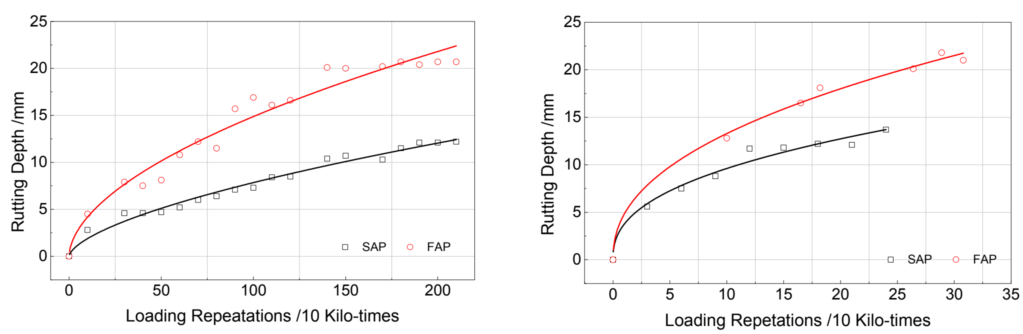


Figure 1. Structure type of f-APT

3 Analysis of Development Regulation of Rutting

Owing to space constraints, taking semi-rigid base asphalt pavement (SAP) and flexible base asphalt pavement (FAP) for instance, the development regulation of rutting is analyzed below.

3.1 Development trend of rutting depth

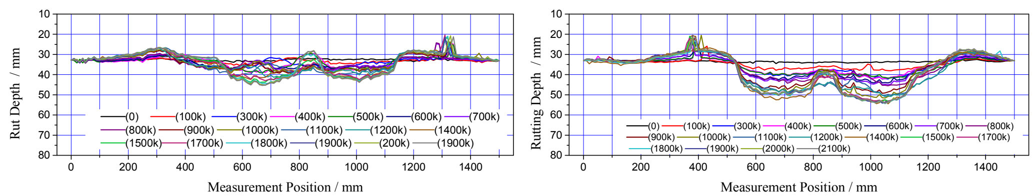


(a) Normal temperature **(b) High temperature**

Figure 2. Development trend of rutting depth

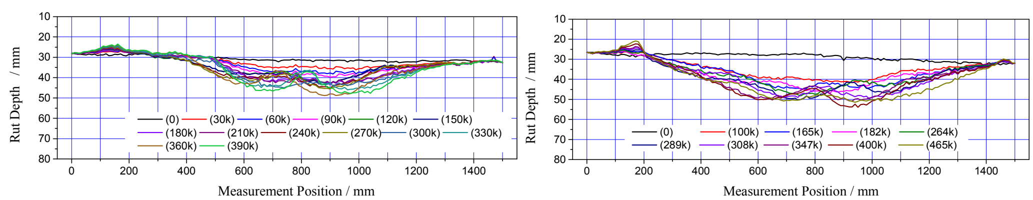
From the development trend of rutting depth under different temperature conditions shown in Fig.2, we can clearly see that high temperature has significant effect on the development of rutting. Compared with semi-rigid structure, the rutting depth of flexible structure increased faster under the same axle load repetitions and temperature conditions. In initial loading stage, the rutting depth of both structures increased rapidly. With the load repetitions increased, the rutting depth increased linearly to final. The inflection point can be easily found in the development trend of rutting depth. The development trend is consistent with the permanent deformation regulation of asphalt mixture in initial stage and steady stage, but the accelerated damage stage did not appear. To analyze the reason, the loading repetitions are limited so that the accelerated damage stage did not appear; or it may be due to the strong lateral constrain of loading section.

3.1 Development of rutting profile



(a) Semi-rigid base structure **(b) Flexible base structure**

Figure 3. Development of rutting profile under normal temperature condition



(a) Semi-rigid base structure **(b) Flexible base structure**

Figure 4. Development of rutting profile under high temperature condition

From the figures above we can clearly see that the degree of deformation under high temperature condition is greater. Under high temperature condition, the vertical permanent deformation is distinct in the initial loading stage. With the load repetitions and temperature increase, the rutting profile formed protuberance at unfixed position and presented W-shape, and the maximum depth of rutting almost kept constant. At this point the shear deformation occurred. Compared with semi-rigid structure, the deformation of rutting profile is significantly more serious.

By analyzing the development trend of rutting depth and rutting profile, the conclusion on developing mechanism of rutting is consistent with the research results that have been generally accepted, that is the permanent deformation of asphalt mixture consists of two parts: compaction deformation and shear deformation, and the shear deformation has significantly effect on pavement performance. The shear deformation is more seriously under high temperature condition.

4 Rutting Prediction Model Based on f-APT

4.1 Regression analysis of experimental data

By analyzing the experimental data and summarizing the achievements of previous researches on effect factors of rutting, the loading repetitions, temperature and thickness of asphalt layer are determined as the main effect factors. Thus, the relationship between rutting depth and main effect factors is achieved by adopting multivariate nonlinear regression analysis. The major type of pavement structure in China is semi-rigid base pavement, thus the prediction model established in this paper just for semi-rigid base pavement structure. The experimental date was selected from several semi-rigid base asphalt pavement structures. The regression results are shown as follows:

$$RDD = (-0.0019h^2 + 0.0650h - 0.0973)\cdot N^{0.4147}\cdot e^{0.0434T} \tag{1}$$

with *RDD* is the absolute rutting depth of asphalt pavement(mm), *N* is the loading repetitions(10 kilo-times), *T* is the representative temperature at 2cm beneath the pavement surface(℃), *h* is the thickness of asphalt layer(cm).

The effect of regression analysis is shown in table 1.

Table 1. Results of regression analysis

Root Mean Squared Error (RMSE)	Sum of Squares for Error (SSE)	Coefficient of Correlation (R)	Coefficient of Determination (R^2)	F-statistics
1.3244	145.5945	0.9440	0.8912	663.3856

From the results of regression analysis shown above, we can see that the coefficient of determination is 0.89, and the coefficient of correlation is 0.94, the results show that the model precision is high theoretically. According to correlation test result, when the level of significance is 1%, the critical value F_{α} is 4.15, less than F-statistics, which reveals that the rutting depth has a significantly linear relationship with loading repetitions *N,* temperature *T* and thickness of asphalt layer *h*.

The relationship between calculated value by prediction model and actual value is shown in figure 5. The calculated value and actual value uniformly distributed on both sides of level curve.

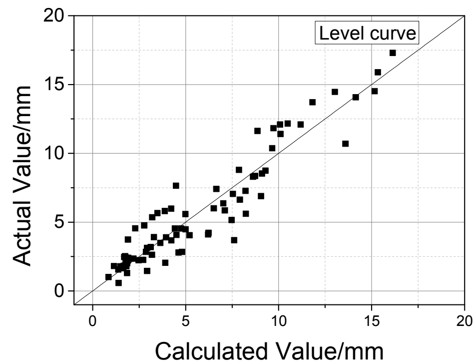


Figure 5.Relationship diagram for calculated value and actual value

4.2 Analysis of uplift coefficient

From the development of rutting profile showed in Fig.3 and Fig.4, we can see that the sides of wheel path bulged compared with the origin profile. Thus, the uplift deformation should be considered in the rutting prediction model. In order to analyze conveniently, uplift coefficient K_L is defined here, which is a ratio of uplift deformation to down concave deformation(*RDD*).

By analyzing the development tendency of uplift coefficient, we can determine that it is relevant to the thickness of asphalt layer. When the thickness of asphalt layer is thinner, the uplift coefficient is smaller, while when the thickness of asphalt layer is larger, the uplift coefficient is greater. The uplift coefficient of long-life asphalt pavement, semi-rigid base pavement of expressway and general asphalt pavement is about 0.53, 0.3 and 0.2 respectively. Thus, the range of uplift coefficient is recommended as 0.2~0.5, the lower limit value should be selected when the thickness of asphalt layer is thinner, and upper limit value should be selected when the thickness of asphalt layer is thicker.

4.3 Axle load conversion of equivalent rutting based on f-APT

Refer to the conversion formulas of deflection equivalent, when taking the standard axle load(100kN) as the conversion benchmark, the relationship between axle load and load repetitions is as follows:

$$k_{ec} = \frac{N}{N_i} = \left(\frac{P_i}{P}\right)^b \tag{2}$$

with k_{ec} is the equivalent coefficient of rutting, N is the load repetitions under standard axle load(BZZ-100), N_i is the load repetitions when the axle load is P_i, P is the standard axle load, i.e. 100kN, P_i is the conversion axle load, b is the axle conversion coefficient.

Refer to the test results of ALF, the equivalent coefficient of rutting is 2.08, according to Eq. 2, the axle conversion coefficient is determined as 1.56

4.4 Vehicle velocity conversion of equivalent rutting based on f-APT

JianFeng Hua deduced the linear relationship between rutting depth and vehicle velocity is shown as follows:

$$\frac{D_{rut}(v)}{D_{rut}(v_0)} = \left(\frac{v_0}{v}\right)^{m+1} \tag{3}$$

With $D_{rut}(v_0)$ is rutting depth at the speed of v_0, $D_{rut}(v)$ is the rutting depth at the speed of v, m is the material parameter related to creep property, the recommended value is 0.5

The wheel speed of the facility is 22 km/h, according to Eq. 3, the vehicle velocity conversion based on f-APT is computed as follows:

$$\frac{D_{rut}(v)}{D_{rut}(v_{22})} = \left(\frac{v}{22}\right)^{-(m+1)} \tag{4}$$

4.5 Rutting prediction model based on f-APT

Considering uplift deformation, axle load and vehicle velocity conversion, the rutting prediction model under standard axle load is shown as follows:

$$RD = (1+K_L)\cdot(-0.0015h^2 + 0.0500h - 0.0749)\cdot N^{0.4147}\cdot e^{0.0434T}\left(\frac{v}{22}\right)^{-0.5} \tag{5}$$

With RD is the rutting depth including uplift deformation.

4.6 Rutting prediction model validation

In order to verify the model accuracy, the author investigated the rutting deformation on several expressways nearby Shenyang, and collected the associated parameters, which is shown in table 2.

As the rutting deformation under low temperature is insignificant, the axle loads below 15℃ are ignored. The representative temperature at 2cm beneath the pavement surface is 25℃，and the reduction factor of axle loads is 0.5, the uplift coefficient is 0.3. Thus, the estimated rutting depth is shown at the last column in table 2. It can be seen through comparison that the estimated value is close to measured value.

Table 2. Estimated rutting depth of actual pavement

Investigated Section	Equivalent Single Axle Loads (10 kilo-times)	Thickness of Asphalt Layer (cm)	Large Vehicle Velocity (km/h)	Actual Rutting Depth (mm)	Estimated Rutting Depth (mm)
SF	1671	16	55	10.5	13.5
BL	677	18	87	5.4	7.3
LL	1505	18	70	12.7	11.4
LX	465	16	60	7.23	7.6

5 Conclusions

Taking semi-rigid base asphalt pavement and flexible base asphalt pavement for instance, the development regulation of rutting is analyzed in this article. The main effect factors of rutting are determined, and the rutting prediction model is achieved by adopting multivariate nonlinear regression analysis. Besides, the range of uplift deformation is determined by analyzing the experimental data of different pavement structure. Finally, a rutting prediction model considering uplift deformation, axle load and vehicle velocity conversion is achieved.

References

Brown E R, (2001). “Performance testing for hot mix asphalt”. *National Center for Asphalt Technology Report* (01-05).

Hugo, F. and A. L. Epps (2004). “NCHRP Synthesis 325: Significant Findings from Full-Scale Accelerated Pavement Testing.” National Cooperative Highway Research Program, Transportation Research Board，Washington，DC.

JianFeng Hua (2000). “Finite element modeling and analysis of accelerated pavement testing devices and rutting phenomenon”. Purdue University.

NCHRP synthesis 433: significant findings from full-scale accelerated pavement testing.

Vertical Vibration Characteristics of a Concrete Sleeper with Cracks in a Heavy-Haul Railway

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Abstract: With the continuous development of heavy-haul transportation, the dynamic interaction between heavy-haul train and track structure has dramatically intensified. Track structures bear repeated and huge loads over a long period of time, and concrete sleeper acting as an important load-bearing component inevitably generates various damages, in which transverse crack in the middle cross section of the sleeper occupies a large proportion. On the basis of the theory of linear elastic fracture mechanics, the concrete sleeper model is established through finite element method to analysis vertical vibration characteristic of damaged concrete sleeper under train loads, including the rail-sleeper forces calculated by vehicle-track coupled dynamics theory. Then stress intensity factor is introduced as an index to investigate the propagation of the transverse crack. The results show as follows: the modal frequencies of damaged concrete sleeper reduce to some extent; under train load, vertical acceleration and displacement of damaged concrete sleeper rise evidently; dynamic response of stress intensity factor in the crack tip shows that the intensity of stress field near the crack tip is controlled by Stress Intensity Factor Type-I.

Keywords: Heavy-haul railway; Concrete sleeper; Crack; Stress intensity factor; Finite element method.

1 Introduction

Freight transportation requires considerably heavier trains than passenger transportation. The static axle load, which reflects the gravity loading of the train, normally does not exceed 170 kN for passenger trains, while for freight trains it may vary between 250 kN and 350 kN. Hence, track structures in heavy-haul railway bear repeated and huge loads over a long period of time. The advantages of concrete technology led to its use for sleepers in the 1950s. Over the last six decades, researchers in different parts of the world have been investigating the failures of concrete sleepers and looking for sustainable solutions. Therefore, greater control over the materials and design of railway track foundations is needed.

(Dyk, 2012) ranked the most common causes of concrete sleeper failures using the results obtained from their North American and worldwide surveys (Figure 1). They indicated that concrete sleeper acting as an important load-bearing component inevitably generates various damages, in which transverse cracking from dynamic loads, center binding and environmental or chemical degradation occupies a large proportion. (Ferdous, 2014) pointed out the main Failures of mainline railway sleepers and suggested remedies. (Oregui, 2014) indicated that the FRF-based statistical method in combination with the non-destructive hammer test measurements had the potential to be employed to identify the characteristic frequencies of damaged conditions in railway tracks in the frequency range of 300–3000 Hz. (Kaewunruen, 2009) constructed a high-capacity drop weight impact testing machine evaluate the ultimate capacity of prestressed concrete sleepers under impact loads. (Zhu, 2012) and (Lin, 2010) studied the vibration characteristics of double-block ballastless roadbed with cracks.

The above studies indicate that the damaged sleeper has a significant influence on the dynamic response of track structure. Therefore, this paper establishes a vehicle－track coupled dynamic model for the heavy-haul freight with double suspension systems to acquire the rail-sleeper forces. In addition, on the basis of the theory of linear elastic fracture mechanics, the concrete sleeper model is established through finite element method to analysis vertical vibration characteristic of damaged concrete sleeper under train load, including rail-sleeper forces acquired from the above model. Finally, stress intensity factor is introduced as an index to investigate the propagation of the transverse crack.

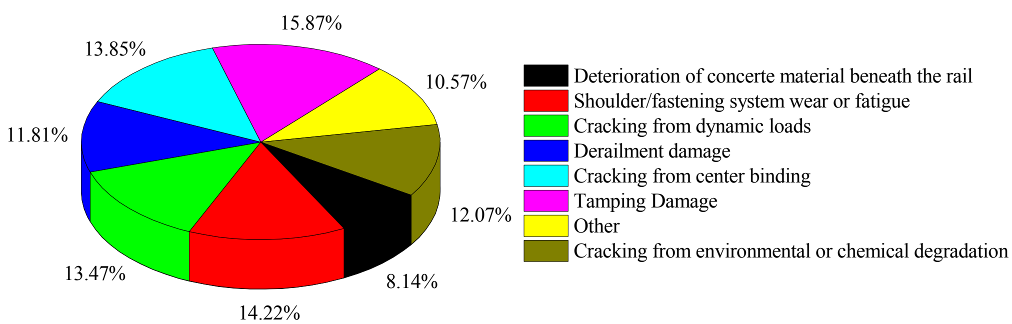


Figure 1. Types of concrete sleepers failures

2. Numerical Model

2.1 Vehicle－Track Coupled Model

The train–track interaction is a classic railway dynamics topic that has been studied for a long time. As shown in figure 2, the paper adopts a freight truck－track coupled model (Zhai, 1996), in which a freight subsystem is modeled as a multi-body system with 47 DOFs running on the track with a constant velocity, and the track substructure is modeled as an infinite Euler beam supported on a discrete-continuous elastic foundation consisting of the three layers of rail, sleeper, and ballast, including completely and incompletely hanging sleepers. Based on the study, the model is built to solve the problems in heavy haul railway.

The equations of motion of the freight car subsystem are regularly derived according to D'Alembert's principle, which are second order ordinary differential equations expressed in the matrix form as follows (Garg et al., 1984):

$$[\mathbf{M}]\{\ddot{X}\}+[\mathbf{K}]\{X\}+[\mathbf{C}]\{\dot{X}\}=\{\mathbf{F}\} \quad (1)$$

where [**M**], [**C**] and [**K**] are mass, damping and stiffness matrices, respectively; and $\{X\}$ and $\{\mathbf{F}\}$ are the generalized displacement and external force vectors, respectively.

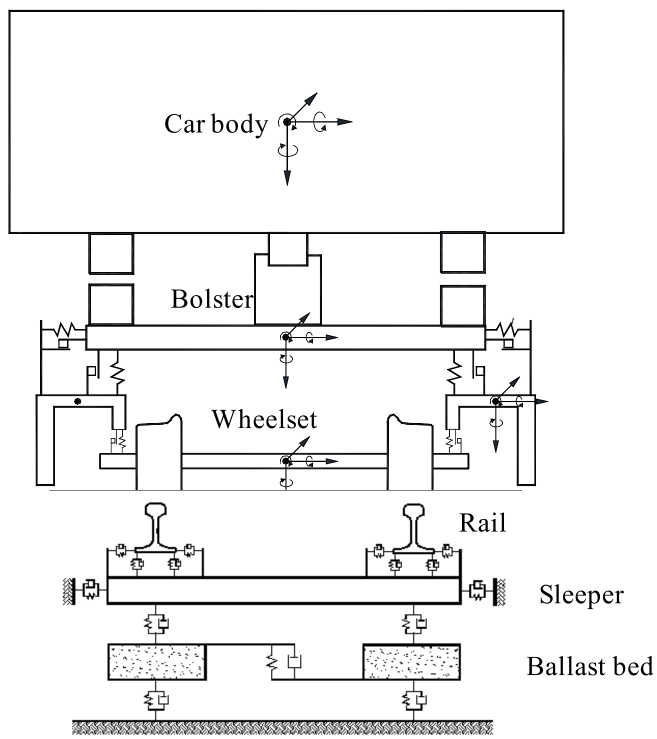
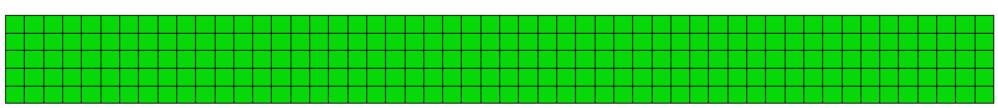


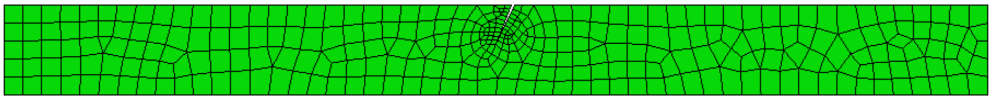
Figure 2. Vehicle－track coupled model

2.2 Concrete Sleeper Model

The finite element method is applied to build the concrete sleeper model though the Abaqus software. Type-III concrete sleeper was selected to study, as shown in figure 3. Its overall dimension is 2.6m×0.23m×0.314m, and CPS4 element was used to mesh for the concrete sleeper.



(a) Normal concrete sleeper



(b) Damaged concrete sleeper

Figure 3. Concrete sleeper finite element model

Stress intensity factor (SIF) is introduced as an index to investigate the propagation of the transverse crack, which can be used to evaluate the stress in the field of crack tip. However, it is difficult to determine the analytical expression of SIF with the complex loads and irregular structure. Thus, a numerical calculation named extrapolation method based on the node displacement is applied to solve SIF with the finite element method. In the software of Abaqus, the displacement is a primary variable and the stress connected by stain and displacement is a secondary variable. So it is a precise way to calculate SIF with the node displacements. The vertical displacement υ can be read directly in the finite element analysis. Therefore, SIF can be expressed as follows,

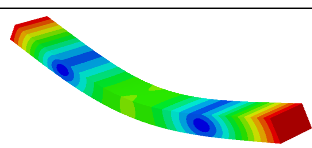
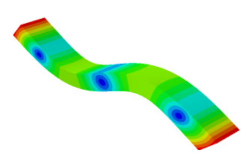
$$K_{1i} = \frac{2\mu}{\kappa+1}\upsilon_i\sqrt{\frac{2\pi}{r_i}} \tag{2}$$

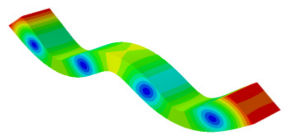
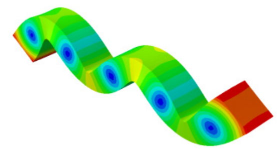
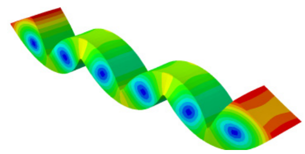
where $\mu = E/2(1+v)$; $\kappa = (3-v)/(1+v)$; E is elasticity modulus and v is poisson's ratio. The data pair (r_i, K_{1i}) can be structured and the SIF is finally defined by least square method.

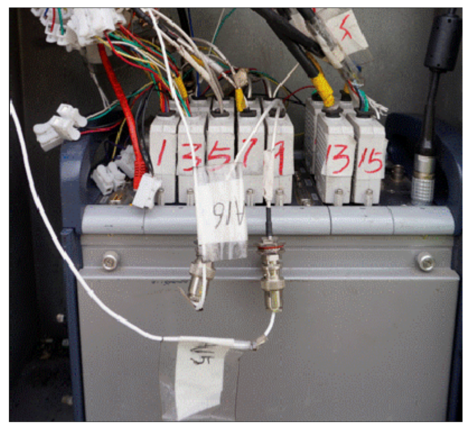
3. Model Verification

Based on the concrete sleeper model, the first five order mode frequencies are 125 Hz, 326 Hz, 603 Hz, 934 Hz, 1303 Hz, respectively, as shown in table 1. To verify the concrete sleeper vibration modes, a field test has been conducted in a heavy-haul railway line. Figure 4 describes the test site where the concrete sleeper vibration displacement and acceleration are measured by the tapping test using a hammer.

Table 1. Concrete sleeper modes

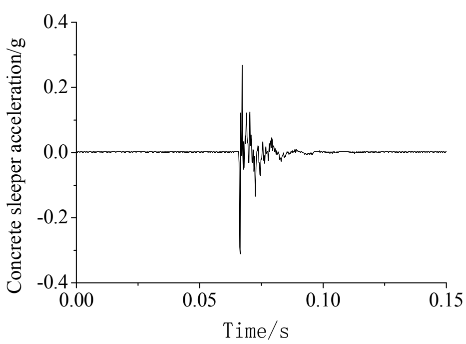
Modal frequency	Mode shape	Modal frequency	Mode shape
Mode 1 125Hz		Mode 2 326Hz	

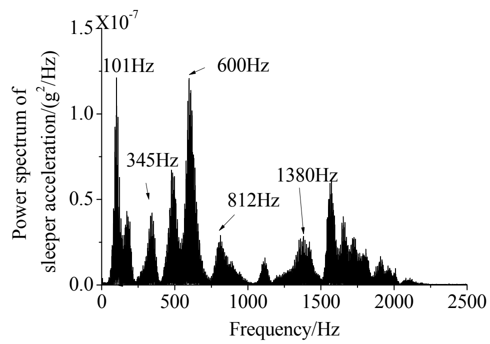
Mode 3 603Hz		Mode 4 934Hz	
Mode 5 1303Hz			

(a) Test site (b) IMC(test instrument)

Figure 4. Field test in a heavy-haul railway line





(a) Sleeper acceleration **(b) Power spectrum of sleeper acceleration**

Figure 5. A typical test data

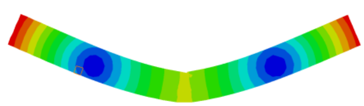
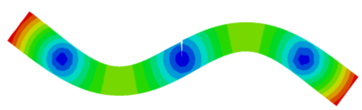
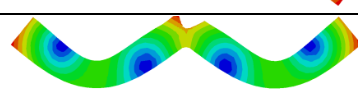
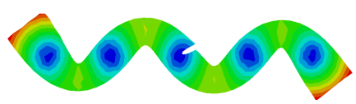
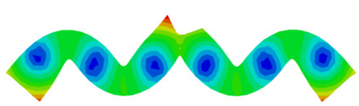
As shown in Figure 5, the vibration acceleration of concrete sleeper can exceeds about 0.3g in the case of tapping test. In order to acquire the sleeper vibration mode frequencies, FFT of sleeper acceleration is shown in figure 5, in which the first five order bending modes are 101 Hz, 345 Hz, 600 Hz, 812 Hz, 1380 Hz, respectively. Therefore, the bending modes of concrete sleeper calculated by numerical calculation and measured by field test are coincident.

4. Vibration Characteristics of Damaged Concrete Sleeper

4.1 Vibration Modes

Transverse crack in the middle cross section of the sleeper occupies a large proportion. So a damaged concrete sleeper considering transverse crack is built in Abaqus software and the modal analysis is conducted. As shown in table 2, the first 5 order natural frequencies are 124 Hz, 324 Hz, 511 Hz, 914 Hz, 1186 Hz, respectively. Compared with the modal frequencies of normal concrete sleeper, the modal frequencies of damaged concrete sleeper reduce to some extent. The first 2 order modal frequencies of the two different concrete sleepers have little change, whereas the 3rd order frequency and the 5th order frequency have obvious difference, reducing by15.3% and 9.0%, respectively. Therefore, modal frequency of concrete sleeper in high frequency range would decrease clearly when the transverse crack appears in the middle crossing section of the concrete sleeper.

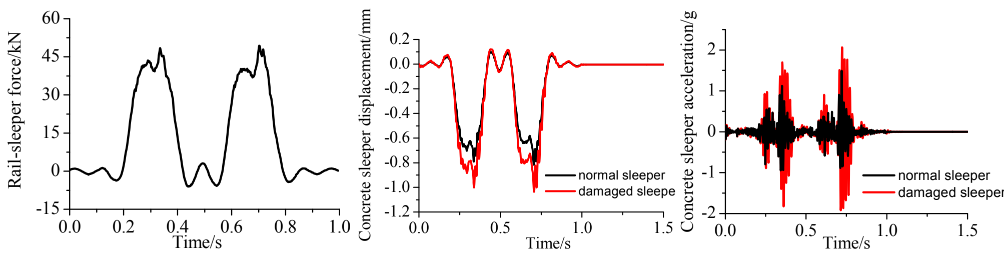
Table 2. Damaged concrete sleeper modes

Modal frequency of damaged sleeper/Hz	Mode shape	Modal frequency of normal sleeper/Hz	Changing rate/%
124		125	-0.8
324		326	-0.6
511		603	-15.3
914		934	-2.1
1186		1303	-9.0

4.2 Vibration Response under Train Loads

In order to simulate the vibration characteristics of the concrete sleepers, the rail-sleeper forces calculated by vehicle－track coupled dynamics theory were applied to the sleeper finite element model. Figure 6(a) gives the rail-sleeper forces which can exceed about 50 kN when a freight car with the axle load of 25 t passes though the track with a constant velocity.

Figure 6(b) and figure 6(c) describes the displacement and acceleration of concrete sleeper in the cases of normal concrete sleeper and damaged concrete sleeper. It can be seen obviously from figure 6(b) and figure 6(c) that the displacement and acceleration of the damaged concrete sleeper are a little higher than normal concrete sleeper. The maximum of normal concrete sleeper displacement is only 0.80 mm while that of damaged concrete sleeper displacement is about 1.04 mm, increasing by 30%. For the acceleration of the concrete sleeper, the two cases are 2.06 g and 1.51 g, respectively. The former increases by 36% compared with the latter. Therefore, the vibration characteristics of damaged concrete sleeper would deteriorate dramatically, which affects the running safety and reduces the track lifetime. It is necessary to control the appearance of crack to ensure the normal traffic.



(a) Rail-sleeper force; (b) Concrete sleeper displacement; (b) Concrete sleeper acceleration

Figure 6. Vibration characteristics of concrete sleepers

4.3 SIF

As shown in figure 7, in order to investigate the propagation of the transverse crack, the stress intensity factor is introduced. It can be seen that ΔK_1 exceeding about 50 $N{\cdot}mm^{-1.5}$ is much larger than ΔK_2. Dynamic response of stress intensity factor in the crack tip shows that the intensity of stress field near the crack tip is controlled by Stress Intensity Factor Type-I. Fracture toughness K_{IC} was usually used to describe the capacity of concrete resisting fracture, which is in the range of 20~30 $N{\cdot}mm^{-1.5}$(Carpinteri et al., 1984). Therefore, crack instability propagation would occur under the train loads and it is important to control the crack size to prolong service life of concrete sleeper.

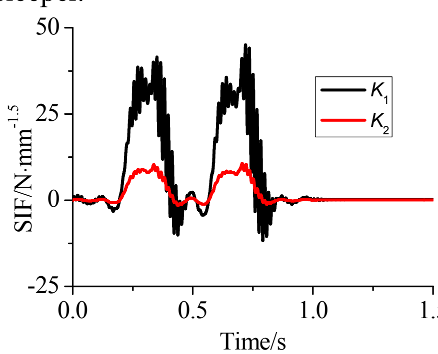


Figure 7. Stress intensity factor (SIF)

5 Conclusions

This paper presents an investigation on the effect of transverse crack in the middle cross section of the sleeper on vibration characteristics of concrete sleepers on the basis of the vehicle—track coupled dynamics. From the above studies, the following conclusions can be reached:

(1) Modal frequencies of damaged concrete sleeper reduce to some extent;

(2) Vertical acceleration and displacement of damaged concrete sleeper increase obvious;

(3)The intensity of stress field near the crack tip is controlled by Stress Intensity Factor Type-I and crack instability propagation would occur under the train loads.

Acknowledgement

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References

Carpinteri, A., Ingraffea, A. R., (1984). "Fracture mechanics of concrete: Material characterization and testing."

Dyk, B.J.V., Dersch, M.S., Edwards, J.R., (2012). "USA: International concrete crosstie and fastening system survey." United States Department of Transportation (US DOT), Federal Railroad Administration (FRA). Washington DC

Ferdous, W., Manalo, A., (2014). "Failures of mainline railway sleepers and suggested remedies review of current practice." Engineering Failure Analysis, 44: 17-35.

Garg, V. K., and Dukkipati, R.V., (1984). "Dynamics of Railway Vehicle Systems." Academic Press

Kaewunruen, S., Remennikov, A. M., (2009). "Impact capacity of railway prestressed concrete sleepers." Engineering Failure Analysis, 16(5): 1520-1532.

Lin, H. S., Liu, X. Y., Zhou, W., (2010). "Preliminary study on the effect of ballastless bed cracks on track vibration." Journal of the China Railway Society, 6: 0-16.

Lin, H. S., Li, P. G., Yan, H., et al. (2010). "Mechanical analysis of ballastless track with damaged cracks under train load." Journal of Southwest Jiaotong University, 45(6): 904-908.

Oregui, M., Li, Z, Dollevoet, R., (2014). "Identification of characteristic frequencies of damaged railway tracks using field hammer test measurements." Mech. Syst. Signal Process, http://dx.doi.org/10.1016/j.ymssp.2014.08.024i

Zhai, W. M., Cai, C. B. and Guo S. Z., (1996). "Coupling model of vertical and lateral vehicle/track interactions." Vehicle System Dynamics, Vol.26, No.1, pp.61-79

Zhu, S. Y., Cai, C. B., (2012). "Analysis on vertical vibration characteristics of double-block ballastless roadbed with cracks." Journal of the China Railway Society, 34(8): 82-86.

Influences of the Material Properties of Cement Asphalt Mortar on Box Bridge Structure Vibration-Born Noise

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Abstract: Due to growing concerns on the low-frequency box bridge structure vibration-born noise, the noise and vibration reduction design becomes a research focus at present. In this paper, based on the slab ballastless track- box bridge coupling dynamic model developed by the finite element method, the influences of stiffness and damping of the cement asphalt mortar (CAM) layer on the elevated box bridge structure vibration and noise radiation are studied. The results show that: the effect of stiffness of the CAM layer on the sound pressure level (SPL) caused by the box bridge structure vibration is not obvious, but the radiation scope of the box bridge structure noise is expanded by the greater stiffness of the CAM layer; with the damping of CAM layer increasing, the sound pressure of vertical acoustic field decreases, and the radiation scopes above and below the box bridge are also smaller, but the sound pressures of the noise concentration areas near the box bridge increases.

Keywords: Elevated box bridge; Cement asphalt mortar; Stiffness; Damping; Vibration-born noise radiation.

1 Introduction

The elevated bridge structure will become an important noise source, when a train moves quickly on it (Thompson, 2009). The main characteristics of the bridge structure noise are of low frequency, slow attenuation and large radiation area. According to, the previous studies on the bridge structure noise focus on noise radiation laws, spectrum characteristics analysis and test verification. As the research going, the controls of bridge structure vibration and noise are taking more and more attention. The articles found that for the railway box bridge, there are some differences between the low vibration deduction design and noise reduction design due to that the spectrum characteristics of its vibration and noise are different. He also did an optimization design for the box bridge structure noise by changing the thickness of the panels and the inclination of web panels (Zhang, 2013; Zhang, 2013). HAN Jianglong carried out the vibration and noise reduction design for the concrete groove bridge by adding horizontal ribs (Han, 2012). GAO Fei found that the stiffness of bearings has important effects on the bridge structure vibration, but has not obvious influences on bridge structure noise (Gao, 2012). GENG Chuanzhi developed a metro vehicle-elastic fasteners coupling dynamic model to analyze the influence of stiffness of fasteners on the wheel/rail forces (Geng, 2007). LIANG Shangyan established a dynamic model of the floating slab track structure, and studied the influences of the positions of loads, the length of slab and the stiffness and damping of steel springs on the vibration isolation performance of the floating slab track (Liang, 2013). CAI Chengbiao analyzed the effects of the stiffness of CAM layer or rubbers on the dynamic responses of track (Cai, 2011). GUO Yajuan studied the influences of the stiffness of fasteners, the stiffness and damping of steel springs on the dynamic responses of floating slab track structure (Guo, 2006). Nelson J. T. found that fasteners the flexible fasteners of stiffness 10 MN/m, compared to the common fasteners of stiffness 20 ~ 25 MN/m, can reduce the ground vibration noise of more than 30Hz by 5 dB (Nelson, 1996).

In order to study the influences of the stiffness and damping of CAM layer of the ballastless CRTS-I slab track on the elevated box bridge structure noise, the vehicle-track coupling dynamic model is firstly established by the Simpack software, and the vertical wheel/rail forces excited by Germany low interference spectrum is obtained. The track-box bridge coupling dynamic model is secondly established by the Ansys finite element software, and the wheel/rail forces are taken as the load boundary conditions to calculate the bridge structure vibration responses in time domain using the transient analysis method. At last, the bridge structure vibration acceleration responses are taken as the acoustic radiation boundary conditions to calculate the box bridge structure-born noise by the Virtual Lab software. On this basis, the influences of the stiffness and damping of CAM layer on the acoustic field distribution and the frequency spectrum characteristics of the box bridge structure noise are studied, aiming at providing some references to the noise reduction designs for bridge structure.

2 Acoustic boundary element theory of box bridge structure

The noise radiation caused by the vibration of a closed structure in the fluid medium meets the acoustic wave equations, the Neumann boundary conditions for the fluid-structure interface and Sommerfeld radiation condition, expressed as:

$$\nabla^2 \vec{p} + k^2 \vec{p} = 0 \tag{1}$$

$$\frac{\partial \vec{p}}{\partial \vec{n}} = -i\rho_0 \omega \vec{v}_n \tag{2}$$

$$\lim_{r\to\infty}\left[r\left(\frac{\partial \vec{p}}{\partial r} - ik\vec{p} \right) \right] = 0 \tag{3}$$

Where ∇ is the Laplace operator, $\vec{p}$ is the sound pressure, $k=\omega/c$ is the wave number, ω is the circular frequency, c is the sound velocity in the air, $\vec{v}_n$ is the normal vibration velocity vector, ρ_0 is the fluid density, $r=\left|\vec{X}-\vec{Y}\right|$, X is a point on the surface of the structure A and Y is a point in the sound field, A is the surface area of the structure.

Using the Green function of the free space, the Helmholtz integral equation is

$$\vec{p}(Y)=\int_A\left(\frac{e^{-ikr}}{4\pi r}\Delta\vec{v}(X)+\frac{e^{-ikr}}{4\pi r}\left(ik+\frac{1}{r}\right)\cos\beta\Delta\vec{p}(X)\right)dA(X) \qquad (4)$$

Where β is the angle between the point normal vectors of structure surface X and the radius vector r; D is the fluid media area; $\Delta\vec{v}(X)$ is the velocity difference of either side of point X on the boundary surface, and $\Delta\vec{p}(X)$ is the sound pressure difference of either side of point X on the boundary surface, which are expressed as, respectively:

$$\begin{cases}\Delta\vec{v}(X)=-i\rho_0\omega(\vec{v}_{n1}(X)-\vec{v}_{n2}(X))\\ \Delta\vec{p}(X)=\vec{p}_1(X)-\vec{p}_2(X)\end{cases} \qquad (5)$$

Where $\vec{p}_1(X)$ and $\vec{p}_2(X)$ are the pressures of either side of point X on the boundary surface, respectively; $\vec{v}_{n1}(X)$ and $\vec{v}_{n2}(X)$ are the normal vibration velocities of either side of point X on the boundary surface, respectively.

Dividing the structure surface by boundary elements obtain the pressure difference and vibration velocity difference of each node on the structure surface, expressed as

$$\begin{Bmatrix}\Delta\vec{v}(X)\\ \Delta\vec{p}(X)\end{Bmatrix}=C^{-1}F \qquad (6)$$

Where C is the full rank symmetric plural matrix which is also the function of excitation frequency, which is related with the shape of the surface of the structure, the size and the interpolation shape function. F is the vector of external excitation which is determined by the vibration velocities of the boundary surface.

The sound pressure of any point out the structure surface calculated by formula (7), shown as

$$\vec{p}(Y)=B\begin{Bmatrix}\Delta\vec{v}(X)\\ \Delta\vec{p}(X)\end{Bmatrix}=BC^{-1}F \qquad (7)$$

Where $\vec{p}(Y)$ is the sound pressure of any point out the structure surface, and B is the interpolation matrix, which are determined by formula (4).

3 Influences of the material properties of CAM layer on box bridge structure vibration

3.1 Finite element model of track-bridge coupling dynamics

Taking the 32m simply supported concrete railway box bridge as the research object whose height is 3m, poisson's ratio 0.25 and density 2500*kg/m³*.The thickness of the top, web and bottom plates are 0.315m, 0.48m and 0.3m, respectively. The tracks on the box bridge are comprised of CRTS-I slabs, and the length, width and height of slab are 4.93m, 2.4m, 0.2m, respectively. Tab. 1 and Tab. 2 shows the dynamic parameters of the finite element model and the element type, and the element sizes are 0.3m.

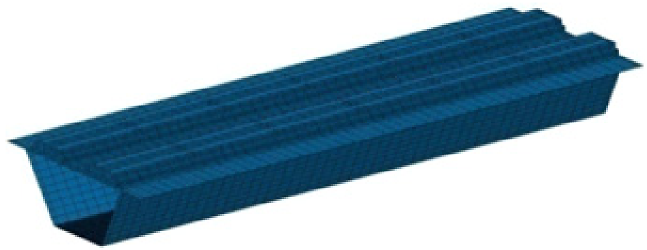

Figure 1.Finite element model of CRTS-I slab ballastless track-bridge coupling dynamics

Table 1. Dynamic parameters of track and box bridge

Dynamic parameter	Value
Stiffness of fastener/(N·m^{-1})	4×10^{7}
Damping of fastener/(N·s·m^{-1})	2.2656×10^{4}
Elastic modulus of slab /(N·m^{-2})	3.6×10^{10}
Poisson ratio of slab	0.2
Density of slab /(kg·m^{-3})	2500
Stiffness of CAM layer /(N·m^{-1})	9.375×10^{9}
Damping of CAM layer/(N·s·m^{-1})	7.5×10^{5}
Elastic modulus of base /(N·m^{-2})	3.3×10^{10}
Poisson ratio of base	0.2
Density of base /(kg·m^{-3})	2500
Elastic modulus of bridge /(N·m^{-2})	3.8×10^{10}
Poisson ratio of bridge	0.25
Density of bridge /(kg·m^{-3})	2500

Table 2. Element types of the element model

Component	Element type
rail	Beam4
fastener	Combin14
slab	Solid45
CAM layer	Combin14
bridge	Shell63

3.2 Dynamic responses of box bridge

For a high-speed train composed of 8 vehicles with a speed of 200 km/h runing on a elevated bridge, the wheel/rail forces excited by the track irregularity are shown in Fig. 2. The parameters of train are listed in reference.

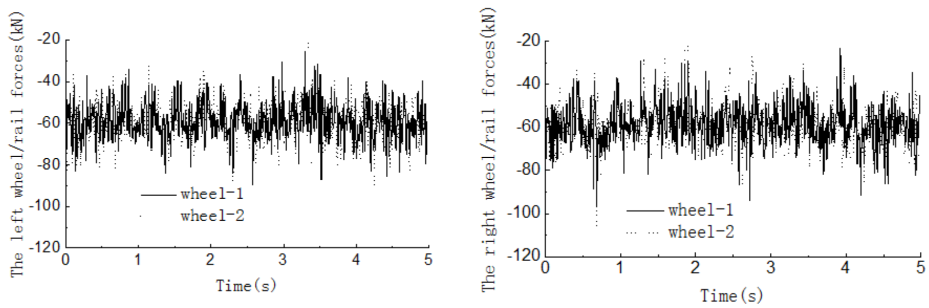

Figure 2.Vertical wheel/rail force

Figure 2 shows that the wheel/rail force fluctuations near 60 kN, wholes maximum value reaches 108.28 kN. Compared to the left wheel/rail force, the right is larger. Those wheel/rail forces are applied on the finite element model of CRTS-I slab ballastless track-bridge coupling dynamics to calculate the bridge structure dynamic responses. The time history and spectrum diagram of the acceleration of the bridge are shown in Figure 3.

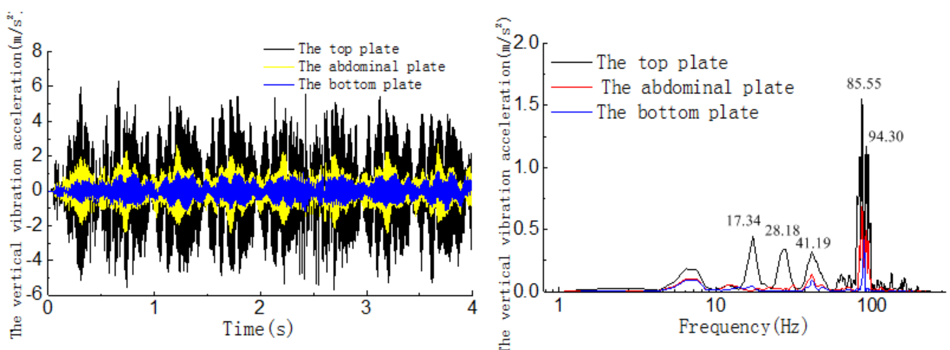

Figure 3.The acceleration responses of the bridge at 1/2 span

From Figure 3, we can find that the box bridge structure vibration are mainly concentrated in 0-200 Hz; the vibration of top plate is most obvious and its peaks appear mostly in 10-100 Hz, and its maximum is at 85.55Hz and it also has some peaks at 17.34 Hz, 28.18 Hz, 41.19 Hz and 94.30Hz.

3.3 Influences of the material properties of CAM layer on box bridge structure vibration

Previous research had shown that the influences of the material properties of CAM layer on the wheel/rail forces are tiny, so the effects of the material properties of CAM layer on the wheel/rail forces are not taken into consideration.

Tab. 3 Selected material parameters

Component	Stiffness/MPa	Damping/N·s·m^{-1}
CAM layer	937.5	75e^4
	750	75e^4
	1250	75e^4
	1500	75e^4
	937.5	37.5e^4
	937.5	150e^4
	937.5	225e^4

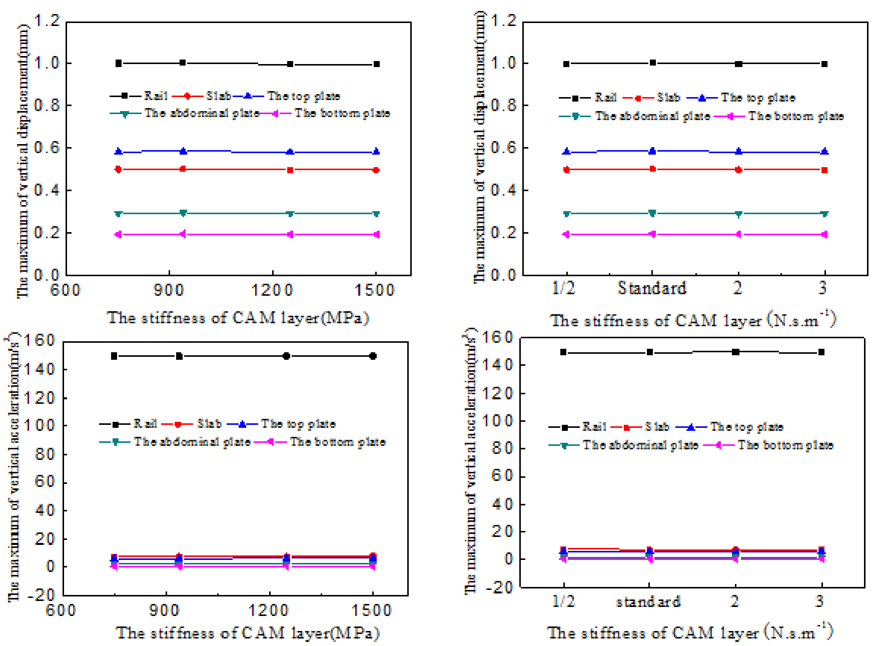

Figure 4.Influences of the stiffness and damping of CAM layer on the vertical displacement and acceleration of rail, slab and bridge

From Fig. 4, we can find that the influence of the stiffness of CAM layer on the vibration displacements of rail, slab and bridge is small; the vibration displacements of slab and bridge have slight increase; the influence of the damping of CAM layer on the vibration displacements of rail, slab and bridge is also small; the greater damping can slightly reduce vibration displacements of bridge.

4 Influences of the material properties of CAM layer on box bridge structure noise

In this paper, we put focuses on the influences of the material properties of CAM layer on box bridge structure noise and taking the effect of the ground reflection will be disadvantage to our analysis, so it is better to neglect the ground reflection.

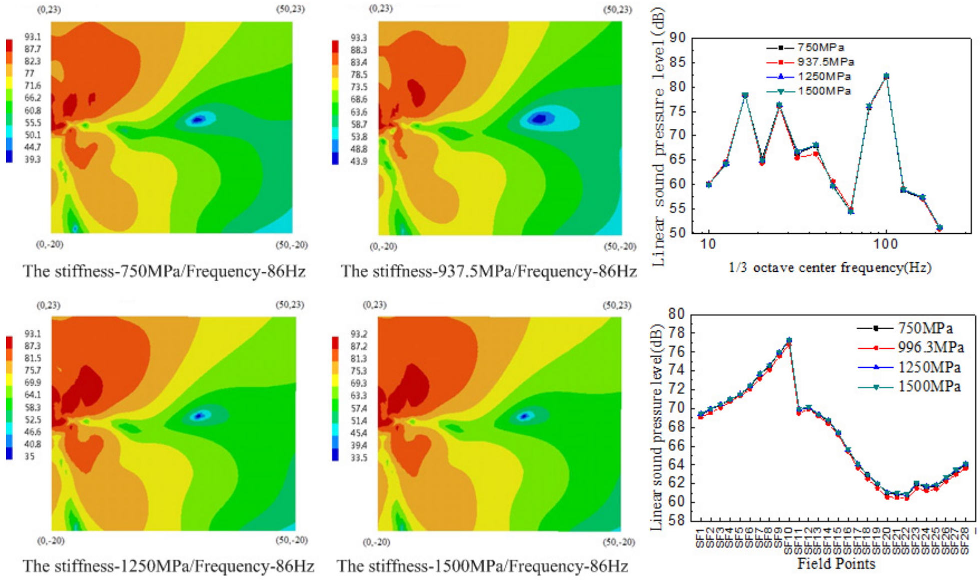

Figure 5.Influences of the stiffness of CAM layer on box bridge structure noise

From the sound field frequency spectrum, we can find that the effect of stiffness of the CAM layer on the SPL caused by the box bridge structure vibration is not obvious, but the radiation scope of the box bridge structure noise is expanded by the greater stiffness of the CAM layer.

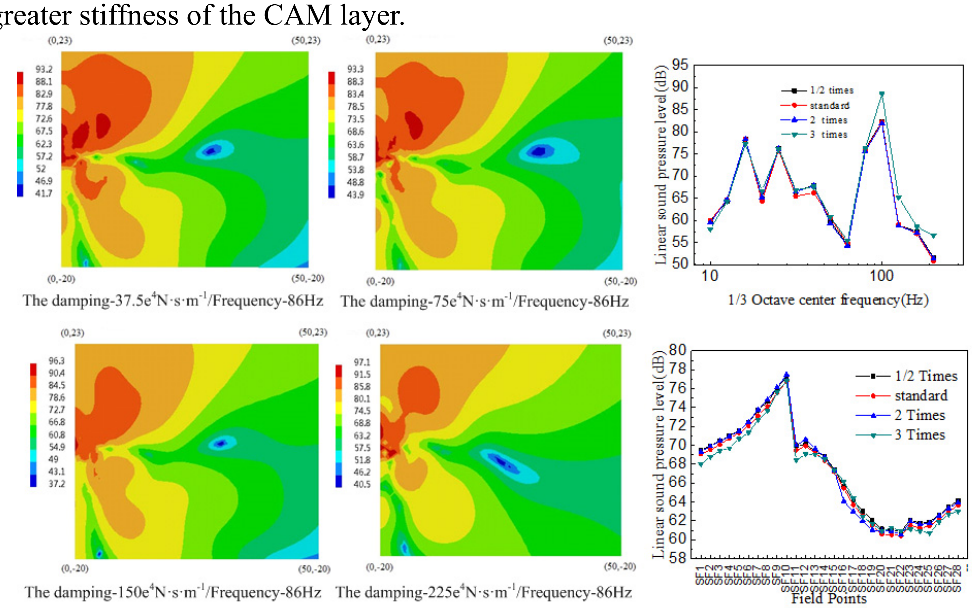

Figure 6.Influences of the damping of CAM layer on box bridge structure noise

From the sound field frequency spectrum, we can find that with the damping of CAM layer increasing, the sound pressure of vertical acoustic field decreases, and the transverse sound field not obviously changes; when the center frequency is above 80Hz, the greater the damping is, the greater the SPL is. From the sound field distribution, we can find that with the damping of CAM layer increasing, the sound pressure of the sound pressure of vertical acoustic field radiation scopes above and below the box bridge are smaller, but the sound pressures of the noise concentration areas near the box bridge increases.

5 Conclusions

(1) The effect of stiffness of the CAM layer on the sound pressure level (SPL) caused by the box bridge structure vibration is not obvious, but the radiation scope of the box bridge structure noise is expanded by the greater stiffness of the CAM layer;

(2) With the damping of CAM layer increasing, the sound pressure of vertical acoustic field decreases, and the radiation scopes above and below the box bridge are also smaller, but the sound pressures of the noise concentration areas near the box bridge increases.

Acknowledgement

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References

Thompson, D. J. (2009). “Railway Noise and Vibration : Mechanisms, Modeling and Means of Control.” *Elsevier Science Ltd*. UK.

Zhang, X., Li, X. Z, Liu, Q. M., et al. (2013). “Study of MTMDs on the structure-borne noise control of High-speed Railway simply supported box-girder bridge.” *Journal of Vibration and Shock*, 32 (13), 194-200.

Zhang, X., Li, X. Z. Q., Liu, M., et al. (2013). “Study on structure-borne noise of concrete box-Girder and its influence factors.” *Journal of Southwest Jiaotong University*, 48(3), 409-414.

Han, J. L., Wu, D. J. and Li, Q. (2012). “Influence of deck thickness and stif feners on structure-borne noise of the trough beams.” *Journal of Vibration Engineering*, 25 (5), 589-594.

Gao, F., Xia, H., Cao, Y. M., et al. (2012). “Vibration and noise influences of elevated structures in urban railway.” *Journal of Vibration and Shock*, 31(4), 72-76.

Geng, C. Z., Dong, G. X. and Zhu, J. Y. (2007). “Analysis of wheel-track force with elastic rail fastener.” *Urban Mass Transit*, (4), 20-21+25.

Liang, S. Y., Xiao, A. X. and Geng, C. Z. (2013). “Analysis of Vibration Isolation Performance of Floating Slab Track Structure with Damping Steel Springs.” *Noise and Vibration Control*, (1), 136-139.

Cai, C. B. and Xu, P. (2011). "Dynamic Analysis for Frame Slab Track of High-speed Railway." *Journal of Vibration Engineering*, 24(2), 164-169.

Guo, Y. J., Yang, S. P. and Guo, W. W. (2006). "Analysis of Dynamic Characteristics of Steel Spring Supported Floating Track Bed." *Journal of Vibration, Measurement & Diagnosis*, 26(2), 146-150.

Nelson, J. T. (1996). "Recent development in ground-borne noise and vibration control." *Journal of Sound and Vibration*, 193(1), 367-376.

Zhai, W. M. (2007). "Vehicle-Track Coupling Dynamics (Third Edition)." *Science Press*, Beijing.

Luo, Z. (2008). "Analysis of Structure Mechanics and Wheel/rail Dynamic Interaction of Allastless Track in High-speed Railway." *PhD. Southwest Jiaotong University*, Chengdu.

Seismic Isolation and Energy Absorption Properties Research for a Dry Joint Segment Fabricated Pier Viaduct in a Highly Seismic Region

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Abstract: This article proposes a bilinear stiffness plastic hinge simplified model , based on the existing experimental research on dry joints fabricated pier; Using of nonlinear time history analysis method, seismic isolation performance of combination system of dry joints fabricated pier with laminated rubber bearing is discussed in the perspective of damping isolation. Results indicate that the dry joints fabricated pier system can reduce the seismic force and energy. The conclusion has some practical significance for the applications of dry joints fabricated pier bridge in high earthquake region.
Keywords: Seismic isolation performance; Fabricated pier; Time history analysis method; Simplified calculation mode.

1 Introduction

The harsh construction conditions or restrictions on traffic interference, promotes the application of precast segmental bridge columns which mainly used as wet seam application form in low seismic intensity areas（LAN, 2012）. Considering of the advantages and application requirement of precast segmental bridge columns on high earthquake zone, seismic performance study on precast segmental bridge columns rises.

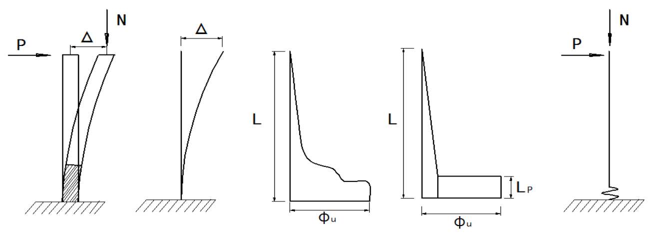
Currently, the scholars have carried out some related researches, including theoretical and experimental studies (WANG, 2009). Theoretical methods includes analytical method, concentrated plastic hinge method, the fiber model method and reinforced concrete solid finite element model (GE,2008). Experimental research regards to component failure mode (Mander, 1997, Hieber,2005). The foundation for the relevant experimental and theoretical studies of Segmental pier was laid. However, the research for the highly seismic performance of precast segmental pier bridge is still in its infancy and mainly component level.

Seismic must be withstood by the bridge structure and seismic isolation philosophy is a necessary means to resist earthquakes. Therefore, the possibility of dry joints pier high earthquake zone applications is explored, with some practical value, in the perspective of the bridge system, combined with seismic isolation measures.

2 Calculation mode for dry joints precast segmental piles

Segmental pier nonlinear factors including analog tendons and mechanical properties of the seam area is much. Calculation of nonlinear seismic response is not realistic using of the precise method. It needs to be simplified. Concentrated plastic hinge method is a suitable, systematic, efficient methods, widely used in the whole cast piers.

Mechanical model of the plastic hinge is to set up a spring in the plastic hinge to simulate the elastic-plastic rotation (Figure 1).



Pier	Deform	Actual curvature distribution	Ideal curvature distribution	Plastic hinge model

Figure 1. Plastic hinge model

Centralized plastic hinge method requires determining the restoring force model for Segmental pier. Restoring force model is an important parameter to reflect the dynamic characteristics of the structure, and indispensable for structural analysis and design. Restoring force model and its parameters reasonable will have a significant impact on nonlinear seismic response of Segmental analysis piers.

2.1 Moment Curvature Analysis

According to quasi-static test result of the dry joint sections pier (GAO, 2011), precast segmental bridge columns occurs through three stages (joints closing, open, the plastic deformation of concrete, prestressed reinforcement yielding process) under cyclic loading (Figure 2). Sectional moment curvature can be calculated by finite method.

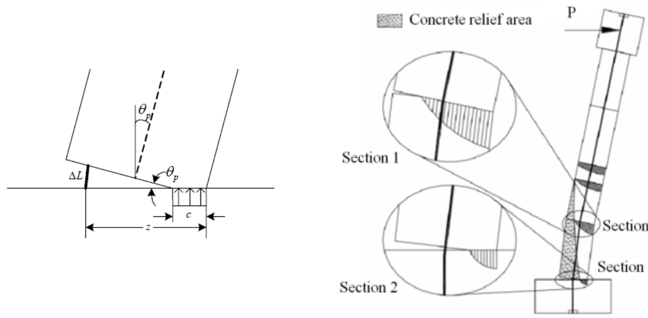


Figure 2. Elastic-plastic analysis

According to the equilibrium condition, relationship between section internal forces and stresses satisfy is as following:

$$N=\int \sigma dA=\int \sigma_c dA+\int \sigma_s dA+\int \sigma_{sp} dA \qquad (1)$$

$$M=\int y\sigma dA=\int y\sigma_c dA+\int y\sigma_s dA+\int y\sigma_{sp} dA \qquad (2)$$

Among, σ_c, σ_s, σ_{sp} Respectively Stress of concrete, steel, prestressing steel.

Concrete material uses Kent-Park model, reinforced using Giuffré- Menegotto-Pinto model, prestressing steel using ideal elastic-plastic models.

2.2 Restoring force model

Restoring force model is necessary to consider the hysteresis characteristics of components, and should also be maximum simplified for the present level of seismic response analysis. Seeing from the existing experimental results (LIU, 1994), skeleton curve of prestressed beams can be simplified to forward and reverse three polylines (Figure 3), reflecting strengthening properties of tendon.

Based on a number experiments (Clarkp,1999), the hysteresis curve of segments pier plastic hinge can be simplified as follows (Figure 4): After the force component exceeds the yield strength, load path along the skeleton curve; Hysteresis loop no stiffness or strength degradation; Unloading stiffness smaller then initial stiffness.

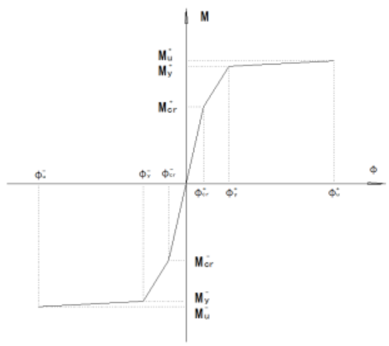


Figure 3. Skeleton curve

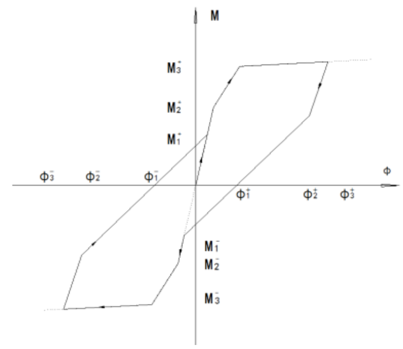


Figure 4. Hysteresis curve

2.3 Plastic hinges number

Prestressed Concrete Segmental piers destruction mainly occurs at the joints. According to the results, according to the joint position, a plurality of plastic hinges is set.

3 Calculate schema validations

In order to ensure the correctness of the analysis method, the calculation results and existing research results of concentrated plastic hinge analysis were compared (Figure 5). The foundation for the analysis of seismic isolation system of precast segmental bridge piers is laid.

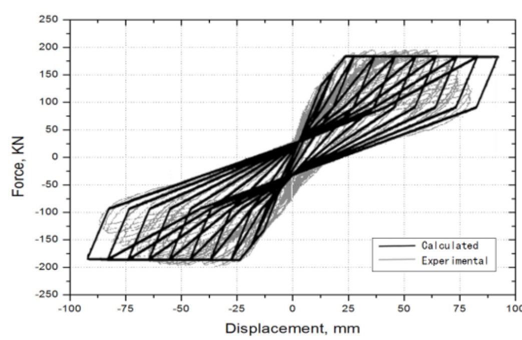


Figure 5. Comparison of Hysteresis curve

Compared with the experimental results (LIU,2008), hysteresis curve of centralized pier plastic hinge analysis resulting is good agreement with experiments, and simulation error can be negligible before its stiffness degradation. The simulation results can be used to meet the bridge seismic isolation system analysis.

4 Isolation Performance Research

Prestressed concrete continuous bridge with 5 spans set as the example engineering shown in Figure 6. Pier height variation makes dynamic response for the isolated bridge is more representative.

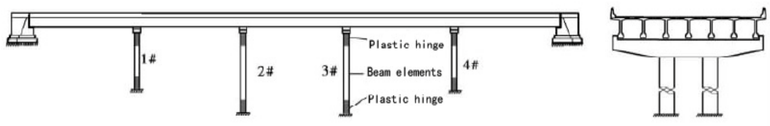


Figure 6. Example engineering

The main beam is simulated by elastic beam elements, and the mass simulated by concentration mass method; Use of centralized plastic hinge method to simulate the pier, each bearing simulated by connection elements. EI Centro seismic waves and Rayleigh damping ratio of 5% damping is used. And compared the precast segmental bridge columns (Normal bearing), precast segmental bridge columns (lead core bearing), the whole piers (lead core bearing) continuous beam bridge seismic performance.

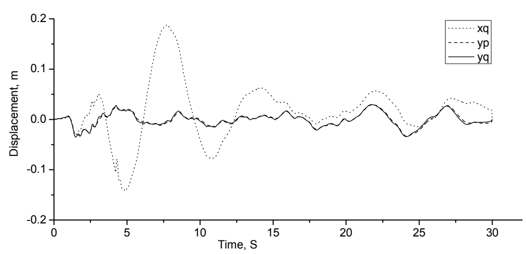


Figure 7. The 1st pier top displacement time history results

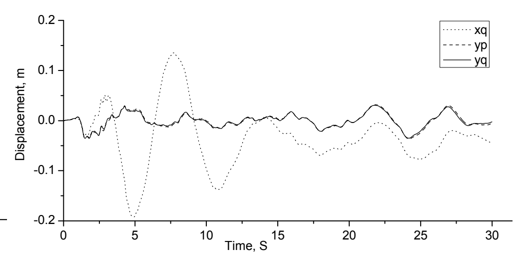


Figure 8. The 2st pier top displacement time history results

Comparison of Pier top displacement time history response (Figure 7, Figure 8) shows: prefabricated bridge pier and overall pier displacement time history during the first 2 seconds is consistent; Thereafter displacement time history response are different, and both frequency components are different. Segmental Piers displacement extreme response is smaller to the corresponding overall bridge pier. The two forms of precast pier bridge bearing displacement process are basically the same. The results proved the possibility of application of precast segmental bridge pier in highly seismic region.

5 Conclusions

Here we may draw the following conclusions.

(1) The simplified calculation method proposed is reasonable, and can be applied to structural analysis.

(2) A meaningful discussion on the application in highly seismic region is made,

and accounts segmental pier with appropriate isolation measures can be applied.

References

Clarkp A., Kasai K. (1999). Design procedures for buildings incorporating hysteretic damping devices.

Hieber D.G., Wacker J.M. (2005). State-of-the-art report on precast concrete systems for rapid construction of bridges. *Department of Transportation, Washington State Transportation Commission.*

Mander J. B., Cheng C.T. (1997). Seismic Resistance of Bridge Piers Based on Damage Avoidance Design. Technical Rep.

GE, J. P. (2008). Experimental study on seismic performance of Segmental piers and theoretical analysis.

GAO J., GE, J. P. (2011). Dry joints precast segmental bridge columns quasi-static test study. *Vibration and Shock.*

LAN, H.Y. (2012). Research status of segmental pier seismic performance. *Highway Traffic Technology.*

LIU, F. (2008). Segmental Prestressed Concrete piers quasi-static test and analysis. *Civil Engineering, Tongji University.*

LIU, Z. C. (1994). Partially prestressed concrete beams experimental study on seismic performance.

WANG Z. Q. (2009). Progress of seismic performance study for precast segmental bridge columns. *Earthquake Engineering and Engineering Vibration*.

Analysis of Visual Adaptability in the Threshold Zone of Tunnels

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Abstract: Compare to the ordinary road sections, the traffic environment of tunnels is particularly different, especially when considering the visual environment. Due to the black hole effect, the threshold zone is regarded as accident-prone location. But in the engineering practice in China, the greatest change of the illumination in tunnels happened not at the tunnel portal but at somewhere inside the tunnel. This paper aims at discovering the distance range with the highest driving risk in threshold zone of tunnel. A field experiment has been conducted in a typical tunnel in Hunan Province, China. Based on the experimental data analysis, the relationship is built between the target detection distance, the distance from the tunnel portal, and the ratio of illumination, respectively. The results showed that at operating speed of 60 km/h, the distance range with the highest driving risk is 70 m to 109 m from the tunnel portal. The distance range is 50 m to 87m from the tunnel portal for 80 km/h and 42 m to 79 m from the tunnel portal for 100 km/h. Based on target detection distance, the illumination design for tunnel lighting can be optimized.
Keywords: Visual adaptability; The threshold zone; Target detection distance; The ratio of illumination.

1 Introduction

Today there are over 11,359 highway tunnels in China in 2013 while more than 1,337 new tunnels are built each year (China Statistics, 2013). The visual environment in tunnels is quite different from the ordinary road sections, especially the threshold zone, which is the first entrance zone of the tunnel. Due to the "black hole" effect, it is regarded as the accident-prone location.

The driver's visual adaptability in the threshold zone is determined from the ratio between the threshold zone luminance and the access zone luminance. Usually, the illumination of natural light is still high at the tunnel portal. Therefore, the greatest change of the illumination appears not at the tunnel portal but at somewhere inside the tunnel.

In order to assess the driver's visual ability (Bre´mond, 2007), several indicators (illuminance, luminance, Visibility Level, etc.) have been proposed by now. The most popular indicator used is the Visibility Level (VL), which is proposed as a quality index in the American standard (IESNA, 2000) and French standard (AFE, 2002), but not in the European standard (European Norm, 2004–2005). The VL is defined as the ratio between the measured contrast ΔL (between the target and its background, which is, typically the road surface) and the contrast threshold ΔLt (Adrian, 1989, 2004).

This study investigated the target detection performance by conducting a field experiment in a typical tunnel in Hunan Province, China. The detection distance of the target inside the tunnel was obtained at three different speeds. The ratio of illumination was chosen as the visual adaptability indicator. The relationship was built between target detection distance and the ratio of illumination, then the distance range with the highest driving risk in threshold zone of tunnel was found out.

2 Method

2.1 Participants

Ten participants (3 women and 7 men) aged 26–35 years old took part in this study. 8 were drivers and 2 were field operators. All drivers had been driving for at least 3 year with a valid driving license. Their vision was good or good with glasses. And all participants were requested to be familiar with the experiment tunnel where the test drive was to be conducted.

2.2 Apparatus

2.2.1 Experimental Tunnel

A field experimental was conducted in a typical two-lane highway tunnel in Hunan Province, China. The lane width is 3.75m, and the design speed is 80 km/h. The tunnel was not open to traffic and was free of other vehicles during the experiment. (See Figure 1)

Figure 1. The experimental tunnel and target

2.2.2 Equipment

The instrumented vehicle was a 2004 Mazda Premacy. Driving speed and detection distance were collected using a non-contact speedometer (CTM-8C). The illumination photometers were used by the field operators to measure the illumination of two typical places (the tunnel portal and the target surface).

2.2.3 Target specifications

In roadway visibility research, the target specifications were almost consistent. For instance the American standard (IESNA, 2000a, 2000b) used a 20 cm uniform square as the target, with reflectance of 50%. While in Japan, a 20 cm width square flat target with a diffuse reflectance of 9-11% was used in the visibility research (K Narisada, K Yoseoikawa, 1974). In this experiment, the target specifications were the same as mentioned above and the diffuse reflectance was 30%.

2.3 Procedure

The field experiment was conducted on both sunny and cloudy days, for illumination was greatly influenced by natural light. The target was placed in the center of the left lane, while the experimental vehicle drove in the right lane. Several target locations were chosen in order to get relevant illumination values. Each participant completed three drives, one for each of 60, 80, 100 km/h conditions.

Experimenters started to record the non-contact speedometer as soon as they detected the target stimulus placed on the experimental section, and stopped the record when the vehicle drove past the target. The detection distance was recorded by the speedometer in each drive. In each test drive, two field operators used illumination photometers to measure the illumination of the tunnel portal and the target surface at the same time. Thus, the illumination was recorded.

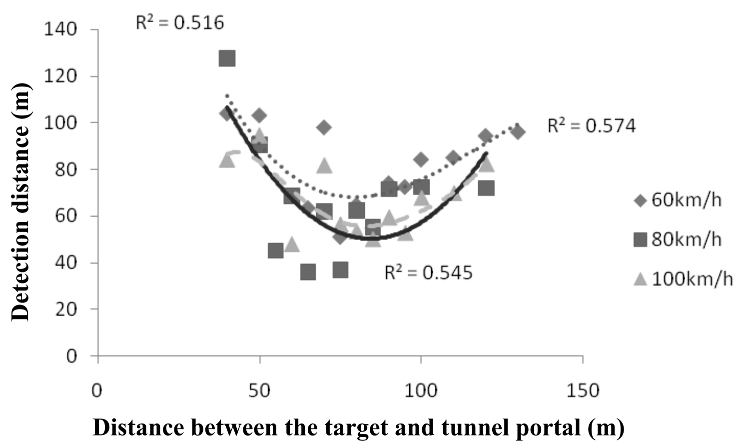
3 Results and Discussion

3.1 Analyses of the distance between the target and tunnel portal

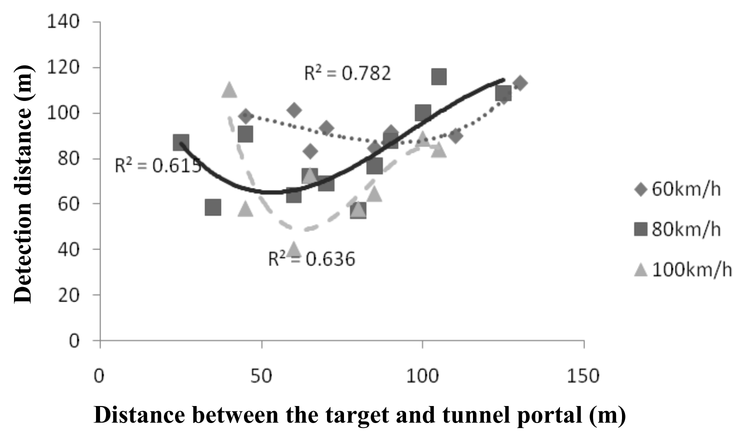
Figure 2 shows how the distance between the target and tunnel portal affects the detection distance on both cloudy and sunny days. As the target distance increases, the detection distance decreases at first and then increases. When the target distance range is between 50m to 100m, the detection distance is smaller than that in the other zones. It is the same at the operating speed of 60, 80, 100 km/h on both cloudy and sunny days.

When the drivers are close to the tunnel portal, the illumination of natural light is still high, so the detection distance is long. When the drivers are far away from the tunnel portal, the dark adaptation has already generated. Thus the drivers have actually adapted to the dark environment, and then the detection distance increases.

The smaller the detection distance, the higher driving risk exists for drivers. Therefore, the distance range with the highest driving risk for drivers is between 50m to 100m from the tunnel portal.



(a) The detection distance on cloudy days



(b) The detection distance on sunny days

Figure 2. The detection distance on different weathers

3.2 Analyses of the ratio of illumination

In order to make the connection between the detection distance and illumination, the ratio of illumination is proposed which can be calculated as following:

$$v = \frac{\left| \lg E_{out} - \lg E_{object} \right|}{\lg E_{out}} \tag{1}$$

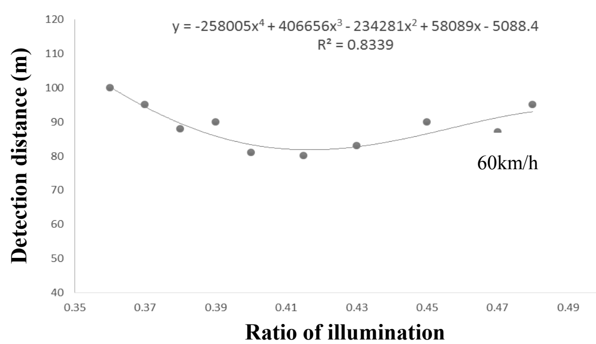
Where,

E_{out} = illumination at the tunnel portal,

E_{object}= illumination on the target surface.

Figure 3 displays the relationship between the detection distance and the ratio of illumination. As the ratio of illumination increases, there is a significant reduction in the detection distance. At operating speed of 60 km/h, when the ratio of illumination is 0.416, the detection distance reaches the minimum of 80.4m. The detection distance decreases to 69.4m for the ratio of illumination 0.425 at 80 km/h and decreases to 51.0m for the ratio of illumination 0.410 at 100 km/h.

Otherwise, for each operating speed, the detection distance doesn't decrease continuously with the increase of the ratio of illumination. As the ratio of illumination continues to increase, the detection distance grows as well. Thus, the ratio of illumination with high driving risk has been found out. At operating speed of 60 km/h, the range of ratio is from 0.391 to 0.449. The ratio is from 0.391 to 0.440 for 80 km/h and the ratio is from 0.380 to 0.440 for 100 km/h. (See Figure 3)



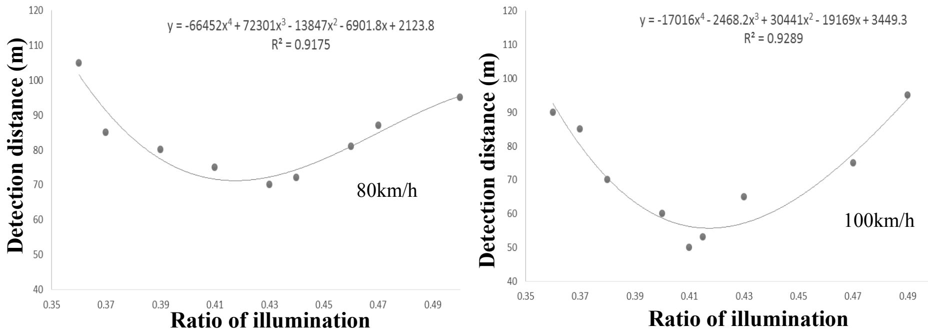


Figure 3. The relationship between the detection distance and the ratio of illumination

Based on Figure 3, the distance range with high driving risk in threshold zone of tunnel has been found out. At operating speed of 60 km/h, the distance range is 70m to 109m from the tunnel portal. The distance range is 50m to 87m from the tunnel portal for 80 km/h and 42m to 79m from the tunnel portal for 100 km/h. (See Figure 4)

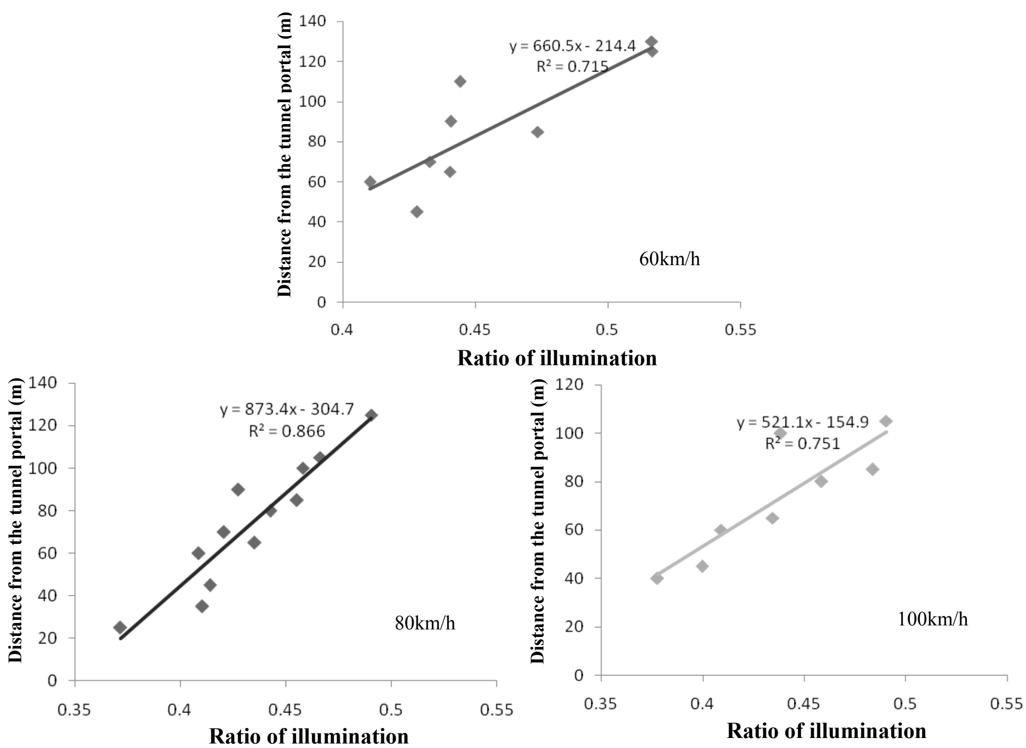


Figure 4. The relationship between the distance from the tunnel portal and the ratio of illumination

4 Conclusions

The following conclusions have been drawn:

The distance between the target and tunnel portal plays an importation role on the detection distance on both cloudy and sunny days. As the target distance increases, the detection distance decreases at first and then increases.

When the target distance range is between 50m to 100m, the detection distance is smaller than that in the other zones. It is the same at the operating speed of 60, 80, 100 km/h on both cloudy and sunny days.

When the drivers are close to the tunnel portal, the illumination of natural light is still high, so the detection distance is long. When the drivers are far away from the tunnel portal, the dark adaptation has already generated. Thus the drivers actually have adapted to the dark environment, and then the detection distance increases.

The impact of increased operating speed is clearly reflected in the results of detection distance. The higher the operating speed, the smaller the detection distance is.

The distance range with highest driving risk in threshold zone of tunnel has been found out. At operating speed of 60 km/h, the distance range is 70m to 109m from the tunnel portal. The distance range is 50m to 87m from the tunnel portal for 80 km/h and 42m to 79m from the tunnel portal for 100 km/h.

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References

Adrian W. (1989). "Visibility of targets: model for calculation." *Lighting Research and Technology* 21, 181–188.

Adrian W. (2004). "Fundamentals of roadway lighting." *Light & Engineering* 12 (2), 57–71.

AFE (2002). Recommandations relatives a`l'e´clairage des voies publiques *Guidelines for public road lighting*. France, Paris.

Bre´mond R. (2007). Quality indexes for road lighting: a review. In: Proceedings of the 26th session of the CIE, 2(4), 100–103.

China Statistics of Traffic and Transportation Industry (2013). *Year Book of China Transportation and Communication*. Ministry of Transport of the People's Republic of China. Beijing.

European Norm (2004–2005). 13 201 series: Road lighting.
IESNA (2000). American National Standard Practice for Roadway Lighting, RP-8-00.New-York: Author.
K. Narisada, K. Yoseoikawa (1974). Tunnel entrance lighting-effect of fixation point and other factors on the determination of requirements. *China Journal of Highway and Transport*, 6(5), 9–18.

Design and Analysis on Rail Anti-Head Check Profile for a Curve Rail of a Heavy-Haul Railway

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Abstract: Based on the characteristics of the head checks (HCs) in curve rail of a heavy-haul railway, the design method for lower rail profile where the HCs occurred frequently by the cubic interpolation spline curve was presented. The algorithm including control points and the key control parameters in the profile, equations of the curve between adjacent control points and the boundary conditions were discussed. The control parameters was researched by applying the designed profile to a vehicle-track model for simulation of wheel-rail contact patch area and contact stress, wheel-rail lateral force and contact position in the rail. Results show that for curve radius below 800m, the designed 75kg/m rail profiles which lower profile from rail center to gauge side can make the acreage area of contact patch over 100 mm^2 and both contact stress and lateral force smaller when the maximum lower amount of 0.1-0.6mm, the maximum lowering position of 26-30 mm, the start point position 5-8mm away from rail center.

Keywords: Rail; Rail profile; Rolling contact fatigue; Cubic interpolation spline curve.

1 Introduction

The life of curve rail of the heavy-haul railway is seriously affected by the rolling contact fatigue cracks, especially the head checks (HC) in rail shoulder and corner (Zhou, 2014). Ameliorate the rail profile of fatigue cracks prone areas to realize a anti-HC profile was important methods to improve the wheel-rail relationship and prolong the life of HC initiation and propagation in rails. (Olofsson, 2002).

Based on the research by Magel (Magel, 2002), Persson (Persson, 2004), Dollevoet (Dollevoet, 2010) etc., the design method for lower rail profile by cubic interpolation spline curve (Wang T.Y,2014)was presented through field observations of curve rail of a heavy-haul railway in which HCs occurred frequently (Hamid,2008). The multi-body dynamics model of vehicle-track was used to analyze the effect of anti-HC profile and confirm the range of control parameters of the cubic interpolation spline curve (Chongyi,2010).

2 Characteristics of rail RCF crack

From the analysis of static wheel-rail contact on 500 m radius curve of the heavy-haul railway in China it shows that the contact patch of the new wheel -new rail and worn wheel -new rail located at a distance about 10-25mm and 9-31mm away from rail center. The distribution scope was both in gauge shoulder - gauge corner area. In-situ observation found that after about 10 million gross tonnages (MGT), the RCF cracks had initiated and propagated. They mainly distributed in the range 12-33 mm away from the rail center, and shown 20~30 degrees with the lateral direction of rail (Zhou, 2014).

3 The design method of rail anti-HC profile by using cubic interpolation spline curve

The cubic interpolating spline curve for designing anti-HC rail profile should ensure the veracity of lowering rail profile in fatigue crack prone area. Moreover, the designed profile should be continuous, smooth and tangent to the rest parts of the existing rail profile.

Figure 1 show control points and control parameters of the designed rail anti-HC profile. There were n+1 control points, (x_0, y_0), $\ldots$, (x_n, y_n), in the designed profile. The starting point was (x_0, y_0) while the terminal point was(x_n, y_n). The parameters for rail profile optimization are as follows:

(a) The start point position: horizontal distance between the start point to origin coordinate.

(b) The maximum lowering amount “d”: vertical distance between the control point P_m which was the maximum lowering point at the new rail and the same abscissa point at the standard rail.

(c) The maximum lowering position “L”: horizontal distance from P_m to the rail crown center.

(d) The lowering mode of the profile on each side of the maximum lowering point: it required that on the left maximum lowering position (towards rail center), the profile between control points should change slowly. On the right side of the maximum lowering position (towards rail gauge side), the profile between control points should change steeply.

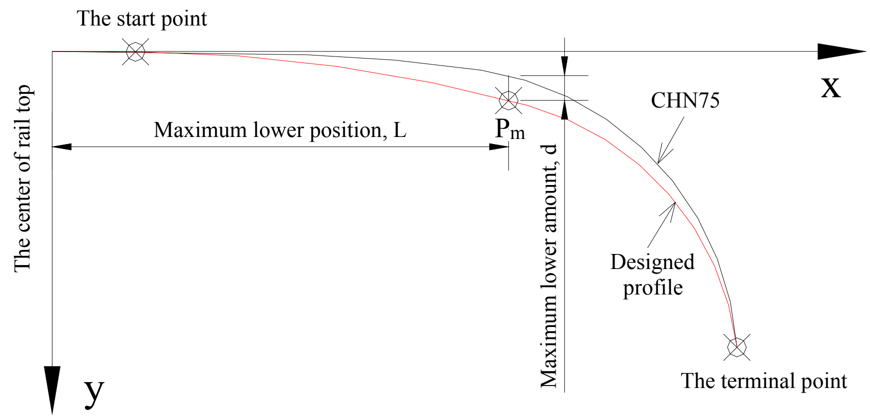

Figure 1.Control points and control parameters of the designed anti-HC rail profile

3.1 The determination of control parameters

(1) The design scope: regarding a point between the coordinate origin and the control point P_m as the start point, the terminal point was located at 16mm below rail crown which on the guage side.

(2) The control point P_m: the position of the maximum lowering point was at 26mm from the rail center.

(3) "d" is change from 0.1mm to 1.5mm with 0.1mm interval in this paper.

(4) The lower mode on each side of P_m: to guarantee the smoothness of rail profile, it should be a continuously gradual changing process of the profile changing from 0 to "d" and then to 0. The lowering function defined as the exponential function of the ratio between the abscissa of each control point and L, as follows:

$$\begin{cases} D_1(x) = \mathrm{d} \times (x/L)^Q, x < L, & Q_1 \quad (a) \\ D_2(x) = \mathrm{d} \times [(36 - x)/(36 - L)]^Q, x > L, & Q_2 \quad (b) \end{cases} \quad (1)$$

Where Q_1 equaled 1,2,3,4 and Q_2 equaled 1,1/2,1/3,1/4 to realize the gentle change of the profile from the start point to P_m and the fast change of the profile from P_m to the end point which can be seen from Figure 1 respectively.

In this way it satisfied that the values of ordinate change along with the increasing abscissa respectively smaller or larger on two sides of the control point.

(4) The density of control point: 1mm interval from 0mm to 34mm, 0.25mm interval from 34mm to 36mm (the horizontal ordinate of the end point in the rail profile).

3.2 Curve equation between control points

The equation between the two adjacent points (Point i and i+1) was derivated by the cubic spline interpolation curve to smooth the designed profile as follows:

$$y = F(x) = y_i + C_{i,1}(x_{i+1} - x_i) + C_{i,2}(x_{i+1} - x_i)^2 + C_{i,3}(x_{i+1} - x_i)^3 \quad (2)$$

Where x and y were the abscissa and ordinate of the control points in Figure 1, $C_{i,1}$,$C_{i,2}$, $C_{i,3}$, were the coefficients.

The second order derivative of the Equation (2) was $S_i = F(\ddot{x_i})$. The relationships between y and its first and second order derivatives were as follows respectively:

$$F'(x) = \frac{-(x_i - x)^2}{2h_i} S_{i-1} + \frac{(x - x_{i-1})^2}{2h_i} S_i - \frac{h_i}{6}(S_i - S_{i-1}) + \frac{y_i - y_{i-1}}{h_i} \tag{3}$$

$$F(x) = \frac{-(x - x_i)^3}{6h_i} S_{i-1} + \frac{(x - x_{i-1})^3}{6h_i} S_i + (y_{i-1} - \frac{h_i^2}{6} S_{i-1}) \frac{x_i - x}{h_i} + (y_i - \frac{h_i^2}{6} S_i) \frac{x - x_{i-1}}{h_i} \tag{4}$$

Since the first derivative of $F(x)$ is continuous as $F'(x_i - 0) = F'(x_i + 0)$, when the distance between the two adjacent points was the same, that is to say, $h_i = h_{i+1} = h$, the equation (3) can derived as:

$$S_{i-1} + 4S_i + S_{i+1} = \frac{6(y_{i+1} + y_{i-1} - 2y_i)}{h^2} \tag{5}$$

Then, the coefficients in Equation (2) can be definited as:

$$\begin{cases} C_{i,1} = \dfrac{y_{i+1} - y_i}{h_{i+1}} - \dfrac{2S_i + S_{i+1}}{6} h_{i+1} \\ C_{i,2} = \dfrac{S_i}{2} \\ C_{i,3} = \dfrac{S_{i+1} - S_i}{6h_{i+1}} \end{cases} \tag{6}$$

3.3 The tangent and continuous between starting/end point and the rest of the curve

In order to guarantee the starting/terminal point (x_0/x_n) to be tangency with the endpoint of existing profile, the first derivative of starting/end point should be succession. The boundary conditions can be available from (2) When $x = x_i$ and $x = x_0$:

$$\begin{bmatrix} 2 & 1 & & & \\ \mu_1 & 2 & \lambda_1 & & \\ & \vdots & \vdots & & \\ & & \mu_{n-1} & 2 & \lambda_{n-1} \\ & & & 1 & 2 \end{bmatrix} \begin{bmatrix} S_0 \\ S_1 \\ \vdots \\ S_{n-1} \\ S_n \end{bmatrix} = 6 \begin{bmatrix} M(x_0, x_0, x_1) \\ M(x_0, x_1, x_2) \\ \vdots \\ M(x_{n-2}, x_{n-1}, x_n) \\ M(x_{n-1}, x_n, x_n) \end{bmatrix} \quad (7)$$

Where the distance between the two adjacent points was the same, $u_i = \lambda_i = 1/2$, $i = 1, \cdots n-1$.

The whole cubic interpolation spline curve just to be confirmed (Chongyi, 2010).

4 Simulated analyses on rail anti-HC profile

A vehicle-track model was established by Simpack, to analyze the effect of the designed anti-HC rail profile. The model parameters: C70 open wagon, with axle load of 23t, worn-type wheel, running speed of 60km/h, friction coefficient between wheel and rail of 0.3, and track with a curve of 800m radius, super elevation of 90mm, and rail inclination of 1:40, both the high and low rails applied the designed profiles that L=26mm. The track geometry irregularity was not considered.

4.1 Wheel-rail contact position on rail surface

The wheel-rail contact position caused by the designed rail profiles with different lowering amount as the high rails was shown in the Figure 2:

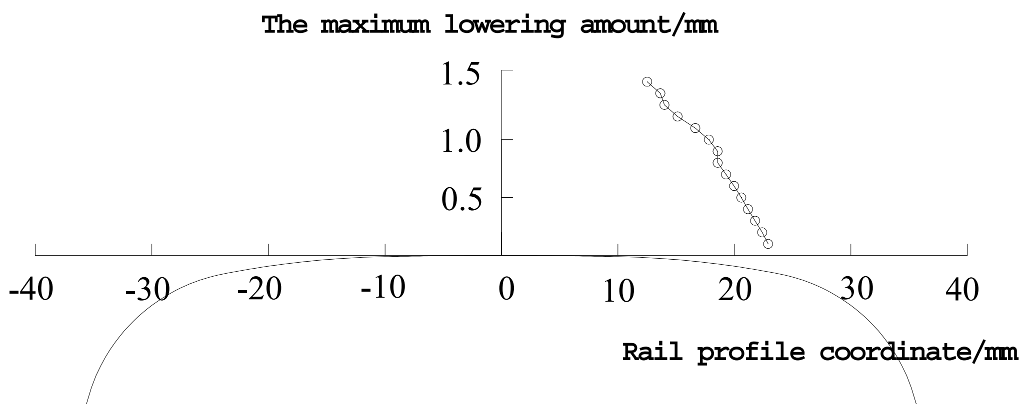

Figure 2.Wheel-rail contact position changes with variation of the maximum lowering amount

From Figure 2, it can be observed that the contact position on the high rail gradually moved from 23mm to 15mm away from the rail center. So we could conclude that the more of the maximum lowering amount, the closer contact point is to rail center.

4.2 The acreage of contact patch

Figure 3 shows variation of contact patch on the high rail by the designed rail profiles with different start point locations and different maximum lowering amount:

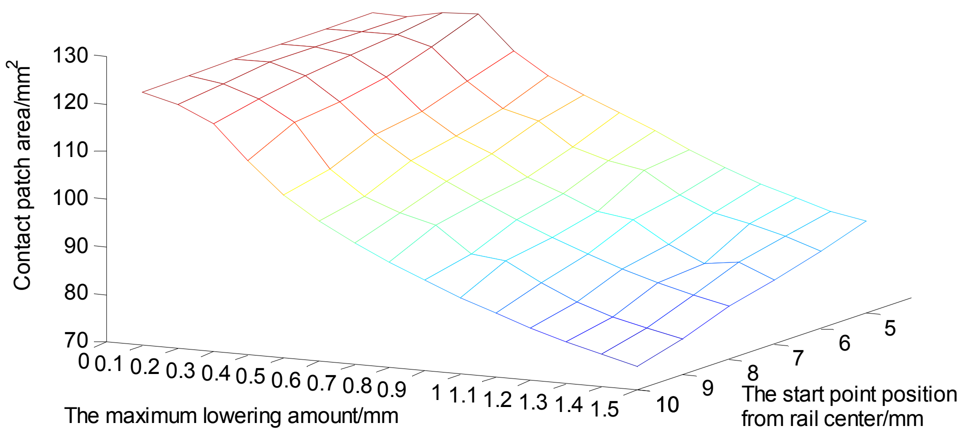

Figure 3.Contact patch on the high rail

It can be seen from Figure 3 that the acreage area of contact patch was over 100 mm^2 when the designed rail profiles with the maximum lowering amount of 0.1-0.6mm, the start point position was 5-8mm away from rail center. At this situation, the wheel/rail contact stress was about 1.5-1.9Gpa. When the start point was 5mm and the maximum lowering amount was 0.4mm, it achieved the maximum area of contact patch. So the acreage area of contact patch decreased when the maximum lowering increased and the start point kept away from rail center.

4.3 The wheel-rail force

The wheel-rail lateral force varied as different lowering amount, seeing in Figure 4:

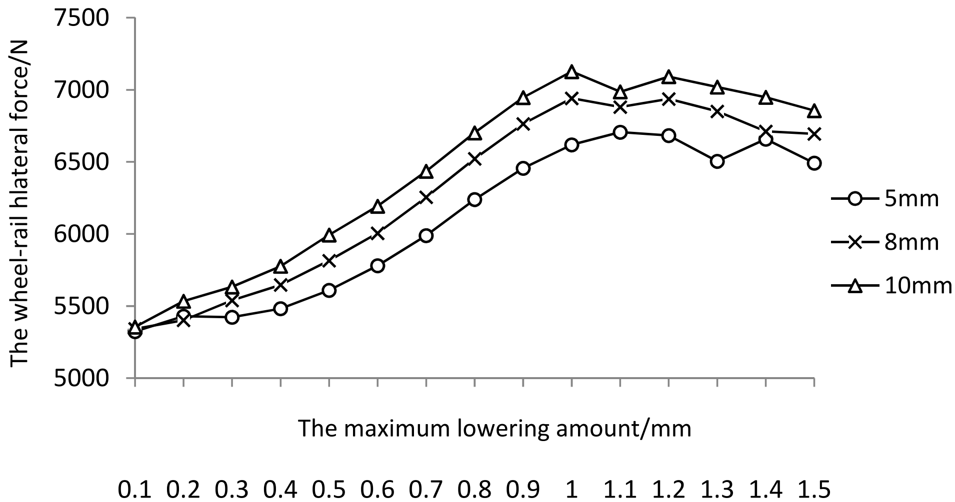

Figure 4.Wheel-rail lateral force changes as variation of the maximum lowering amount

It can be seen from Figure 4, although the start point location was different, the wheel/-rail lateral force increased with the increasing of the maximum lowering amount from 0.1-0.9mm. After the maximum lowering amount was over 1.0mm, the development trend of the wheel/rail lateral force got slowly. Therefore it was the maximum lowering amount “d” of 0.1~0.6mm that the lateral force kept in lower situation of 5.3 kN-6.3kN.

In addition, the effect of the designed rail profile with different maximum lowering amounts on the wheel-rail vertical force was small.

5 Conclusions

(1) Based on the cubic interpolation spline curve, the special designed anti-HC rail profile was realized. The change of rail profile was decided by four control parameters, namely, the start point, the position of the maximum lowering point in the profile, the maximum lowering amount and the lower mode of the profile on each side of the maximum lowering point.

(2) The designed profile could make the wheel/rail contact point move to rail center and the more of the maximum lowering amount, the closer contact point is to rail center.

(3) The special designed anti-HC rail profile can make the acreage area of contact patch over 100 mm^2 and both contact stress and lateral force smaller when the maximum lower amount of 0.1-0.6mm, the maximum lowering position of 26-30 mm, the start point position 5-8mm away from rail center.

Acknowledgement

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References

Chongyi C, Chengguo W, Ying J. (2010), Study on numerical method to predict wheel/rail profile evolution due to wear. *Wear, 269(3): 167-173*

Dollevoet P R, (2010),Design of an anti-head check profile based on stress relief. The Netherland: University of Twente,

Hamid J, Behronz F, Morvarid K. et. al., (2008), A numerical optimization technique for design of wheel profiles. *Wear, 264(1-2): 1-10.*

Magel, E., Kalousek, J. (2002), The Application of Contact Mechanics to Wheel/Rail Profile Design, and Rail Grinding. *Wear, 253(1): 308-316*

Olofsson U, Nilsson R. (2002), Surface cracks and wear of rail: a full-scale test and laboratory study . *Journal of Rail Rapid Transit, 216: 249-264.*

Persson I, Iwnicki S D. (2004),Optimisation of railway wheel profiles using a genetic algorithm, in Dynamics of Vehicles on Roads and on Tracks. Vehicle System Dynamics, 41(Supplement): 517–526.

Wang T.Y. Research on Rail Profile Designing Method for Heavy-haul Railway with Sharp Radius Curves, Tongji University, 2014. (in Chinese).

Zhou Y., Wang S.F., etc. (2014), Field and laboratory investigation of the relationship between rail head check and wear in a heavy-haul railway, *Wear, 315(1): 68-77.*

Effect of Crumb Rubber Powder on the Pavement Performance of Cement Concrete

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Abstract: For the problem what particle size and dosage of crumb rubber powder is best for road concrete, 24 groups of rubber powder concrete were prepared using four kinds of particle size (60,80,100 and 120 meshes) and 6 kinds of dosage (0%, 10%, 15%, 20%, 25% and 30%). And its pavement performance was measured, such as, strength, toughness, crack resistance, frost resistance and permeability. The results showed that: strength of crumb rubber powder concrete decreased with dosage and fineness degree of rubber powder increasing, and it had a higher sensitivity for dosage. Add crumb rubber powder into concrete has a positive effect to improve toughness, crack resistance and permeability of concrete, and the effect can be more obvious when the dosage increasing. However, the ability of frost resistance increased at first, and then decreased when the dosage increasing. The optimum dosage for 60, 80, 100 and 120 meshes rubber powder was 15%.

Keywords: Road engineering; Crumb rubber powder; Pavement performance.

1 Introduction

Crumb rubber powder modified concrete made with discarded tires not only can reduce pollution, is also benefit to development circular economy. Because of a low modulus, good toughness and other characteristics, it has been a major focus of the current concrete science. The strength of rubber powder modified concrete decreased with increasing of rubber powder dosage, but the deformation capacity increased (Zhao Li-yan and Xu Jing, 2009. Li Guang-yu, 2008. PAN Zuan-feng, 2010). A detailed study on cracking, impact resistance, abrasion resistance and permeability and other road performance of rubber powder modified concrete was done. It showed that although added rubber powder into concrete reduced the strength, an appropriate dosage and fineness had benefit to improve the durability (Meng Yun-fang and Guo Can-xian, 2006. ZHOU Lu, 1994.)

In view of this, in order to study the pavement performance of recycled tire crumb rubber powder modified concrete, 24 groups concrete specimen were prepared. The fineness of crumb rubber powder in it was 60, 80, 100 and 120 meshes, and the dosage was 0%, 10%, 15%, 20%, 25% and 30%. Then, a series of experimental was carried out to research the effect law that fineness and dosage of crumb rubber powder to the performance of concrete, such as, strength, toughness, crack resistance, frost resistance and permeability.

2 Raw Material And Test Methods

2.1 Raw Materials

P.O 42.5 cement in this test was made in Witton in Yuncheng. The physical-mechanical properties were shown in Table 1. It meets the requirements in the specification that GB175-2007 "Common Portland Cement".

The fineness of fine aggregate was 2.8 and density was 2.70 g/cm^3.

The density of coarse aggregate was 2.77 g/cm^3, with well graded.

The water in this test was Ordinary tap water.

There were four kinds of crumb rubber powder with different fineness was selected in this test, such as, 60, 80, 100 and 120 meshes. The apparent density was about 1.01 ~ 1.04g/cm^3, and the specific surface area was about 0.47 ~0.55kg/m^2.

Table 1. Physical-mechanical properties of cement

fineness /（m^2/kg）	Setting time /min		Compressive strength /MPa		Flexural strength/MPa		Stability
	Initial setting	Final setting	3d	28d	3d	28d	
350	180	275	30.6	52.8	6.1	9.0	Qualified

2.2 Test Methods

In order to accurately measure the effect of crumb rubber powder fineness and dosage to the performance of cement concrete, the test used univariate analysis method to avoid mutual interference between multiple factors. First, prepare 24 groups concrete specimen using four kinds of crumb rubber powder based on the mix proportion was shown in Table 2. The fineness of the four kinds of crumb rubber powder was 60, 80, 100 and 100 meshes. The dosage of every crumb rubber powder was 0%, 10%, 15%, 20%, 25% and 30%, and it replaced with equal volume fine aggregate in concrete. In order to make the workability of concrete similar, water reducer was added into it to guarantee all the slump of fresh concrete was between 30 to 50mm. Then, carry out the test such as, strength, toughness, crack resistance, frost resistance and permeability.

Table 2. Mix Proportion

Cement / kg	Water / kg	Fine aggregate / kg	water reducer /%	Corase aggregate/ kg		
				0.5cm-1cm	0.5cm-1cm	0.5cm-1cm
370	155	693	0.3～1	246	246	246

In the test, compressive strength, flexural strength and frost resistance was carried out in accordance with the specification JTG E30-2005. The permeability test carried out in accordance with the specification ASTM C1202. The crack resistance test carried out in accordance with the specification GB T50082-2009. The toughness test carried out in accordance with the specification ASTM Cl018.

To facilitate comparison of test results, 24 group of concrete specimen were numbered with following rules. The fineness 60, 80, 100 and 120 meshes was labeled A, B, C and D. Meanwhile, the dosage 0%, 10%, 15%, 20%, 25% and 30% was labeled 0, 10, 15, 20, 25 and 30. So, for 80 meshes crumb rubber powder concrete, when the dosage was 10%, the specimen label was B-10.

3 Test Results And Analysis

3.1 Compressive strength of crumb rubber modified concrete

The 28d compressive strength of concrete specimen with different crumb rubber powder fineness, dosage was shown in Figure 1. Overall, the compressive strength decreased with the crumb rubber powder dosage and fineness increasing. But, it had a higher sensitivity for crumb rubber powder dosage. When dosage of crumb rubber powder was equal, the greater the fineness, the lower the compressive strength; and the effect continued to enlarge when increasing dosage. When the dosage was 15%, the compressive strength of concrete used 120 meshes was lower 19.3% than 60 meshes. When the dosage was 30%, this value was 46.4%.

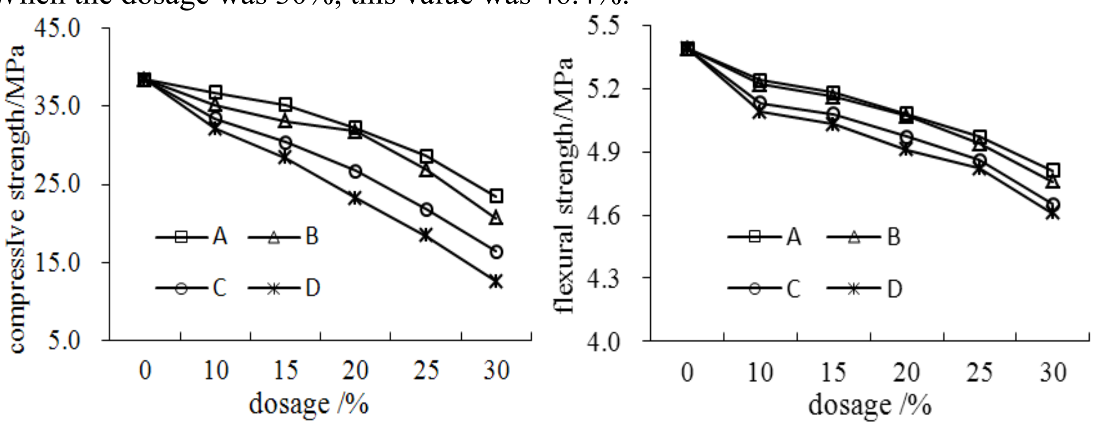

Figure 1. Effect of rubber powder on compressive and flexural tensile strength

In terms of the downward trend of compressive strength, when the dosage was less than 15%, decreased rate was slower. But, when the dosage was more than 15%, the decreased rate increased significantly.

3.2 Flexural tensile strength of crumb rubber modified concrete

The 28d flexural strength of concrete specimen with different crumb rubber powder fineness, dosage was shown in Figure 1. The change law was similar with compressive strength. The flexural strength decreased with the rubber powder dosage and fineness increasing. It had a higher sensitivity for rubber powder dosage. The difference was that the effect of rubber powder on flexural strength of concrete was not significant as compressive strength. When the rubber powder dosage was 30%, the flexural strength of specimen decreased by about 5% to 13%, but, the compressive strength decreased by 30% to 70%.

Furthermore, with increasing rubber powder dosage, the ability resistance to deformation of concrete increased. When the dosage was 30%, the vertical displacement of specimens that used 100 meshes increased about 22%.

3.3 Toughness of crumb rubber modified concrete

For general rubber concrete, the specimen had been destroyed before its vertical deflection has been reached first crack point. Therefore, the toughness index takes the area ratio that the stress-strain curves when the specimen completely fracture and reached first crack point.

The toughness index of concrete specimen with different rubber powder fineness, dosage was shown in Table 3. When the fineness was equal, the toughness index of concrete specimen linearly increased with the increase of rubber powder dosage. When the dosage was 30%, the toughness index of A-30 increased by 28.6%. Meanwhile, D-30 increased by 38.1 %. When the dosage was equal, increasing the fineness can improve toughness, especially when the dosage was small. When the dosage is bigger than 15%, improving toughness by increasing dosage was not effective.

Table 3. Effect of rubber powder on toughness index

Crumb rubber powder fineness	Toughness index			
	A	B	C	D
0	1.26	1.26	1.26	1.26
10	1.31	1.32	1.36	1.34
15	1.38	1.41	1.45	1.41
20	1.46	1.49	1.56	1.52
25	1.53	1.58	1.64	1.64
30	1.62	1.66	1.71	1.74

3.4 Cracking resistance of crumb rubber modified concrete

Effect of crumb rubber powder fineness and dosage on the total cracks area in unit area and the number of cracks in unit area of concrete was shown in Figure 2.

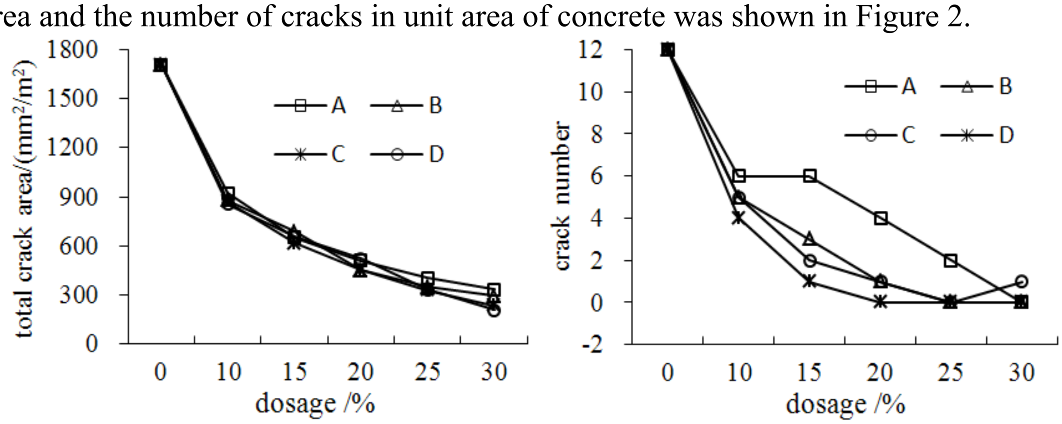

Figure 2. Effect of rubber powder on concrete cracking

Added crumb rubber powder into concrete was benefit to inhibit cracks happened. The total cracks area in unit area and the number of cracks in unit area of concrete specimen declined when the rubber powder dosage increased. When the dosage was 15%, the number of cracks was only 20to 25 present of concrete not use rudder powder. The fineness of rubber powder had little effect on the total cracking area in unit area of the concrete. Even if increased the fineness from 60 meshed to 120 meshed, the total cracking area was basically the same. However, the number of cracks reduced significantly when the fineness increasing. So, when the rubber powder dosage was equal, increasing the fineness can reduce the numbers of cracks.

3.5 Frost resistance of crumb rubber modified concrete

In the test, the freeze-thaw cycles when loss rate of flexural strength reached 40% was called extreme frost resistance cycles. And it was take to evaluate the frost resistance ability of crumb rubber powder concrete. Effect of rubber powder fineness and dosage on extreme frost resistance cycles of concrete was shown in Figure 3.

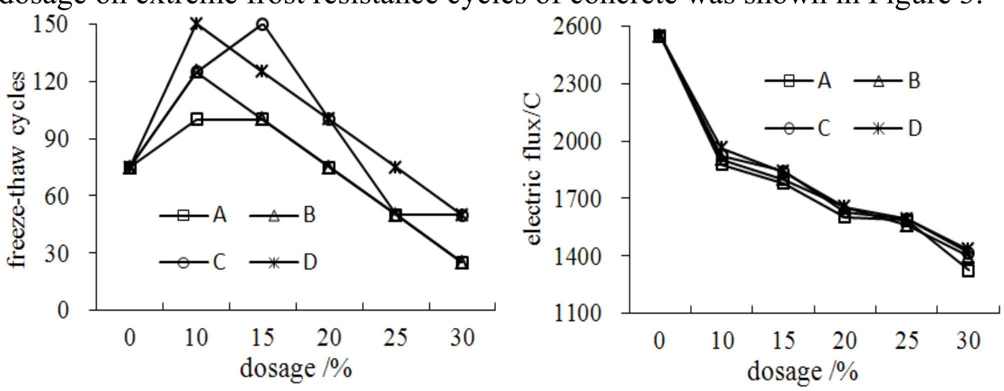

Figure 3. Frost resistance ability and permeability

When the fineness of rubber powder was equal, the extreme frost resistance number presented with increasing trend and then decreased. When the dosage was 15%, the frost resistance ability improved more than 70%. When the dosage was greater than 15%, the frost resistance ability began to decline rapidly. When the dosage was greater than 20%, the frost resistance ability of concrete bad than concrete not used rubber powder. In addition, when the dosage was equal, the frost resistance ability of concrete increased with the fineness increased.

3.6 Permeability of crumb rubber powder modified concrete

Effect of crumb rubber powder fineness and dosage on concrete permeability was shown in Figure 3. Added rubber powder into concrete had significant effect on its impermeability. The impermeability ability of concrete increased with dosage of rubber powder increasing. When the dosage was equal, the impermeability of concrete was slow-growth with the fineness increasing. In accordance with the specification, when the rubber powder dosage was bigger than 15%, the impermeability of all concrete can meet the actual needs.

4 CONCLUSIONS

(1) The compressive strength and flexural strength of crumb rubber powder concrete decreased with dosage and fineness degree of rubber powder increasing, and it had a higher sensitivity for dosage.

(2) Add crumb rubber powder into concrete has a positive effect to improve toughness, crack resistance and impermeability of concrete, and the effect can be more obvious when the dosage increasing. However, the ability of frost resistance increased at first, and then decreased when the dosage increasing.

(3) The optimum dosage for 60, 80, 100 and 120 meshes rubber powder was 15%. In the vicinity of dosage, except frost resistance ability, effect of fineness on other properties of concrete can be ignored.

Acknowledgements

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References

Guo, C. X. (2006). Study on waste tire rubber modified concrete and its pavement performance. *Nanchang University*.

Li, G. Y. (2008). Experimental study on frost resistance ability of rubber powder concrete. *Concrete, 04: 60-62.*

Meng, Y. F., Wang, D. Z., Han, J. Y. (2006). Effect of fly ash and rubber powder on crack resistance ability of concrete. *Concrete, 06: 49-52 + 55*.

PAN, Z. F., LU, Z. T.(2010). Shrinkage and creep tests and prediction model of high-strength concrete. *Journal of Highway and Transportation Research and Development*, 27(12):10-15.

Xu, J., Hong, J. X. (2009). Effect of rubber powder on for concrete shrinkage cracking. *Concrete, 10: 96-98.*

Zhao, L. Y. (2009). Experimental study on rubber powder modified concrete. *Dalian University of Technology.*

ZHOU, L. (1994). *Shrinkage and Creep*. Beijing: China railway publishing house.

Mechanical Properties of Concrete Containing Ceramsite Sand

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Abstract: Lightweight aggregate concrete has been widely used due to its excellent performance, such as the light weight, the high strength and the thermal insulation. Ceramsite sand is a kind of artificial fine lightweight aggregate, which could be used as an effective internal curing material for concrete with low water-binder ratio. In this paper, the mechanical properties of concrete with the water to cement ratio of 0.3, 0.35 and 0.4, in which the natural sand was replaced by ceramsite sand at 20%, 40%, 60%, 80% and 100% in volume were studied. The hydration degree of cement in the paste around ceramsite sand particles was also tested. The research results showed that with the increasing of the ceramsite sand content, the compressive strength, the flexural strength and the static elastic modulus of concrete decreased. Ceramsite sand promoted the hydration degree of cement at the interface area, and this effect became more obvious for the concrete with lower water to cement ratio.
Keywords: Ceramsite sand; Concrete; Mechanical property.

1 Introduction

Cement concrete is an important building material widely used in constructions in nowadays. With the history of over a century, the performances of concrete have been improved a lot with the progress of technology, and concrete has been developing towards high quality and high strength. Concrete with low water to cement ratio is more likely to be used in order to improve the concrete strength, leading to the compact structure of concrete. Moreover, the cement particles used in concrete are getting smaller by effective grinding, resulting in the accelerated hydration of the cement. Therefore, the self-desiccation is very common for modern cement concrete, and the risk of cracking of concrete at early ages rises. And then the reliability of structures decreases significantly within the service life.

Ceramsite sand is a kind of artificial porous material with the ability to absorb and release water, which could be used as the fine lightweight aggregates of concrete. When pre-wetted ceramsite sand is mixed into concrete, the water contained in pre-wetted ceramsite sand could be gradually released in the process of hydration of cement, acting as self-curing for concrete. Thus, the cement hydration degree increased and the microhardness at the interface area is improved. The cracking resistance of concrete at early ages is also improved effectively. Meanwhile, the compaction degree at the interface between ceramsite sand and cement increases and the cracking risk under stress at the interface area is reduced, so the impermeability of concrete can be effectively improved. In this work, the effect of ceramsite sand on the mechanical properties and the hydration degree of cement in the concrete with different water to cement ratio were studied.

2 Materials and test program

2.1 Materials

A typical Chinese type P·O 42.5 cement made by Harbin Cement Plant was used in this investigation, and its physical and mechanical properties are shown in Table 1. Locally available natural river sand was used as the ordinary fine aggregate, which has the continuous gradation, the fineness modulus of the 3.0, the apparent density of 2620kg/m^3 and the stacking density of 1500kg/m^3. Shale ceramsite sand produced by Heilongjiang Hegang was used as the lightweight fine aggregate (LWAs). Table 2 provides the details of the properties of LWAs. Crushed basalt with the grain size of 5~26.5 mm was used as coarse aggregates. Polycarboxylate based superplasticizer with a water reducing ratio of 30%, which was produced by Qiangshi Concrete Admixtures Company, was used as the water reducing agent. Tap water in Harbin area was used in the tests.

Table 1. Properties of cement

Name	Water requirement of normal consistency (%)	Setting time (min)		Flexural strength (MPa)		Compressive strength (MPa)	
		Initial set	Final set	3d	28d	3d	28d
P·O 42.5	30	190	250	4.2	6.5	21.7	43.2

Table 2. Properties of ceramsite sand

Particle size (mm)	Bulk density (kg/m^3)	Apparent density (kg/m^3)	Water absorption (%)	
			1h	24h
0~2.36	625	1035	13.0	20.2
2.36~4.75	435	725	11.2	16.4

2.2 Mix proportions and test program

The control concrete mixtures with the water to cement ratio of 0.30, 0.35 and 0.40 were designed, as shown in table 3. On the basis of the control mixtures, the 20%, 40%, 60%, 80% and 100% ordinary fine aggregates in volume were replaced by ceramic sand respectively in each group. The mechanical properties, including the compressive strength, the flexural strength and the static modulus of elasticity were tested on concrete specimen according to the standard test methods. The microhardness of cement mortar at the interface area and the cement hydration degree were also measured. Hardened cement paste was extracted near the interface area by removing the coarse aggregate and the ceramic sand in crushed concrete, and then the paste was put into absolute ethyl alcohol to stop the hydration process. The chemical bond water content of the paste was tested after been ground (particle size <80μm) and drying.

Table 3. Proportions of concrete mixtures

No.	Ceramsite sand content (%)	*W/C*	Cement (kg/m^3)	Water (kg/m^3)	Ordinary sand (kg/m^3)	Ceramsite sand (kg/m^3)	Coarse aggregate (kg/m^3)	Water reducer (%)
A1	0	0.30	523	157	628	0	1117	1.0
A2	20	0.30	523	157	502	126	1117	1.0
A3	40	0.30	523	157	377	251	1117	0.9
A4	60	0.30	523	157	251	377	1117	0.8
A5	80	0.30	523	157	126	502	1117	0.8
A6	100	0.30	523	157	0	628	1117	0.7
B1	0	0.35	504	176	628	0	1117	0.7
B2	20	0.35	504	176	502	126	1117	0.7
B3	40	0.35	504	176	377	251	1117	0.6
B4	60	0.35	504	176	251	377	1117	0.6
B5	80	0.35	504	176	126	502	1117	0.5
B6	100	0.35	504	176	0	628	1117	0.5
C1	0	0.40	486	194	628	0	1117	0.5
C2	20	0.40	486	194	502	126	1117	0.5
C3	40	0.40	486	194	377	251	1117	0.5
C4	60	0.40	486	194	251	377	1117	0.5
C5	80	0.40	486	194	126	502	1117	0.4
C6	100	0.40	486	194	0	628	1117	0.4

3 Results and analysis

3.1 Cement hydration degree

The mechanical properties of concrete are affected by the microstructure, which is mainly related to the cement hydration process and the structure of interface area. In addition, the structure of concrete containing ceramsite sand is more complex. The hydration degree of the cement paste surrounding the lightweight aggregate and the interface area structure would be greatly influenced by the water desorption of the pre-wetted ceramsite sand in concrete.

The chemical bond water content of cement in hardened concrete contained 0%, 20% and 40% ceramsite sand at 28d was tested, and the results are shown in Figure 1. The results showed that with the increasing of the water to cement ratio, the chemically combined water content of the hardened paste around aggregates gradually increased, no matter the ceramsite sand was added or not. For example, the chemical bond water content in the 28d control concrete with the water cement ratio of 0.30, 0.35 and 0.40 were 12.03%, 12.85% and 14.27%, respectively.

Furthermore, when the ceramic sand was added, with the increasing of the content of ceramsite sand, the chemical bond water content of the hardened cement paste also increased. The increasing extent of concrete with lower water to cement ratio was greater than that of concrete with higher water to cement ratio. At the content of ceramsite sand of 40%, the chemical bond water content of concrete with the water cement ratio of 0.30, 0.30 and 0.40 was increased by 24.4%, 20.7% and 15.3% respectively, compared with the control concrete. Therefore, the hydration degree of cement could be significantly improved with the addition of pre-wetted ceramsite sand.

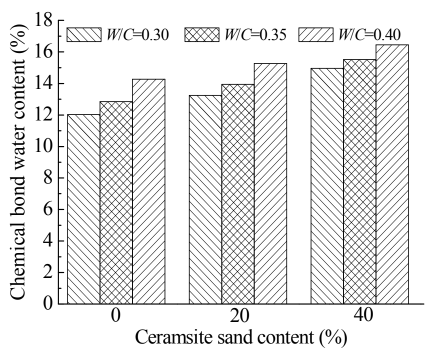

Figure 1. Chemical bond water of harden cement paste in concrete with ceramsite sand

3.2 Mechanical behaviors

3.2.1 Compressive strength

The mechanical properties of concrete were influenced by the addition of the pre-wetted ceramsite sand, along with the hydration degree of cement. The test results of the compressive strength were shown in Figure 2. The results showed that the compressive strength of concrete decreased with the increasing of the ceramsite sand content. For example, at the ceramsite sand content of 40%, the compressive strength of the concrete with the water to cement ratio of 0.30, 0.35 and 0.40 at 28d was 95.3%, 92.3% and 92.2% of the control concrete respectively. However, the ceramsite sand had a more obvious reducing effect on the compressive strength of concrete with higher water to cement ratio.

In addition, with the growth of the age, the increasing rate of the compressive strength of concrete with lower water cement ratio was higher. For instance, for the concrete mixtures A2~A6, of which the water to cement ratio was 0.3, the compressive strength at 28d was increased by 10.9%, 12.9%, 14.0%, 22.1% and 25.3%, respectively, compared to the compressive strength at 7d. For the mixtures with water to cement ratio of 0.40, C2~C6, the compressive strength at 28d was increased by 8.5%, 6.5%, 9.4%, 9.1% and 13.8% from 7d.

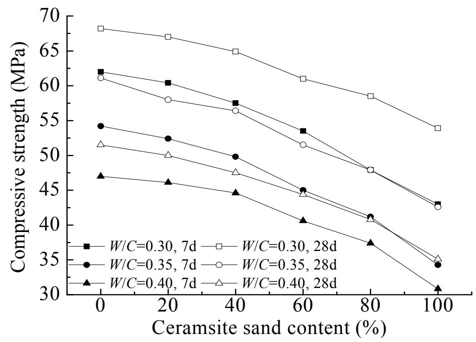

Figure 2. Compressive strength of concrete with ceramsite sand

3.2.2 Flexural strength

The flexural strength of concrete with and without ceramsite sand was shown in Figure 3. Similarly, the flexural strength decreased with the increasing of the ceramsite sand content, while the reducing rate was lower than that of the compressive strength. At the ceramsite sand content of 40%, the flexural strength of concrete with the water to cement ratio of 0.3, 0.35 and 0.4 at 28d was 91.3%, 90.5% and 88.2% of the control concrete, respectively. With the growth of the age, the increasing rate of the flexural strength of the concrete with lower water to cement ratio was greater. The flexural strength of each test group with water to cement ratio of 0.3 at 28d was increased by more than 20% compared to that at 7d.

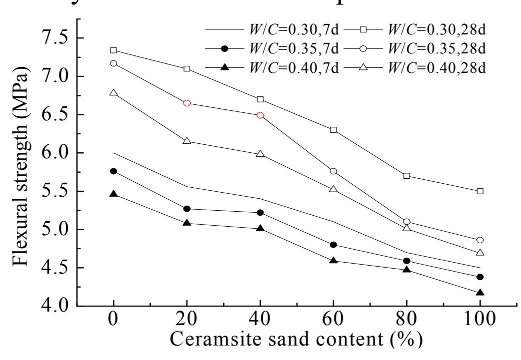

Figure 3. Flexural strength of concrete with ceramsite sand

3.2.3 Elasticity modulus

The results of the static elasticity modulus of concrete with the water to cement ratio of 0.30 at 7d and 28d are shown in Figure 4. The static elasticity modulus of concrete decreased with the increasing of the ceramsite sand content. At the ceramsite sand content of 80% and 100%, the static elasticity modulus of concrete was close. The static elasticity modulus of concrete with the ceramsite sand content of 100% at 7d was 73.4% of that of control concrete, and 82.8% at 28d.

The lower elasticity modulus of the ceramsite sand than that of the ordinary sand resulted in the lower elasticity modulus of LWA concrete. However, when the ceramsite sand content increased, the hydration degree of the cement was increased due to the self-curing effect of the ceramsite sand and the structure of the hardened cement paste tended to be compact. The final static elasticity modulus of the concrete was increased as a result of the combined two actions.

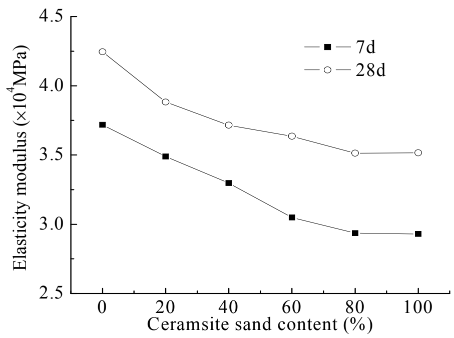

Figure 4. Static elasticity modulus of concrete with ceramsite sand

4 Conclusions

The hydration degree of the cement at the interface area and the mechanical properties of the concrete with ceramsite sand were studied. The following conclusions can be drawn.

The ceramsite sand promoted the hydration degree of the cement at the interface area, and this effect was more obvious for the concrete with lower water to cement ratio. At the ceramsite sand content of 40%, for concrete with the water cement ratio of 0.30, 0.35, 0.40, the chemically combined water content increased by 24.4%, 20.7% and 15.3% respectively compared with the control concrete at 28d.

The compressive strength and the flexural strength of concrete decreased when the ceramsite sand was added. But when the ceramsite sand content was lower than 40%, the strength reduced less than 12% compared with the control group.

The static elasticity modulus of concrete containing ceramsite sand decreased as well. For concrete with the water cement ratio of 0.30, the static elasticity modulus of concrete with 100% ceramsite sand was 73.4% and 82.8% of that of the control group at 7d and 28d, respectively.

Acknowledgement

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References

A.S. El-Dieb (2007). Self-curing concrete: Water retention, hydration and moisture transport. *Construction and Building Materials.* 21, 1282-1287

CHENG Yunhong, HUANG Fei, LIU Jia, XU Jiang (2011). College of Resources and Civil Engineeringline, *Northeastern University, Shenyang, China*. *Test Research on Workability of Waste Ceramics Aggregate Concrete*

D. P. Bentz, K. A. Snyder (1999). Protected paste volume in concretecExtension to internal curing using saturated lightweight fine aggregate. *Cement and Concrete Research*. 29, 1863-1867

DONG Shuhui, ZHANG Baosheng, GE Yong, YUAN Jie (2009). "Influence of lightweight aggregate on shrinkage reducing efficiency of concrete. *Journal of the Chinese ceramic society.* 37(3), 465-469

DONG Shuhui, ZHANG Baosheng, GE Yong and ZHENG Xiuhua (2009). "Research on the Microstructure Characteristics in the Interfacial Transition Zone (ITZ) Between Lightweight Aggregate and Cement Paste." *Journal of building materials.* 12(6), 737-741

Javier Castro, Lucas Keiser, Michael Golias, Jason Weiss (2011). Absorption and desorption properties of fine lightweight aggregate for application to internally cured concrete mixtures. *Cement & Concrete Composites*. 33, 1001-1008

Kong Lijuan (2009). Effect of Ceramsite Structure on Microstructure of Interfacial Zone and Durability of Combined Aggregate Concrete. *Journal of Wuhan University of Technology* (*Materials Science Edition*). (1): 145-149

L. H. Nguyen, A.-L. Beaucour, S. Ortola, A. Noumowé (2014). Influence of the volume fraction and the nature of fine lightweight aggregates on the thermal and mechanical properties of structural concrete. *Construction and Building Materials.* 51, 121-132

Li ZuiXiong, Zhao Liyi, Li Li (2012). Light weight concrete of Yangshao Period of China:The earliest concrete in the world. *Science China* (*Technological Sciences*). (3): 629-639

O. Kayali (2008). Fly ash lightweight aggregates in high performance concrete. *Construction and Building Materials*. 22(12), 2393-2399

Passarin Jongvisuttisun, Camille Negrello, Kimberly E. Kurtis (2013). Effect of processing variables on efficiency of eucalyptus pulps for internal curing. *Cement & Concrete Composites*. 37, 126-135

Influence of Heavy Axles on the Dynamic Response of the Existing Railway Ballast Track under Freight Vehicle Running

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Abstract: In order to relief railway transportation pressure in China, the load-raising reform of existing railway lines is paid much more attention. In load-raising reform of existing railway lines process, the most obvious improvement is the increase of vehicle axle load. Using the theory of wheel-track dynamics, The vertical dynamic model for the ballast rail track and heavy haul train interaction could be built. In this model, the heavy haul train is regarded as a subsystem with 10 degrees of freedom, and the ballast track structure is built using finite element method. The two subsystems are coupled using via non-linear Hertz contact mechanism considering the influence caused by track irregularity. This paper analyzes the dynamic response between train and track using the combination method of new rapid explicit integration method and Newmark integration method. And the dynamic response of existing ballast track under heavy haul train of different loads which are 25t, 27t and 30t is specialized analyzed. During the analysis process, the dynamic performance indexes include: rate of wheel load reduction, wheel-rail vertical force, dynamic displacement of the ballast track, vibration acceleration of ballast track, and dynamic stress distribution of ballast track. The research results show that: 1). When heavy haul train are running on ballast track, every dynamic performance index is still within the national standards, and it can meet the dynamic requirement for running heavy haul train. 2). The trends of the dynamic displacement of the track structure under different loads are similar to one another. And the dynamic displacements of the rail under 27t-axle-load and 30t-axle-load increase 16% and 22% respectively, compared with the 25t-axle-load. 3). In general it can be concluded that the growth proportion of the dynamic stress of the track structure is similar to the dynamic displacement. And the dynamic stresses of the rail under 27t-axle-load and 30t-axle-load increase 15% and 22% respectively, compared with the 25t-axle-load.
Keywords: Load-raising reform of existing railway lines; Vehicle axle load; Theory of wheel-track dynamics; Dynamic response.

1 Introduction

In order to relief railway transportation pressure in China, the load-raising reform of existing railway lines is paid much more attention. In the process of the load-raising reform of existing railway lines, we have to recognize that, with the increase of vehicle axle load, the interaction between wheel and rail will get stronger, adding to the wear of vehicle and track, which will increase the pressure of maintenance of track structure and reduce the economic benefits of heavy transport.The development model of load-raising reform of existing railway lines were reviewed by scholars (Du Xusheng, 2013) from line facilities, rolling stock, station layout and train operation, etc. Relatively speaking, the theory of dynamic response for both aspects of the process line in heavy-duty yet to be perfected. Relatively speaking, the theory of the dynamic response in load-raising reform of existing railway lines is still evolving.

Based on the theory of wheel-track dynamics, the vertical dynamic model for the ballast rail track and the heavy haul train interaction is built. This paper analyzes the dynamic response between the train and the track using the combination method of new rapid explicit integration method and Newmark integration method. And the dynamic response of the existing ballast track under heavy haul train of different loads which are 25t, 27t and 30t is specialized analyzed.

2 Numeric Calculation Model

2.1 The Vehicle submodel

In order to study the heavy haul train, the vertical model for vehicle dynamics is deduced in the paper. The vehicle is considered as a multi-rigid-body system running on the track at a steady-state velocity in the longitudinal direction, regardless of the elastic deformation of the wagon body, bogies and wheel sets, etc. Compared with the traditional model of the cargo train, the model of the heavy haul train is built as secondary suspension structure. While the wagon body and bogies are allowed vertical displacement and in-plane rotation (bounce and pitch motions respectively) the wheelsets are allowed vertical displacement (bounce motion) only as shown in Figure 1. The wagon is thus represented by a 10 degree of freedom (DOF) system.

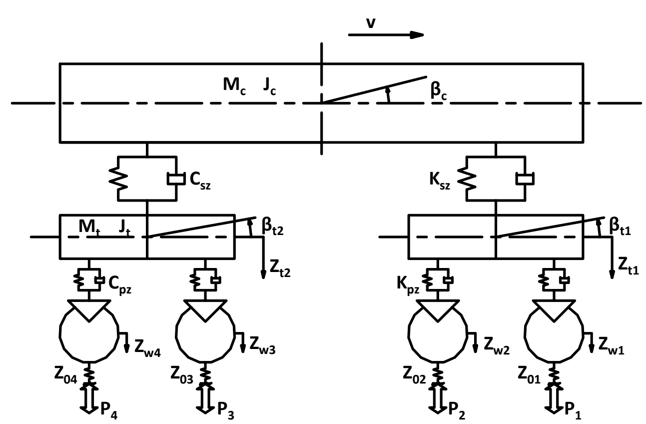


Figure 1. The vehicle submodel

The dynamic vibration equation of each component of the heavy haul freight vehicle system can be obtained from the reference (Zhai Wanming, 2007).

2.2 The track submodel

The track submodel consists of the rail, the pads, the fasteners, the sleepers, the ballast and the subgrade. In this paper, the rail is constructed using beam elements; the pads and fasteners are constructed using spring-damper elements; the sleepers and ballast are constructed using solid elements; the subgrade is constructed using spring-damper elements. The three-dimensional finite element model is shown in Figure 2.

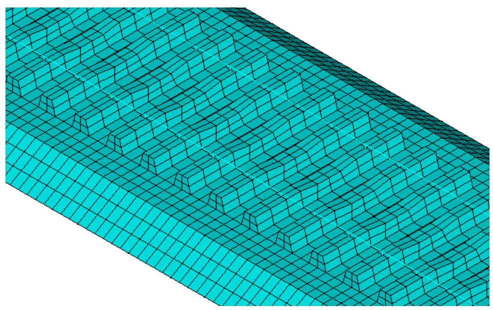


Figure 2. The finite element model

2.3 the numerical integration method

The dynamic equation of the vehicle-track coupling system can be given as

$$[M]\{\ddot{q}\} + [C]\{\dot{q}\} + [K]\{q\} = \{P\} \quad (1)$$

where $[M]$, $[C]$ and $[K]$ are the global mass and the damping and stiffness matrices of the vehicle-track coupling system, respectively; $\{P\}$ is the generalised load vector of coupling system; $\{q\}$ is the generalised displacement vector of the coupling system; $\{\dot{q}\}$ is the generalised velocity vector of the coupling system; and $\{\ddot{q}\}$ is the generalised acceleration vector of the system. Flow chart of the numerical solution of the vehicle and track systemis shown in Figure 3.

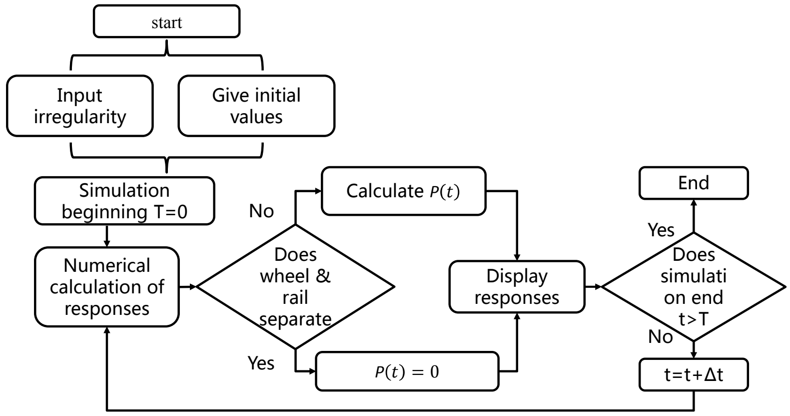


Figure 3. Flow chart of the numerical solution of the vehicle and track system

3 The Influence of Heavy Axles on the Dynamic Response of the Existing Railway Ballast Track under Freight Vehicle Running

3.1 Calculation Parameters of heavy haul trains and the Ballast Track

Calculation Parameters of heavy haul trains of 25t, 27t and 30t load refer to references (Zhai Wanming, 2007; Liu Xinli, 2013).

The elastic modulus, Poisson's ratio and Rail mass per meter of the rail are 2.11×10^5 Mpa, 0.3 and 60kg/m, respectively; the spacing, damp and vertical stiffness of the fasteners are 600mm, 75kN·s/m and 9×10^7 N/m, respectively; Ⅲ concrete sleepers is used, laid spacing 1760 / km.

The elastic modulus, density, Poisson's ratio and thickness of the ballast are 140Mpa, 2500kg/m^2, 0.27 and 0.35m, respectively.

The support stiffness of the subgrade is 180MPa/m, respectively.

3.2 The track irregularity

The harmonic excitation modal is taken as the wheel-rail excitation model in this paper, and the equation of which can be given as

$$Z_0(t) = \frac{1}{2} a \left(1 - cos \frac{2\pi v}{L} t\right) \left(0 \le t \le \frac{L}{v}\right) \quad (2)$$

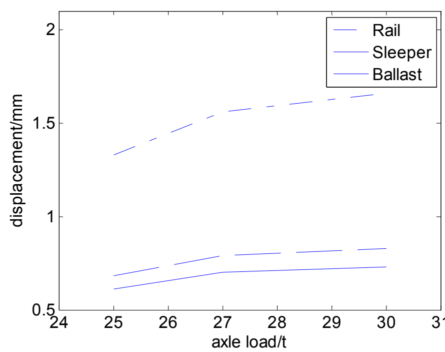
Where L is wavelength(L=1m in the paper) and a is wave hollow(a=0.7mm in the paper).

3.3 The analysis of the response of the wagon and track

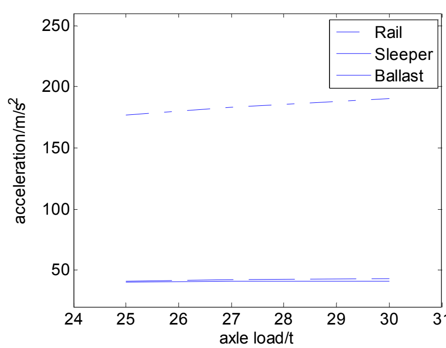
Under the premise of steady-state velocity, the dynamic responses of existing ballast track under heavy haul train of different loads is calculated, which are shown in Sheet 1 and Figure 4.

Table 1. The Dynamic response of the existing railway ballast track under haul vehicle of different loads running at 100km/h

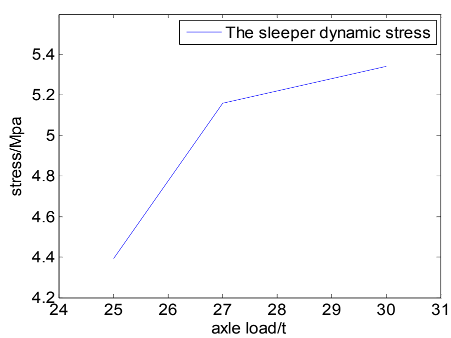
results	units	axle loads of vehicles		
		25t	27t	30t
The vertical displacement of the rail	mm	1.33	1.56	1.66
The vertical displacement of the sleeper	mm	0. 68	0. 79	0. 83
The vertical displacement of the ballast	mm	0. 61	0. 70	0. 73
The vertical acceleration of the rail	m/s^2	177.07	182.84	189.94
The vertical acceleration of the sleeper	m/s^2	41.12	42.50	42.76
The vertical acceleration of the ballast	m/s^2	40.38	40.76	40.93
The sleeper dynamic stress	Mpa	4.39	5.16	5.34
The ballast dynamic stress	Mpa	0.097	0.11	0.12
The Wheel/rail vertical force	kN	165.77	190.21	202.69
The rate of wheel load reduction	—	0.344	0.309	0.279



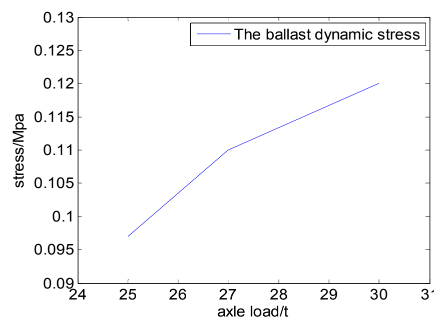
(a) The vertical displacement of the track



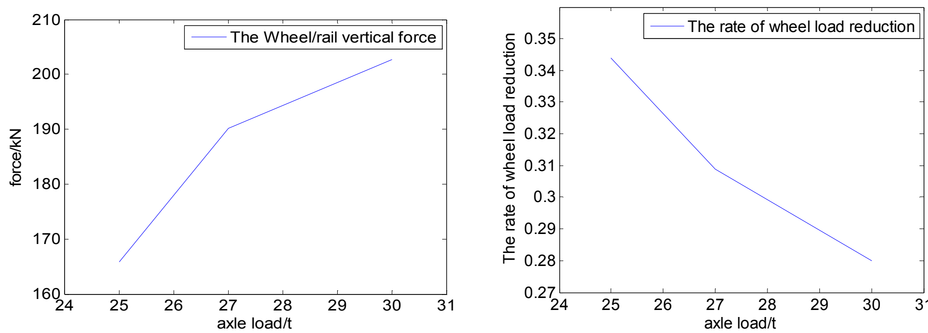
(b) The vertical acceleration of the track



(c) The sleeper dynamic stress



(d) The ballast dynamic stress



(e) The Wheel/rail vertical force (f) The rate of wheel load reduction

Figure 4. The Dynamic Response of the Existing Railway Ballast Track under Freight Vehicle of different loads Running at 100km/h

5 Conclusions

(1) As the vehicle axle load increases, The Wheel/rail vertical force Increases to 202.69kN from 165.77 kN, which is still within the national standards. The maximum of The rate of wheel load reduction is 0.344, 0.309, 0.279, respectively, which does not exceed the safety limit.

(2)As the vehicle axle load increases, every dynamic index of tracks shows a growing tendency. The change of displacement is rather more obvious. And the dynamic displacements of the rail under 27t-axle-load and 30t-axle-load increase 16% and 22% respectively, compared with the 25t-axle-load. The displacements of sleepers and ballasts are more gradual, and that's because the existence of fasteners' damp can make interaction force decays effectively. The change of acceleration is relatively unconspicuous.

(3)As the vehicle axle load increases, the press of tracks also shows a growing tendency. In general it can be concluded that the growth proportion of the dynamic stress of the track structure is similar to the dynamic displacement. And the dynamic stresses of the rail under 27t-axle-load and 30t-axle-load increase 15% and 22% respectively, compared with the 25t-axle-load.

Acknowledgement

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References

Du Xusheng. (2013). "Research on the Development model Existing Railway Developing Heavy Transport." *Railway freight*, 10(1): 1-11.

Galvin P, Romero A, Dominguez J. (2010). "Vibrations induced by HST passage on ballast and non-ballast track". *Soil Dynamics and Earthquake Engineering*, 30(9): 862-873.

Li Yanping. (2012). "Scheme of the Existing Line Heavy transport organization." *Beijing Jiaotong University*, Beijing.

Liu Xinli. (2013). "Research on Dynamic Performance Simulation of 30t and Above Axle-load Freight Wagon." *Railway Construction Technology*.

Lou huibin. (2014). "Mechanics Analysis of ballastless Track Structure under heavy Haul Vehicle loads." *Southwest Jiaotong University*, Chengdu.

Sun Lu, Duan Yufen, Zhao Lei, Zhang Yongming. (2014). *Dynamic Response Analysis of CRTS Ⅱ Ballastless Track Structure of High-Speed Railway*. *Journal of Southeast University*, 44(2): 406-412.

Zhai Wanming.(2007).Vehicle-TrackCouplingDynamic."Science Press, Beijing.

Study of Mineral Powder Effects on the Performance of an Asphalt Rubber Mixture

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Abstract: This study was conducted in-depth study by doing several more important road performances of asphalt rubber mixture through laboratory tests, firstly, comparing the relationship of the content of mineral powder and asphalt bitumen membrane thickness at different asphalt content, through film thickness to determine the range of gradation and asphalt content in laboratory tests, Grade 1 and grade 4 asphalt content 5.5%, 6.0% and 6.6% are set for the benchmark, then mixes adhesion, anti-damage and fatigue properties of the test are carried out in the established range, the study found that: With the addition of mineral powder, asphalt film thickness decreases, but the adhesion of Modified Cantabro testis influenced little by mineral powder added to the asphalt or not; whatever the grade adding 6.5% mineral powder or not, TSR values were greater than 80%,which meets regulatory requirements, but without mineral powder grade slightly better; fatigue properties of asphalt rubber mixture will reduced, when mineral powder added in, especially when the asphalt content is high.
Keywords: Mineral powder; Asphalt rubber mixture; Mixture; Performance.

1 Introduction

The controversy also exists in Chinese domestic asphalt rubber mixture gradation. Through laboratory test and on the premise of correspond voidage, this study conducted the test on water stability and adhesion of asphalt rubber mixture with and without applying mineral powder, and compared the difference of their performances.

2 Dosage of Mineral Powder and Thickness of Asphalt Membrane

Based on the suggestion from foreign statistics, usually the effective thickness of asphalt membrane in continuous dense gradation asphalt mixture shouldn't be less than 6μm, and the effective thickness of asphalt membrane in dense asphalt macadam mixture shouldn't be less than 5μm. Overall, according to both domestic and foreign experience in research, the asphalt membrane thickness of asphalt concrete should be within 5~8μm. Due to the dosage of asphalt in asphalt rubber is higher, it is required that the maximum value be 8μm.

As for asphalt rubber mixture, since asphalt rubber contains powder particles, there isn't yet definition whether powder particles should be included in the asphalt part or in aggregate part. The gradation design is shown in table 1. In table 1, powder particles are counted in asphalt part and aggregate part individually, coming to the regarding thickness of asphalt membrane, which is shown in table 2. For the accuracy of the test, each group conducted parallel tests for 3 times, and the surpassing mean value 15% tests were rejected and re-conducted.

Table 1. Gradation Applied in Asphalt Membrane Thickness

Sieve Pore Size（mm）	Passing Rate（%）									
	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
Gradation 1	100	94.2	64.5	30.1	19.5	15.5	12.2	9.8	8.1	6.5
Gradation 2	100	94.8	67.8	36.1	26.2	16.2	11.5	6.7	4.2	3.6
Gradation 3	100	94.2	64.5	35.1	25	17.2	14.4	10.9	8.6	1.9
Gradation 4	100	94.5	65.9	39	27.1	16.9	11.9	6.9	4.3	0

Note: all the dust below 0.075 in the test was excluded and replaced by mineral powder, same below.

Table 2. Thickness of Asphalt Membrane

Dosage of Asphalt（%）	Gradation	Mean Voidage（%）	VMA	Thickness of Asphalt Membrane（μm）	
				Thickness 1	Thickness 2
5.0	1	13.1	16.5	6.01	3.57
	2	12.2	15.2	6.90	4.86
	3	11.5	14.6	7.11	6.54
	4	11.0	14.3	7.86	8.68
5.5	1	10.8	15.7	5.54	3.64
	2	9.2	14.5	5.78	4.42
	3	8.5	13.4	6.84	5.18
	4	8.1	12.5	8.83	7.97
6.0	1	9.9	15.8	6.43	4.29
	2	9.0	14.4	7.66	5.64
	3	8.8	13.5	8.60	6.60
	4	7.9	12.3	10.15	8.91
6.5	1	8.1	13.1	7.31	4.99
	2	7.6	12.5	8.16	5.51
	3	7.1	11.4	11.80	7.57
	4	6.6	11.2	13.98	9.68
7.0	1	7.4	13.1	13.43	9.19
	2	7.0	12.2	14.51	10.64
	3	6.3	11.4	14.42	12.70
	4	5.9	10.8	15.12	12.88

Note: asphalt membrane thickness 1: powder particles were counted as part of asphalt; asphalt membrane thickness 2: powder particles were counted as part of padding.

In the system of rubber asphalt, powder particles are partially melted among rubber asphalt, hence, theoretically the thickness of rubber asphalt mixture shall be between value 1 and value 2. From Table 2 we can see that all the thickness of asphalt membrane of gradation 1, 2 and 3 with mineral powder are all below 6~8μm; from the Table, with the same dosage of asphalt, the more we apply mineral powder, the thinner the asphalt membrane will be. And also, the VMA indicated rubber asphalt was absorbed largely, and effective asphalt volume was less, which laterally explained the reason why such a big dosage of asphalt shall be programmed in rubber asphalt. When asphalt's dosage was 5.5%, the asphalt membrane thickness without mineral powder applied in gradation 4 was between 7~8μm, and with the oilstone percentage increased, the thickness of asphalt membrane with mineral powder applied gradation was all above 8μm. Based on the study, when the thickness of asphalt membrane is above 8μm, the asphalt mixture will be free from water damage. Thus for the following study, we chose 8μm as midpoint, and selected the situation that value below 8μm in Thickness 2 and value above 8μm in Thickness 1 for pavement performance research. For this purpose, gradation 1, gradation 4 and asphalt dosage were 5.5%、6.0% and 6.6%.

3 Mineral Powder's Influence on the Adhesive Property of Rubber Asphalt Mixture

The adhesion of asphalt influences mixture's many properties such as water stability, aging stability and fatigue property. And research shows that though the viscosity of rubber asphalt is high, the adhesion was low, and that's due to the application of powder particle had increased the solid content in asphalt, the infiltrating ability decreased and surface porosity of attached aggregated rock. Therefore by applying finer particle mineral powder, this study adopted Cantabro Test for the verifying of rubber asphalt's adhesion. Regarding the test of gradation 1 and gradation 4's rubber asphalt in Table 1, the 5.5%, 6.0% and 6.5% were adopted as dosage of asphalt. Result of the test was shown in Table 3.

Table 3. Cantabro Test Result

Dosage of Asphalt （%）	Gradation	Voidage（%）	Thickness of Asphalt Membrane（μm）	Fly Apart Loss （%）
5.5	1	10.8	3.64~5.54	12.2
	4	8.2	7.97~8.83	11.8
6.0	1	9.9	4.29~6.43	9.0
	4	7.9	8.91~10.15	8.8
6.5	1	8.2	4.99~7.31	6.8
	4	6.5	9.68~13.98	6.8

Required by Chinese standard, modified asphalt's fly apart loss in Cantabro Test shall be below 15%. And in the table showed above, all the fly apart loss for the three dosage conditions were within the standard. With the increase dosage of asphalt, the adhesive property of rubber asphalt mixture increased, and the fly apart loss under both gradations' mixture decreased.

The test showed, however, under the asphalt dosage 5.5% and 6.0%, all the fly apart loss of rubber asphalt mixture in gradation 4 without applying mineral powder was slightly lower than gradation 1 which had applied mineral powder, but the disparity was tiny, and they became same under the value 6.5%. It is thus clear that the applying of mineral powder didn't have major influence on the adhesive property of asphalt fly apart test, and it is not comprehensive to judge the rubber asphalt mixture's water stability performance merely based on the adhesion in fly apart test.

4 Mineral Powder's Influence on Rubber Asphalt Mixture's Water Damage Resistance

By freeze-thaw splitting test, the study evaluated mineral powder's water damage resistance influence on rubber asphalt mixture. The freeze-thaw splitting test was conducted against gradation 1 and gradation 2, and the result was shown in Table 4. It is mentionable that for a better evaluation on the water's function in void and the influence on mixture, Marshall Test out of freeze-thaw splitting test conducted 50 times of two sided compaction instead of 75 times, which increased the voidage with same dosage of asphalt.

Table 4.Result of Freeze-Thaw Splitting Test

Dosage of Asphalt（%）	Gradation	Voidage（%）	Thickness of Asphalt Membrane（μm）	Splitting Value (freeze thaw cycle) KN	Splitting Value (normal temperature) KN	TSR（%）
5.5	1	12.6	3.64~5.54	4.21	5.03	80.7
	4	10.2	7.97~8.83	4.73	5.32	83.9
6.0	1	11.4	4.29~6.43	8.66	10.21	80.8
	4	9.5	8.91~10.15	9.93	11.78	88.1
6.5	1	9.3	4.99~7.31	8.21	9.98	87.8
	4	8.0	9.68~13.98	9.75	10.64	94.1

Under the three dosages of asphalt and by maximizing proper gradation, the voidage of rubber asphalt mixture was maintained, so the freeze-thaw test was conducted. From the result of Table 6 we can see that all the gradation's mixture TSR value were higher than 80%, which met the specifications concerned. Under whatever asphalt dosage, the splitting absolute value of gradation 4 without mineral powder was always higher than gradation 1, and gradation 4's mixture TSR value was also slightly higher than gradation 1, which had applied mineral powder. Thus, when the rubber asphalt mixture applied mineral powder, its asphalt membrane thickness was hard to reach 6~8μm. While if the asphalt membrane was too thin, with the washing of dynamic water pressure, the asphalt mixture would become fragile and cracked, causing early water damage.

5 Mineral Powder's Influence on Rubber Asphalt Mixture's Fatigability

In the present major application and laboratory study, the fatigue life of rubber asphalt mixture is the crucial link. According to the previous study, although the applying of mineral powder can fill in the void of mixture which makes for a lower voidage and furthermore resists fatigue cracking, this meanwhile thins the membrane of asphalt, and the lowed asphalt membrane would not only cause a lower adhesion and water stability but also lead to structural layer's fatigue cracking in an early stage. Based on this contradictory, a balance is needed. Fatigability adopted the gradation in fly off test which is shown in Table 5. And BFA four-point bending test with Nf_{50} of AASHTO method was adopted for this study. When the stiffness modulus decreased to 50% frequency of initial stiffness modulus, it was defined as the fatigue frequency. The test's forming used self-made mold, and then the mold was grinded by roller whose wheel width was 45cm, vibration rate at 4460 times per minute, compacting force 896N, compacting depth 22.86cm. According to calculation and prepressing validation, when the static pressure reached 4 times and vibration rolling was one time, it reached the voidage of Marshall Design (while adjusting voidage, static pressure can be increased or decreased to reach the ideal result). After 24 hours' rest in dry room, it was cut into a 400×63×50mm specimen.

Figure 1. Four-Point Bending Fixture (Left) and Roller for the Test (Right)

Based on current road-vehicle condition, 500με、1000με and 1500με was adopted as load level for simulating of different traffic load.

Table 5. Test Parameter

Loading Method	Loading Waveform	Strain Level	Temperature	Frequency	Intermittence
Strain Control	Half Sine	500、1000、1500με	15℃	10Hz	No Intermittence

Table 6. Fatigue Testing Result

Asphalt Dosage（%）	Gradation	Voidage（%）	Asphalt Membrane Thickness	Initial Stiffness Modulus （MPa）	Strain Level	Fatigue Times
5.5	1	9.7	3.64~5.54	4762	500	32690
				4643	1000	16390
				4752	1500	6010
	4	7.9	7.97~8.83	4428	500	33690
				4329	1000	17720
				4530	1500	6770
6.0	1	8.9	4.29~6.43	4212	500	62670
				4318	1000	36390

				4381	1500	17930
	4	7.3	8.91~10.15	4123	500	72610
				4087	1000	46390
				4007	1500	12040
6.5	1	7.6	4.99~7.31	3760	500	86500
				3649	1000	47230
				3693	1500	10260
	4	6.8	9.68~13.98	3353	500	125430
				3384	1000	76390
				3240	1500	22020

From Table 6 we can directly tell that with the applying of mineral powder, the fatigability of rubber asphalt mixture would have a certain decrease especially with a higher dosage of asphalt. Hence, considering the long-term effects of rubber asphalt, in northern China area where the temperature is low, if rubber asphalt is used for pavement, the dosage of asphalt should be higher, which is supposed to apply less mineral powder or even no mineral powder. Thus, these areas where cold cracking often happens can have a better fatigability.

6 Epilogue

Due to rubber particle's partial reaction which degraded and dissolved in asphalt, the actual rubber asphalt membrane hence is supposed be within the range of higher limit and lower limit. According to domestic and overseas research experiences, in terms of asphalt concrete usually the asphalt membrane should be 5~8μm. because the dosage of asphalt is higher, it is required to adopt the maximum value which is 8μm, and observing the requirement of maximum value, adopting gradation 1 and gradation 4 without asphalt dosage 5.5%, 6.0% and 6.6% as standard for testing research. Results are listed as below:

1.The adhesion relation between mineral powder's dosage and fly off test was not largely relevant, and considering the complexity and comprehension of adhesion test, we shall not judge the water stability property of rubber asphalt mixture simply from the fly off test.

2.Mixture TSR of all gradation were over 80% which was within the required standard. No matter under what dosage of asphalt, gradation 4 which was without mineral powder was higher than that of gradation1, and the mixture TSR of gradation 4 was all slightly higher than gradation which applied with mineral powder.

3.With the applying of mineral powder, the fatigability of rubber asphalt mixture would decrease to a certain extent, especially when the dosage of asphalt is higher.

The application of mineral powder has a disadvantageous influence on the performance of rubber asphalt mixture. Under the condition that leaking and bleeding would not happen, less or no mineral powder should be applied.

References

Arizona Department of Transportation.(2000) Standard specifications for road & bridge construction. Phoenix : Department of Transportation Engineering Records

Section .
Roads and Traffic Authority of NSW.Scrap Rubber Bitumen Guide. VicRoads. Main Roads, Western Australia & RTA, 1995
SHRP-A-407.The Superpave Mix Design Manual for New Construction and Overladys.N.C.R.USA.1994.8
Standard Specification for Superpave Volumetric Mix Design. AASHTO Designation M P2-10
SHRP-A-312.Fatigue Response of Asphalt Mixtures .N.C.R.USA.1990

Influence of Geometry on the Capacity of the MIMO System in Transportation Tunnels

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Abstract: This paper investigates the influence of tunnel geometry on the capacity of multiple-input multiple-output (MIMO) wireless communication system in underground environment. Due to the geometry of underground tunnels, such as mine and transportation tunnels, there are sufficient scattering objects, and MIMO system can take great advantage of such geometry. Through the experimental evaluations, it is shown MIMO systems in underground tunnel with complicated geometry can achieve an obvious improvement on channel capacities.
Keywords: Transportation tunnels; MIMO wireless communications.

1 Introduction

In underground mine and transportation tunnels, a reliable and efficient wireless communication system is in great demand to improve the safety and productivity. Since multiple-input multiple-output (MIMO) wireless communication system, due to its spatial diversity on both transmit and receive ends, can significantly increase the channel capacity and provide higher link reliability (Foschini, 1998; Telatar, 1999), deploying MIMO systems in underground tunnels is a promising approach to fulfill communications needs.

The propagation of electromagnetic (EM) waves in underground tunnels is different from that in terrestrial environment. According to the geometry of the tunnel, the EM waves are confined in the restricted internal space, and there are always lots of scattering objects (e.g. pipes, brackets, vehicles, machines, and human being). Hence, the underground tunnels are sufficiently rich in multipath components (MPCs), which are yielded by the abundant reflections and diffractions from the boundary walls and scattering obstructions. This "rich multipath" environment, which is considered as a drawback in traditional wireless communications systems, but is a major advantage in MIMO systems (Shiu, 2000). The MIMO system can mitigate the impact of multipath fading and potentially take advantage of it to achieve a preferred performance in underground tunnels.

In this paper, we provide evaluation and demonstration of the influence of the tunnel geometry on the capacity of MIMO system in underground environment. In particular, we firstly review the MIMO system model and channel capacity in Section 2. Then, in Section 3, a sophisticated tunnel model based on physical underground tunnel is developed in Wireless InSite (a 3D ray-tracing software)

(Remcom, 2009), including empty tunnel and detailed tunnel model (with pipes, machines and other obstructions). The experimental scenarios are conducted in the tunnel models and post-analyzed, and the evaluation results are provided in Section 4. It is shown that the MIMO system deployed in the detailed tunnel has obvious improvements in channel capacity than the system deployed in the empty tunnel. Finally, the paper is concluded in Section 5.

2 MIMO Channel Model and Capacity

Figure 1 shows a generic MIMO wireless communication system with N_T transmit antennas and N_R receive antennas, and a variety of approaches to model the MIMO channel have been proposed (Jensen, 2004 ; Almers, 2007).

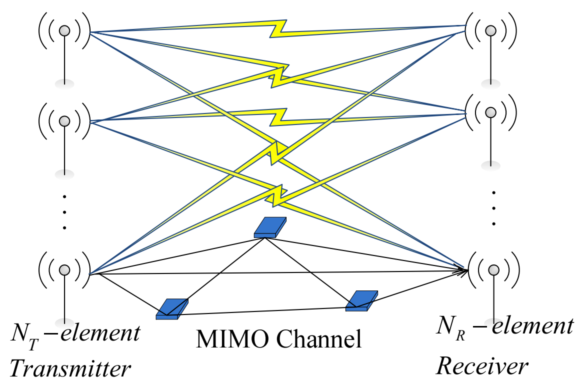

Figure 1. Illustration of a MIMO system

From a system level perspective, the baseband input-output relationship between the length-N_T transit signal vector $\mathbf{s}(t)$ and length-N_R receive signal vector $\mathbf{y}(t)$ can be formulated as

$$\mathbf{y}(t) = \int_\tau \mathbf{H}(t,\tau)\mathbf{s}(t-\tau)d\tau + \mathbf{n}(t) \tag{1}$$

where, $\mathbf{n}(t)$ is Additive White Gaussian Noise (AWGN) at the receive end, and $\mathbf{H}(t,\tau)$ is an $N_T \times N_R$ channel impulse response matrix represented as

$$H(t,\tau) = \begin{pmatrix} h_{1,1}(t,\tau) & h_{1,2}(t,\tau) & \cdots & h_{1,N_T}(t,\tau) \\ h_{2,1}(t,\tau) & h_{2,2}(t,\tau) & \cdots & h_{2,N_T}(t,\tau) \\ \vdots & \vdots & \ddots & \vdots \\ h_{N_R,1}(t,\tau) & h_{N_R,2}(t,\tau) & \cdots & h_{N_R,N_T}(t,\tau) \end{pmatrix} \tag{2}$$

where, $h_{ij}(t,\tau)$ denotes the time-variant complex impulse response between the *j*-th transmit antenna and the *i*-th receive antenna.

Then, the Capacity C of a MIMO system as figure 1 shown, with N_T transmit antennas and N_R receive antennas, is given b

$$C = \log_2\left[\det(\mathbf{I}_{N_R} + \frac{\rho}{N_T}\mathbf{H}\mathbf{R}_{xx}\mathbf{H}^T)\right] \tag{3}$$

where, (T) denotes the transpose-conjugate, $\mathbf{I}$ is the identity matrix, $\mathbf{H}$ is the normalized $N_R \times N_T$ channel matrix in frequency domain, ρ is the average signal-to-noise ratio (SNR) per receiver branch, and $\mathbf{R}_{xx}$ is the correlation matrix of the transmit data (with an assumption, for data at the different antenna elements that are uncorrelated, it is a diagonal matrix with entries that describe the power distribution among the antennas). Thus, if we assumed that all the N_T transmit antenna elements have equal power and are uncorrelated, the $\mathbf{R}_{xx}$ becomes a identity matrix, and we get a simple formula of the capacity of MIMO channel from (6)

$$C = \log_2\left[\det(\mathbf{I}_{N_R} + \frac{\rho}{N_T}\mathbf{H}\mathbf{H}^T)\right] \tag{4}$$

Furthermore, in the case of channel changes into many instances, there are two statistical capacity to evaluate the performance of MIMO channel:

(1) **The ergodic capacity.** This is the mean value (expectation) of the capacity, taken account of overall realizations of the channel.

(2) **The outage capacity.** This is the minimum capacity that is achieved at a certain fraction of the time, for example, 90% or 95%.

3 Description of Experimental Scenarios

With the perspective of measurement campaign in future, we choose an actual site to construct a floor plan model in Wireless InSite now. The chosen underground tunnel, is a suitable site considering its ease of access, long and narrow pathways, and rich infrastructure in mimicking mines or transportation tunnels.

Figure 2. Snapshot of the physical tunnel cross-section

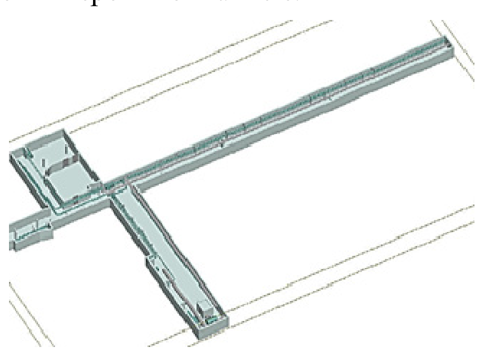

Figure 3. Snapshot of the detailed tunnel floor plan

3.1 Description of the Experimental Tunnel

The entire structure of the underground tunnel resembles a general cross-shape with a total length of 103.1 meters and a width of 55.7 meters. The widths of the tunnel substructure vary from 2.8 to 6.3 meters with almost same height of 2.4 meters. As shown in figure 2, there are a large number of metal pipes and brackets in the tunnel. Additionally, other extensive infrastructures such as the elevator section, steel doors, large scale equipment, also exist in the tunnel.

With the view of distinguishing the geometry of the tunnel on MIMO channel capacity, we construct two version of 3D floor flan in Wireless InSite: empty tunnel and detailed tunnel.

(1) **Empty tunnel**

This floor plan model is designed to incorporate only the basic structure with support pillar and two steel doors.

(2) **Detailed tunnel**

This floor plan model is based on the empty tunnel, and filled with extensive infrastructures such as pipes, brackets, equipment, etc. Figure 3 shows the 3D detailed tunnel floor plan, and we make the shape and property of all infrastructures materials (such as thickness, permittivity, conductivity, reflection and transmission coefficient, etc.) close to the corresponding prototypes in the physical tunnel.

3.2 Setups of Experimental Scenarios

A MIMO system with complete setups is designed in the experimental scenario. Considering a narrow band system, the operation frequency is 2.4GHz with the bandwidth of 1MHz. Ignoring polarization, Omni-directional antennas are chosen to install at both transmit and receive ends, and the radiation powers are equal zero dBm. As shown in figure 4, the transmit route, which consists of 4 transmit points with equal height of 2 meters, is positioned parallel with the tunnel ground; and, the receive grid, which is comprised of 9×9 receive points, with equal height of 1.5 meters, is positioned parallel with the tunnel ground and away from the transmit route. Especially, the spacing distance apart from adjacent points in both transmit route and receive grid, is equal 0.25 meters, i.e., double wavelength of operation frequency (2λ).

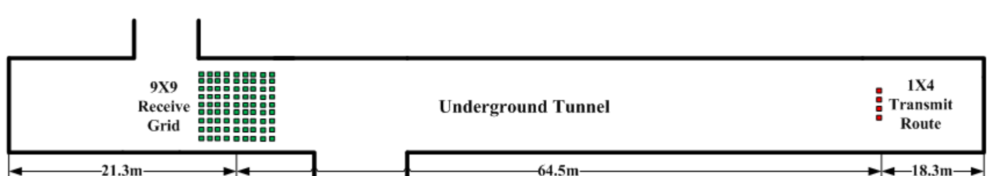

Figure 4. Sky view of MIMO scenario in the tunnel

In order to capture different performance of MIMO channel, the MIMO system mentioned above is deployed in both the empty and detailed tunnel floor plans. Since

EM waves are approximately modeled as optical rays in Wireless InSite, and the EM filed and other outputs dependent on EM filed are obtained by summing the contributions of rays undergoing reflections and diffractions from the tunnel geometry, numerical results are acquired after the time-consuming computation, which dramatically increases as the geometry of tunnel becomes more complicated. In particular, the number of propagation paths is limited to 100 in this experimental scenario. There is no transmission in underground environment, and the upper limit number of reflections and diffractions in each propagation path is set to 6 and 1, respectively.

4 Evaluations

In this section, we present the capacity of MIMO channel in both empty and detailed tunnels to evaluate the influence of the tunnel geometry. The evaluation results are obtained from post-analysis of Wireless InSite numerical outputs.

4.1 Experiment Algorithm

Even through there is a receive grid in the experimental scenario (figure 4), only 4×4 MIMO channel is concerned. In particular, the receive route selected from the receive grid, consists of 4 receive points, and is perpendicular to the tunnel wall with spacing equal 2λ as well as the unique transmit route. Then, there are a quantity of arrangements for receive routes, and numerous instances of 4×4 MIMO channel is realized. Because of the diversity of channel realization, the statistics of capacity can be collected in the post-analysis.

Variety of outputs are generated by the computation in Wireless InSite, and we can employ them to achieve characteristics of MIMO channel, such as capacity, sub-channel complex gains, etc. The H-matrix of MIMO channel in (2) is comprised of complex impulse responses of each possible transmission pair between transmit point and receive point in (5). Since experimental setups in section III are in accordance with the assumption that data at the different antenna elements that are uncorrelated, all the antennas at transmit point have equal radiation power and are uncorrelated, the capacity of MIMO channel is calculated by formula (7).

4.2 Experiment Results

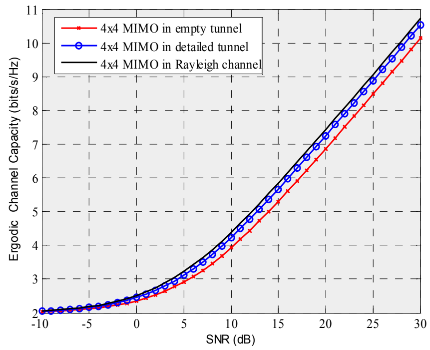

Figure 5.The ergodic capacity of MIMO channel in different tunnel geometries as a function of SNRs within [-10, 30] dB

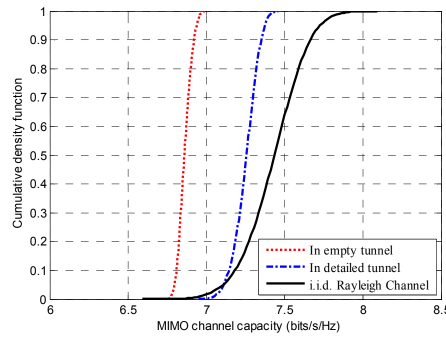

Figure 6. The cumulative density function of channel capacity in different tunnel geometries at SNR=20dB.

In figure 5, the ergodic capacity of MIMO channel in different tunnel geometries as a function of average SNR at each receive point is shown. The capacities of all 4×4 channel realizations are collected, and the mean values of them at different SNRs are plotted. It indicates that the capacity in detailed tunnel is lower than in the ideal Rayleigh channel, but higher than in empty tunnel. With specific SNR at receive route, the cumulative density function (CDF) of channel capacity in both empty and detailed tunnels are shown in figure 6. Through the comparison among the three CDFs of channel capacities, the same result, i.e., the MIMO channel in detailed tunnel has preferable agreement with that in ideal Rayleigh case, is revealed. In a sense, the existence of rich scattering objects in detailed tunnel and its associated MPCs, make the MIMO channel more close to the ideal Rayleigh channel.

5 Conclusions

In this paper, a sophisticated 3D tunnel model based on physical underground site is designed, and experimental scenarios with complete setups are conducted in this model. After analysis of the experimental results, we provide an evaluation and demonstration of the influence of the tunnel geometry on the capacity of MIMO system in underground environment. It is concluded that the MIMO system deployed in detailed tunnel has obvious improvement on channel capacity, and the complicated geometry of the underground transportation tunnel, always with sufficient scattering objects, is a benefit in the context of MIMO system. Therefore, deploying MIMO system in the transportation tunnel is a promising way to construct a wireless communication with substantial improvement on channel capacity.

Acknowledgement

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References

Foschini, G. J., and Gans, M. J. (1998). "On limits of wireless communications in a fading environment when using multiple antennas." *Wireless Personal Communications*, 6(3), 311-335.

Telatar, E. (1999). "Capacity of multi-antenna Gaussian channels." *European Trans. on Telecommunications,* 10(3), 585-595

Shiu, D., Foschini, G. J., Gnas, M. J., and Kahn, J. M. (2000). "Fading correlation and its effect on the capacity of multi-element antenna systems." *IEEE Trans. on communications,* 48(3), 520-513.

Remcom Inc. (2009). "Wireless InSite User's ManualVersion 2.5." http://www.remcom.com/wireless-insite.

Jensen, M. A., and Wallace, J. W. (2004) "A review of antenna and propagation for MIMO wireless communications." *IEEE Trans. Antennas Propag.*, 52(11), 2810-2814.

Almers, P., et al. (2007). "Survey of Channel and Radio Propagation Models for Wireless MIMO Systems." *EURASIP Journal on Wireless Communications and Networking,* vol. 2007.

Safety Assessment Methods of a Rail Transit Signal System

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Abstract: As a massive public traffic, the safety of rail transit system directly concerns the lives and properties of all the passengers. The signal system, playing a crucial role in ensuring operation safety of rail transit, must be evaluated to make sure its safe running. However, it lacks of the comparative research of safety assessment methods that are suitable for the key equipment of rail transit signal system. Based on the signal system of rail transit related research and safety assessment theory, several safety assessment methods, including fuzzy comprehensive method which was explored in the safety assessment of switches, have been analyzed in this paper so as to present the characteristics of these methods and applicable range and conditions.
Keywords: Rail transit; Signal system; Safety assessment methods; Fuzzy comprehensive assessment.

1 Introduction

With some characteristics such as large capacity, high speed and low pollution, rail transit has got rapid development fully in multiple countries around the world. Comparatively perfect rail transit network has been formed in many big cities. Improving the safety of rail transit operation has aroused the public attention. As for the command of safe train plan and efficient operation of rail transit, signal system plays a great role in the operation safety. As a safety-related system, the safety assessment work of signal system is responsible for running.

As it comes to safety assessment methods study, Li Jin , Song Rui et al. used the fuzzy comprehensive evaluation method for rail transit operation safety assessment. The hierarchy structure of evaluation index is established from four aspects, operations management, facilities, staff and external conditions. He Qinghai applied the fuzzy comprehensive evaluation method to the highway traffic safety assessment, putting forward the 'human-vehicle-road-environment' evaluation index. Zhu Wenhai, He Shanshan used the gray comprehensive evaluation method in the study of rail transit passenger satisfaction. Combining qualitative and quantitative analysis and integrating expert experience and scientific computing, the multilevel gray comprehensive evaluation method has very strong practicability, and the results have higher credibility in application examples.

From the literature review above, it can be seen that many experts and scholars have studied safety evaluation of rail transit signal system and put forward many feasible assessment methods. But these methods have their own characteristics and range of application, so in-depth study and comparison of these methods is particularly important in safety assessment of the complex rail transit signal system. In this paper, based on the signal system of rail transit related research and safety assessment theory, several safety assessment methods, including fuzzy comprehensive method which was explored in the safety assessment of switches, have been analyzed so as to present the characteristics of these methods and applicable range and conditions.

2 Concept of transit signal system

Signal means "signal (display), interlocking, block". Made up of all kinds of signs, track circuit and other equipment and ancillary facilities, rail transit signal is a complete system. Signal system mixed with computer, communication and other advanced technology into an organic whole develops in the direction of digital, intelligent, and automatic. Figure 1 shows that rail transit signal system has three parts, the station signal system, wayside signal system and operation control system.

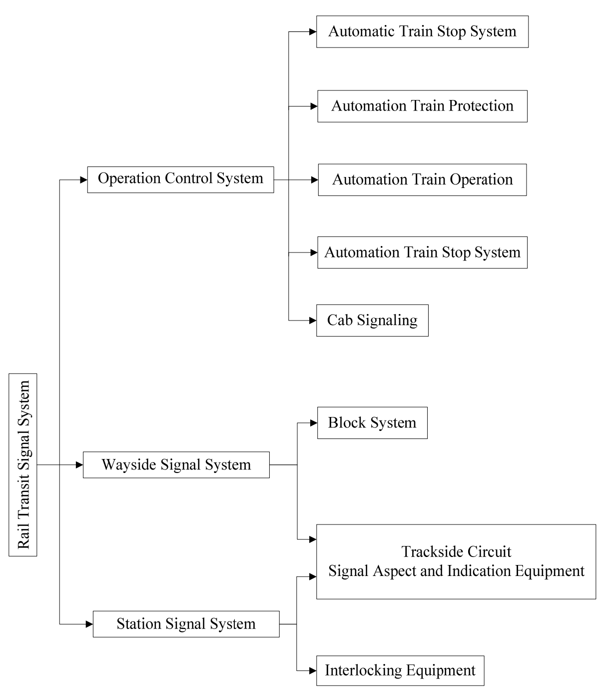

Figure1.Rail transit signal system composition

On the premise of the train operation safety, signal system improves the quantity and efficiency by raising the train speed or shortening the train operation interval or both the two ways. As a part of rail transit signal system, switches play a very important role in the operation safety. So safety assessment of the key equipment, switches is needed. There are many factors that influence the safety of switches, such as operating conditions, operation state, product material, the natural environment and so on. A suitable assessment method should be found out to accomplish the analysis work.

3 Safety assessment and methods research

3.1 Safety assessment content and process

Signal system safety assessment is based on system safety analysis by using various methods to find out the potential danger and weak links that exist in the system, to determine whether the system can meet the safety requirements or not. In the process of safety assessment in rail transit signal system, certain standards needed to judge whether the system meets the requirements and though the assessment or not. The process of safety assessment is shown as Figure 2.

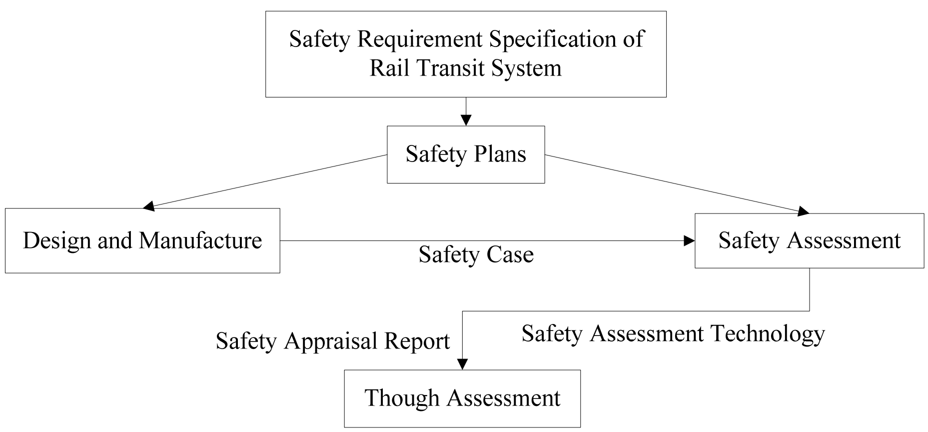

Figure2. Process of safety assessment

3.2 Analysis and research of safety assessment methods

With the development of safety assessment work in various fields, many safety assessment methods emerge, such as fuzzy comprehensive evaluation method and gray comprehensive evaluation method. Choosing appropriate assessment method has significant impact on the final result in safety assessment of rail transit signal system. Because of the complexity of the rail transit signal system, the choice of safety assessment method is demanding, however each method has its own characteristics and scope of use. So how to choose the appropriate method can refer to the following process: preliminary and quantitative analysis is need firstly in order to obtain a qualitative concept, then make detailed analysis according to the risk level and select a appropriate assessment method for a certain object finally. At present, the safety assessment methods can be divided into two main categories, namely, qualitative assessment methods and quantitative ones.

3.2.1 Fuzzy comprehensive evaluation method

Fuzzy comprehensive evaluation comprehensively evaluates the membership of degree from multiple factors using fuzzy set theory and principle of fuzzy synthesis. It can effectively solve the problem of the fuzziness and uncertainty of judgment in two ways, one is evaluating and sorting the object according to the size of the comprehensive scores, the other is evaluating the object according to the value of fuzzy evaluation set.

The advantage of fuzzy comprehensive evaluation is to estimate a system which involves fuzzy factors comprehensively. As a commonly used method of fuzzy mathematics, it is widely used in economic, social and other fields. However, with the continuous application of comprehensive evaluation in economy or society system, it is hard for human beings to make objective evaluation and decision due to complexity of the problem, insufficient information and multiple factors. But fuzzy comprehensive evaluation method can not solve the problem of information overlapping, and there is no systematic method to determine membership function. What's more, the synthesis algorithm also needs to be further discussed. In general, fuzzy comprehensive evaluation is a comprehensive evaluation method based on the subjective information which comes from people's judgment. The reliability and accuracy of this method depends on the reasonable selection of factors, weight distribution and composition operator of comprehensive evaluation.

Fuzzy evaluation method can be used in safety assessment of rail transit signal systems, such as evaluating track circuit or switches. A low class hierarchy assessment model should be built firstly, then determine evaluation index weights, and accomplish the assessment with this method.

3.2.2 Gray comprehensive evaluation

Gray comprehensive evaluation method is a combination of qualitative analysis and quantitative analysis.

In gray correlation analysis, the closer between geometric curves of several statistical sequences, the greater correlation degree between them. Grey correlation coefficient:

$$r_{ij} = \frac{\min_i \min_j \left| x_{oj} - x_{ij} \right| + \xi \max_i \max_j \left| x_{oj} - x_{ij} \right|}{\left| x_{oj} - x_{ij} \right| + \xi \max_i \max_j \left| x_{oj} - x_{ij} \right|} \begin{pmatrix} i = 1, 2, \ldots, m \\ j = 1, 2, \ldots, n \end{pmatrix}$$

Level two minimum differences: $\min_i \min_j \left| x_{oj} - x_{ij} \right|$.

Level two maximum differences: $\max_i \max_j \left| x_{oj} - x_{ij} \right|$.

Resolution ratio: $\xi \in [0,1]$, usually $\xi = 0.5$.

So, the correlation degree between the sequence and the reference sequence is:

$$r_{oi} = \frac{1}{n}\sum_{j=1}^{n} r_{oj} .$$

We can know the degree of correlation between the sequence and the reference sequence through r_{oi}.

If weight of each evaluation index is not equal, weight matrix is: $w_j\ (\mathrm{j}=1,2,\ldots,\mathrm{n})$

Grey correlation matrix is: $A = W \times R^T$

So the degree of correlation between evaluation objects is: $a_i = \sum_{j=1}^{n} w_j \times (r_{ij})^T\ (\mathrm{i}=1,2,\ldots,\mathrm{m})$

We can know the degree of closeness between the evaluation index and the optimal index through a_i.

This method can well solve the problem that evaluation index is difficult to accurately quantified, and eliminate the effects of the human factors, making the evaluation results more objective and accurate. Raw data can be directly calculated and normalization processing of experimental data is no needed. Without a large number of samples, this method just needs a small amount of representative ones. But this method requires the sample data with the characteristic of time series, and calculating the resolution ratio is needed. There is a need to explain that how to choose the object evaluation index system and weight distribution will affect the final evaluation result. In addition, there is a positive or negative correlation relationship between things. But the correlation is always positive using gray correlation degree, so it can not fully reflect the connection between things. The usage of this method should be especially careful in analyzing work.

3.2.3 The analysis of the above methods

Each safety assessment method has its own characteristics. When choosing method, according to the evaluated object's characteristic and needs of evaluation to determine whether the qualitative method or quantitative method should be used. When evaluating rail transit signal system, it’s not to say that can only use quantitative or qualitative methods. At the start of the assessment, purely qualitative assessment can be undertaken and then on the basis of the result of the qualitative assessment to decide whether need to do further work. When quantitative evaluating, two or more than two quantitative methods can be applied in combination according to complex features of the evaluated object.

4 Safety assessment of rail transit switches based on fuzzy comprehensive evaluation method.

From the comparative research above, it can be seen that the fuzzy comprehensive evaluation method is more suitable than the gray comprehensive evaluation method in the safety assessment of the switches, the key equipment of rail transit signal system, as the switches involve fuzzy factors comprehensively and the evaluation index can be quantified by the analytic hierarchy process.

So we choose the fuzzy comprehensive evaluation method to achieve the assessment work, and choose the economic life, physical life and technical life as the evaluation criterion for switches, then we establish the following hierarchy model as Table 1.

Table 1 Comprehensive weight table of switches safety assessment model

<table>
<tr><th rowspan="2">A</th><th colspan="2">B</th><th colspan="2">C</th><th colspan="2">D</th><th colspan="2">E</th><th rowspan="2">Comprehensive weight</th></tr>
<tr><th>Key element</th><th>Weight</th><th>Key element</th><th>Weight</th><th>Key element</th><th>Weight</th><th>Key element</th><th>Weight</th></tr>
<tr><td rowspan="18">Safety assessment criteria of switches</td><td rowspan="3">B1</td><td rowspan="3">0.157</td><td>C1</td><td>0.246</td><td colspan="4" rowspan="3"></td><td>0.039</td></tr>
<tr><td>C2</td><td>0.456</td><td>0.071</td></tr>
<tr><td>C3</td><td>0.298</td><td>0.047</td></tr>
<tr><td rowspan="15">B2</td><td rowspan="15">0.562</td><td rowspan="6">C4</td><td rowspan="6">0.219</td><td rowspan="4">D1</td><td rowspan="4">0.472</td><td>E1</td><td>0.079</td><td>0.005</td></tr>
<tr><td>E2</td><td>0.255</td><td>0.015</td></tr>
<tr><td>E3</td><td>0.517</td><td>0.030</td></tr>
<tr><td>E4</td><td>0.149</td><td>0.009</td></tr>
<tr><td>D2</td><td>0.172</td><td colspan="2" rowspan="6"></td><td>0.021</td></tr>
<tr><td>D3</td><td>0.258</td><td>0.032</td></tr>
<tr><td>D4</td><td>0.098</td><td>0.012</td></tr>
<tr><td rowspan="3">C5</td><td rowspan="3">0.099</td><td>D5</td><td>0.463</td><td>0.026</td></tr>
<tr><td>D6</td><td>0.351</td><td>0.020</td></tr>
<tr><td>D7</td><td>0.186</td><td>0.010</td></tr>
<tr><td rowspan="4">C6</td><td rowspan="4">0.222</td><td rowspan="3">D8</td><td rowspan="3">0.202</td><td>E5</td><td>0.531</td><td>0.013</td></tr>
<tr><td>E6</td><td>0.329</td><td>0.008</td></tr>
<tr><td>E7</td><td>0.140</td><td>0.003</td></tr>
<tr><td>D9</td><td>0.798</td><td colspan="2" rowspan="2"></td><td>0.100</td></tr>
<tr><td>C7</td><td>0.124</td><td>D10</td><td>0.058</td><td>0.004</td></tr>
</table>

					D11	0.118			0.008
					D12	0.102			0.007
					D13	0.234			0.016
					D14	0.488			0.034
			C8	0.187	D15	0.105			0.011
					D16	0.216			0.023
					D17	0.431			0.045
					D18	0.248			0.026
			C9	0.149					0.084
	B3	0.281							0.281

A: safety assessment criteria of switches; $B_{1:}$ economic life; $B_{2:}$ physical life;
B_3: technical life; $C_{1:}$ the annual cost; $C_{2:}$ maintenance cost;
$C_{3:}$ operation cost; $C_{4:}$ inherent design; $C_{5:}$ system interface;
$C_{6:}$operating conditions; $C_{7:}$operation state; $C_{8:}$maintenance and management;
$C_{9:}$engineering reform; D_1:product design; D_2:product manufacturing;
D_3:product material; D_4:product inspection; D_5:switches interface; D_6:point switch interface; D_7:relay interface; D_8:the natural environment; D_9:ballast bed environment; D_{10}:practical serviced life; D_{11}:number of times; D_{12}:general failure rate; D_{13}:serious failure rate; D_{14}:dangerous failure rate; D_{15}:management system; D_{16}:periodic replacement; D_{17}:daily maintenance; D_{18}:technical training;
E_1:designed service life; E_2:reliability design; E_3:fault-safety design;
E_4:environmental adaptability design; E_5:ice and snow; E_6:hydrops;
E_7:thunder.

Based on the evaluation model, experts give scores for each layer of influence factors by choosing one level from "excellent, good, normal, bad". Finally count the total number of each element .We can use the frequency of factors as the membership degree of fuzzy evaluation. Then fuzzy comprehensive evaluation can be done by the following the formula.

$$B = A\begin{bmatrix} B_{B1} \\ B_{B2} \\ B_{B3} \end{bmatrix} = \begin{bmatrix} 0.157 & 0.562 & 0.281 \end{bmatrix}\begin{bmatrix} 0.27 & 0.6 & 0.13 & 0 \\ 0.330844 & 0.441804 & 0.183917 & 0.042528 \\ 0.27 & 0 & 0 & 0.73 \end{bmatrix}$$

$$= \{0.304195 \quad 0.342494 \quad 0.123771 \quad 0.229031\}$$

According to the principle of maximum membership degree, the grade of the switches is good.

By comparing the actual operation condition of rail transit lines, it's clear that the evaluation result is coincided with the physical truth. So the method selected in this paper is reasonable and feasible.

5 Conclusions

In order to ensure the stability and safety in the field of rail transit development in our country, from the historical experience shows that the safety assessment of signal system is very important. In the safety assessment, the choice of assessment methods directly affects the whole efficiency and accuracy of results. In this paper, the composition of rail transit signal system and the research status of safety assessment were introduced. On the basis of deep analysis and research the current safety assessment methods, proposed and summarized the advantages and disadvantages and using range of several main methods, accomplished the safety assessment of rail transit switches based on the fuzzy comprehensive method, put forward the basis and reference for safety assessment work in method selection.

Acknowledgement

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References

Gao, C.H., Yan, F. and Tang, T. (2005). "Study on safety assessment of rail traffic signalling system" *China Safety Science Journal*, 10, 75-79.

He, Q.H. (2011). "Highway Traffic Safety Assessment Research Based on the Fuzzy Comprehensive Evaluation" *China Water Transport*, 5, 56-57.

Hu, X. (2012) "Urban Rail Transit Signaling System Safety risk Assessment, *Southwest Jiaotong University Master Degree Article*.

ICE61508-2000. Function Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems, 2000.

Li, J., Song, R. and Jing, J.L. (2011). "Safety evaluation of rail transit based on comprehensive fuzzy evaluation model" *Journal of Transport Science and Engineering*,6,92-94.

Ma, G.F. and Chen, Z.Q. (2011). "Rail Transit Station Project Assessment Research Based on the BP Neural Network" *Project Management Technology*, 7, 56-59.

Sao, Y.H. (2012). "Safety assessment of urban rail transit signaling system" *Urban Mass Transit*, 1, 19-22.

Wang, H.L. (2011). "Comprehensive Evaluation for Urban Rail Transit Network Planning Based on BP Artificial Neural Network" *Urban Public Transport*, 6, 56.

Yan, F. and Tang, T. (2005). "Research and development of safety technology in signalling system of tail transit" *China Safety Science Journal*, 6, 95-97.

Zhu, W.H. and He, S.S. (2009). "Traffic Passenger Satisfaction Grey

Comprehensive Evaluation" *Modern Urban Transit*, 4, 79-80.

Railway Information Sharing Platform Security Management Technologies Analysis

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Abstract: Railway information sharing platform is the key technology to realize the railway information systems connectivity, integration and optimization of all kinds of information resource in railway companies. Security technologies of railway information sharing platform are the foundation of the long-term stable operation of the platform. Through analysis of security requirements and technical characteristics, the key security technologies are pointed out, mainly including access control technology, single sign-on technology, authentication technology and unified security center technology, etc. The security technologies laid a foundation for safety management implementation of the platform.
Keywords: Railway information sharing platform; Security management technology; Information security.

Chinese railway information systems have been isolated from each other since they are built. In order to solve the problem, railway information sharing platform need urgently to be constructed. The main functions of the information sharing platform include information exchange, cross-system messaging, data format conversion, building a shared database and providing shared services, etc.

On the other hand, the platform will face great security challenge from very different railway applications. In the paper, multiple security technologies are selected and analyzed, laying the foundation for the realization of the railway information sharing system security management and operation.

1 Railway Information Sharing Platform Security Demand

By investigation of current and potential customers of the railway information sharing platform, combined with analysis of platform function and realization technology, it can be summarized that the security requirements include: access control security, information transmission security, data storage security and the safety control center.

1.1 Access control security

Access control security is the primary issue to ensure system safety. It includes global identity management, the customer identity authentication, single login problem etc.

(1) Global Identity Management

Chinese railway information sharing platform uses a service-oriented architecture. Different systems have different set of roles, different permission schemes and different user identities. This will lead to the problem how to identify which are legal customers and which are invalid, which have "A" privilege and which have "B" privilege. So the global identity management technology is needed.

(2) Authentication Problem

Due to the complexity of the shared platform, a large number of access points from in or out of railway system. If the legitimacy of the remote client is not clear and hastily provides services, there will be a big security risk. Meanwhile, legitimate requestors are also needs "identified" to guarantee security. So technology of verification is clearly needed. Making railway information sharing platform authentication is an important part to protect the security interoperability.

(3) Single Sign-on Problem

If one will log in different services in current rail applications, he must enter username and password each time. It is a very tedious problem for people who need to share a lot of services and data. Now single sign-on technology can be used to solve the problem. The technology can reduce login and authentication times, reduce the possibility of loss or forgotten passwords.

2.2 Information Transmission Security

Enterprise Service Bus (ESB) technology is used to realize different systems sharing data and service in the railway information sharing platform. But information security is a basic problem in the transmission process.

Web services is an important means of information sharing platform, and to enhance Web service security is very important. The secure transmission protocol (HTTPS), Transport Layer Security STL/SSL technology will be used in Chinese railway information sharing system.

2.3 Data Storage Security

Data storage security is an important issue to build railway information sharing platform facing. Using technology such as cloud data storage and management of decentralized computing technology can improve the safety of the railway store important data, but also brings a complex system structure, management and complex problems. Therefore, study off-site storage, disaster recovery, data recovery, security technology, response information sharing platform to build the new data security situation.

2.4 Unified Security Prevention Center

Railway Information Security Center can centralized manage globe security services and some important basic globe database. The public railway infrastructure and critical information database backup and recovery management, centralized monitoring and dealing with security threat is its main objective. Information

Security Center realize security control through security audits, intrusion detection, virus analysis etc. On the other hand, scheduling and balancing the entire railway information sharing platform resources, optimize the using of computing, storage system capacity and network bandwidth for the entire railway safety and efficient operation of information systems services.

3 The security technology analysis

According to design objective and security requirements, combination of the technology and infrastructure of the information sharing platform, the security management technology should include service authentication, access control, single sign-on technology, dynamic data encryption technology etc.

3.1 Access control of information sharing platform

The railway information sharing platform users come from companies in and out of railway system. Various types of users having different security risks, should be adopted different access control technology. The users in existing railway system had existed roles. If they will access other application to get shared information they should be deployed other roles from the objective system. For users outside the railway system, they bring higher risks. Require the use of access control technology is the first to carry out a global role and user permissions match, then authentication technology to enhance security control.

Limited to the complexity of railway information system structure and the number of user roles, united access roles and permissions are more appropriate for globally applications. For example, information sharing platform set up three roles : P1, P2, P3, corresponding to different privileges. At the same time, each connected application set up information sharing accessing roles and permissions.

As bellow in figure 1, A and B system are two railway information systems in information sharing platform, each has user roles: A system with A1, A2, A3 and A4, B system with B1, B2, and B3. In order to transform roles between system A and B and others, the information sharing platform will build information sharing roles P1, P2 and P3.Through the information sharing platform to implement A system of shared services system service mode access B, can build A system of information sharing system and B respectively access roles (PA1, PA2, PA3, and PB1, PB2, PB3). When A system user A3 access B system, according to a certain mapping rules, it can be transformed to P2 role, which dedicated PB2 role corresponds to B, so as to realize an A3 system role to PB2 system role.

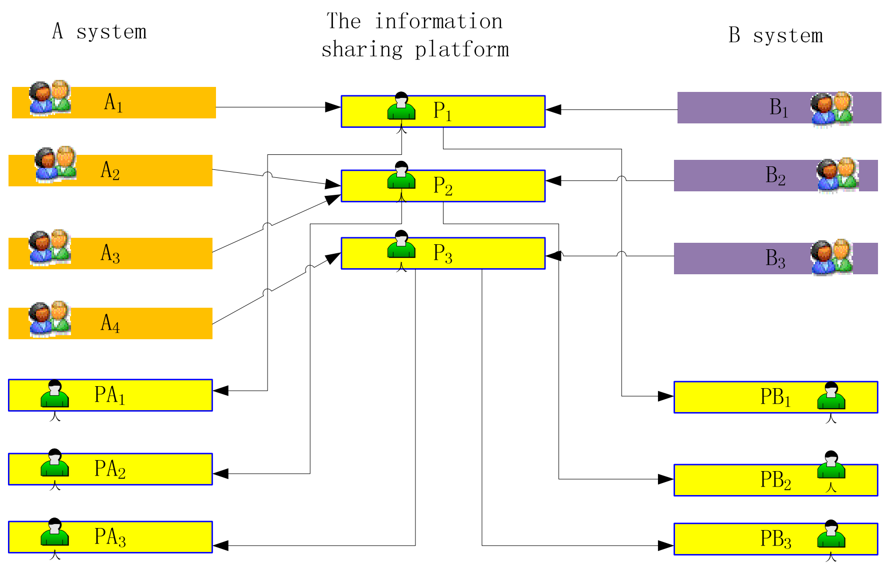

Figure 1. Roles mapping between different applications

Outside railway system users are at highest risk to the platform, this group should be given the most strict access control. Firstly, they need to be identity authentication, Secondly, according to the users categories, when they login, they should be given the lower permissions. For example, for logistics companies even individual users can be given the lowest level, but for government users, can be given a higher privilege. More security technologies should be used such as firewalls, data encryption, VPN and so on.

3.2 Single sign-on technology

Single sign-on technology (SSO), is one of the most popular enterprise integration solutions. SSO is used in multiple application systems. The users need only login once to access all applications by SSO.

By using the SSO technology, the whole railway system users authentication and unified service can be realized. Considering the railway information sharing platform connecting a large number of railway information systems, and theses systems are distributed in the whole country, centralized management for authentication and single sign-on authentication are a higher risk. We can set up the technical architecture based on cloud computing, certification service in a big field. So national certification server and regional certification servers are both needed.

As shown in figure 2, multiple authentication servers are built in different locations, and through the Security Assertion Markup Language (SAML), authentication information can be exchanged by geographically distributed single sign-on service. But there is no difference when customer login. When a user access TDCS system, he get authentication and ticket from the first authentication server. When he visited the SCADA system, the other authentication server (server n) can exchange authentication information via SAML and identify this ticket.

Single sign-on technology will integrate all systems certification services together. And user identity, credentials, login information and other management can use the lightweight directory access technology (LDAP).

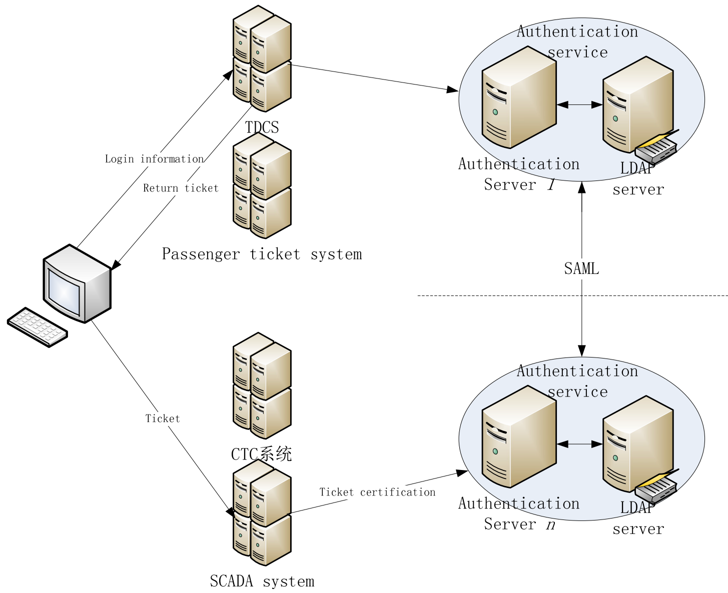

Figure 2. Multi-server distribution of single sign-on technology

3.3 The identity authentication technology

The identity authentication technology is the foundation of the railway information sharing platform. According to the characteristics of the authentication technology, combined with the actual situation of the platform, prospective and standardized authentication PKI authentication system should be used. Complete PKI system includes PKI certification authority (CA), digital certificate library, key backup and recovery system, invalid certificate system, application interface (API) and other basic components.

Railway information sharing platform can first choose certification institution to obtain a digital certificate, such as Chinese electronic certification service industry alliance, or apply for certification bodies, to establish a digital certificate issued, backup, invalid system.in the Center of the Security built the whole way digital certificate libraries, build the digital certificate backup and recovery system, the construction of a digital certificate invalid system, research and development application interface, complete digital authentication system form the railway information system.

3.4 Unified security center technology

Because of the complexity and huge size of the railway information sharing platform, a unified security management center should be built to improve the whole system security. The security center includes national node and regional nodes. The security management center can deploy security technology centrally and uniformly, dispose security threat, strengthen security control in a more rapid mode.

The main security services and technology in security management center include: authentication and single sign-on authentication services, security monitoring, invasion warning, prevention and procession. On the other wise, railway public basic information database and shared business database backup and disaster management are also its functions. Main services in the unified security center can be shown in figure 3:

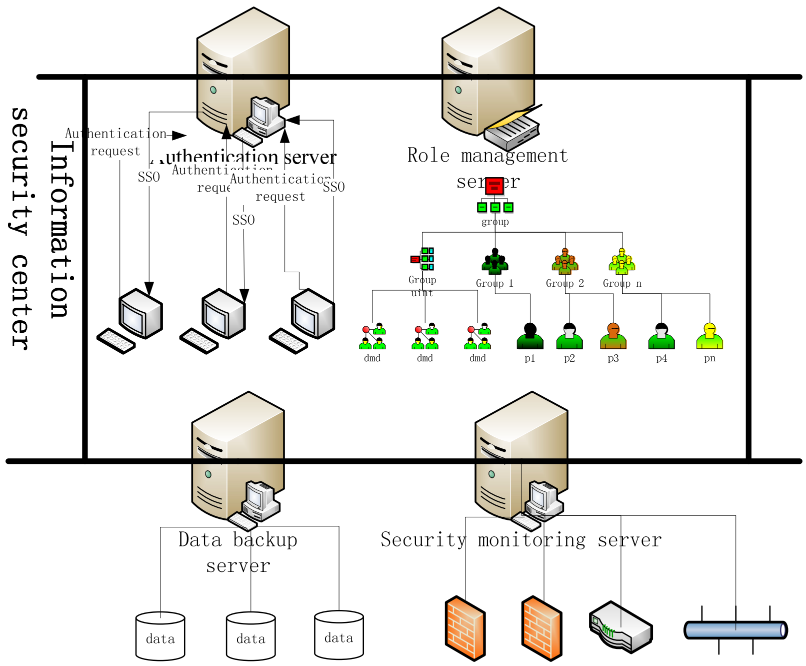

Figure 3. The unified information security control center

4 Conclusion

Railway information sharing platform security technologies are directly related to the system security and stability of operation for a long time. According to information sharing platform security requirements analysis, the security technologies and configuration are put forward. These technologies include access control technology, single sign-on technology, authentication technology, security control center, etc. By using these information security technologies, the railway information sharing platform will gain necessary security and stability. With the construction of the platforms, it will face a more complex security environment, and new security technology also needs to be deployed.

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References

Li Ping. (2008). "Chinese Railway information sharing platform architecture". Chinese Railway, (05):23-26.

Ma Xiaoning. (2009). "The key techniques of composition Web service on Railway information sharing system". Beijing Jiaotong University.

Southwest Jiaotong University. "Security management technology in railway information sharing platform". Southwest Jiaotong University, 2014.

Zhang Ji. (2008). "Research on Railway information sharing platform based on SOA security policy". Beijing Jiaotong University.

Evaluation of Travel Time Estimation Models with Different Inputs

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Abstract: Although plenty of models have been proposed in previous researches on bus travel time estimation/prediction, little attention has been paid to the effective usage of the historical travel time. In this research, comparisons on performance of historical travel time estimation model were made among different statistical values, namely the mean, the median and the maximum probability values. The research results show that, to the wholly speaking, when buses are far away from the target stop, the model with input of the mean value performs the best on the estimation accuracy and precision, while the model with input of the median value shows the best performance when buses are near the target stop. During peak periods, the model with input of the maximum probability value is superior to that with input of other estimated values. Finally, a multi-stage usage of statistical values in travel time estimation is suggested on basis of the estimation results.

Keywords: Bus transit; Travel time estimation; Mean value; Median value; Maximum probability value.

1 INTRODUCTION

Bus travel time plays an important role in operation and management, and the accurate prediction of it can help transit agencies take proactive controls on buses to maintain the service regularity or provide bus arrival time information service to transit riders.

Before the equipment of automatic vehicle location (AVL) devices, it was hard for transit agency to acquire the travel time information unless by manual collected data. With the rapid development of Advanced Public Transit System (APTS), AVL devices have been widely equipped by transit agencies all over the world. In 2000, 88 transit agencies in the United States had operational AVL systems, and 142 were planning such system. In China, the document "Suggestions on the priority development of public transit system" issued by the General Office of the State Council on September 23, 2005 promotes the nationwide rapid development of intelligent transit systems. At present, all transit agencies in metropolis have built operational AVL systems, and more and more transit agencies in medium-sized cities, with population over 500,000, have started incorporating such systems, which is supported by both the local governments and the Ministry of Transport.

The construction of passenger information system has been implemented or considered by more and more transit agencies as a method to improve the service quality of bus system. However, the low accuracy of travel time prediction in real application has troubled the passenger information system all the time. The prediction errors of bus travel time can be affected by many factors, to which the input of prediction model is an important source. This research is an extension work for bus travel time estimation on basis of historical data, and a further insight was made into how to efficiently make use of the collected historical data to improve the accuracy bus travel time estimation.

2 LITERATURE REVIEW

Bus travel time is affected by quantities of factors, which have been validated in previous researches. Generally speaking, those factors can be clustered into five categories, which include: (1) Infrastructure, such as number of stops, number of traffic signal lights , length of segment, and whether a low-floor bus or not; (2) Running Environment, such as weather, traffic pattern (time-of-day and day-of-week), congestion, and incident; (3) Operation and Management, such as scheduled travel time, dwell time, and time-check points. (4) Passenger demand and activity, such as boarding and alighting time, passenger arrival rate; (5) Driver Behavior, such as schedule recovery.

In order to explain the relationship between bus travel time and factors, several typical models or algorithms have been proposed in previous researches, like the historical travel time based model, the regression model, the kalman filter algorithm, the artificial neural network model, the markov chains model, the trajectory-based model, and the tendency-based model. Among those models, the accuracy of the historical travel time based model is in general considered to be unsatisfied, but it has an advantage in its scalability to account for other routes. In real application, it is still a favorite method in the passenger information system in China and some other countries, for its easiness for development, the less computation burden on information processing centre and stability in a data missing condition. The principle of the historical travel time model is that it tries to seek the most similar historical bus travel time to predict the real-time bus travel time, which is based on the assumption that bus travel time remains constant under similar condition. Therefore, the performance of the historical travel time model is largely determined by the degree of similarity between the real-time travel time and the historical travel time. Therefore, how to make an efficient usage of the historical data is meaningful for improving the performance of the historical travel time based model. In previous researches, the mean value was much more preferred for estimating bus travel time, and had not been compared with other forms of statistical values.

Focusing on this problem, comparisons were made on the performance of the historical travel time based model with input of different estimated values—the mean, the median, and the maximum probability values respectively. The rest of paper is organized as follows: in the next section, the historical travel time based model was represented, with different estimated values as the input of the model. Followed is an experiment carried out for travel time estimation, and the estimation accuracy and precision was evaluated. Finally, conclusions were addressed and future studies were suggested.

3 MODEL DEVELOPMENT

A historical travel time based estimation model is proposed as a common platform for validating and evaluating its performance on estimation accuracy and precision with different estimated values as inputs of model.

Bus Travel Time Estimation Model

Define Target Stop is the terminal of the estimation zone, and buses are approaching to the target stop after depart from the departure stop. Bus travel time is composed of an inter-zone link travel time (ILTT) and a section travel time (STT) (as shown in Figure 1). ILTT is defined as the time that buses travel from the current position in a link to the end stop of the link, and they are assumed to be running with the uniform velocity; while STT stands for the time that buses travel from the end stop of the link to the target stop.

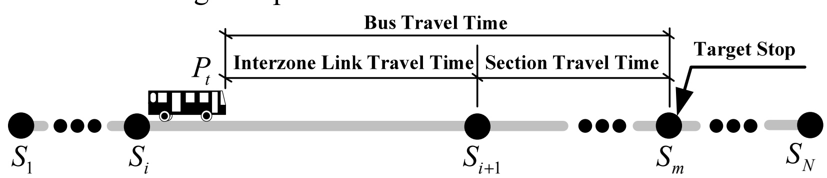


Figure 1. Illustration of the bus travel time estimation model

Thus, bus travel time can be described as the sum of an ILTT and a STT.

$$t_{P_tS_m(t)} = \left(1 - \frac{d_{S_iP_t}}{d_{S_iS_{i+1}}}\right) t_{S_iS_{i+1}}\left(\tau_{S_i}\right) + \sum_{j=i+1}^{m-1} t_{S_jS_{j+1}}\left(\tau_{S_j}\right) \tag{1}$$

Where, $d_{S_iP_t}$ is the traveled distance from the stop S_i to the current position P_t,

$d_{S_iS_{i+1}}$ is the length of the link S_iS_{i+1},

τ_{S_i} is the time-interval when the bus vehicle enters the link S_iS_{i+1}, and

$t_{S_iS_{i+1}}\left(\tau_{S_i}\right)$ is the estimated link travel time on the time-interval τ_{S_i}.

Note that the time-interval τ_{S_i} specifying the link travel time $t_{S_iS_{i+1}}\left(\tau_{S_i}\right)$ is determined by the time when buses arrive at the stop S_i, and the relationship between the time-interval τ_{S_i} and the arrival time t_{S_i} meets the followed equation.

$$\left(\tau_{S_i} - 1\right) \times \Delta T < t_{S_i} \le \tau_{S_i} \times \Delta T \ , \ \ 1 \le \tau_{S_i} \le 24/\Delta T \tag{2}$$

Where, t_{S_i} is the time when the bus arrives at the stop S_i, and

ΔT is the length of the time-interval, which is equal to a quarter of one hour in this research.

Estimated Values of Link Travel Time

The day-of-week pattern of the bus travel time for the experimental route has been validated in a previous research. It was found that the travel time is similar among days among weeks on Tuesday, Wednesday, Thursday, Saturday, and Sunday (for example, travel time on successive Tuesdays among weeks is similar), and similar among days in one week on Monday and Friday (for example, travel time on successive weekdays in one week is similar).

With this consideration, the travel time of last four days with the same day-of-week characteristic was preferred as the historical data needed for link travel time estimation, and used to estimate the link travel time.

The mean value of historical link travel time

The mean statistical value of link travel time is on basis of the travel time samples of previous four days with the same characteristic.

$$t_{S_iS_{i+1}}^{Mean}\left(\tau_{S_i}\right)=\frac{1}{N}\sum_{k=1}^{N}t_{S_iS_{i+1}}\left(k,\tau_{S_i}\right) \tag{3}$$

Where, $t_{S_iS_{i+1}}^{Mean}\left(\tau_{S_i}\right)$ is the mean value of historical link travel time on the time-interval τ_{S_i},

N is the number of trips (four days) on the time-interval τ_{S_i}, and

$t_{S_iS_{i+1}}\left(k,\tau_{S_i}\right)$ is a sample link travel time on the time-interval τ_{S_i}.

The median value of historical link travel time

A percentile is the value of a variable below which a certain percent of observations fall. Firstly, a general definition of the α percentile value of link travel time is given in Equation (4), which is the maximum one that α percent of observations fall below it.

$$\begin{aligned} & t_{S_iS_{i+1}}^{\alpha}\left(\tau_{S_i}\right)=\underset{k=1}{\overset{N}{MAX}}\left\{t_{S_iS_{i+1}}\left(k,\tau_{S_i}\right)\right\} \\ & s.t.\ \frac{\sum_{k=1}^{N}n_k}{N}\le\alpha \end{aligned} \tag{4}$$

Where, n_k is a Boolean variable, and the value is determined by whether a travel time sample is larger than the selected one or not (see equation (5)).

$$n_k=\begin{cases}1, t_{S_iS_{i+1}}\left(m,\tau_{S_i}\right)\le t_{S_iS_{i+1}}\left(k,\tau_{S_i}\right); \\ 0, t_{S_iS_{i+1}}\left(m,\tau_{S_i}\right)> t_{S_iS_{i+1}}\left(k,\tau_{S_i}\right).\end{cases}\left(m=1,2,...,N\right) \tag{5}$$

$t_{S_iS_{i+1}}^{50\%}\left(\tau_{S_i}\right)$ is the median value of historical link travel time on the link.

The maximum probability value of historical link travel time

In travel time estimation, it is always expected that the difference between the estimated value and the true value meets the need of prediction accuracy and precision; in other words, we always wish that the estimated one is within the expected accuracy and precision at the most probability. Therefore, it is reasonable to have a try on estimating bus travel time with input of the maximum probability value, which is determined by the maximum ratio that the deviation between the estimation value and overall observations is within a tolerant range (see equation (7)).

$$\max \quad z = \sum_{k=1}^{N} n_k / N$$

$$s.t.\ n_k = \begin{cases} 1, \left(\dfrac{\left| t_{S_i S_{i+1}}\left(m, \tau_{S_i}\right) - t_{S_i S_{i+1}}\left(k, \tau_{S_i}\right) \right|}{t_{S_i S_{i+1}}\left(k, \tau_{S_i}\right)} \le \phi_{offset} \right); \left(m = 1, 2, ..., N\right) \\ 0, else. \end{cases} \tag{6}$$

Where, ϕ_{offset} is the tolerant deviation range between the estimated value and overall observations. In this research, it was set to be 50% for the reason that an estimation value with deviation larger than 50% is assumed to be unacceptable.

4 MODEL COMPARISONS AND EVALUATIONS

Test Bed and Data Collection

The southbound corridor of the bus route No.49 in Shanghai, which has 20 stops and is 12.17 kilometers long, was selected as the experimental route (as shown in Figure 2). It starts from the Hankou-Road stop and ends at the Shanghai-Stadium stop. The experimental route is frequent-serviced, with the scheduled headway 5 to 8 minutes during the weekday peak periods, 6 to 10 minutes during the weekend peak periods, and 10 to 15 minutes during the weekday and weekend non-peak periods.

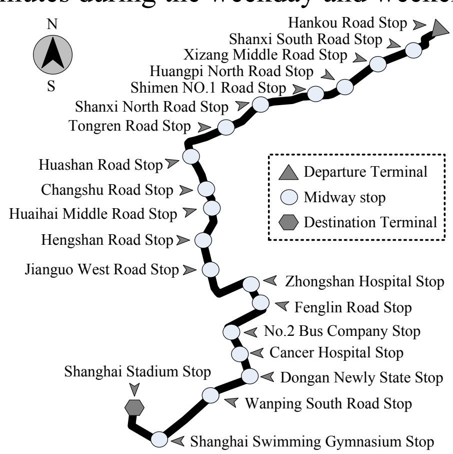


Figure 2. Illustration of the experimental route (Southbound)

AVL devices are equipped on all buses in service, and detailed information can be collected and archived in real time. Three types of location data are collected—the location-at-time data (when buses have traveled for 30 seconds between stops), the location-at-distance data (when buses have traveled 250 meters within 30 seconds between stops), and the location-at-stop data (when buses arrive at a stop or leave it). The status that buses arrive at or depart from the stop is judged by the relative position between the location of buses and two interest-points which are located before and after the stop-point (as shown in Figure 3). If the GPS coordinate of the bus is within a certain range (10 meters) of the interest-point that before the stop-point, the status of the bus is set to be arrival at the stop; while in turn, if within a certain range (10 meters) of the interest-point that after the stop-point, the status is set to be departure from the stop.

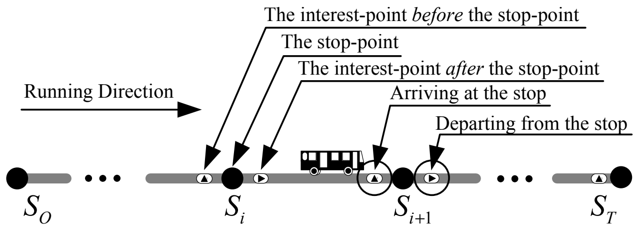


Figure 3. Relationship between two interest-points and the stop-point

The historical AVL data collected for analysis ranges from April 1 to April 30 in 2011, with a total number of nearly 5 million records. The collected raw AVL records were clustered by trips with a self-designed program, and link travel time was calculated by the two AVL records in one trip.

Measures of Performance

All measures developed below made use of the difference between the estimated travel time and the actual travel time, which is known as estimation error.

$$\varepsilon_i = T_{Pi} - T_{Ai} \tag{8}$$

Where, ε_i is the estimation error of sample i,

T_{Pi} is the estimated value, and

T_{Ai} is the actual value.

Accuracy is the degree of closeness of the estimated value to the true value. Mean Error (ME) and Mean Absolute Error (MAE) are chosen as the measures to evaluate the accuracy of models. A lower MAE value and a closer ME value to zero indicate a higher accuracy of the prediction model.

$$ME = \frac{1}{N}\sum_{i=1}^{N} \varepsilon_i \tag{9}$$

$$MAE = \frac{1}{N}\sum_{i=1}^{N} \left|\varepsilon_i\right| \tag{10}$$

Precision is the degree to which repeated measurements under unchanged conditions show the same results. It can be described as the central tendency of the estimated values around the true value. Mean Percentage Error (MPE) and Mean Absolute Percentage Error (MAPE) are chosen as the measures to evaluate the precision of models. The lower the MAPE is and the closer the MPE to zero is; the higher precision of the prediction model is.

$$MAPE = \frac{1}{N}\sum_{i=1}^{N} \frac{\varepsilon_i}{T_{Ai}} \tag{11}$$

$$MAPE = \frac{1}{N}\sum_{i=1}^{N} \frac{|\ \varepsilon_i\ |}{T_{Ai}} \tag{12}$$

Performance Evaluation

172 trips on May 2 in 2011 were estimated with input of the mean, median, and maximum probability values of link travel time respectively, and the performance on the estimation accuracy and precision was compared on basis of the performance measures.

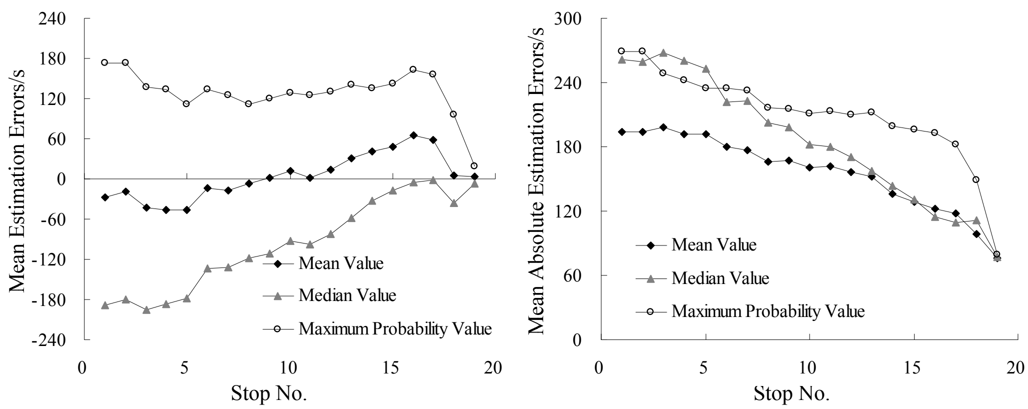
The terminal stop (the Shanghai-Stadium Stop) was chosen as the Target Stop for the reason that it can help make a further insight into the effect of the length of segment on the estimation accuracy and precision when buses are approaching to the target stop. Besides, the estimated trips on May 2, which begin from 5:00AM and end at 23:00PM, help show the effect of time periods on the performance of model with input of different statistical values. With this consideration, the estimation errors were grouped by stops and trips respectively to show the effect of the *length of segment* and *time periods* on the estimation accuracy and precision.

Accuracy Evaluation

The ME and MAE were calculated by stops and trips respectively to show the accuracy of model on different length of segments and during different time periods with input of the mean, the median and the maximum probability values.

Generally speaking, the model with input of the mean value performs the best on the estimation accuracy when buses are far away (more than five stops) from the target stop (No. 49020); while when buses are near (less than five stops) the target stop, the model with input of the median value achieves the best estimation accuracy. (As shown in Figure 4(a))

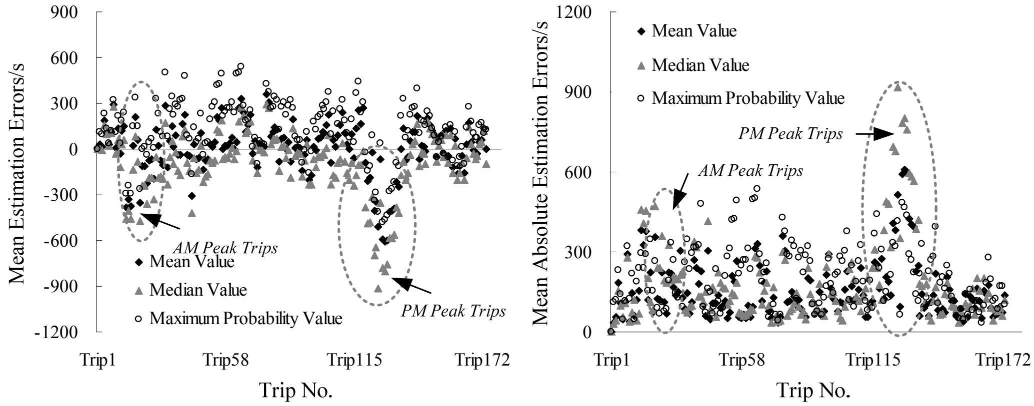
Moreover, it is interesting to be found that the accuracy of the historical travel time based model increases gradually when buses are approaching to the target stop (as shown in Figure 4 (b)), which is reasonable that the value of travel time is decreasing as well when buses are approaching to the target stop.



(a) Mean Errors with different inputs (b) Mean Absolute Errors with different inputs

Figure 4. ME and MAE with different inputs (Grouped by stops)

When the ME and MAE are grouped by trips, it was found that the historical travel time based model with input of the mean and median values performances worse than that with input of the maximum probability value during peak periods (as shown in Figure 5(a) and 5(b)). On the other hand, the model with input of the mean and median values performances better than that with input of the maximum probability value on midday periods. On the early morning and late night, few differences exist on the estimation accuracy and precision between the model with input of the mean, the median and the maximum probability values.



(a) Mean Errors with different inputs (b) Mean Absolute Errors with different inputs

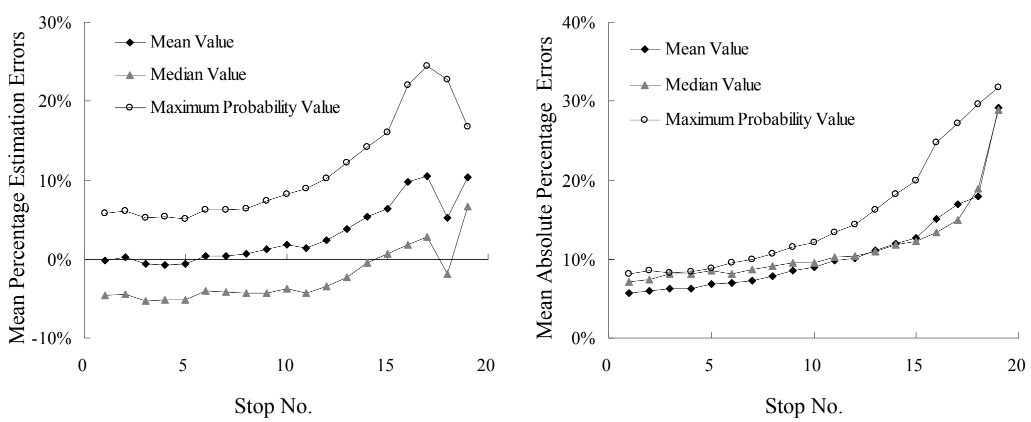
Figure 5. ME and MAE with different inputs (Grouped by trips)

Precision Evaluation

In the same way, the MPE and the MAPE were calculated by stops and trips respectively to show the precision of the model on different segments and time periods with inputs of the mean, the median and the maximum probability values.

In general, the model with input of the mean value shows the highest estimation precision when buses are relative far away (more than six stops) the target stop, while the model with input of the median value perform best on the estimation precision when buses are near (less than six stops) the target stop. (As shown in Figure 6(a))

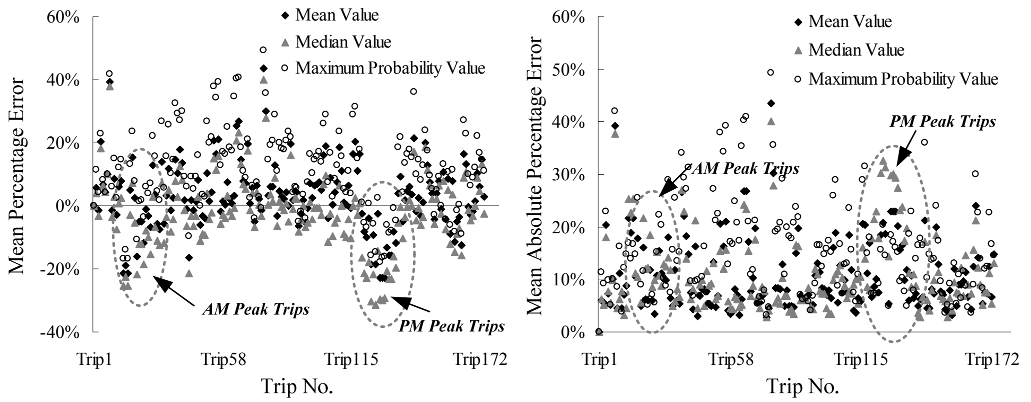
When buses are approaching to the target stop, the precision of the historical travel time based model decreases gradually because the variation of link travel time is larger on a shorter segment. (As shown in Figure 6(b))



(a) Mean Percentage Errors with different inputs (b) Mean Absolute Percentage Errors with different inputs

Figure 6. MPE and MAPE with different inputs (Grouped by stops)

When the MPE and the MAPE are grouped by trips, it was found that the historical travel time based model with input of the mean and the median values performs worse than that with input of the maximum probability value on the estimation precision during peak periods (as shown in Figure 7(a) and 7(b)). During the other time periods, the model with input of the median value performances slightly better than that with input of the mean value, but significantly better than that with input of the maximum probability value.



(a) Mean Percentage Errors with different inputs (b) Mean Absolute Percentage Errors with different inputs

Figure 7. MPE and MAPE with different inputs (Grouped by trips)

5 DISCUSSIONS AND CONCLUSIONS

Plenty of researches have been carried out on travel time estimation/prediction, but seldom of them have validated the effect of different estimated values on the performance of models. In this research, comparisons were made on the estimation accuracy and precision on basis of the historical travel time based model with input of the mean, median and maximum probability values of historical travel time.

The estimation results show that the performance of model varies a great deal with the different estimated link travel times on different lengths of segment and during different time periods. When buses are far away from (more than five stops) the target stop, the model with input of the mean value shows the best estimation accuracy and precision, while the model with input of the median value achieves the best estimation accuracy and precision when buses are near (less than five stops) the target stop. It is not unreasonable why the mean travel time is much more preferred in previous researches, as it does help the proposed model achieve a well comprehensive performance on the estimation accuracy and precision. Although the overall estimation accuracy and precision of the model with input of the maximum probability value is worse than that with input of the mean value and median value during early morning, midday, evening and night periods, it performs the best during the peak periods, which has not been validated in previous researches yet. Therefore, a multi-stage usage of statistical values of historical travel time is suggested in travel time estimation to achieve a better performance on both estimation accuracy and precision; that is to say, for the experimental bus route, it is preferred to use the mean value when buses are far away (more than five stops) from the target stop, while the median value is given priority to when buses are near (less than five stops) the target stop, and the maximum probability value is strongly suggested during peak periods.

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Reference

Abkowitz, M., and I. Engelstein. Temporal and Spatial Dimensions of Running Time in Transit System. *Transportation Research Record* **877**, 1982, pp.64-67

Alfa, A.S., W.B. Menzies, J. Purcha, and R. Mcpherson. A Regression model for Bus Running Times in Suburban Areas of Winnipeg. *Journal of Advanced Transportation*, Vol.21, No.3, 1988, pp.227-237.

Chen, M., X. Liu, and J. Xia. Dynamic Prediction Method with Schedule Recovery Effect for Bus Arrival Time. *Transportation Research Record* **1923**, 2005, pp.208-217.

Chen, G., X. Yang, J. An, and D. Zhang. Bus-arrival-time Prediction Models: Link-based and Section-based. *Journal of Transportation Engineering,* Vol.138, No.1, 2012, pp.61-66.

Chien, S., and Kuchipudi, C.M., 2003. Dynamic Travel Time Prediction with Real-time and Historical Data. *Journal of Transportation Engineering*, Vol. 129, No.6, pp.608-616.

Cathey, F.W., and D.J. Dailey. A prescription for transit arrival/departure prediction using automatic vehicle location data. *Transportation Research Part C: Emerging and Technology*, Vol. 11, No. 3, 2003, pp.241-264

Chen, M., X. Liu, and J. Xia. A dynamic bus arrival time prediction method based on APC data. *Computer-Aided Civil Engineering and Infrastructure*, Vol.19, No.5, 2004, pp.364-376

Chien, S.I.J., Y. Ding, and C. Wei. Dynamic bus arrival time prediction with artificial neural networks. *Journal of Transportation Engineering*, Vol. 128, 2002, pp.429-438.

Chen, G., X. Yang, J. An, and H. Liu. Real-Time Prediction Model of Bus-arrival-time Based on Transit Pattern. In Proceeding of 90th Annual Meeting, Transportation Research Board, 2011.

Chen, G., J. Teng, S. Zhang, and X. Yang. Tendency-based approach for link travel time estimation. *ASCE: Journal of Transportation Engineering*, Vol.139, No.4, 2013, pp.350-357.

Jeong, R., and L.R. Rilent. Bus Arrival Time Prediction Model for Real-Time Applications. *Transportation Research Record* **1927**, 2005, pp.195-204.

Lin, W., and R. Bertini. Modeling Schedule Recovery Processes in Transit Operations for Bus Arrival Time Prediction. *Journal of Advanced Transportation*, Vol.34, No.3, 2004, pp.347-365.

Lin, W-H., and J. Zeng. An Experimental Study on Real Time Bus Arrival Time Prediction with AVL Data. *Transportation Research Record* **1666**, 1999, pp.101-109.

Ni, D., and H. Wang. Trajectory Reconstruction for Travel Time Estimation. *Journal of Intelligent Transportation Systems*, Vol.12, No.3, 2008, pp.113-125.

Padmanaban, R.P.S., K. Divakar, L. Vanajakshi, and S.C. Subramanian. Development of a real-time bus arrival prediction system for Indian traffic conditions. *IET Intelligent Transportation System,* Vol.4, No.3, 2010, pp.189-200.

Shalaby, A., and A. Farhan. Bus Travel Time Prediction Model for Dynamic Operations Control and Passenger Information Systems. In Proceeding of 82nd Annual Meeting, Transportation Research Board, 2003.

Sun, A., and M. Hickman. Vehicle Travel Time Prediction Using Primitive AVL Data. Proceeding of Transportation Research Board of the National Academies, Washington, D.C., 2006.

Transit Cooperative Research Program (TCRP) Synthesis 48. Real-Time Bus Arrival Information Systems: A Synthesis of Transit Practice. Transportation Research Board of the National Academies, 2003.

Tétreault, P.R., and A.M. El-Geneidy. Estimating bus run times for new limited-stop service using archived AVL and APC data. *Transportation Research Part A: Policy and Practice,* 2010, 44, pp.390-402.

Yeon, J., L. Elefteriadou, and S. Lawphongpanich. Travel Time Estimation on a Freeway Using Discrete Time Markov Chains. *Transportation Research Part B: Methodological*, Vol.42, No.4, 2008, pp.325-338.

A Method to Determine the Number of Parking Spaces in a Taxi Station Based on the Queuing Theory

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Abstract: Based on the traffic impact assessment of construction project, the thesis applied random queuing theory to determine the number of parking spaces in a taxi station. The study calculated the changes of some operational index in queuing system, such as the probability of passengers taking a taxi without waiting, the average waiting time of taxi drivers and taxi leave rates based on the change of taxi arrival rates. Through case analysis, queuing theory was proved to be an effective method in determining the number of parking spaces in a taxi station.
Keywords: Random service system; Construction project; The parking spaces for taxi; Utilization rates.

1 Introduction

Planning the number and the scale of parking spaces in a taxi station scientifically is an important safeguard to regulate drivers and passengers' behavior, reduce the influence of taxi parking on traffic capacity and organize different public transportation mode properly. Current *Taxi Management Approach* only gave principles about the taxi station layout and some factors. It mainly referred to the prediction method of bus stations in real planning, which means that the planning was measured by the distance between the stations or calculated by traffic capacity of bus stations (TRB, 2003). According to the relationship between travel demand and land utilization, Ye Haifei (2013) determined the gross of taxi parking in a traffic zone. As the background of traffic impact assessment in the construction project, this study analyzed the scale of taxi station by traffic demand characteristics based on queuing theory. In addition, the study illustrated the rationality and feasibility of this method by comparing it with the turnover rate of taxi stations in peak hour which was the common method at present.

2 The establishment of queuing model

Queuing theory was widely used in the field of transportation, such as solving problems about optimizing configuration of airport runways design and airport capacity, about optimizing traffic organization in passenger terminals and about highway toll facility design. According to queuing theory, the process of taxi carrying passengers in taxi parking spaces in the construction project could be regarded as a random service system with limited capacity served for passengers getting on the taxi and leaving the taxi station. When an empty taxi arrived at the taxi station or waited there, passengers could get on and leave, finishing the whole service. In order to avoid the influence on traffic led by random parking of taxis, taxis were required to leave the taxi station immediately if there was no empty space upon arrival.

(1) The definition of symbols

N —the demand for taxi parking spaces

n —the number of taxis in taxi parking spaces

P_n —the probability of having n taxis in taxi parking spaces

W_q —the average waiting time of a taxi

L_q —the average number of taxis in parking spaces

(2) The description of queuing system

The usual input process in queuing system including Poisson distribution and Erlang distribution could be used to describe the passenger's arrival law. The choice of distribution should be made after some surveys in analogous projects. Passenger's arrival law usually complied with the Poisson distribution. Assuming the number of passengers in unit time was μ, thus the service capability in the service station in unit time was μ taxis. A service system where taxis were required to leave the parking spaces in accordance with the arrival sequence could be regarded as a queuing system with one service station.

Not considering the influence on taxi's arrival led by passenger's appointment and calling for a taxi by a phone, it was believed that the relationship between passengers' arrival and taxis' arrival was independent. If both passengers' arrival and taxis' arrival complied with Poisson distribution, the process of taxi carrying passenger was a Markov queuing system of M/M/1/N.

(3) The targets of system optimization

Assuming parking was the queuing system of M/M/1, the demand for parking spaces was the capability in queuing system and the demand forecasting of parking spaces was optimization problems in queuing system. It was required to set the targets of optimization. If passengers want to reduce the waiting time as much as possible, the target was the probability of passengers getting on a taxi without waiting. Taxi drivers hoped that there were empty spaces when they came to the station and waiting time was as little as possible. The utilization ration of parking spaces should be taken into consideration due to the limited road resource.

3 The method to optimize the queuing system

Due to the analysis above, when the targets of optimization were different, the demands for parking spaces were different. According to following different targets, the parking spaces in a taxi station were analyzed.

(1) Passengers could get on a taxi without waiting as soon as possible

Passenger getting on a taxi without waiting means that when passengers arrived at the station, there had empty taxis in the station. Therefore, the probability of passengers getting on a taxi without waiting was 1-P_0. Assuming the arrival rate for taxis and passengers were λ and μ respectively and $\rho = \frac{\lambda}{\mu}$, the formulas were

$$P_0 = \begin{cases} \frac{1-\rho}{1-\rho^{N+1}} & \rho \neq 1 \\ \frac{1}{N+1} & \rho = 1 \end{cases} \quad (1)$$

The probability of passengers getting on a taxi without waiting could be set to determine the number of parking spaces in a taxi station.

(2) The taxi drivers' waiting time could be reduced

$$W_q = \frac{L_q}{\lambda(1-P_N)} \quad (2)$$

Among them: $L_q = L_s - (1-P_0)$ (3)

$$L_s = \begin{cases} \sum_{n=0}^{N} nP_n = \frac{\rho}{1-\rho} - \frac{(N+1)\rho^{N+1}}{1-\rho^{N+1}}, \rho \neq 1 \\ \frac{N}{2} \qquad , \rho = 1 \end{cases} \quad (4)$$

(3) There were empty spaces when drivers came to the station

If the parking spaces are not fully occupied when drivers came to the station, the taxis could park. Thus, the probability of having empty spaces when drivers came was 1-P_N.

$$P_n = \begin{cases} \frac{1-\rho}{1-\rho^{N+1}}\rho^n, \rho \neq 1 \\ \frac{1}{N+1} \qquad , \rho = 1 \end{cases} \tag{5}$$

4 Case analysis

The case took the demand for parking spaces in traffic influence analysis of the construction project of a certain hospital as an example. According to the prediction of the project, trip generation of taxis in the evening peak hour μ was 160 pcu/h and trip attraction of taxis in the evening peak hour λ was 90 pcu/h.

(1) The computing method of turnover rate

According to the common method to determine the demand for parking spaces through the turnover rate in peak hour at present, the formula was

$$n = \frac{Q}{\gamma} \tag{6}$$

Among them: Q— trip generation and attraction of taxis in evening peak hour

γ— turnover rate of taxi parking spaces in peak hour

According to taxi operation conditions of the city in this project combined with characteristics of the project itself, it was obtained that the turnover rate of peripheral parking spaces in peak hour was 50 pcu/h and was calculated that the demanding number of parking spaces was 5.

(2) Optimization of queuing system

Three aforementioned optimization targets did not have clear quantitative indicators. Assuming that the number of demanding parking spaces in this project was 5, the taxi operation conditions could be analyzed though the optimization targets above. Using formulas (5), the probability of queuing system could be calculated: P_0=0.4158, P_1=0.2541, P_2=0.1430, P_3=0.0804, P_4=0.0452, P_5=0.0254.

Through formulas (1)-(3), the probability of passengers getting on a taxi without waiting was 0.5482, the average waiting time of a taxi W_q was 23s and the probability of having empty spaces when drivers came was 0.9746.

From the perspective of operational targets, 5 taxi parking spaces could fully meet the demand of taxi drivers and passengers in the hypothetical conditions. Then, it assumed that the number of parking spaces was 1, 2, …, 6 respectively and the operation indexes were compared with each other. The results were listed in table 1.

Table 1. Comparison of related operation indexes

N	The probability of passengers getting on a taxi without waiting$(1-P_0)$(%)	The average waiting time of a taxi W_q(s)	The probability of having empty spaces when drivers came $(1-P_N)$(%)
1	0.3600	0	0.6400
2	0.4678	8	0.8316
3	0.5138	14	0.9135
4	0.5364	19	0.9536
5	0.5482	23	0.9746
6	0.5546	25	0.9859

As the calculation results showed, the more parking spaces it had, the higher probability of passengers getting on a taxi without waiting and having empty spaces when drivers came it might be. However, the average waiting time of a taxi would increase. When N=2, there were 32 taxis could not park per hour. When the number of parking spaces N=3, there were 15 taxis could not park per hour. When $N \geq 4$, the number of taxis that could not park would be less than 8. When $N \geq 3$, more than a half of passengers could get on a taxi without waiting. When N was bigger, the probability of having empty spaces was bigger. When N=4, the probability of having 2 empty spaces was 0.8711 and the probability of having 3 empty spaces was 0.7244. When N=5, the probability of having 2 empty spaces was 0.9293 and the probability of having 3 empty spaces was 0.8489. If there lacked traffic control when it had empty spaces, social vehicles might occupy these empty spaces, influencing the parking of taxis.

The probability of the taxi carrying passengers without waiting P_0 and the probability of passengers getting on a taxi without waiting were exclusive. The model took the small rate of taxi leaving empty as the first target, and the interest of taxi drivers against passengers should be weighed and the utilization rate of parking spaces be considered. Thus, it was believed that it was appropriate when the number of parking spaces was 4.

With the development of the technology of communication and internet, passengers could take a taxi by telephone and some related software applications, increasing the taxi arrival rate. According to the formulas (1) and (2), the function diagram between taxi arrival rate λ and the probability of passengers getting on a taxi without waiting 1-P_0, the function diagram between taxi arrival rate λ and the average waiting time of a taxi W_q and the function diagram between taxi arrival rate λ and the probability of having empty spaces when drivers came 1-P_N could be drew when the number of parking spaces was invariable (N=4). (Figure 1,2,3)

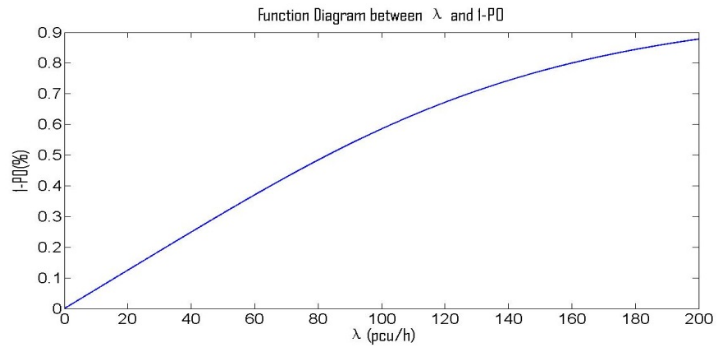

Figure 1 Function diagram between λ and 1-P_0

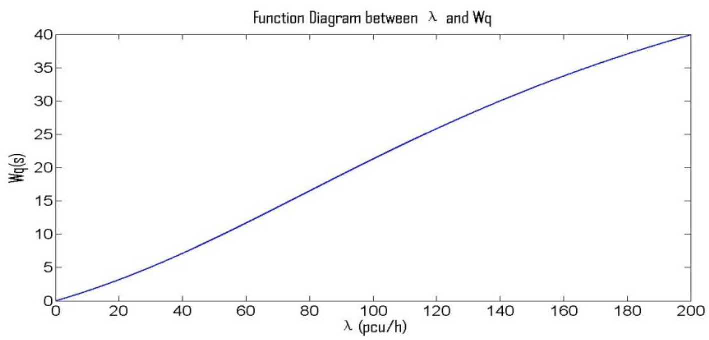

Figure 2 Function diagram between λ and W_q

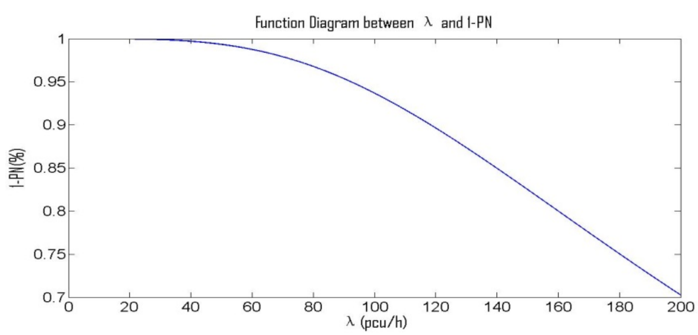

Figure 3 Function diagram between λ and 1-P_N

Obviously, it was beneficial for passengers with the taxi arrival rate increasing but the probability of having empty spaces when drivers came would decrease.

Therefore, more parking spaces were required to meet the demand and when taxi arrival rate increased, the average waiting time of a taxi would increase quickly. To solve these problems, the parking spaces should follow passengers' demand rather than simply increase the parking spaces and the best management method was controlling the taxi rate through effective information transfer.

4 Conclusions

Taxi parking spaces in the construction project could be regarded as a random queuing system due to the independence of taxis and passengers arrival. Passengers and taxis arrival law could be obtained by a lot of surveys and the demand of parking spaces could be analyzed based on queuing theory. This study assumed that passenger arrival rate and taxi arrival rate complied with Poisson distribution and both passengers getting on a taxi without waiting and average waiting time of a taxi deemed as optimization targets. The study also analyzed the change of operation indicators in queuing system with the increasing of taxi arrival rate when the parking spaces were invariable. Distinct characters and locations of construction projects directly or indirectly resulted in the differences of passenger arrival law and taxi arrival law. In practical application, all these influence factors were expected to be taken into consideration in order to analyze the traffic characteristics of passengers and taxis in peak time, determining the appropriate scale of parking spaces in a taxi station. The design standards of case analysis in this study were determined after analyzing multiple optimization targets comprehensively. If the queuing theory was seen as normal optimization method, the requirements of system service, such as utilization rate of parking spaces, the probability of passengers getting on a taxi without waiting and the probability of having empty spaces when drivers came, should be quantified due to specific requirements and standards of the design.

Acknowledgement

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References

Transportion Research Board (2003). *Transit Capacity and Quality of Service Manual*-2nd Edition.

Wayne L. Winston(2004).“22 Queuing Theory”.*Operations research ---- applications and algorithms*, Thomson. 1124-1132.

Yan Qiu, Zhu Wentong(2013). ”Application of Queuing Theory in Highway Toll Station Design”. *Processing of the Fourth International Conference on Transportation Engineering*. Chengdu, China, 607-612

Yan Qiu, Zhang Yuyang(2014). ”Traffic Analysis and Improvement Measures of On-ramp Joint of Elevated Expressway.” *Proceedings of the 4rd*

International Conference of Logistics Engineering and Management, Shanghai, China (Accepted)
Ye Haifei(2013). "Forecast Method of the Scale of Taxi Stands Based on Land Use". *Journal of Transportation Engineering and Information* No.4 Vo1.11 Dec. 2013. 76-81

Berthing Speed Control Law for Large Vessels Based on AIS Data

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Abstract: A vast ocean of AIS (Automatic Identification System) data broadcast by ships contain characteristic of marine traffic, from which information that reflects latent principles of characteristics of ship movements can be gathered. To extract features of vessels during the berthing phase with as little error as possible, using data mining method and mid-latitude sailing in combination, based on AIS database. Then applying the algorithm to Xiamen Songyu port area and Tianjin Beijiang port area for data of full year 2014 in these two waters. Lastly, in-depth analysis is carried out to discover the berthing speed control law for large container vessels when remaining distance to berth is about 20 times own ship LOA (Length Overall). The research may help competent authority advance the rule of safe speed, while it also provides the basis of speed control during berthing phase for pilot or self-pilot personnel.
Keywords: Shipborne AIS data; Large vessel; Berthing speed; Control law.

1 Introduction

Even if there is tug assistance, personnel who are on large vessel feel stressed while berthing maneuvering is being undertaken. Therefore, it is important to study how to ensure vessels, especially those large vessels or vessels carrying special cargoes, berthing with as little risk as possible.

In recent years, academics at home and abroad carried out research focusing on the field of aids to safe berthing, which includes simulating large vessel maneuvering (Inoue, 2013) (Liu 2014), effect of large-scale vessel on berthing safety (Yang, 2011), critical analysis on piloting vessel berthing safely and so forth (You, 2013). However, there is little research on berthing speed control law for large vessel.

Distributions of ship speed during processes of entering and leaving port have been put forward recently (Xiao, 2014). The study could be better convinced if they have given a deep and comprehensive analysis on speed control. This paper is based on data received by AIS Data Acquisition Subsystem (Shao, 2007), which plays a key part in the VISSEA (Vessel Information Service System based on ECDIS and AIS). In this paper, data mining method is utilized to analyze berthing speed control law for large containers. And it focuses on speed change within range of 20 times own ship LOA (Length Overall) to the berth. We believe that it can both provide valid data and quantitative analysis for competent authority to advance rule of safe speed within the port, and help pilots or ship officers make a berthing plan and ensure safe berthing.

2 Details of Large Vessel Berthing

2.1 Berthing characteristics of large vessel

The large vessel has structural features of a large mass and great hull lines scale. The special structure of large vessel makes it more complicated to complete an already difficult procedure of berthing handling. Large vessel's speed is generally lower than the usual's, while berthing is being undertaken. While berthing, large vessel is seriously affected by wind when it is empty. In contrast, it is affected a lot by currents when it is full loaded. In addition, both shallow-water effects and narrow water do have effects on the berthing vessel. The navigating officer must carefully draw up a berthing plan according to actual conditions, taking the above-mentioned key points into account.

Ship officers should pay more attention to berthing speed, berthing angle and departure between ship and wharf. Generally, in order to avoid keeping engine a long-time astern or frequently changing engine order, it is important to maintain speed within a reasonable range, on the premise of ensuring steerage well performing. The experienced ship master or pilot always estimates the remaining speed of approaching berth by the relatively moving speed of shore-side objects.

2.2 The definition of large vessel berthing speed

In nautical navigation, ship's speed means the speed measured when sailing under the condition without any wind or current effect. Often, the natural factors are inevitable. It is significant to note that there are two kinds of speed used in nautical navigation. Speed over the ground (SOG), also called true speed, is the vessel's speed relative to the surface of the Earth and is calculated empirically by measuring the time required for a vessel to travel a known distance. Speed through the water is measured by instruments that sense the vessel's motion through the water, using some mechanical or electromagnetic principle.

GPS units provide speed readings of the SOG type because they are calculated relative to the Earth's surface and are measured without being affected by the water surrounding the vessel. Considering that the original data used in the research are derived from shipborne AIS, whose speed data are on the basis of GPS receiver, therefore, the speed discussed in this paper is the SOG.

The studies we have performed showed that large container carrier slackens her berthing speed significantly since the moment that the distance between destination and vessel is within about 20 times own ship's LOA. Hence, this research mainly discuss the distribution of berthing speed at the "20 times own ship's LOA" distance stage.

3 Characteristics of Berthing Vessel Extraction Algorithm

Data in the research are based on Microsoft SQL Server AIS information database, which is the main body of Data Analysis Subsystem (Shao, 2007). There are two kinds of information tables in the database, they are dynamic information table and static information table. The data size of the table, especially size of the former, are so huge that picking up those subjects we need is advised.

3.1 Ship arrival distance model design

(1) Confirm the samples we used in the research. They are target vessel, targe berth and range of the longitude and latitude of the pier she locates at. Associate dynamic information table with static information table by using the exclusive MMSI (Maritime Mobile Service Identities) of each vessel. Extract the time point of the first moment when constant zero of Temporary Table A;

(2) Extract the longitude and latitude corresponding to ST by associating the dynamic information table and table A. Define them as berth positions, symbolized by "Berthlong" and "Berthlat". Put the result of berth point into Temporary Table B;

(3) Confirm the start point of calculating according to the circumstances of different harbour water. Then extract the AIS data between the start point and berth point of vessel's track. Insert the result into Berthing table C;

(4) Build a function "CalDist" to calculate the distance between any track point and berth point belong to one ship. And have the function call in Table C. Considering that the distance between start point and berth point are relatively not too far, the method of mid-latitude sailing (Guo, 2005) is put forward to calculate the distance between any two adjacent track points. Then accumulating calculated distances belong to any vessel, her remaining distance is acquired, marked as "DistToBerth". Taking a M/V berthing for instance, calculating the distance between A_i and A_{i+1}:

$$\begin{aligned}\overline{A_i A_{i+1}} = D_i &= \sqrt{D^2\varphi_i + Dep_i^{\,2}} \\ &= \sqrt{D^2\varphi_i + (D\lambda_i \times \cos\varphi_{n_i})^2} \\ &\approx \sqrt{D^2\varphi_i + (D\lambda_i \times \cos\varphi_{m_i})^2} \\ &= \sqrt{(\varphi_{i+1}-\varphi_i)^2 + (\lambda_{i+1}-\lambda_i)^2 \times \cos^2\left(\frac{\varphi_{i+1}+\varphi_i}{2}\right)}\end{aligned} \tag{1}$$

For the sake of convenience, the middle latitude φ_n can be replaced by the mean latitude φ_m. Because sea areas of China locates in the low and middle latitude zone, moreover, the distances to berth are not too far.

Assume that the track of berthing as illustrated in Figure 1, then calculating the distance between start point $A_1(\varphi_1, \lambda_1)$ and berth point $A_n(\varphi_n, \lambda_n)$, so:

$$\overline{A_1 A_n} = D_{sum} = \sum_{i=1}^{n} D_i \tag{2}$$

$$DistToBerth = D_{remaining} = D_{sum} - \sum_{i=1}^{k} D_i (0 \le k \le n) \tag{3}$$

Because the unit of the distances mentioned above is n mile (nautical mile), for the sake of convenience for analyzing data law by using similarity comparison method, using a single dimension to measure the distance, that is the multiple of LOA (Length Overall) which is equivalent to the distance between ship and berth. It is symbolized as D_L, so:

$$D_L = \frac{DistToBerth}{Length} \tag{4}$$

In the course of berthing, because of large container ship has better maneuverability, she always stands by engine when she is about 10n mile apart from the berth (Hong, 2008). Without loss of generality, it is considered as 50 times own ship LOA, namely $50D_L$. Thus, obtain the distance no more than $50D_L$ by further extraction in Berth Table C. Some results of the processed data presents as Figure 2.

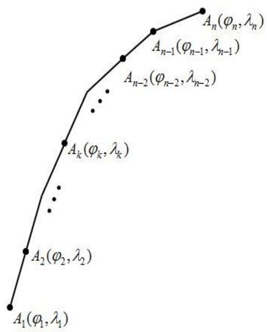


Figure 1. Model of track line

	MMSI	NAME	LENGTH	BREADTH	SOG	RECDATATIME	LONGITUDE	LATITUDE	BerthLong	BerthLat	DL
403	565747000	MAERSK ALFIRK	338.0	44.0	15.000	20140112232927	118.090446	24.410767	118.031104	24.441488	20.4334948068891
404	565747000	MAERSK ALFIRK	338.0	44.0	14.900	20140112232950	118.088981	24.411637	118.031104	24.441488	19.910887362732
405	565747000	MAERSK ALFIRK	338.0	44.0	14.800	20140112233003	118.088167	24.412134	118.031104	24.441488	19.6183336868034
406	565747000	MAERSK ALFIRK	338.0	44.0	14.700	20140112233015	118.087419	24.412587	118.031104	24.441488	19.3501217220929
407	565747000	MAERSK ALFIRK	338.0	44.0	14.600	20140112233027	118.086670	24.413033	118.031104	24.441488	19.0827982168835
408	565747000	MAERSK ALFIRK	338.0	44.0	14.500	20140112233050	118.085246	24.413888	118.031104	24.441488	18.5734759920916
409	565747000	MAERSK ALFIRK	338.0	44.0	14.400	20140112233115	118.083716	24.414797	118.031104	24.441488	18.0278695724563
410	565747000	MAERSK ALFIRK	338.0	44.0	14.300	20140112233127	118.083040	24.415230	118.031104	24.441488	17.7818187171131
411	565747000	MAERSK ALFIRK	338.0	44.0	14.200	20140112233150	118.081608	24.416050	118.031104	24.441488	17.2761880475568
412	565747000	MAERSK ALFIRK	338.0	44.0	14.100	20140112233203	118.080835	24.416520	118.031104	24.441488	16.9989198013031
413	565747000	MAERSK ALFIRK	338.0	44.0	14.100	20140112233215	118.080111	24.416949	118.031104	24.441488	16.7410334457441
414	565747000	MAERSK ALFIRK	338.0	44.0	13.800	20140112233250	118.078035	24.418164	118.031104	24.441488	16.0040789694193
415	565747000	MAERSK ALFIRK	338.0	44.0	13.400	20140112233326	118.075952	24.419381	118.031104	24.441488	15.2651489546379

Figure 2. Part of berthing table C

3.2 Curve fitting and law mining

Present data for characterized berthing in the form of discrete point on a coordinate plane. Then, using maneuverability characteristics of vessels in conjunction with practical experiences of pilots to analyze relation between berthing speed and remaining distance of the same kind of large vessel under different conditions. After that, do a specific fitting at the stage of reducing berthing speed. Comparing the scatter diagram with curves of given functions, pick up the most similar one to fit it. The studies that have been conducted report that Polynomials Regression Forecast Method (Wang, 2014) based on least square (Xu, 2009) is preferred here. Lastly, regression equation and regression curve are obtained. General form of the equation is described as follow:

$$\hat{y} = a_0 + a_1 x + a_x x^2 + \ldots + b_n x^n \tag{5}$$

Utilize the MATLAB to generate prediction interval with confidence level of 95 percent (Larose 2011), namely, intervals of berthing speed distribution.

4 Algorithm Implementation and Example

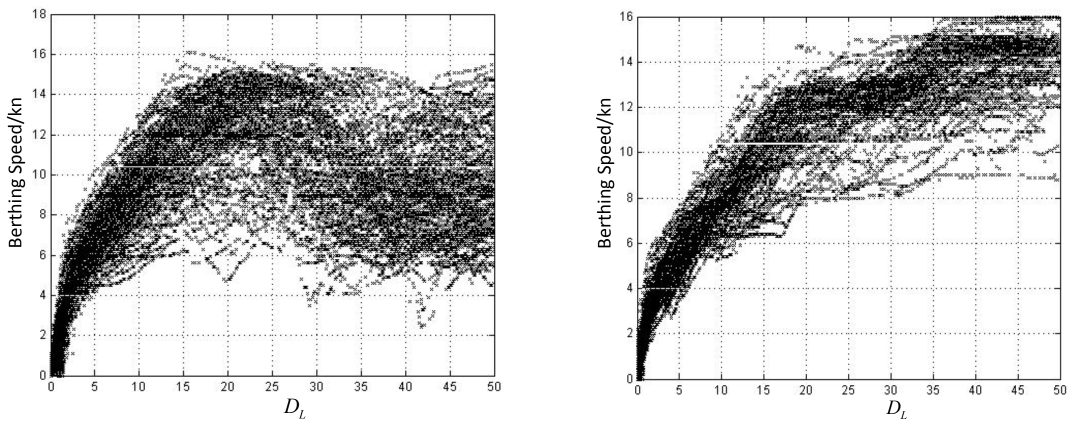
4.1 and data processing

Utilize the established AIS Information Service Platform, gathering data of vessels whose LOA no less than 300m and berthing at pier of Xiamen Songyu and Tianjin Beijiang. The geographical area of Xiamen Songyu confines latitude between 24°26′.48N and 24°27′.03N, longitude between 117°59′.52E and 118°02′.26E. The geographical area of Tianjin Beijiang confines latitude between 38°58′.68N and 39°00′.57N, longitude between 117°46′.36E and 117°47′.38E. And the time range from the first day of 2014 to the last day of the year, totally 365 days. The data processed have been shown in Table 1.

Table 1. Details of AIS data

Time Span	Port Area	Original Data	Processed Data	
			AIS Data	Number of berthing voyage
Whole year of 2014 (365 d)	Xiamen Songyu	70 694 735	25 868	346
	Tianjin Beijiang	98 611 753	20 098	230

4.2 Results of Berthing Speed



(a) Xiamen Songyu **(b) Tianjin Beijiang**

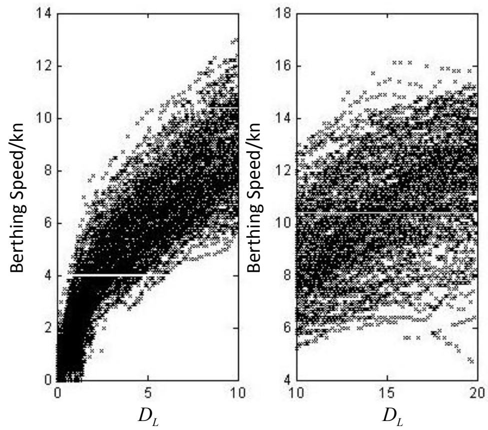
Figure 3. Scatter diagram of berthing details in 2014

The container ship who berths at Xiamen Songyu firstly sails by about $40D_L$ where the pilot embarkation area locate at (The Navigation Guarantee Department, 2009). Then her speed reaches local maximum value when she is about $20D_L$ from the berth. The local maximum value is approximately the upper limit of the water area, namely 15 knots (The Navigation Guarantee Department, 2009). The container ship who berths at Tianjin Beijiang firstly slackens her speed slightly when she is about $33D_L$ from the berth. Then the trend of reducing speed at the range of $20D_L$ is similar to the ship berth at Xiamen Songyu.

4.3 Result Analysis

Based on the similarity of the two port areas mentioned above, distribution of berthing speed is studied in combination. Continue the further analysis on macrosopical law of large container ship at the range of $20D_L$. The results shows as

Figure 4. From this, table for distribution of berthing speed can be deduced, summarized as Table 2.



(a) $0 \sim 10D_L$ **(b)** $10 \sim 20D_L$

Figure 4. Scatter diagram of large container vessels' berthing speed within the range of 20D_L

Table 2. Distribution of large container vessels' berthing speed within the range of 20D_L

D_L	15~20	10~15	5~10	2.5~5	1~2.5	0~1
Berthing speed/kn	10~15	8~13	5~10	4~6	1~4	0~2

Inertial distance of large container ship for reducing full speed to stop-ship state is nearly $9.8D_L$ (Hong, 2004). It's not hard to see that, from Figure 4, the berthing speed is about 8 knots though the remaining distance is $10D_L$. When it is close to about $1.5D_L$, the approaching speed slackens significantly. The berthing speed is approximately 3 knots at that moment. Compared with other kinds of ships, container ship is of small block coefficient, her C_B is smaller than 0.68. Her main engine power per DWT (Deadweight Tonnage) is greater than most of the ships', her $P_{\max} / m_{DW}$ is always greater than 0.60. Her ratio of rudder area to LOA, namely $A_R / L_{PP}d$ is generally greater than 1/55 (Hong, 2004). It is those factors mentioned above that result in the features that container carriers with. They are high stability, good stopping ability and steerability. Furthermore, the displacement of container carrier is so large that she should keep appropriately high speed to ensure efficiency and steerage, with taking safety into account.

Some pilots have commented that they, in the final stage of the berthing maneuvering, are used to undertaking good timing to carry way with engine stopped. It usually takes long time to complete the process of berthing. Therefore, the AIS data in this period is huge and discrete points are especially dense in the interval $0 \sim 2D_L$. In addition, pilots sometimes kick ahead to improve steerage.

4.4 Curve fitting

Considering the above-mentioned, we adopt the data derived from Xiamen Songyu and Tianjin Beijiang for curve fitting in the interval of $0 \sim 20D_L$, which is shown as Figure 5. And the berthing speed distribution in the form of formula is:

$$SOG = 2.25\times10^{-5} D_L^5 - 0.0014 D_L^4 + 0.0316 D_L^3 - 0.3507 D_L^2 + 2.341 D_L + 0.0784 \quad (6)$$

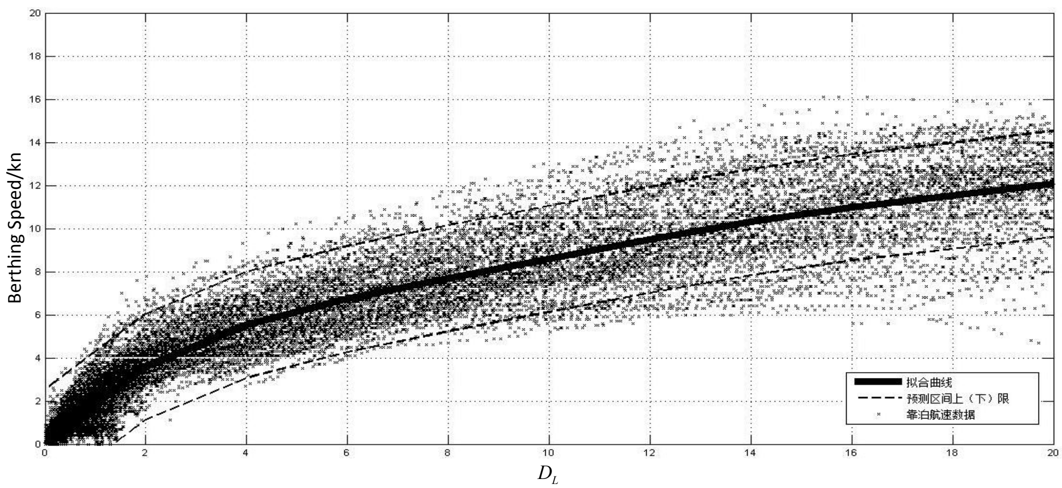


Figure 5. Curve fitting and prediction interval of distribution of LOA>300m container vessel

The recommended speed and corresponding variance for large container carrier berthing can be deduced from the fitting curve and formula 6, which shown as Table 3. The variances display in the table are used to evaluate the deviation between recommended speed and sample speed. As the ship approaches the berth, the difference of different container ships' speed control becomes tiny. Especially when the ship is within the range of $8D_L$, the variance is relatively smaller than the outsides'. It suggests the consistency of most ships' speed control in the range.

Table 3. Recommended speed and corresponding variance for large container carrier berthing

D_L	20	19	18	17	16	15	14	13	12	11
Speed/kn	12.1	11.8	11.5	11.2	10.9	10.6	10.3	9.9	9.4	9.0
Variance	3.458	3.831	3.947	2.783	3.176	3.659	3.529	3.443	3.539	2.994
D_L	10	9	8	7	6	5	4	3	2	1
Speed/kn	8.6	8.1	7.6	7.2	6.7	6.1	5.5	4.7	3.5	2.0
Variance	2.573	2.230	1.721	1.602	1.531	1.417	1.397	1.080	1.096	0.988

5 Conclusions and future work

In this paper, we propose the model of arrival distance for extracting ship berthing features. To get macroscopical law that can reflect large vessel's berthing speed, the experiments on AIS data collected from Xiamen Songyu and Tianjin Beijiang were conducted successfully. The results have been applied on the ship maneuvering simulator developed by Dalian Maritime University and practiced by four experienced masters in simulated Xiamen Songyu port area. The processes of simulative berthing handling were all successful, which shows the ubiquity of the berthing speed law.

The existing provisions of safe speed in harbor regulations were set based on the surveys from experienced ship masters and shore-based personnel, lacking effective support of data. This paper studies the macroscopical law of large container ship berthing speed. It makes a contribution for assisting the competent authorities have a better understanding of the habit of speed control in the water, then effective measurements for advancing rules of safe speed are intended to be raised and launched. Moreover, it is also beneficial to ships' officers or pilots enhance coordination, utilize the aids to berthing like engine, anchor, lines, thruster, tug and so forth with as little mistake as possible.

However, in the future work, the law of berthing angle, the effects of winds or currents or both on the velocity and course should be conducted. Furthermore, correlational researches on other special cargo carriers like VLCC (Very Large Crude Carrier) or LNG (Liquefied Natural Gas) carrier has a practical significance.

References

Guo Yu. (2005). *Nautical Navigation*, Dalian Maritime University Press, Dalian.

Hong Biguang, Shi Guoyou, Liu Shengli, Jia Yinshan. (2004). "Maneuverability of Large Container Ship." Journal of Dalian Maritime University, 30(1), 1-4.

Hong Biguang. (2004). *Ship Maneuvering,* Dalian Maritime University Press, Dalian.

Inoue K., Okazaki T., Murai K., Hayashi Y. (2013). "Fundamental Study of Evaluation at Berthing Training for Pilot Trainees Using a Ship Maneuvering

Simulator." *Transnav,* 7(1), 135-141.

Larose. Daniel T. (2011). *Data Mining methods and models,* Wiley-IEEE Press.

Liu Yihua, Xiao Yingjie. (2014). "Risk Evaluation of Berthing and Departing of LNG Vessel for Yangkou Port Based on Ship Handling Simulator." *Journal of Wuhan University of Technology,* 38(2), 290-293.

Shao Zheping, Sun Tengda, Pan Jiacai, Ji Xianbiao. (2007). "Development of the Integrated Vessel Information Service System Based on ECDIS and AIS." *Journal of China,* 2007(2), 30-33.

The Navigation Guarantee Department of The Chinese Navy Headquarters. (2009). *Guide To China Ports.* China Nautical Publications Press. Tianjin.

Wang Yan, Sui Silian. (2014). *Mathematical statistics & MATLAB data analysis*, Tsinghua University Press. Beijing.

Xiao Xiao, Shao Zheping, Ji Xianbiao, Chen Lingling. (2014). "Speed Control Model of Ships Entering and Leaving Ports Based on AIS Data". *Journal of Shanghai Maritime University,* 35(4), 11-14.

Xu Lunhui, Fu Hui. (2009). *Intelligent Prediction Theory and Methods of Traffic Information,* Sceince Press. Beijing.

Yang Dingzhao. (2011). "Effects of Large-scale Ship on Safety of Berthing". *Marine Technology.* 2011(2), 8-10.

You Qinghua, Chen Jie, Hu Shenping. (2013). "Risk Assessment of Berthing Container Ships in Fair Current Condition and Hints on Operation." *Navigation of China.* 36(4), 143-146.

Design of Variable Message Signs for Real-Time Berth Guidance in Indoor Parking

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Abstract: For the problems with driver's dissatisfaction about cruise and parking in indoor parking, this paper provides some solutions. First, this paper analyzes the current problem of the indoor parking guidance system and the superiority of variable message sign for real-time berth guidance, and then the specific design focuses on the setting mode, location and layout of variable message signs. Finally, taking Dalian Ansheng Shopping Plaza Underground Parking for instance, this paper designs real-time berth guidance information of variable message signs and solves the problem of real-time berth guidance when the optimal berth was occupied.
Keywords: Parking guidance system; Real-time berth guidance; Variable message signs; Layout design.

1 Introduction

Currently, the parking guidance bases on that the driver fully accept the guidance. But When the driver is not satisfied with the parking berth which is provided by the parking guidance system, he may find the parking berth himself. That phenomenon can result in the loss of the best effect of berth guidance. On the contrary, when the traffic environment changes affect the original guidance, the effective guidance system can change the optimal berth and path guidance in real-time.

Variable message sign is a traffic sign which changes display with the change of traffic, road, weather, etc. (LI Junli, 2001) .Because the sign is bright adequately and is not affected by the reflected light, so it is indeed suitable for berth guidance in parking. The sign can provide the right direction for vehicles, and help the driver park in the best berth conveniently, all these advantages will reduce driving distance and save time, and increase the parking efficiency. Meanwhile, due to the sign's lower cost, current parking guidance system's imperfection and the developer's less intention to invest too much, we have many reasons to consider that the variable message sign is the economical and effective method on parking guidance.

2 Variable message sign design for berth guidance in indoor parking

2.1Setting height and position design

Because indoor parking structures and limited space, and also there are many beams and columns inside, so gantry and attachment style are used. Due to the speed in indoor is low and different heights are designed by different architectural , the height design is selected by the height limit of parking.

Generally the road of indoor parking is two-way two-lane or one-way lane road, and also the speed is lower, so the driver do not have to change lanes, accelerate and decelerate, which means action distance is 0. As a result , the long front distance setting is not suitable .

Variable message sign can be set at the intersection of the exit road or entry road, or above the intersection directly. Thus it can be deduced that the distance of reading the end point to screen at the most unsatisfactory state in the actual parking guidance is the reaction distance. The schematic diagram is shown in Figure 1.

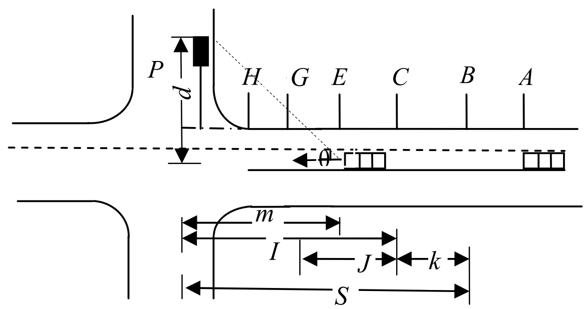


Figure 1. Setting position schematics of variable message signs

Critical point in the figure: *A*—visibility point, *B*—start reading point, *C*—end reading point , *E*—disappeared point, *G*— turning prepare point, *H*—turning point *P*—variable message sign; Key distance in the figure: *S*—distance of visual cognition, *k*—distance of reading sign , *J*—judgment distance, *I*—distance of end reading point to sign ,m—disappeared distance, *d*—the distance between height of the driver's vision field and sign in the roadside or the height between the height of the driver's vision field and the top edge of sign above the intersection, generally, the height of the driver's vision field is 1.2m.

Thus ensure that the driver can fully see the variable message sign and complete the entire decision-making process， following formulas should be met：

$$J \leq I \text{ and } \quad I \geq m \tag{1}$$

In order to make a more detailed and accurate guidance，variable message sign should not only be set up at the main intersection, it should also be set up at the corner of the road. Generally, under normal circumstances the number of signs set as follows: 1 to 2 at the corner, 2 to 3 at T intersection, 2 to 4 at cruciform intersection.

2.2 Layout design of variable message sign for berth guidance

1) Height of layout design

Formula (1) can derive the minimum value and reference values of the height.

$$J = v_s t_0 \le I \quad (2)$$

$$I \ge m = d / \tan\theta \quad (3)$$

v_s— travel speed ,m/s ; t_0— response time,2~2.5s.

θ—the angle between disappearance point and sign in the roadside , generally, it is 15° ,or the angle between disappearance point and sign above the intersection, it is 7° .

In the best case, $J = I = m$, reaction distance equal disappear distance . For sign above the intersection,

$$d = L + H - 1.2 \quad (4)$$

L— the clear height from the bottom of sign to the ground.

Formula (2) (3) (4) can derive the minimum value of the height in the best case.

$$H_{\min} = v_s t_0 \tan\theta - L + 1.2 \quad (5)$$

2) The actual word height of layout design

Word height is calculated by the formula of the word height of the general traffic sign, there is a relationship between I and the actual word height as follows(YANG Jiuling and LIU Xuehui,1999):

$$I = f(h^*) = 5.67 * K_1 * K_2 * K_3 * h \quad (6)$$

h*—the effective word height; h —the actual word height;

K_1—languages correction factor, Chinese is 0.6, Latin alphabet is 1.2;

K_2—word complexity correction factor, Object to the most complex word，value of less than 10 strokes is 1,10-15 strokes is 0.9, more than 15 strokes is 0.85;

K_3—speed correction factor， Values are shown in Table 1.

Table 1.Speed correction factor

speed（*km/h*）	walk	20	30	40	50	60	70	80	90	100
K_3	1	0.96	0.94	0.91	0.89	0.87	0.85	0.82	0.79	0.77

3)Word color and graph design

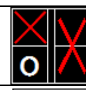
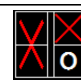
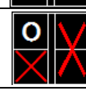
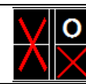
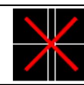
Basic orange or orange-red is used to display words in color of choice, such as berth number, license plate number, serial number, etc. White should be used to distinguish other messages and highlight the importance in the dark environment of indoor parking .The green guide arrow is used to express the direction information.

The graph of green arrow include turn left “” ,straight “”, turn right “”, U-turn “”.graph include: “”, “O”, “ ”, “P”, among them “ ” stands for “"no parking in front of the road”, it use color of red or orange, “O” stands for “the best berth in front of the road,“ ”stands for “lane dividers”, it use color of white,“P”stands for parking.

4) Concrete berth guidance information design

In this paper, the road between two intersections, is divided into four portions according to the roadway left, right and the distance , five items of berth information are shown in Table 2 . Variable message signs design are shown in Figure 2:

Table 2. Berth information

The optimal berth / Distance from the intersection	Optimal berth in the side of the travel direction	
	On the left	On the right
Short distance		
Long distance		
No optimal berth at this section		

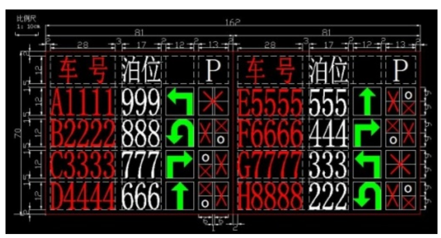


Figure 2. Berth guidance information design

3 Case Analysis

3.1 Introduction of basic information

Taking Dalian Ansheng Shopping Plaza Underground Parking for instance, we suppose that the parking space status is shown in Figure 3 at certain moment. If a vehicle reached parking entrance at this time, there are eight berths available :No. 012, No. 055, No. 087, No. 144, No. 163, No. 185, No. 230, No. 245 .

3.2 Basic setting of variable message signs

L values 2m , by limit of parking height. v_s is 15km / h by the maximum speed limit in the parking, t_0 is 2.5. H_{min} is 47.9cm according to the formula (5). If H of the actual design is 70cm, the disappeared distance m = 12.2m. Considering the following numeric fields :license plate number, berth number, travel direction , “P”, in the worst situation K_1=0.6,K_2=0.85,K_3=0.97, If h is 12cm, according to the formula(6) there are I = 33.7,m> 12.2m, meet the actual.

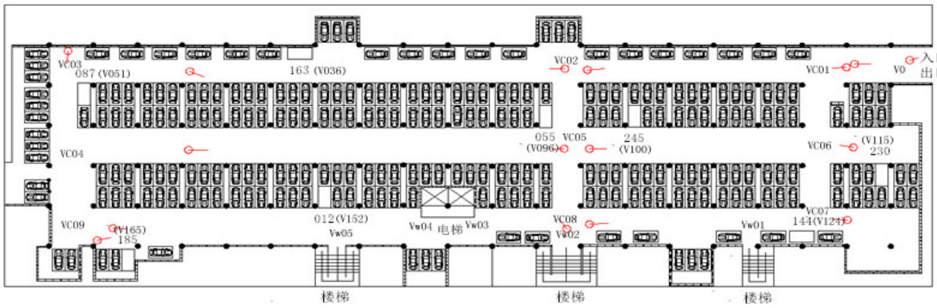


Figure3. Parking Current Situation

3.3 Real-time berth guidance in the best situation

First the optimal berth is calculated according to the optimal berth choice algorithm (FENG Lulu, 2013)for the vehicle A, it is berth No. 230 at node V115, and the optimal path to reach berth 230 is the V0-VC01- VC06-V115. It passes the two intersections VC01 and VC06.The next job is to guide the driver to go to the optimal berth. On this path at least two variable message signs（L11, L62） should be set to provide guidance information for the vehicle A. Assuming the car license plate number is A1234, the guide information display through L11 at the intersection VC01 and L62 at the intersection VC06,they are shown in Figure 4 and Figure 5

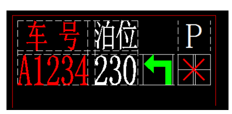


Figure 4. Layout information on L11

Figure 5.Layout information on L62

3.4Real-time parking guidance when the berth has be occupied

Assuming that when the vehicle A drives to the intersection VC06, and No. 230 berth is found to be occupied by the vehicle B , meanwhile No. 219 berth has be vacated at the intersection V104 . At this time the optimal berth and path guidance is needed to supply for vehicle A. The status is shown in Figure 6.

At this situation ,the berth No. 144 on node V124 is the optimal berth .Now, the vehicle's arrival to the berth No. 144 requires the way to via two intersections VC06 and VC07 , and should also be guided by L62 and L72, whose display should be updated to the following information on figure7 and figure8.

Figure 6. The case of berth is occupied

Figure7.Layout information on L62

Figure 8. Layout information on L72

4 Conclusions

The conclusions are as follows:

(1) The condition which the driver can fully see the variable message signs and complete the entire decision-making process is derived.

(2) The height of the variable message sign is derived，diagram of berth guidance information are designed.

(3)Specific examples are given to demonstrate the design of variable message signs during real-time berth guidance.

References

FENG Lulu. (2013). Key technology Research of the Parking Guidance System Based on Internet of Things. *Jilin University* ,52-57.

LI Junli .(2001).Traffic engineering facility design. *China Communications Press*.

YANG Jiuling and LIU Xuehui.(1999). Traffic signs and marking Application Guide. *Standards Press of China*, 67-68.

BRT Signal Priority Control Strategy Model Based on Travel Social Benefits

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Abstract: In order to solve the problem of the ignorance of the purpose of resident trips when establishing the bus priority strategy, an BRT signal priority control strategy is presented based on social benefits and exponential smoothing in this paper. Firstly, weights used by G_1 are given to resident trips which are in different period and for different purposes. Secondly, the number of vehicles, the average rate of loading and the travel proportions for different purposes at the intersection are predicted by exponential smoothing, the value of the social benefits are calculated through the indicators above, and the BRT priority strategy is determined by comparing the value of the social benefits. Finally, the feasibility of the model is validated according to the example.
Keywords: BRT signal priority; Purpose on resident trips; G_1 method; Social benefits.

1 Introduction

Giving public transit priority at signalized intersection is an effective means to improve the competitiveness of public transit, generating strategy of public transit access preferentially at intersection is of great importance for reducing residents travel delays and improving operational efficiency together with service level.

Priority strategies of public transit signal are numerous at present, the research achievements can be divided into two categories: The control objectives of one category were to study the priority control strategies on single-point(ZHANG Chun,2011), main line(BIE Yiming,2011) and network(XU Lunhui,2009) based on the delays of per capita and public transit vehicles at intersections(ZHANG Juanzi,2013& ZHANG Weihua,2004); The other kind of research which based on the residents trips were to establish the priority strategies which are subjected to the maximal social benefits of resident trips(ZHANG Zhiliang,2012&ZHAO Bei,2010) through the study of the functional relationship of residents travel time, costs, and the proportion of travel mode.

The methods above have improved the priority strategies of public transit from different perspectives. However problems still exists: (1) The establishment and calculation were complex, the solution of the modes was difficult; (2)The definition of social benefits place particular emphasis on travel mode and time benefits of residents, but ignore the fact that different purposes of residents trip should be taken into consideration when establishing priority strategy. Having realized the shortages above, in order to speed the BRT system, the conception of social benefits of purposes on resident trips is proposed in this paper. And it considers the satisfying of the maximal social benefits of resident trips for different purposes as a goal when establishing priority of BRT system.

2 Travel weight calculation based on social benefits

2.1 Definition of resident travel social benefits

In urban traffic, according to different purposes on resident trips, trips mainly consists of commuting trip and non-commuting trip(PAN Chi,2011): commuting trip mainly includes on and off duty etc, non-commuting trip mainly includes shopping, entertainment, returning home, else etc.

Social benefits of vehicles are based on different purpose on resident trips which means the social benefits achieved by residents for different purposes include social assets and other non-economic benefits, in other words, value, income, satisfying one's own need or additional utility created by the social activities exists by trips for different purposes.

The objective of BRT priority strategy developed in this paper is to maximize the social benefits of trips for different purposes. Therefore, before calculating the social benefits for different purposes, weighting all kinds of travel purposes.

2.2 Weight calculation of travel purpose index

The purposes on resident trips can be influenced by the periodicity of social factors which be with regularity. Generally, going to work, school and other commuting trip have high requirement for time, entertainment and shopping have less demanding on time(ZHAO Shuzhi,2011). Therefore, in different periods, giving different weights to different travel purposes, the principle of weighs given to purposes as follows:

On the morning and evening peak hours at weekdays, weighting greater to going to work, school and other commuting trip; During the holidays, weighting greater to non-commuting trips such as shopping, entertainment and tourist etc;

Giving maximal weight to emergency trip (infinity) such as emergency patients' first aid, traffic accident, firetruck going to firefighting etc.

G1 method is a subjective weighting method which was proposed by GUO Ya-jun, because G1 method can avoid the shortage of AHP, and this method does not require consistency test(Tian Long-hui,2009), give different weights to different purposes of trip at different period by using G1 method. The steps are described as follows:

Step1 Determine travel indexes on different purpose, including m indicators such as going to work, going to school, shopping, entertainment, going home, emergency trip, other non-emergency trip.

Step2 Assign the weight of the indexes by G_1 method.

Firstly, it is necessary to determine the sequence relationship of the every two travel indexes.

If the social benefits importance of travel index X_i is greater than travel indicator X_j,denoted $X_i > X_j$;

If the social benefits of travel indexes $X_1, X_2, \cdots, X_p$ have been determined to

$$X_i > X_j > \cdots X_k \tag{1}$$

$i, j, \cdots, k = 1, 2, \cdots, p$, the sequence relationships of travel inexes have been determined by" > ".

Secondly, determine the relative importance of adjacent travel indexes:

$$r_k = \frac{\omega_{k-1}}{\omega_k} \tag{2}$$

$k = p, p-1, \cdots, 3, 2$, represents the degree of importance (i.e., weight) ratio of two adjacent travel indexes,

Table 1. r_k **Assignment reference table**

r_k	*Description (during the same period)*
1.0	*Travel index* s_{k-1} *and travel index* s_k *are compared with the same importance*
1.2	*Travel index* s_{k-1} *is slightly important than travel index* s_k
1.4	*Travel index* s_{k-1} *is obviously important than travel index* s_k

1.6	*Travel index* s_{k-1} *is strongly important than travel index* s_k
1.8	*Travel index* s_{k-1} *is extremely important than travel index* s_k

Therefore,

$$\omega_p = \frac{1}{1+\sum_{k=2}^{p}\prod_{i=k}^{p} r_i} \qquad (3)$$

$$\omega_{k-1} = r_k \omega_k$$

ω_k—the weight of k-th travel index; $\omega_{k-1} = r_k \omega_k$, $k = p, p-1, \cdots, 3, 2$。

From Equation 3, the weight of every travel index can be calculated by calculating the value of ω_p.

As for emergency trip, giving weight alone, the weight is infinite.

3 Prediction of arriving vehicles at import of intersection

Due to rapid increase of private car, and exponential smoothing method has better timeliness, the changes is more sensitive to recent data in short-term and gain a high accuracy of prediction, so use this method to predict the number of arriving vehicles at every import of the intersection in different period of weekdays and rest day.

First order smoothing formula for exponential smoothing is（Tian Longhui ，2009）

$$Y_{t+1} = \alpha F_t + (1-\alpha) Y_t \qquad (4)$$

Y_{t+1} is predicted value, F_t is observed value (actual value), α is smoothness index, t is time series.

Recursive by recurrence formula,

$$\begin{aligned} Y_{t+1} &= \alpha F_t + (1-\alpha) Y_{t-1} \\ &= \alpha F_t + \alpha(1-\alpha) F_{t-1} + \alpha(1-\alpha)^2 F_{t-2} + \cdots + \\ &\quad \alpha(1-\alpha)^{t-1} F_1 + (1-\alpha)^t Y_1 \end{aligned} \qquad (5)$$

α is determined on the basis of experience, $0 < \alpha < 1$,the more value the smoothing coefficient is, the role of the recent actual value is put more emphasis on, and the reflect on the change of the actual value is more sensitive; Initial value $Y_1 = \frac{1}{n}\sum_{t=1}^{n} F_t$; Error $e_t = Y_t - F_t$.

Take Δt ($10 \le \Delta t \le 30\min$)as interval,detect and investigate the numbers of the arriving social vehicles and the BRT vehicles, average rate of loading, proportions of residents on different travel purposes, The value of Δt should be moderate(if the value is too small, there is no statistical significance, the number of vehicle may fluctuate intensely; If the value is too large, there is no way to statistic the characters of traffic flow at different period).

Statistic the numbers of arriving vehicles $V_{l,m,n}$ （pcu/h） in the j-th period on the the i-th day of all weeks at one year, construct time series $\{V_{1,m,n}, V_{2,m,n}, \cdots, V_{q,m,n}\}$, $l = 1,2,\cdots,q$; $m = 1,2,\cdots,7$; $n = 1,2,\cdots,\frac{1440}{\Delta t}$,the number of vehicles from all directions $\{V_{1,m,n}, V_{2,m,n}, \cdots, V_{q,m,n}\}$ can be predicted in the n-th period of the m-th day in the q+1-th week by Equation 5.

Similarly, the average load ratio $A(N)$, $A(S)$, $A(W)$, $A(E)$ and the proportion of residents on various travel purposes of social vehicles $P_{S_i}(N)$, $P_{S_i}(S)$, $P_{S_i}(W)$, $P_{S_i}(E)$; Average rate of loading $A(N)_{BRT}$, $A(S)_{BRT}$ and the proportion of residents on various travel purposes $P(N)_{BRT}$ 、 $P(S)_{BRT}$ of BRT vehicles can be predicted by Equation 5.

4 Design for priority control strategy at intersection

For example, the intersection has two phases, the direction of BRT lane is north-south. Predict the proportion of residents from different import, period and purposes, weight by G_1 method, calculate the social benefits of all residents from one import in the period of Δt.

As for the direction of east-west, in the period of Δt, the whole social benefits of trips on purposes X_k can be calculated as follows

$$PI(W-E)_k = [A(W)\cdot P_{X_k}(W)\cdot V(W) + A(E)\cdot P_{X_k}(E)\cdot V(E)]\cdot \omega_k \cdot \bar{H}_s \qquad (6)$$

$PI(W-E)_k$ —the whole social benefits of trips on purposes X_k on the east-western direction, （people/ h）; W —western import direction; E —eastern import direction; $\overline{H}_s$ —average rated capacity of social vehicles in the period, （people/ pcu）.

In the n-th period of the day, the m-th day of the week,, the q+1-th week, the whole travel social benefits of the phase can be calculated as follows

$$PI(W-E)=\sum_{k=1}^{p}PI(W-E)_k \qquad (7)$$

Similarly, the whole travel social benefits of the arriving BRT vehicles in the period of Δt

$$PI(o)_{BRT}=\sum_{k=1}^{p}\sum_{z=1}^{r}A(o)_{BRTz}\cdot P_{X_k}(o)_{BRTz}\cdot\omega_k H_{BRT} \qquad (8)$$

r —the number of the arriving BRT vehicles in the period of Δt; H_{BRT} —rated capacity of one BRT vehicle.

At the import which includes BRT lane, the social benefits are the social values of all residents on the social vehicles and BRT vehicles, then the social benefits of all the residents at the import can be calculated as follows

$$PI(o)_{总}=PI(o)_{BRT}+PI(o) \qquad (9)$$

$PI(o)=A(o)\cdot P_{X_k}(o)\cdot V(o)\cdot\omega_k$, $o=N,S$ 。

The social benefits of the BRT phase is

$$PI(N-S)=PI(N)_{总}+PI(S)_{总} \qquad (10)$$

Modeling by indicator function,

$$\phi_{q+1,m.n}=\begin{Bmatrix}1 & if\ PI(N-S)>PI(W-E)\\ 0 & else\end{Bmatrix} \qquad (11)$$

In the n-th period of the day, the m-th day of the week,, the q+1-th week, the value of the function is 1, the whole social benefits of BRT phase is higher than the other phase, open the signal priority strategy to the BRT phase, that is to say turn signal priority to the arriving BRT vehicles in the period; On the contrary, in order to satisfy the whole trip society benefits, do not open signal priority strategy, keep the original signal program.

5 Example Analysis

For example, on the morning 8:00—8:15(during the morning peak, Δt =15 min ,operating hours are 7: 00-22: 00) of one Wednesday, the intersection has two phases.

Step1 In the morning peak, arrange the order relations of trip indexes for different purposes(no emergency travel situations exist);

$$\{X_1\text{=go to work}; X_2\text{=go to school}; X_3\text{=shopping}; X_4\text{=entertainment}; X_5\text{=go home}; X_6\text{=other non}-\text{emergency trip}\}$$

Then $\{r_2 = 1;\ r_3 = 1.6;\ r_4 = 1;\ r_5 = 1.2;\ r_6 = 1.2\}$

Step2 Determine the weights of trips for different purposes;

Calculate by Equation 2,3

$$\{\omega_6 = 0.1034;\ \omega_5 = 0.1241;\ \omega_4 = 0.1489;\ \omega_3 = 0.1489;\ \omega_2 = 0.2383;\ \omega_1 = 0.2383\}$$

Step3 Predict the number of the arriving vehicles, the average rate of loading, the percentage of residents for different purposes;

Predict the data of every import of the intersection, the social benefits of every phase can be calculated by Equation 6-10 which can be shown in the following table(α=0.3) ,

Table 2. Every imported lane's social benefits at the intersection

	N		*S*		*W*	*E*
	Social vehicles	*BRT vehicles*	*Social vehicles*	*BRT vehicles*		
Number of arriving vehicles	*323*	*1*	*329*	*2*	*341*	*336*
Average rate of loading	*0.77*	*1.32*	*0.89*	*1.27*	*0.82*	*0.83*
Rated capacity (average)	*6.56*	*88*	*7.02*	*88*	*5.69*	*7.21*
Proportion of residents going to work	*0.29*	*0.39*	*0.34*	*0.41*	*0.33*	*0.50*
Proportion of residents going to school	*0.36*	*0.31*	*0.30*	*0.23*	*0.27*	*0.23*
Proportion of residents going shopping	*0.18*	*0.12*	*0.11*	*0.20*	*0.15*	*0.09*
Proportion of residents going entertainment	*0.07*	*0.11*	*0.17*	*0.11*	*0.16*	*0.14*
Proportion of residents going home	*0.04*	*0.02*	*0.06*	*0.03*	*0.07*	*0.02*
Proportion of other	*0.06*	*0.05*	*0.02*	*0.02*	*0.01*	*0.02*

residents						
Social benefits PI	*331.67*	*24.24*	*418.74*	*45.70*	*316.39*	*427.79*
	820.35				*744.18*	

Step4 Determine whether the BRT vehicles in the period can be given signal priority strategy.

It can be obtained by comparing the social benefits value that $\phi_{q+1,3,5} = 1$, then giving signal priority to the three arriving BRT vehicles and other social vehicles coming through this intersection on the morning 8:00—8:15 of the Wednesday.

6 Conclusion

In this paper, with the satisfaction of the maximal social benefits produced by resident trips which on different purposes as a goal, the paper established signal priority control strategy model of BRT system. The main conclusions are as follows:

(1) Weighted for travel indexes for different purposes and in different period;

(2) Intersection vehicle indexes needed for calculating social benefits were put forward, and through it the paper predicted the value of these indexes by exponential smoothing method;

(3) The priority strategy of the BRT vehicles were determined by the value of the social benefits at the intersection.

As for this paper, the next job is the perturbation analysis on the influence that the value of period to the priority strategy.

Reference

BIE Yiming, WANG Dianhai, ZHAO Ying-ying etc (2011) Multiple-Phase Bus Signal Priority Strategy for Arterial Coordination Intersection. *Journal of South China University of Technology(Natural Science Edition)* .10:111-118

CHEN Shu, YU Di, WU Liming(2014) Fatigue risk fuzzy evaluation for high-risk operations based on G1 method. *Journal of Safety Science and Technology*.04:90-95

PAN Chi, ZHAO Shengchuan(2011) Discrepancy Analysis on parking behavior of different travel purpose. *Construction Economy*.S1:245-248

Tian Longhui, Su Houqi, FengJuan(2009) Application Research of Time Series Analysis on Passenger Flow Forecast of Rail Transit. *Computer Applications and Software*.01:176-177+202

XU Lunhui, LI Minsheng(2009) Bus-priority Traffic Signal Multi-phase Fuzzy Control Based on Neutral Network. *Modern Transportation Technology*.03:82-84+98

ZHANG Chun(2011)Study on Improved Methods of Signal Control Based on Bus Priority at Isolated Intersection. *Beijing Jiaotong University*

ZHANG Juanzi(2013) Research on Optimization Methods of Average Delay-based Transit Priority Signal Intersection Timing. *Chang'an University*

ZHANG Weihua, SHI Qin, LIU Qiang(2004)Study of Vehicle Delay Calculation and Optimal Signal-planning Method for Intersection s with Induced Signal Based on Bus Priority. *Journal of Huazhong University of Science and Technology(Urban Science Edit ion)*.04:30-33

ZHANG Zhiliang, ZHAO Bei, TIAN Qingfei(2012)Residents Trip Model Structure and Social Benefit Maximization Based on Transit Priority. *Journal of Highway and Transportation Research and Development*.08:127-131

ZHAO Bei, ZHAO Shuzhi(2010)Resident trip mode structure and social benefits maximization based on transit priority. *Intelligent Information Technology Application Research Association (IITA Association), Hong Kong、Shenzhen University, China.Proceedings of 2010 The 3rd International Conference on Power Electronics and Intelligent Transportation System(Volume 6)[C].Intelligent Information Technology Application Research Association (IITA Association), Hong Kong、Shenzhen University, China*.4

ZHAO Shuzhi, ZHAO Bei(2011)Value of travel time of urban resident under multifactor influence.*Journal of Jilin University(Engineering and Technology Edition)*.01:46-50

Distribution Characteristics of Headway at Weaving Section of Signalized Intersection Upstream

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Abstract: The headway distribution is a vital foundation for the work of traffic control, capacity calculation, traffic safety analysis, etc. In this paper, based on the analysis of data collected in Shanghai, the statistical features of headway distribution of different road section at the same volume are investigated at weaving section of signalized intersection upstream. The method of $\chi^2 - test$ is adopted to analyze the time headway distribution. The results indicate that in the normal period, headway distributions of three typical sections of the fast lane are fitted well with the negative exponential distribution, and the average headway of the stop line section is the minimum, and the average headway of the weaving section is the maximum. This investigation provides a useful basis for further research on capacity of weaving section of signalized intersection upstream, signalized intersection upstream planning and management.
Keywords: Headway distribution; Weaving area; Typical cross-sections; Mathematical statistics.

1 Introduction

Having a knowledge of vehicle time headway distribution is important for the study of the traffic efficiency and safety. Domestic and foreign scholars made researches of headway distribution on the basic section(TAO etal,2011; Abtahi etal,2011), expressway weaving area(ZANG and ZHOU,2010), ramp connection(PEI and GAO,2007) and so on ,and obtained the negative exponential distribution, shifted negative exponential distribution, M3 distribution, Weibull distribution and so on. Murat analyzed the headway distribution in the off-peak period in signalized intersection, and found it can be described by exponential distribution and Weibull distribution (Murat and Gedizlioglu,2007). Distribution characteristics of headway at weaving section of signalized intersection upstream is important for analysis of traffic flow characteristics of urban road, signalized intersection design and intersection capacity calculation. However, the current research on this part is relatively less. This paper acquired data through investigation, then analyzed the headway distribution of different sections on urban road signalized intersection upstream by the method of mathematical statistics and lay the foundation for further study.

2 Data Acquisition

This paper selected a typical intersection in Shanghai - Tianmu Road Hengfeng Road Intersection. There are three lanes on the south import road of this intersection and two lanes on the road section. The author carried out the survey at 7:00 - 8:30am on July, 10th, 2013(Wednesday). The diagrammatic sketch of invested road and road section is as shown in Fig.1. Respectively, the basic road section is section A, and weaving area section is section B, and stop-line section is section C.

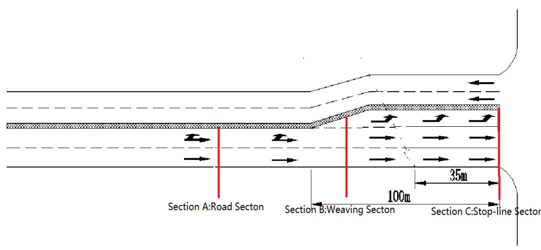


Figure1. Diagrammatic sketch of invested road and road section

Through analysis of collected survey data, the author gets the headway of different sections under the same flow rate (i.e 614vel/h) in the normal period. The value of each section is shown in Table 1 ~ Table 3.

Table 1 Headway of section A on the fast lane

Headway（s）	Median value（s）	Number	Frequency	Cumulative frequency
0~2	1	55	0.447	0.447
2~4	3	48	0.390	0.837
4~6	5	7	0.057	0.894
6~8	7	5	0.041	0.935
8~10	9	1	0.008	0.943
10~12	11	0	0.000	0.943
12~14	13	4	0.033	0.975
14~16	15	3	0.024	1.000
average（s）	3.049			

Table 2 Headway of section B on the fast lane

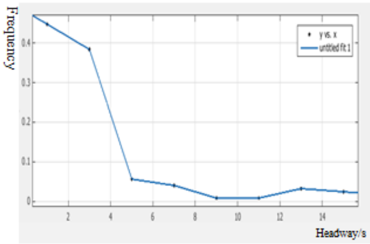
Headway（s）	Median value（s）	Number	Frequency	Cumulative frequency
0~2	1	46	0.404	0.404
2~4	3	40	0.351	0.754
4~6	5	17	0.149	0.904
6~8	7	3	0.026	0.930
8~10	9	2	0.018	0.947
10~12	11	1	0.009	0.956
12~14	13	2	0.018	0.974
14~16	15	3	0.026	1.000
average（s）	3.263			

Table 3 Headway of section C on the fast lane

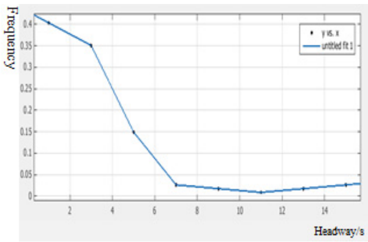
Headway（s）	Median value（s）	Number	Frequency	Cumulative frequency
0~2	1	43	0.457	0.457
2~4	3	28	0.298	0.755
4~6	5	13	0.138	0.894
6~8	7	6	0.064	0.957
8~10	9	3	0.032	0.989
10~12	11	1	0.011	1.000
12~14	0	0	0.000	1.000
14~16	0	0	0.000	1.000
average（s）	2.894			

3 Data Analysis

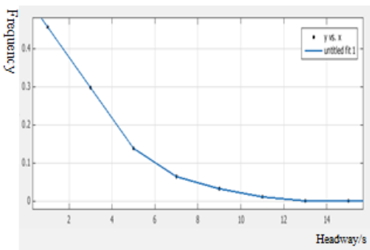
Headway refers to a certain time interval in which when traffic traveling in the same direction, the front two cars passing through the adjacent road section. This paper took the south imports of Tianmu Road-Hengfeng Road Intersection to study the headway distribution in the normal period of the road section, weaving area section and stop-line section. The distribution is shown in Figure 2.



（a） Section A



（b） Section B



（c） Section C

Figure2. Collected data of automobile headway distribution

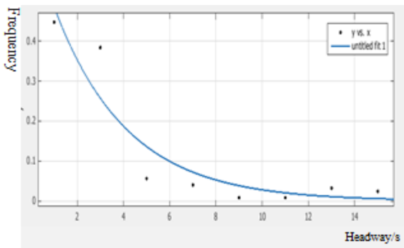
As shown in Figure 2, under the same flow rate, the headway distribution measured in different sections is closer, and this further proved that the headway distribution is closely related to the rate of traffic flow.

Obtained from Table 1~3, the average headway of section A is 3.049s, the average headway of section B is 3.263s, and the average headway of section C is 2.894s.It can be found that the average headway of section C, or the stop-line section is the minimum. There are two probable reasons:

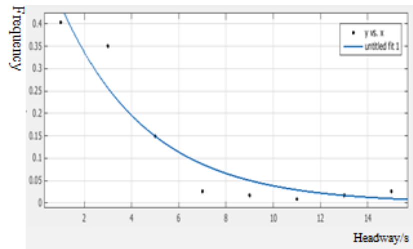
(1) In the actual situation, the stop-line section exists in a queued vehicles because of red light, and most of these vehicles pass the stop-line section with the saturation headway and thus in the stop-line section, the headway distribution is more concentrated;

(2) In the weaving section , vehicles need to slow down to change lane or slow down to provide clearance for the insert car to change lanes, and thus the average headway of section B ,or the weaving section is the maximum.

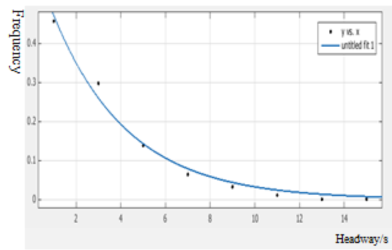
The author used negative exponential distribution to fit the headway distribution of different section and used $\chi^2 - \text{test}$ ($\alpha = 0.05$) to test the goodness of fit of the theoretical distribution. The fitting curve is shown in Figure 3. The χ^2 −test results are shown in Table 4.



(a) Section A



(b) Section B



(c) Section C

Figure3. Frequency curve of different sections

Table 4 Test results of headway distribution ($\alpha = 0.05$)

Section	negative exponential distribution		
	$\chi^2_{observed}$	$\chi^2_{theoretical}$	Fitting results
Road section	0.263	5.991	Recognized
Weaving section	11.585	12.592	Recognized
Stop-line section	1.696	9.488	Recognized

Fitting results show that in the normal period, the headway distribution of each section in signalized intersection upstream obeys negative exponential distribution.

4 χ^2 −Test of Headway Distribution

In traffic engineering, we usually use χ^2 −test to test the goodness of fit of the theoretical distributions. Take the χ^2 −test of section B for example.

(1) the observed parameters of the distribution

$$M = \frac{\sum_1^8 f_i t_i}{\sum_1^8 f_i} = \frac{372}{120} = 3.1, \quad (1)$$

$$D = \frac{\sum_1^8 f_i t_i^2}{N-1} - \frac{\left(\sum_1^8 f_i t_i\right)^2}{N(N-1)} = \frac{2274}{120} - \frac{372^2}{120*119} = 10.433, \quad (2)$$

$$\lambda = \frac{1}{M} = \frac{1}{3.1} = 0.323, \quad (3)$$

f_i——the observed frequency

t_i— —the observed median headway

N— —the number of sample

(2) χ^2 −test

Assume theoretical distribution model as a negative exponential distribution, and use Matlab to obtain the distribution model for fitting.

$$f(t) = 0.5792 * exp\,(-0.2712 * t), \quad (4)$$

t— —the headway

χ^2 −test calculation results are shown in Table 5.

Table 5 Weaving Area Calculation Section χ^2 −test Results

Median Value（s）	Observed Number f_i	Theoretical Number F_i	F_i >5	$\chi^2{}_i = \frac{(f_i - F_i)^2}{F_i}$
1	46	50.34	50.34	0.375
3	40	29.27	29.27	3.935
5	17	17.01	17.01	0.000
7	3	9.89	9.89	4.802
9	2	5.75	5.75	2.446
11-15	6	6.42	6.42	0.027
$\chi^2{}_{observed}$				11.585

DOF = 8-2 = 6, taking α = 0.05, $\chi^2{}_{theoretical}$ =12.592, it can be seen that $\chi^2{}_{observed}$ < $\chi^2{}_{theoretical}$, so the hypothesis is recognized and therefore the headway of section B obays negative exponential distribution. Similarly, examine the observed distribution of headway of section A and section C, the result is shown in Table 4.

5 Conclusion

Here we may draw the following conclusions.

(1) In the normal period, the average headway of the stop line section is the minimum, and the average headway of the weaving section is the maximum.

(2) The above results indicate that in the normal period, the weaving section may become the bottle neck point of signalized intersection upstream.

(3) When traffic flow rate is in the normal period (614vel/h), the headway distributions at different road section are fitted well with the negative exponential distribution.

This investigation provides a useful basis for further research on capacity of weaving section of signalized intersection upstream, signalized intersection upstream planning and management.

6 Recommendations for Future Research

The headway distribution is a vital foundation for the work of traffic control, capacity calculation, traffic safety analysis, etc. So the headway distribution at different flow rate and different lanes at weaving section of signalized intersection upstream can be further studied to provide the theoretical basis for the capacity calculation of signalized intersection, so as to find out the bottle neck point of signalized intersection upstream.

Acknowledgement

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References

Abtahi S M,Tamannaei M,Haghshenash H.(2011).“Analysis and modeling time headway distributions under heavy traffic flow conditions in the urban highways: case ofIsfaha.”*Transport*, 26(4) : 375-382.

CHEN Xiaohong, XIAO Haifeng.(2001).“micro-simulation study of the characteristics of weaving area”.*China journal of highway and transport*, 14（sp）: 88-91.

LI Aizeng, SONG Xianghong, et al(2013).“Time Headway Distribution on Downstream Section of Signalized Intersection.”*Journal of transportation systems engineering and information technology*,13(4):66-75.

Murat Y S,Gedizlioglu E.(2007). “investigation of vehicle time headways in Turkey.” *transport*,160(2) : 73-78.

PEI Yulong, GAO Han. (2007). “Headway distribution model in urban freeway.” *Computer and Communications*, 25(5) : 4-7.

RAKA H, ZHANG Y H.(2006). “Analytical Procedures for Estimating Capacity of Freeway Weaving, Merge, and Diverge Sections.”*Journal of Transportation Engineering*,132(8):618-628.

TAO Pengfeng ,WANG Dianhai,JIN Sheng(2011). “Mixed distribution model of vehicle headway.” *Journal of Southwest Jiaotong University*, 46 (4) : 633-

637，644.

ZANG Xiaodong， ZHOU Wei.(2010). “Time headway distribution characteristics of merging area on urban expressway interchanges.” *Journal of Beijing University of Technology*, 36(7) : 961-965.

ZHONG Liande, RONG Jian, SUN Xiaoduan, et al.(2006). “study on the operation analysis of weaving section of urban expressway”.*Journal of Beijing university of technology*，32（10）: 907-911.

Highway Application Service Framework Based on ETC Data

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Abstract: Highway without a stop charging system (ETC) is an important subsystem in the field of intelligent transportation. The system has accumulated a large number of charge transaction data, which contains the traffic flow characteristic information and many kinds of feature information of highway users. Based on the analysis of ETC related data, The article did investigation of the ETC user demand investigation. And conducted requirement analysis for the highway travelers which contains transportation information types, information provision methods, service functions and so on. Finally, put forward the application service framework based on data ETC for highway users, highway regulators and highway operation management, covers the analysis of characteristics of highway basal network, the highway customer analysis and management, travel path planning and so on.

Keywords: Intelligent transportation; Highway; Trade data of the ETC; Demand analysis; Application service framework.

1 Introduction

As a new source of traffic data, Electronic Ton Collection system overcomes the defects that traditional artificial charge information can't obtain the vehicle running state. With the improvement of the technology and the promotion, the users of the system will be gradually increased and the volume of trading rapidly growth that will make the ETC system accumulated huge amounts of transaction data. The data not only contains the information of traffic flow characteristics from the traditional coil and video detector data, but it also contains many kinds of feature of the highway users. Xiao et al. (2008) thought that ETC (electronic toll collection) could significantly improve the handling efficiency of the toll station and the capacity traffic ability of toll road because of no parking troll collection.

The ETC system application in China started relatively late, the domestic scholars also less mining research for ETC transaction data. At present. Weng et al. (2010) conducted a preliminary analysis of the ETC data, studied the application method of ETC data. Fu (2008) carried out the exploratory research of ETC data mining. Foreign Levinson (2003) were emphatically studied on the application scope of the ETC data and travel time prediction method based on ETC data, Zarrillo et al. (1997) summarizes the available kinds of traffic information with ETC data. Currently, Myung et al. (2011) could get highway travel time and travel time prediction for the next period. Qian et al. (2012) only from the angle of statistics discussed the extracting, screening and analysis method of ETC trading data, had carried out access the indexs methods such as travel speed, traffic flow and highway station OD distribution and so on. But research for potential information of ETC data had no depth mining, such as the network running status.

The current study is lack of application of ETC data, and ignoring the more depth acquisition of road traffic information that combined with applications and services. Therefore, in this paper, through establishing the ETC data application service framework to provide basis for scientific monitoring highway running state, provide ways for fully excavating the existing system resources. It is also the foundation of the future related objects such as management departments, operating units and the vast majority of traveler and so on, real-time release and apply the monitoring information of highway condition.

2 ETC relevant data base

ETC relevant data includes ETC transaction data, customer information and other basal data, these data laid a foundation for establishing the application and services framework of ETC data.

(1) ETC trading data

The original ETC transaction data table has a total of 74 field and records a large number of trading information, and also details records the vehicle information in and out of the highway. ETC trading data mainly can be divided into two aspects: one is the actual transaction amount, mainly including defined the class of the card by card issuers, the OBU (On board Unit) status, type of payment and the amount of accounts receivable and other fields; Another is the traffic information, mainly including entrance square number, export square number, entry time, export time and vehicle types and other fields. These fields are the main data base of the highway operation monitoring, is also closely related to the main research content of application service requirements. As shown in table 1.

Table 1. ETC raw deal data part of the main content of the field

Field Name	Annotation	Data Sample	
PLAZAID	Export square number	100124	100433
UP_DOWN	1: Ascending 0: Descending	1	0
ENTRY_EXIT	0: Entry 1: Export	0	0
CAR_SERIAL	License plate number	JingPA1234	JingFZ1234
CREATED	Records generated time	2013/9/1 0:08	2013/9/1 0:17
VEHCLASS	Vehicle type	1	1
EN_PLAZAID	Entrance square number	100122	100711
EN_TIME	Export time	2013/9/1 0:01	2013/9/1 0:11

(2) ETC customer information data

ETC customer information data covers the records such as deal and recharge of ETC. And the key information include the customer name, id information, date of birth, contact information and deal with other business transactions. Through the ETC customer information data can identify the identity of the ETC user and make behavior analysis.

(3) Other basic data

Other basic data including name of the toll station, the rate information within the network, the distance between the toll station, toll station routing information, toll station location information, overpass location information, etc.

3 Investigation and analysis for ETC user's requirements

The research take the method of sample survey of the bearer for Beijing ETC users, distributed and recycled effective questionnaire 400.In the sample, the user age mainly concentrated in the range of 30 to 40 years old, the frequency of consumption is focused on the use of 6-10 times a month, accord with typical characteristics of ETC users. In order to grasp the needs of ETC users, this paper analyze the transportation demand and personal information management demand. The proportion of each demand content shown in the following table.

Table 2. Different users demand

Demand content	Traffic Information	Path Planning	Travel Time Prediction	Charging Information	ETC Usage Management	Preferential Information	Social Information
Proportional	68%	94.25%	82%	89%	>50%	91%	82.50%

3.1 Transportation demand analysis

The traffic travel demand analysis for ETC user mainly focused on traffic information, path planning services, travel time prediction, the charge information and so on.

(1)Traffic Information

There are respectively 65.5% and 47.75% of the users want to obtain traffic information through mobile phone text messages and Wechat, and respectively 68% and 53.25% of people want to know the city's congestion information and congestion peak prompt message. The survey results show that the ETC users have urgent request for traffic information services, focusing on global and local road network traffic conditions. The demands of which are not directly affect the information of traffic environment factors such as the construction, the weather are relatively low. Survey for individual users, they prefer to adopt one-to-one directional services such as SMS, Wechat, rather than other widely audiences, weaker targeted or immediacy medium.

(2)Path Planning Services

The questionnaire data show that 94.25% of users are willing to accept the path planning, go around the traffic jam, and respectively 56% and 43.75% of the user wants to obtain path planning information using text messages and phone software. 92.75% of users are willing to accept the guidance of driving and the users prefer to select SMS and Wechat to obtain information; With nearly half of the survey users want to obtain the flow path and information of the next export direction. The results of the survey shows that the ETC users' demand of path planning, traffic guidance is strong, especially the women and less driving experienced investigators. In terms of providing service media, SMS and Wechat, which based on mobile terminal, are the most respected. Respondents also have great interest in the mobile client (APP), vehicle navigation and customer service telephone.

(3)Travel Time Prediction Demand

Survey results show 82% of the users are willing to know the best time to the destination, 92.5% of the users are willing to know the time to the destination, and about half of the users who are surveyed are interested in the time of arrival to the service area, the place of traffic jam and the next exit location. The investigation result indicated that, the ETC users have a strong interest in the prediction of travel time, travel time are required for multiple points of interest, but the arrival time of highway service area is the most attention by respondents.

(4)Charging Information

The questionnaire data show of the users want to see the charge information of road and bridge, and the popularity of the first three methods of obtaining information is: mobile phone, SMS, Wechat, mobile phone client, The demand degree respectively is: 66.5%, 44.5%, 42.25%.

3.2 Personal Information Management Needs Analysis

ETC users not only demand for travel information, also hope to obtain personal information such as ETC usage, ETC preferential information and relevant social information and so on.

(1)ETC Usage Management

Survey data show that more than half of users are willing to know their ETC charge mileage, nearly half of the users want to know their own frequency of using ETC, consumption and mileage and other characteristics. This shows that the respondents have management requirements of use ETC. At the same time, with the gradual lifting of ETC user's awareness of environmental protection, 27.75% of respondents hope to understand their own carbon emission reduction.

(2)The Preferential Information

Survey data shows that ETC users are willing to know the ETC preferential information, and the proportion is as high as 91%, In the investigation to obtain such information channels, SMS and Wechat are still the most popular support rate, accounted for 67.75% and 46.75%.

(3)Social Information

Survey data shows that 82.5% of users are willing to get to know other ETC users and to participate in group activities, and there are 77.75% users want to find the ETC owners who have the same travel habits, and aboard their vehicle in limited number days. For the way of feedback and interaction for experience and problems in the ETC use process, more than half of the survey users choose phone and Wechat. This suggests that ETC users have quite a strong sense of community, hoping to get online and offline social activities through the exchange platform, Limit number day carpooling has also been recognized for most respondents.

4 Application service framework for user requirements

Highway users, highway regulators and highway operation management are the main service objects of ETC data. With the aid of the variable information board, mobile phone terminal, FM radio and other customer service channels, This paper takes highway users as the main service object to achieve the service support for different categories of users, and build ETC data application service framework for user requirements. As is shown in figure 1.

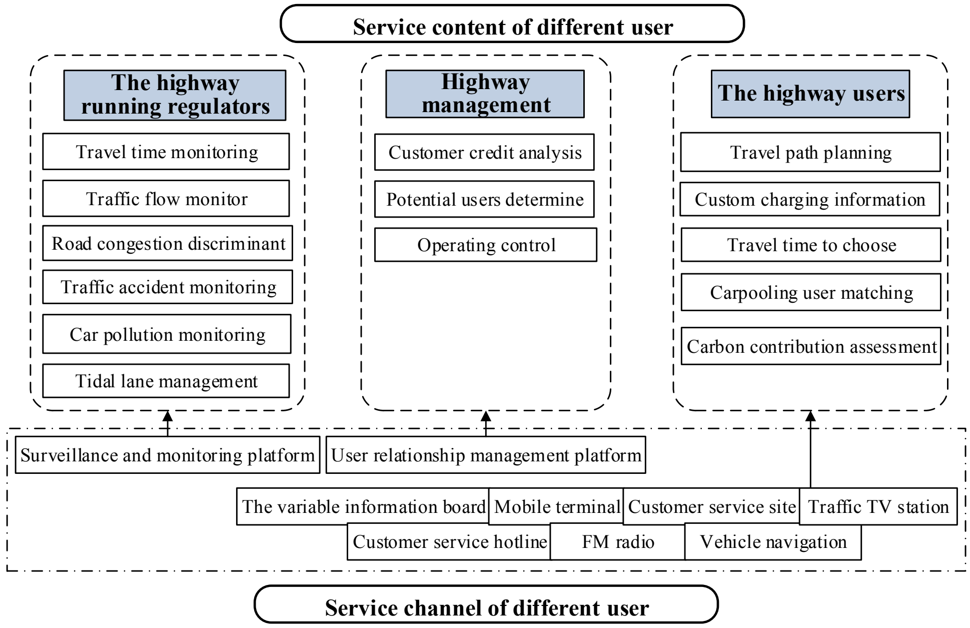

Figure 1. The framework ETC data application service for user requirements

4.1 The Highway Users

The travel satisfaction of highway user in ETC trading data service occupies very important position, providing more abundant travel information service and travel planning services to ETC and highway users .In this way to further improve the highway users satisfaction.

(1) Travel Path Planning

According to the user specified travel origin and destination, and the highway real-time road traffic volume and traffic jam grading discriminant, a proposal is put forward for the users to help users avoid jam and choose the effective path to reach its destination. Meanwhile, When the car drive into the small flow segment or the segment that driving distance is short, to a certain extent, it can also reduce traffic congestion in the entire road network to realize road network traffic assignment.

(2) Charge Information Customization

Road charges information is inherent in every ETC toll station, according to customer requirements, push the ETC charges information ahead for the user. In the way it is convenient for users to know the number, the location, the charging method, charge standard, charge information of road and bridge toll station and so on in advance. If the price of the toll charge change, it is also convenient to notify the user.

(3) Travel Time Choice

Departure time choice can prompt users the morning and evening rush hour to travel, provide a reference for the users to select travel time and reduce the number of users in congestion period into the highway.

(4) Carpooling Users Matching

Some of customers or owners have a need to carpool with others when vehicles are limited. Based on ETC transaction data of individual vehicle information, if users who have a need to carpool with others are matched effectively, it will reduce traffic congestion and benefit the maximum use of transport resources.

(5) Carbon Emissions Contribution Assessment

ETC users want to see their contribution on energy-saving and emission reduction by using the ETC system. According to the information such as models, travel time and so on, the individual carbon emission reduction can be measured.

In order to satisfy the service content of highway users, the application service of ETC data should be effectively explored by the following service approaches such as variable information board, customer service hotline, mobile phone terminal, vehicle navigation, television stations and so on. As shown in table 2.

Table 2. ETC data application service implementation for highway user

Service content	Service channel	Data base	Implementation plan
Travel path planning	1)Variable information board 2)Mobile terminals 3)Customer service website 4)Vehicle-mounted navigation 5)Traffic information television	Travel origin and destination	Traffic jam hierarchical model, cooperate with TGIS auxiliary system, etc
Charging information customization	1)Customer service hotline 2)Mobile terminal 3)Customer service website 4)Vehicle-mounted navigation	Travel origin and destination	Data model of road charges
Travel time choice	1)Customer service hotline 2)Mobile terminal 3)Customer service website 4)Vehicle-mounted navigation 5)Traffic information	Travel origin and destination	Traffic jam hierarchical model, cooperate with TGIS auxiliary system, etc

	television		
Carpooling user matching	1)Customer service hotline 2)Mobile terminal 3)Customer service website	Vehicle information, limit number and commuter interval, traffic habits	Associated with the same properties user, contact to carpool
Carbon emissions contribution assessment	1)Customer service hotline 2)Mobile terminal 3)Customer service website	Travel origin and destination, in and out of the toll station time, vehicle models	Single carbon reduction calculation model

4.2 Highway Running Regulators

Highway running regulators can offer service and improve the governmental regulation and the demand of the public image by using ETC data.

(1) Travel Time Monitoring

Travel time which is got by the record time when vehicles go in or out of the plaza being subtracted each other accurately reflects the running status of road traffic. It can help the supervision department of the highway operation to monitor the travel time of the road network. In addition, the future travel time can be predicted by using a large number of historical data, which provides digital support for the forecasting of traffic congestion, and plays an important role on traffic and logistics planning.

(2) Traffic Flow Monitoring

Traffic flow which is simply obtained according to transaction records of entrances and export is an important index that can reflect the level of road service. And traffic flow OD distribution and the distribution regularity of traffic flow, to a certain extent, reflects the direction of the traffic flow, which build a real foundation for traffic prediction and traffic distribution.

(3) Road Congestion Identification

The degree of urban road congestion is generally characterized by driving speed. In fact, the highway also can imitate the method. Based on the travel speed which is calculated by the section length and the travel time, it can realize the classification of congestion by using the method of classification and assessment of congestion, which facilitates traffic administrative departments to take measures to direct and manage traffic jam.

(4) Traffic Accident Monitoring

An accident on the highway will heavily influence the road traffic. Making predictions on basic feature date- travel time of the road network, and the combination of previous ETC transaction data and travel speed characteristics when accident happened, the corresponding travel time threshold is formulated. Besides, highway road traffic accidents can be effectively monitored by using video information of road monitoring.

(5) Car Pollution Monitoring

Environmental protection is a significant subject that is paid more and more attention by the countries all over the world. In the meantime, exhaust gas released by human into atmosphere is worsening the environment around us. With the growth of cars, car exhaust emissions is increasing dramatically, which is another important factor to influence environment. And by monitoring the highway automobile pollution levels, which can provide support for the relevant departments to develop energy-saving emission reduction measures and make a contribution towards environmental protection.

(6) Tidal Lanes Management

With the development of Beijing highway, the construction of tidal lane is urgent. Combined with ETC transaction data which can count the traffic distribution information in and out of the Beijing at different times and different sections and vehicle travel time distribution, or vehicle models proportion distribution, we can establish tidal lane, adjust the driveway lane number or type, reduce the traffic congestion and improve the service efficiency of lane.

In order to strengthen governmental supervision and enhance the public image, the following measures can be taken: By making full use of the evaluation index from the monitoring and testing platform, analyze the abnormal data from the electronic charge transaction data, then formulate the various index calculation model, and display system users the calculated results in graphical interface.

4.3 Highway Managers

By acquisition and analysis of the transaction data of ETC, highway superintendent need further improve the operational management efficiency, reduce the unfair loss, and provide important support for benefits of scientifically evaluating system.

(1) Reliability Analysis of Users

When ETC system charges, insufficient balance occurs frequently. In order to control the credit sale risk, one step is analyzing users' credit according to the basic information of users, payment information which is got by prolonged exposure to enterprise and customer and other information, the other step is setting the initial credit level and effective credit limits of different customers on the basis of the customer type or level. As a result, it provides decision support for operators to decide to allow overdraft limit and overdraft user and expands the operation benefit.

(2) Judgment of Potential Users

Potential users is the main force of prospective ETC toll lane. Thus, in order to guarantee the construction and development of ETC toll lane in the future, it is necessary to exploit the advantages of ETC toll lane to the full, determine potential users according to the characteristics of the ETC users, find new users, and increase the number of ETC users in the future.

(3) Control of Management Status

ETC lane both bring great convenience to the user, and provide business benefits for the highway construction enterprise. To provide data support for enterprise development in the future, daily / weekly / monthly enterprise accounting statements should be made by using sales data of ETC system and the toll data of toll station, and respective operating conditions and the general trend be analyzed combined with the traffic flow.

Highway managers should integrate users' information from the user relationship management platform and other all kinds of user information which is obtained by other approach, meet their own needs, improve the production efficiency and increase their income.

5 Conclusion and prospect

(1)This study puts forward some service channels and implementation plans for highway users, highway regulators and highway operation management.

(2) This study sets up the application service framework based on ETC data, which paves the way for the application and excavation of ETC dates and the extraction of the highway information.

Of course, in the future, much work need to be carried out around these. Some like: Conduct the related research which is about the extraction and the joint use of ETC data and other types of multi-source data, such as GPS data, detector data, video data and so on. On the basis of ETC dates, to carry out the research about characteristics and preferences of user behavior such as user driving behavior, alternative habits of travel route and so on.

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References

Fu, Y. L. (2008). "The Development of Electronic Toll Collection System for No-Parking", *Shanxi Science & Technology of Communications*, 2, 73-75.

Levinson, D. and Chang, E. (2003). "A model for optimizing electronic toll collection systems ". *Transportation Research Part A: Policy and Practice*, 37(4), 293-314.

Myung, J, et al. (2011). "Travel time prediction using k nearest neighbor method with combined data from vehicle detector system and automatic toll collection system". *Transportation Research Record: Journal of the Transportation Research Board*, 2256(1), 51-59.

Qian. C, et al. (2012). "ETC Data Mining Based on Hybrid Markov Model ". *Journal of Transportation Systems Engineering and Information Technology*, 4, 35-42.

Weng, J. C, et al. (2010). "ETC Data Based Traffic Information Mining Techniques", *Journal of Transportation Systems Engineering and Information Technology*, 2,57-63.

Zarrillo, M. L, et al. (1997). "Modeling traffic operations at electronic toll collection and traffic management systems ". *Computers & industrial engineering*, 33(3): 857-860.

Xiao, Z. H, et al. (2008). "The Research and Development of the Highway's Electronic Toll Collection System". Knowledge Discovery and Data Mining, 2008. WKDD 2008. First International Workshop on. IEEE , 2008: 359-362.

Assessment of Urban Bus Signal Priority Strategy

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Abstract: Current evaluation research of bus signal priority strategy adopting means of traffic simulation, lack of evaluation combined with the actual traffic flow data collected for analysis, based on the common bus priority strategies at home and abroad, on the basis of the current main bus signal priority strategy, including active and passive preference strategy has carried on the analysis and research; Based on HCM method, considering the influence of proportion of buses for intersection saturation flow rate, build the city road bus priority strategy performance evaluation method, On the basis of the traffic data, the urban road bus signal priority control strategies focus on a single point of intersection and compares the implementation of performance evaluation.

Keywords: Bus signal priority; Delay; Traffic capacity; Control strategy.

1 Introduction

This paper in view of the most commonly used bus signal priority strategy in China, based on the study of the control strategy of bus signal priority at home and abroad, using average traffic delay to evaluate the effect after implementation. Analysis signal priority strategies at different times under different proportion of bus transit.

2 Active bus signal priority

Compared with the passive bus signal priority, the active priority control strategy can be based on the specific bus information, the traffic state and the signal control logic, to provide corresponding service for public transport vehicles, it has stronger adaptability.

(Richardson, 1978) and (Heydecker, 1983) consider bus priority signal control may cause phase ignored or jump, but it does not affect the capacity of the intersection, and can be applied to a larger range. (Peter G Furth, 2000) found no signal priority and full signal priority generate more delay than conditional signal priority strategy.

Active priority control strategy generally has the following several control modes: (1) Green Extension, extend the phase of green time. (2) Early Green/Red Truncation, reduce the red light time when vehicles wait for the green light signal. (3) Phase Insertion, add a special phase for bus in the normal phase sequence. (4)Phase Skipping, ignore the green light signal in a certain phase. (5) Phase Rotation: change phase sequence in one phase cycle. (6) Actuated Transit Phase, provide a special phase for bus.

3 Urban road bus signal priority strategy evaluation method

At present the commonly used evaluation index of city road bus signal priority strategy mainly includes: (1)Load factor; (2)Bus travel time on average; (3)Bus stops on average; (4)Intersection queue length; (5)Intersection delay.

In this paper, average traffic delay is the main index to evaluate urban road traffic signal priority strategy, and its estimation method adopts the intersection signal delay model in HCM2000. The estimated value of delay in this model is the average vehicle control delay. During the study period, for a given lane group, the computation formula of average vehicle control delay is as follows:

$$d = d_1 \cdot PF + d_2 + d_3 \tag{3.1}$$

d is control delay of each car;d_1 is uniform control delay, d_2 is increased delay, d_3 is initial queuing delay, if there is no initial queue, d_3=0. *PF* is uniform control delay correction factor of linkage signal, when the traffic flow, PF = 0.95; when the road is slow or congested, PF=1.

Assuming that vehicles arrive uniformly, traffic flow is continuous and at the beginning of the study period without the initial line, according to the first item of Webster delay calculation formula we can find:

$$d_1 = \frac{0.5C\left(1-\frac{g}{C}\right)}{1-\left[\min\left(1,X\right)\frac{g}{C}\right]} \tag{3.2}$$

C is signal cycle, *g* is green time, *X* is the saturation of a given lane, its computation formula:

$$X = \frac{v}{c} \tag{3.3}$$

v is the actual traffic lane group rate; *c* is the capacity of a given lane group, its computation formula:

$$c = s\frac{g}{C} \tag{3.4}$$

s is the saturation flow rate of lane group, its computation formula:

$$s=\sum_{i=1}^{n}s_i \tag{3.5}$$

n is the import lane numbers of lane group; s_i is the saturation flow rate of i import lane, its computation formula:

$$s_i = s_0 f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{Lpb} f_{Rpb} \tag{3.6}$$

s_0 is the flow rate of basic sections, f_w is lane width adjustment factor, f_{HV} is carts adjustment factor, f_g is slope adjustment factor, f_p is the parking adjustment factor of nearby lane group, f_{bb} is the correction factor of bus stop in a intersection, f_a is area type adjustment factor, f_{LU} is lane effective adjustment factor, f_{LT} is turn left vehicle adjustment factor in a lane, f_{RT} is turn right vehicle adjustment factor in a lane, f_{Lpb} is turn left pedestrian adjustment factor, f_{Rpb} is turn right bicycle adjustment factor. f_{HV} can be calculated：

$$f_{HV}=\frac{100}{100+P_{HV}(E_T-1)} \tag{3.7}$$

P_{HV} is the proportion of carts in one direction of traffic, E_T is carts equivalent conversion factor.

Based on actual data collected by microwave vehicle detector in Kunshan, in this paper, its value is 1700 / hour / lane. By formula (3.3), (3.4), (3.5) can be obtained:

$$X=\frac{v}{c}=\frac{v}{s\left(\frac{g}{C}\right)}=\frac{vC}{sg}=\frac{vC}{g\sum_{i=1}^{n}s_i} \tag{3.8}$$

Incremental delay estimation formula is as follows:

$$d_2=900T\left[(X-1)+\sqrt{(X-1)^2+\frac{8klX}{cT}}\right] \tag{3.9}$$

K is incremental delay correction parameter; l is the correction parameter of upstream into the intersection or current-limiting. T is the length of the analysis period. According to HCM2000, in this paper, k=0.5; l=1.0.

In order to facilitate the assessment of bus signal priority strategy, we assume that the implementation of bus signal priority strategy straight on roads in the north-south direction, and the west-east direction will not be considered. Average delay formula is as follows：

$$\overline{d} = \frac{\sum_{i=1}^{n} d_i}{q_1 \times E_1 + q_2 \times E_2} \tag{3.10}$$

d_i is the total delay for the i import lane, q_1 is car traffic flow, E_1 is car traffic equivalent conversion factor, q_2 is bus traffic flow, E_2 is bus traffic equivalent conversion factor.

4 Data description

This paper selects Kunshan city road Kun Tai Road / Changjiang Road intersection as research subjects. Figure 1 shows phase of the intersection.

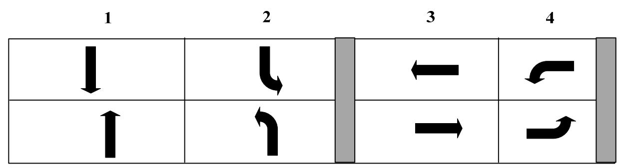

Figure 1. Changjiang Road / Kun Tai Road intersection signal control design phase

Table 1 is the north-south traffic flow data in morning rush hours of the intersection. Table 2 is the east-west traffic flow data in morning rush hours of the intersection. We also have flow data of evening peak hours and flat peak hours.

Table 1. North-south traffic flow data in morning rush hours of the intersection.

Period	Flow							
	North import road				South import road			
	Left	Left	Straight	Straight	Left	Left	Straight	Straight
7:30-7:45	27	23	103	99	58	58	105	71
7:45-8:00	27	23	121	117	55	50	116	73
8:00-8:15	25	22	31	31	27	26	68	47
8:15-8:30	33	36	16	46	36	43	108	89

Table 2. East-west traffic flow data in morning rush hours of the intersection.

Period	Flow					
	East import road			West import road		
	Left	Straight	Straight	Left	Straight	Straight
7:30-7:45	35	42	52	58	95	66
7:45-8:00	45	44	51	50	72	51
8:00-8:15	27	36	67	26	119	88
8:15-8:30	29	42	53	43	92	72

5 Bus signal priority strategy evaluation analysis

In this paper, all buses through the intersection were reduced to the buses with a constant frequency, and assuming their frequencies were 30veh/s, 40veh/s, 50veh/s, 60veh/s.

(1)Total delay

Figure 2 shows the total intersection delay after bus signal priority strategy implementation.

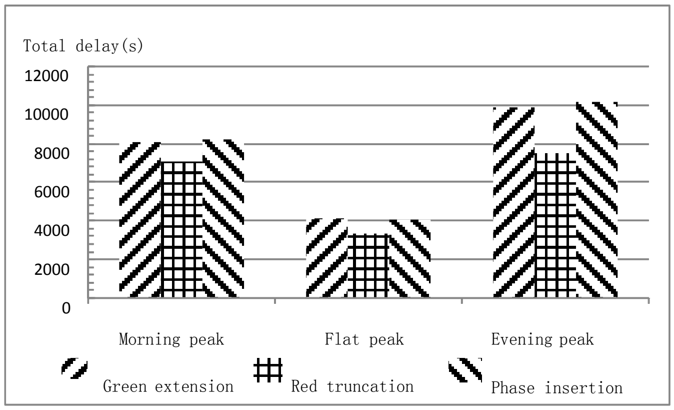

Figure 2. Total intersection delay

(2)Average vehicle delay

Morning peak hours, when the bus arrived frequency is 30 seconds, 40 seconds, 50 seconds and 60 seconds, the proportion of buses were 17.54%, 13.50%, 11.32% and 9.62%. Figure 3 shows average vehicle delay in morning peak hours.

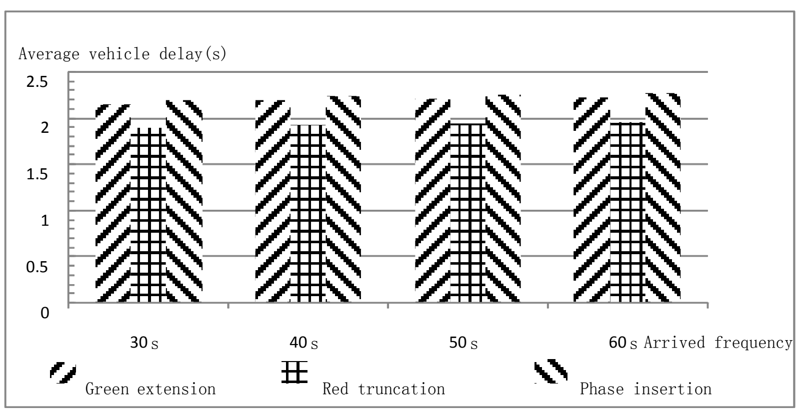

Figure 3. Average vehicle delay in morning peak hours

Flat peak hours, when the bus arrived frequency is 30 seconds, 40 seconds, 50 seconds and 60 seconds, the proportion of buses were 13.71%, 10.44%, 8.71% and 7.36%. Figure 4 shows average vehicle delay in flat peak hours.

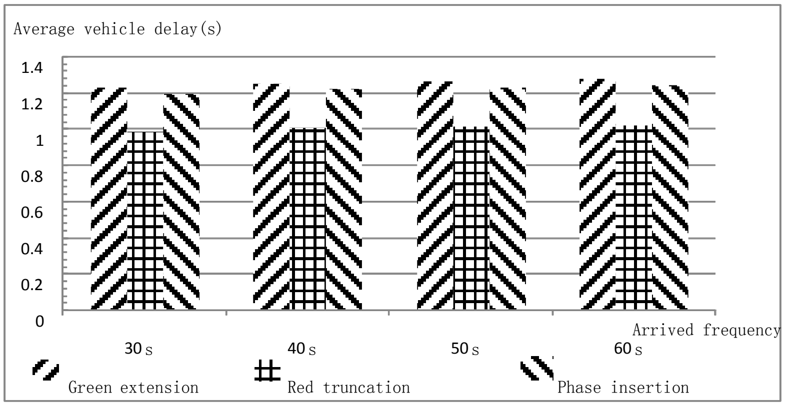

Figure 4. Average vehicle delay in flat peak hours

Evening peak hours, when the bus arrived frequency is 30 seconds, 40 seconds, 50 seconds and 60 seconds, the proportion of buses were 10.44%, 7.88%, 6.54% and 5.51%. Figure 5 shows average vehicle delay in evening peak hours.

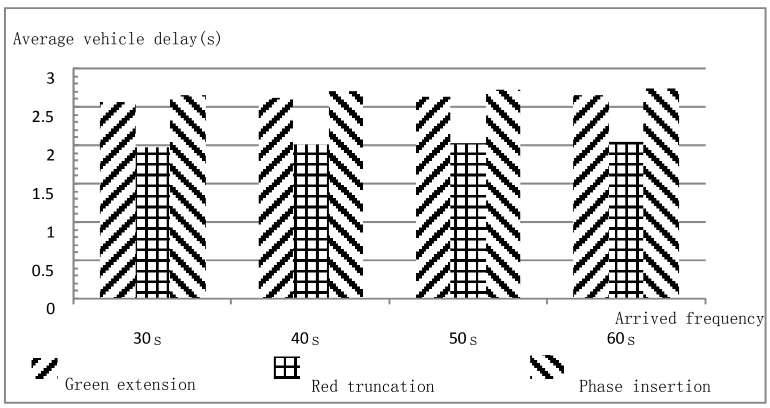

Figure 5. Average vehicle delay in evening peak hours

6 Conclusions

To adopt average vehicle delay as the primary assessment index to measure the bus signal priority strategy, the main findings of the study are as follows:

(1) Study the current major urban road transit signal priority control strategy, clear out the implementation methods and applicable conditions of all kinds of strategies;

(2) Based on HCM method, considering the influence of the proportion of bus for intersection saturation flow rate, and build the city road bus priority strategy performance evaluation method;

(3) Compared to green extension and phase insertion, red truncation strategy can reduce the total intersection delay and average vehicle delay, in addition, when

the proportion of bus become higher, all kinds of bus signal priority strategy can effectively reduce the total intersection delay and average vehicle delay.

References

Furth P G, Muller T H J. (2000). Conditional bus priority at signalized intersections: better service with less traffic disruption. Transportation Research Record: Journal of the Transportation Research Board, 2000, 1731(1): 23-30.

Heydecker B G. (1983). Capacity at a signal-controlled junction where there is priority for buses. Transportation Research Part B: Methodological, 1983, 17(5): 341-357.

Richardson A J, Ogden K W. (1978). An evaluation of active bus priority signals. 1978.

Transportation Research Board. Highway Capacity Manual.2000.

Calculation Model of Variable Parking Lots in Urban Synthesis

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Abstract: The construction of urban synthesis, which combines business, working, living, dining and entertainment in an overall, is an important part of China's urbanization process. The urban synthesis needs to provide enough parking lots to meet the rigid parking demand and the elastic parking demand, etc. Based on the principle that the parking demand of commerce and working alternates with living and the limitation of the surrounding road network's capacity, this paper puts forward calculation model of variable parking lots. By applying it into a case about the calculation of a new urban synthesis' parking lots, this paper finds out that the prediction result of calculation model of variable parking lots is obviously smaller than that of traditional calculation method, which further shows the new calculation model has some kind of reference and guiding meaning when reasonably determining the number of a urban synthesis' parking lots.

Keywords: Urban synthesis; Parking demand; Rigid demand; Elastic demand; Variable parking lots; Road network's capacity; Peak hour of parking.

1. Introduction

Urban synthesis will cause a lot of parking demand in urbanization process. Traffic impaction evaluation in the computing to the parking berth of newly-built urban synthesis, the traditional way (AN S, WANG J, 2001) is to predict according to demand analysis, which does not consider alternating characteristics between office parking demand in urban commercial synthesis with residential parking demand and urban synthesis surrounding road network capacity restriction (ZHANG J, 2005). So in this paper, we put forward a variable parking berth calculation model using the example of checking the number of one new-built architecture synthesis parking berth in the city KunMing and correct the calculation results of traditional method.

2. Analyzing the urban synthesis parking demand characteristics

Parking demand refers to the amount of park attracting amount of the given parking areas during the specified time (NIE T T, 2012). Its randomness is not only difficult to constraints, in some degree but also have the controllability, which can be called the duality of parking demand. On the one hand, it must provide the necessary parking facilities to meet current parking demand.On the other hand it can take advantage of the controllability of parking demand to set up enough and reasonable number of parking garages.

According to different travel purpose, the urban context of parking demand can be divided into two categories:

(1) Rigidity demand. Engaged in commercial activities, office (work) and living (home) of parking demand, this kind of parking demand time is long, commercial, office, and other general parking demand occurs during the daytime, live commonly occur in the evening, more regularity.

(2) Elastic demand. Attracted to the integrated body and its nearby engaged in shopping, dining and entertainment, such as the parking demand, this kind of length of parking demand uncertainty, randomness is larger, general rules.

3. Introduction of road network capacity

Urban road resources consists of time and space resources, any traffic individual travel will occupy a certain amount of time and space resources used by the road. Road network capacity can be known through the lanes space resources, divided by single traffic space and time consumption (BAI Y, XUE K, YANG X G, 2004).

$$C=\frac{L_e\times T_e}{S_a\times T_a} \tag{1}$$

In the formula:

C——road network capacity of the architecture synthesis,

L_e——effective length of the vehicle lane (m),

S_a——the space by the units vehicles (m),

T_e——the road network's peak amount continue time (h),

T_a——unit vehicle's travel time (h).

4. Variable parking berth calculation model

(1) Traditional parking number calculation method

Traditional parking number calculation method uses Parking demand forecasting method, its computation formula just like the formula (2).

$$P=S_0\times\tau+W\times T/(60\times\alpha) \tag{2}$$

In the formula:

P——Synthesis required parking garages (Ind),

S_0——Total number in the synthesis (Include individual business people, workers and residents),

τ——Researchers use proportion of motor vehicle travel in the synthesis,

W——The number of the synthesis allure in the peak time (Not contain taxi)

T——The number of the motor vehicle which alluredby the synthesis's (Not contain taxi) average parking time (min),

α——The utilization rate of the synthesis's parking garages ，about 0.8-0.9.

(2) The paper proposes a variable parking number calculation method like this:

$$P = \min(P_1, P_2) \tag{3}$$

$$P_1 = C \times Los \times \gamma / f \tag{4}$$

$$P_2 = \begin{cases} N \times \tau_n + W \times T / (60 \times \alpha), 当 N \times \tau_n > S \times \tau_s \\ S \times \tau_s + W \times T / (60 \times \alpha), 当 N \times \tau_n < S \times \tau_s \end{cases} \tag{5}$$

$$f = N_{\max} / (N_{15\max} \times 4) \tag{6}$$

In the formula:

P 、W 、T 、α which definition just as the formular (2),

P_1——Based on the Parking garages which calculated by the road network capacities around the road (Ind);

P_2——Based on the Parking garages which calculated by the synthesis's parking demand(Ind),

Los——Synthesis's surrounding road network service level,

γ——Parking behavior proportion in the traffic flow around the road network,

f——Synthesis's parking peak hour coefficient,

S——Staff number in the synthesis (Commercial and office),

N——The number of residents in the synthesis,

τ_n——Per capita vehicle ownership in the synthesis (Mg/peson),

τ_s——Staff（Commercial and office）motor vehicle travel in the synthesis,

N_{max}——Number of parking during peak hours of the synthesis (Mg),

N_{15min}——The largest number of parking within 15 min of the number of parking during peak hours of the synthesis (Mg).

The conception "variable" of Variable number calculation model of parking berthrefers to the combination of parking areas for commercial, office vehicle parking during the day, night due to the residents of private car parking, its USES variable, so can greatly improve the utilization rate of car garages. Formula (6) is parking peak hour coefficient definition.

Formula (5) shows synthes having two kinds of demands. Elasticity parking demand is parked vehicle number drawn to the synthesis during peak period. Rigid parking demand for residents in synthesis parking requirements and business, office needs, in view of the alternant sex is generally occurs in non-working time (night), while the latter is generally occur in the working time (day). Rigid parking lots number selcets the larger value of both. The final parking lots number of synthesis uses the smaller of P_1 and P_2.

5. Case Analysis

5.1 Basic Introduction

Taking a new city synthesis project of KunMing for an example, it takes a net land area of about 1116.33 acres, which includes the ground buildings area of 596740 m^2 and 2870 planning households. The buildings are mainly constituted of low-rise dwelling, supporting commercial, high-rise office and so on. The kind statistics of the synthesis is shown in Table 1.

Table 1. Area and number of different category of the new synthesis

Category	Business	Office	Living	Total
Building area	20660	17310	558770	596740
People's Number	258	577	11175	12011

To the construction project which has clear quantitative thresholds, its impact assessment should be under the range of Table 2. (CJJ/T141-2010)

Table 2. Range of research on construction project

Project scale index/Start threshold(R)	Range of research on construction project
R<2	Enclosure range of urban trunk road nearby the project
Megacity 2≤R＜5， Other city 2≤R＜3	Enclosure range of urban trunk road or freeway nearby the project
Megacity R≥5， Other city R≥3	Enclosure range of urban second trunk road nearby the project

According to the case, R=5.97, which determines the scope of the synthesis study area is shown in blue figure.

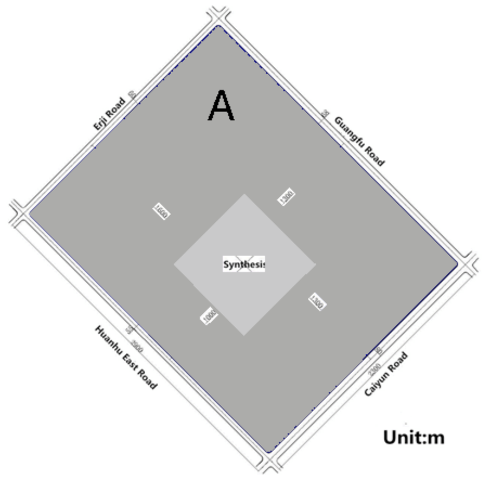

Chart 1. Scope of the study area of new city synthesis (area A)

According to known parameters and scope of the study area as shown, surrounding road network capacity of the synthesis is calculated as Table 3.

Table 3. Surrounding road network capacity of the synthesis

	Huanhu East Road	Guangfu Road	Caiyun Road	Erji Road
Effective Length L_e	2900	2900	2300	2300
Space occupation of each car S_a	8	8	8	8
Duration of rush T_e	1	1	1	1
Transit time of each car T_a	0.121	0.121	0.096	0.096
Road capacity	3000	3000	3000	3000
Road network capacity C		12000		

5.2 Calculate the Number of Berths

(1) By traditional way

Table 4. Calculation of the number of berths (by traditional way)

Parameters	Value
Total number of people in the synthesis S_0	12011
Percent of people going out by car τ	0.31
Car number in rush hours W	1909
Average parking time T	70
Parking utilization rate α	0.9
Parking number required P	6198

(2) By variable parking model

Table 5. Calculation of the number of the berths (by variable parking model)

Parameters	Value
Surrounding road network capacity C	12000
Surrounding road network service levels Los	0.6
Proportion of parking behavior in the traffic flow γ	0.45
Coefficient of rush hours f	0.8
Residents number N	11175
Rate of vehicle ownership per people τ_n	0.3
Number of employees S	835
Proportion of workers traveling vehicle τ_s	0.47
Number of peak hour vehicle attracted W	1909
The average vehicle downtime T	70
Utilizaton of parking lots α	0.9
Based on the surrounding road network capacity Calculated the parking lots P_1	4050
Based on parking demand Calculated the parking lots P_2	5827
Parking number required P	**4050**

(3)Conclusion

① The conclusion in Table 4 and Table 5 shows the results: It considers more comprehensive factors in the variable parking spaces, which reflects actual parking demand better and saving 34.7% parking space. ② commercial synthesis in the evening parking demand daytime parking demand and live with each other alternately office features, plus restricted synthesis surrounding road network capacity, making the combined effect of both reducing the number of parking spaces, indicating a variable number of parking spaces using computational model can effectively improve the efficiency of land use synthesises, urban construction, resource conservation. ③With simplification, we only optimized the calculation for parking place, and did not consider the number of non-motorized vehicles parking spaces. So it needs further study before spreading the calculation model. ④ Many parameters should be considered in the variable parking calculation model, including some ones (such as T_e、γ、f) need further investigation by traditional method, which means that its efficiency of implementation needs to be improved.

6. Summaries

Reasonable foreseeability and science estimate the parking demand of new urban context can provide parking planning and parking policy with reliable quantitative basis. The determination of reasonable parking number can effectively manage urban traffic demand, to alleviate urban traffic congestion produce immediate results. In this paper, the variable parking number calculation model applied to synthesis new city parking for certain instances show that the model can be more scientific and reasonable forecast needed by new urban synthesis parking number, this also for the parking demand research provides a practical and feasible new way of thinking. Variable parking number calculation model to calculate the efficiency of a non-motor vehicle parking demand and implement is the next research direction.

References

AN S, WANG J(2001). The Parking Demand Of Forecasting And Management. *Transportation Engineering and Information*,2001,1(3):212-216.

BAI Y, XUE K, YANG X G(2004). The Parking Demand Forecasting Method Based On Road Network Capacity. *Traffic and Transportation Engineering,* 2004,4(4): 49-52.

CJJ/T141-2010, The Technical Standards Of Traffic Impact Assessment In Construction Project

NIE T T(2012). Prediction Based On the Location Of The City Parking Demand Forecasting. *Xi'an:Chang'an University*.

ZHANG J(2005). The Characteristic Analysis and Parking Demand Forecast in City Vehicles Parking.*Nanjing:South-East University*.

Appropriate Volume on the SHUMA Roundabout

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Abstract: The operation of roundabout is not only affected by its geometric characteristics and operation rules, but also mainly affected by traffic distribution of inlet and outlet flow. To explore the suitability of roundabout traffic under the condition of various distributions from the view of running efficiency will benefit to planning and design of the roundabout, and also benefit to traffic organization in peak. In this paper, based on the field data at SHUMA roundabout, the appropriate traffic under the various kinds of influence volumes was analyzed by using VISSUM simulation.
Keywords: Roundabout; Appropriate volume; Traffic distribution; Operation efficiency.

1 Introduction

The capacity of roundabout has several expressions, such as the entry capacity, the total capacity. The entry capacity is applied widely, but it is changeable by the circulating volume and distribution based on the gap acceptance theory (FHWA, 2000). The total capacity is not the simple sum of the entry capacity or volume, because the entry flow is affected by the circulating flow and exit flow（Guo Ruijun, 2006). Based on above mentioned, the two capacities could be calculated on the operation of existing roundabout, also then the capacity's practicability becomes much less on side of the design and operation. The appropriate volume is put forward to replace the capacity based on the operation efficiency. In this paper, based on the field data at SHUMA roundabout which has four entries, the appropriate traffic under the various volumes was analyzed by using VISSUM simulation.

2 The Appropriate Volume

The operation of roundabout is not only affected by its geometric characteristics and operation rules, but also mainly affected by influence of inlet and outlet flow traffic distribution (Hanping, 2011, 2012). The traffic flow enters roundabout and becomes the circulating flow and exit flow, which also affected the entry flow for the weaving conflict. The sum of volume entering the roundabout is crucial and important to organization and design for less congestion and more efficient self-organizing. The efficiency of operation is used by the LOS generally. So the appropriate volume is defined as the sum of the entry volume based on the acceptable LOS.

3 Method and parameters

3.1 LOS criteria

The level of service (LOS) is a qualitative measure to characterize operational conditions within a traffic stream and their perception by drivers. Control delay is used to define level of service at intersections, as perceived by users. In addition to control delay, roundabout causes drivers to incur geometric delays which increase with the expansion of radius. In this paper, only the control delay is considered at the same roundabout, the level of service as followed (table 1) bases on HCM2000 (TRB, 2000). The level "E" could be perceived for drivers in the peak, so it is defined as the acceptable los for the roundabout and 50s is the max criteria.

Table 1. LOS criteria for un-signalized intersection

Level of service	Average control delay(s/veh)	Level of service	Average control delay(s/veh)
A	0-10	D	>25-35
B	>10-15	E	>35-50
C	>15-25	F	>50

3.2Field data

Field data was collected on SHUMA roundabout in Dalian by the manual and video survey in peak. The speed distribution is the normal distribution, the average is 4.95m/s(figure1). The volume distribution among the entries was analyzed as shown in figure2. The sum of entries volume is changing from 3700 to 4800 pcu/h.

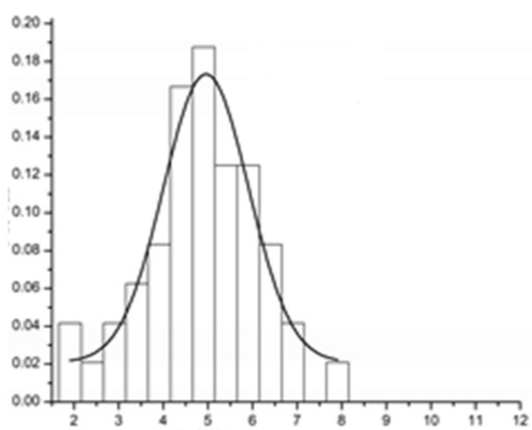

Figure 1. Speed distribution of the SHUMA roundabout

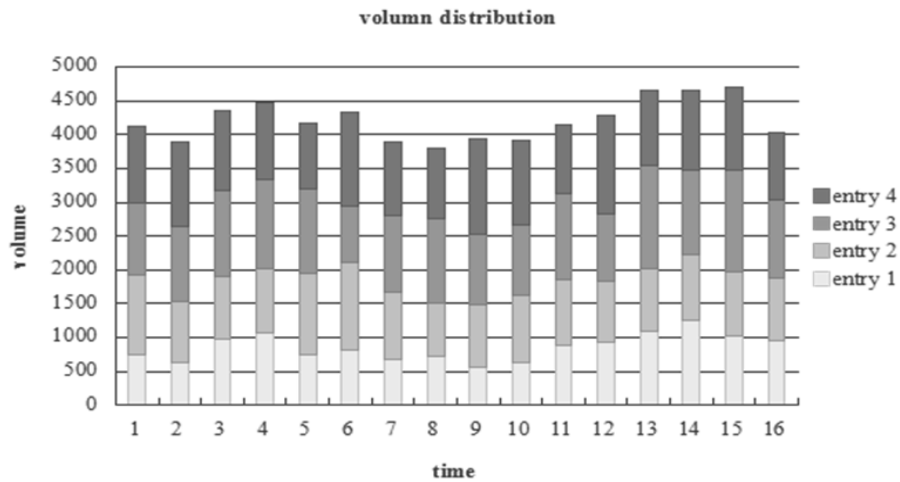

Figure 2. Volume distribution of entry of the SHUMA roundabout

3.3 Parameters in VISSUM soft

The VISSUM model (figure 3) was made according to the map on the video. The conflict rule was the priority of circulating and exit flow. The average speed was 18km/h and the sum volume changed from 1000 to 4500 according to the field data. The five volume distributions of entries were adapted based on the field data. The output of the delay was obtained three times every 500 increasing volumes.

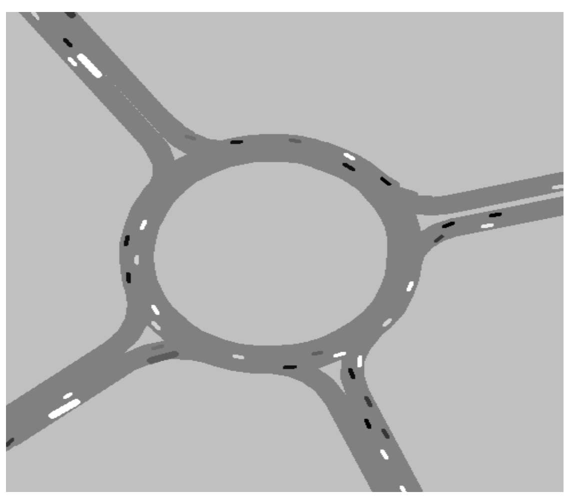

Figure 3. The VISSUM model of SHUMA roundabout in Dalian

4 Discussions of Results

4.1 Relation between volume and delay under the distribution 1:1:1:1

According to the output of VISSUM, the relation between sum of entries volume and control delay is analyzed as following.

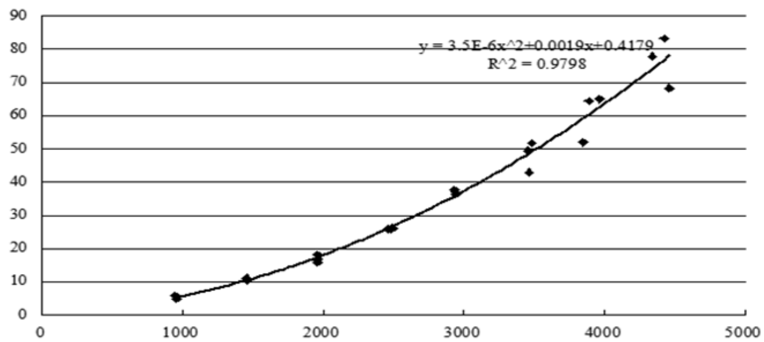

Figure 4.Relationship between the volume and delay on 1:1:1:1

$$y=0.0000035x^2+0.0019x+0.4179 \quad (1)$$

When the acceptable delay is 35-50s,the appropriate volume is 2903-3502 pcu/h based on the formula 1.

4.2 Relation between volume and delay under the distribution 1:2:2:2

When the distribution of the entry volume is 1:2:2:2, the figure 5 could be obtained by the output of VISSUM. We found

$$y=0.0000059x^2-0.0029x+2.7532 \quad (2)$$

When the acceptable delay is 35-50s, the appropriate volume is 2694-3086 pcu/h based on the formula 2.

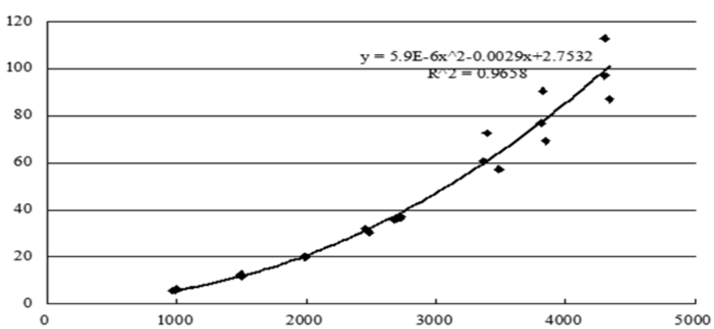

Figure 5. Relationship between the volume and delay on 1:2:2:2

4.3 Relation between volume and delay under the distribution 1:2:1:2

When the distribution of the entry volume is 1:2:1:2, the figure6 could be obtained by the output of VISSUM. We found

$$y=0.0000052x^2-0.0041x+5.156 \quad (3)$$

When the acceptable delay is 35-50s,the appropriate volume is 3018-3357 pcu/h based on the formula 3.

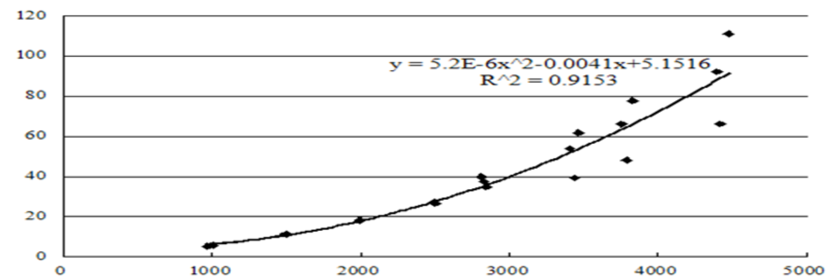

Figure 6.Relationship between the volume and delay on 1:2:1:2

4.4 Relation between volume and delay under the distribution 1:2:2:1

When the distribution of the entry volume is 1:2:2:1, the figure 7could be obtained by the output of VISSUM. We found

$$y=0.000005x^2-0.0028x+3.4193 \tag{4}$$

When the acceptable delay is 35-50s,the appropriate volume is 2940-3345 pcu/h based on the formula 4.

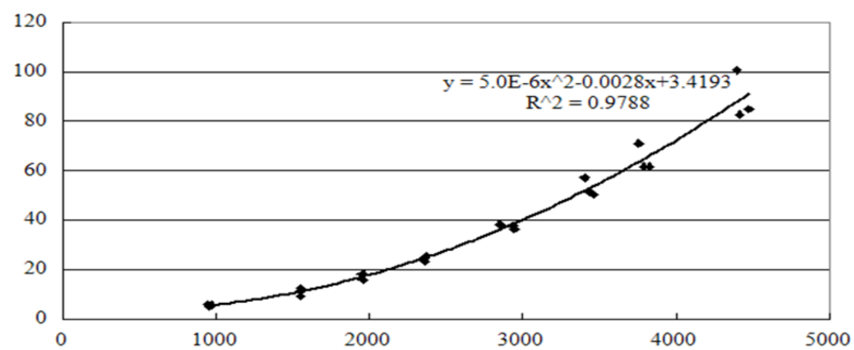

Figure 7.Relationship between the volume and delay on 1:2:2:1

4.5 Relation between volume and delay on the distribution 1:1:2:2

When the distribution of the entry volume is 1:1:2:2, the figure 8 could be obtained by the output of VISSUM. We found

$$y=0.0000049x^2-0.0018x+2.7455 \tag{5}$$

When the acceptable delay is 35-50s, the appropriate volume is 2863-3295 pcu/h based on the formula 5.

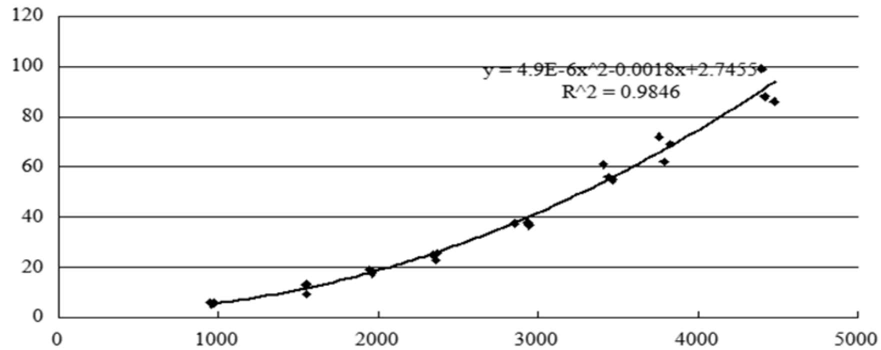

Figure 8. Relationship between the volume and delay on 1:1:2:2

5 Conclusions

Here we may draw the following conclusions.

(1) It is observed that the total volume of the roundabout is changing with the distribution of entry volume.

(2) It is also observed that the delay of the equilibrium distribution is minimum and total volume of the equilibrium distribution is maximum.

(3) It is also observed that appropriate volume of SHUMA roundabout is 2700-3500pcu/h.

6 Recommendations for Future Research

To explore the suitability of roundabout traffic under the condition of various distributions from the view of running efficiency will contribute to planning and design of the roundabout, and contribute to traffic organization in peak. The appropriate volume concluded was lower than the field data, because the VISSUM model based on the absolutely priority rather than sharing priority of field survey. In the future, the sharing priority and more distribution should be taken into consideration to obtain the more practical result.

References

FHWA 00-067, (2000) “4 Operation”, *ROUNDABOUTS: An Informational Guide 82-98*.

Gou Ruijun, WANG Yongliang (2006) A New Calculation Method of Capacity of Roundabout-Settled Proportion Interweave Section Volume Restrict Method, *Journal of Transportation Systems Engineering and Information Technology,* Bejing

Hanping (2011,2012) *Traffic Operation Characteristics of Roundabout.20-100*,JiLin A study on the attraction matrix of land-use on the roundabout.*WAC*

TRB(2000) "2-1 Capacity and level of service concepts" and "17-1 unsignalized intersections", *Highway Capacity Manual*.

Multi-Period Signal Control Methods at One Single Point

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Abstract: The multi-period signal control method at one single point is optimized. The changing situation of every 15 minutes in 24 hours of the different dates is analyzed, and the time division methods aiming at the different intersections and different date are studied. The control phase and phase sequence of traffic control in the different traffic operating characteristics are determined, and the corresponding determination methods of the red clearance time and the pedestrian green time are studied. By recording the control effect parameters on the existing scheme, the practical and easy establishment method of signal time scheme is studied, and the control model of the turning-right vehicle according to the existing standard is defined.
Keywords: Signal control at one single point; Multi-period; Control time division; Red clearance time; Control model of the turning-right vehicle.

1 Introduction

The current traffic signal control method usually divided into a single point of signal control, line coordinated signal control and regional coordinated signal control three kinds of control mode. Line coordinated signal control mode is mainly used in the range of main and minor road in cities. Its application scope is less, but plays an important role in the speed range of traffic; Regional coordinated signal control method at present is still in the theoretical research level. It has little actual application and the practice effect remains to be demonstrated. At present, the most of the road intersection is the single point of control mode. Along with the expansion of the city, single-point signal control intersections are increasing. Therefore, to improve the traffic capacity of urban road intersection, the primary task is to improve the traffic capacity of single-point signal control intersection.

Timing signal control is based on a single intersection's road conditions and intersection traffic flow and traffic direction to determine the signal timing scheme. Equipment requirement is simple, least investment and convenient maintenance is a kind of most basic control mode, the technical principle is the foundation of other control ways and has wide range of applications.

Timing control of single points' basic content including: control period, phase, phase sequence, the green light interval time, full red time, pedestrian green light time, turn right control mode and timing plan, etc.

2 Control Time Division

Along with the increase of urban traffic management pressure, extensive traffic management pattern has already could not adapt to the needs of traffic management. An elaborate traffic management needs to aim at different dates, (holidays and working days) and different times of the traffic running state, set different control objectives and adopt different traffic control strategy, to achieve targeted traffic management mode.

The signal control scheme of time division is to select 15 minutes during weekdays and weekends as traffic statistical units to calculate 24 hours flow. Through the analysis of traffic data, this method uses artificial judgment and the method of clustering analysis to determine the time division. Based on the selection of Jiaxing city, this paper focus on three typical intersections, which are the intersection of Zhongshan East Road-Zhonghuan West Road, central, Hexing Road-Zhongshan Road in central business district, Fanggong Road-Nanxi Road in peripheral city. Through the analysis of traffic data, divide the traffic control time of the weekday and weekend respectively.

2.1 Classification principles

Time division should follow the following principles:

(1) Hospitals with high trip attractions, the intersection time division around schools can be adjusted according to specific flow appropriate division.

(2) Same control area should take the same time, which is easy to take consistent traffic control strategy.

(3) Because controlling scheme needs 10 to 15 minutes to go on transformation process, division of time should guarantee the time interval in more than 30 minutes.

2.2 Workday time division

According to the 15 minutes of Monday to Friday road traffic data line chart, as shown in the figure below, for 24 hours a day, analyze traffic characteristics of each period to develop targeted traffic management measures.

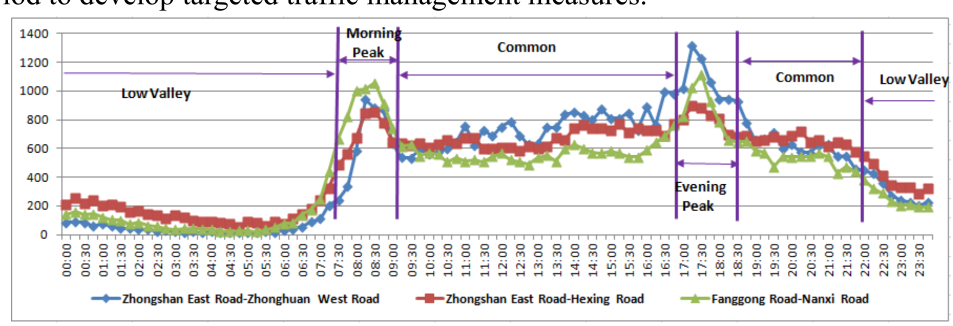


Figure 1. working day 15 minutes traffic flow line chart

Working days (Monday to Friday) classification results are shown in table below.

Table 1. working day (Monday to Friday) classification results

	Session name	Time frame
1	Midnight trough	22:00—07:30
2	Morning peak	07:30—09:00
3	Day time flat peak	09:00—17:00
4	Evening peak	17:00—18:30
5	Flat peak at night	18:30—22:00

2.3 Weekend time division

Use the 15 minutes flow line chart on Saturday and Sunday to compare with working situation. Fanggong Road-Nanxi Road 15 minutes traffic flow line chart at weekend are shown below. There was no peak in morning and evening rush hour traffic flow data and similar to working days flat peak period, which can adopt the same control strategy.

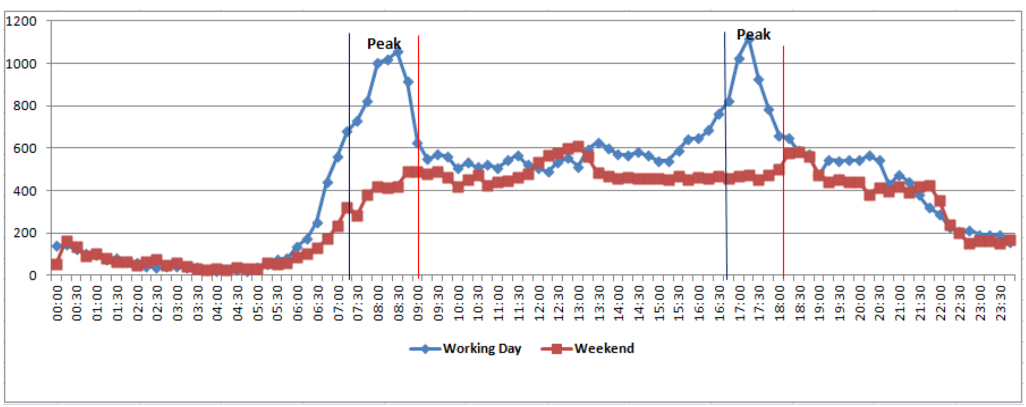


Figure 2. traffic flow line chart 15 minutes at the weekend

Weekend time division results have been shown in the following table.

Table 2. Weekend time division results

	Time frame name	Time frame
1	Low ebb	22:00—07:30
2	Plat peak	07:30—22:00

For weekend traffic flow concentration areas, commercial districts such as 15 minutes traffic flow analysis of Zhongshan Road-Hexing Road intersection, 07:45 08:45 session's traffic flow and working day flat peak period are on same level. 08:45-20:30 session's traffic flow is slightly higher than flat peak period and slightly lower than the rush hour on working day.

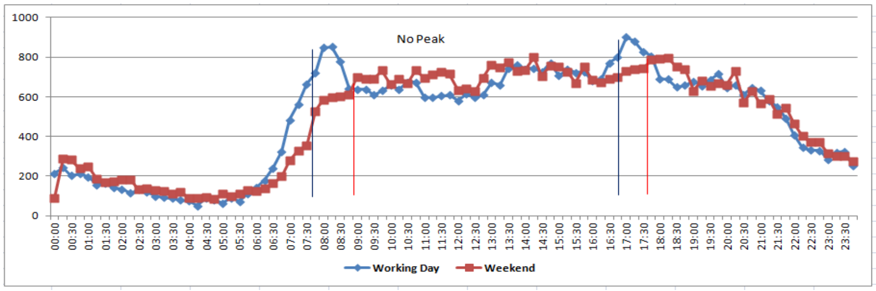


Figure 3. The15 minutes traffic flow line chart at weekend in business areas

Results of business area during the weekend are shown in the following table.

Table 3. Weekend time division results in business area

	Time frame name	Time frame
1	Low ebb	22:00—07:45
2	Morning transition section	07:45—08:45
3	Daytime peak	08:45—20:30
4	Night peak	20:30—22:00

2.4 System time Settings

According to the results of the time division, coordination scheme will be adopted during the beginning time 10-15 min in advance. In the process of transformation, green time and cycle is determined by the signal system. Artificial process is unable to intervene, which is often prone to a phenomenon that certain phase of green light time is too long or too short. When the phase difference is set, this phenomenon is more obvious. Domestic signal typically takes 3-5 cycle adjustment in place and needs 1, 2 cycles to dissipate the impact of the adjustment process. Specific operation is general proposal that start before the peak of the 10-15 min. Ensure that when peak time signal is coming, control scheme has been performed in place.

Implementation plan is that when there is a solution in the process of adjusting individual phase length too long or too short, the start time plan execution could be early or late for 1 minute. Then, observe the changes in the process of green time, which can effectively alleviate traffic impact of scheme transformation.

3. Phase scheme

3.1 Phase design

Phase designers design the first step of signal. Signal phase directly influences the operation of traffic flow operation's safety and intersection traffic capacity and determines the process of signal phase. In fact, it determines the different direction of vehicles or pedestrians' order allocation right of way. In the design of intersection signal timing, because the influence of left turn to traffic intersection operation is very large, in most cases the phase digits, the types of phase and phase sequence is often based on the requirements of left turn traffic flow.

(1) If left traffic flow is small, there is no need that each cycle has left traffic green time. It is reasonable to consider two cycles per running, which should be considered is that at the same time of left turn traffic queue time should not be too long.

(2) If the green light time of the opposite direction traffic flow is staggered, the system could start left green time early or late. The left turn vehicles go through the intersection before or after the opposite direction straight flow.

(3) As long as the traffic flow is not in line or takes traffic obstruction from vehicles with priorities traffic obstruction, it is suggested that give priority to two phase signal control method. The intersection traffic capacity can be the largest. The green light interval time needs for two phases combined less than three phases for the total green light interval time.

(4) On flat peak the intersection uses two phase control. At the peak it can be adjusted to four phase control, which could reduce the number of traffic conflict and improve the traffic efficiency.

(5) Part of the peripheral regions' signal intersection can be controlled by traffic lights during the day. When night traffic flow drops, it can be considered to adjust to the yellow flash control.

(6) Using the classic four phase control, when given symmetric direction's (south and north, east and west) the traffic flow is asymmetric phase, it can be considered to set the overlapping phase. Close the smaller flow early and open bigger flow direction early.

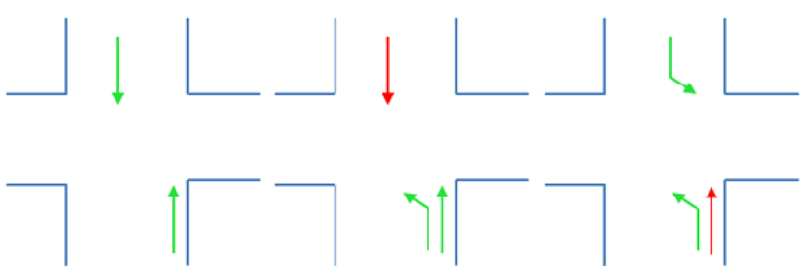

The traffic flow of south entrance driveway is more than the one of north.

Figure 4. Lap phase setting method

3.2 Determine the phase sequence

Phase and phase sequence design are very close to intersection traffic flow characteristics of each phase, the intersection of geometry and space design factors, etc. In the design of signal phase sequence, it is needed to follow the following principles:

(1) From the viewpoint of safety and efficiency, accord with the driving habits and help drivers to understand;

(2) At an import all the direction of the traffic flow release in the continuous phase;

(3) Set turn left waiting area and set straight phase before the left phase;

(4) When turn left queue length longer than left expand driveway, turn left phase should before straight phase to avoid straight lane was blocked by left flow;

(5) When the import or export direction exist bottleneck intersection, phase sequence should be redesigned or consider to run the phase import (export) the bottleneck section 2 times in a cycle. Raise the time utilization ratio of the bottleneck section.

4. The signal control parameters

Intersection signal control scheme including green light interval, full red parameters and pedestrian green time, etc. Finally timing scheme should satisfy the constraint conditions of these three parameters.

4.1 Full red time

The role of full red time is to ensure that, in the last 1 second yellow light, the vehicle come into the intersection can smoothly through the conflict point. In view of the common combination of three kinds of intersections' shape and control mode, the red light time setting is as follows:

(1) When using classic 4 phase, it delimits the left turn to the big crossroads. The conflict distance between turn left phase and straight phase is shorter, where should set 1s full red time after each straight phase.

(2) When two phase control is adopted, it is suggested to set 1 to 2 s full red time at the end of each phase, which is depended on the left turn traffic flow dissipation time.

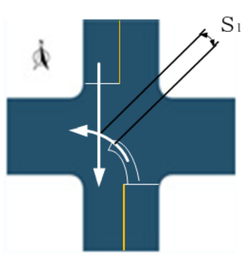
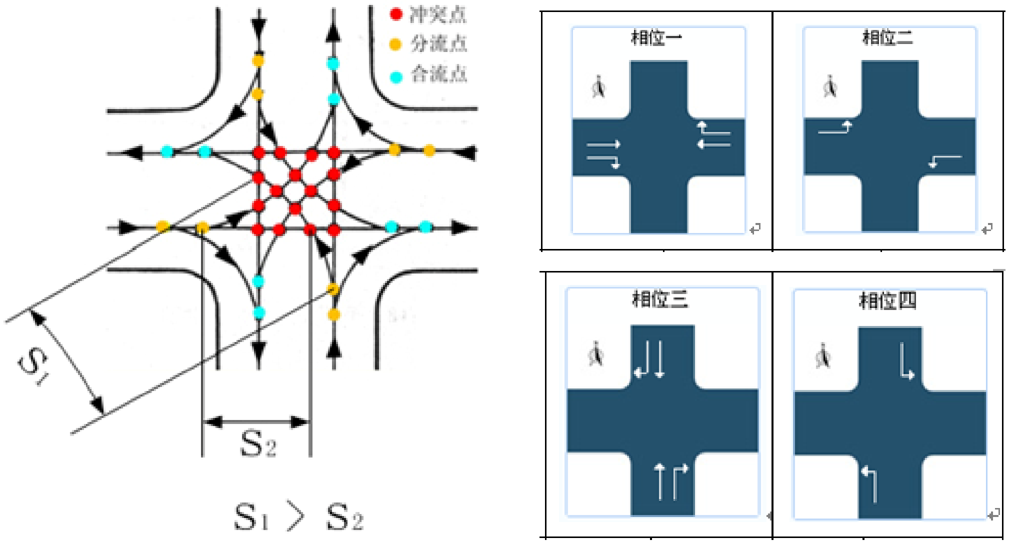


Figure 5. Left turn area conflict point distance

Figure 6. Conflict distance during phase control

(3) Using the classic four phase control, in view of the small corner (no turn waiting area), turn left phase and cross direction's conflict distance is short, should turn left at the end of each phase after full red set 1 second.



Note: S1 is when phase 3 transfers to phase 4, the distance between conflict points.
S2 is when phase 4 transfers to a phase 1, the distance between conflict points.

Figure 7. No left turn waiting area's distance between conflict points

4.2 The pedestrian green time

Motor vehicle shortest straight release time depends on the pedestrian minimum the green light time crossing the street. Pedestrian crossing time is calculated through the pedestrian crossing distance divided by walking speed.

Based on previous accumulation of multiple projects, the elderly, children's average walking speed is 1.0 1.2 m/s and adults' speed is generally 1.5 1.8 m/s. Generally, average pedestrian walking speed is from 1.2 to 1.5 m/s.

Pedestrian the minimum crossing distance usually could be the straight distance between sidewalks and motor vehicle non-motor vehicles separator. In special circumstances, it can be considered to use distance between 2 motor vehicle non-motor vehicle separators.

At present, traffic lights green generally follow the parallel direction motor vehicle lights to start. In the wide cross section road, pedestrian crossing needs a long time, which can be considered to open the traffic lights earlier. In parallel vehicle direction, the previous phase of straight phase (left phase of cross direction) is performing a tail lights that will turn on traffic lights early. Usually arrive 6 s early, namely green flash + yellow flashing time (3 + 3 s). Walking distance at least crosses the non-motor vehicle lane, right lane and a straight line. Walking distance is at least 9m and takes the maximum walking speed 1.5 m/s, which means the pedestrian arrival of the conflict point needs at least more than 6 s. Pedestrian green light turns on 6 seconds earlier, which can avoid motor and non-motor conflict and also can fully ensure the pedestrian crossing time.

5. Timing plan formulation

Single point optimization of intersection's the green time is to look at each phase's the status quo green time and to record the number of vehicles pass through. The presence of stranded vehicles or empty time is recorded

Optimizing green light time could through the following formula.

Optimal green time = green time at present + number of stranded vehicles * the headway

Or = green time at present - empty time

Each phase's green time after measuring is put into signal control system. After scheme's implementation is in place, the result can achieve the optimal by observing and measuring 2-3 times repeatedly.

Commonly used the headway parameter values is as shown below:

(1) Go straight's headway is generally 2s. When pedestrians and non-motor vehicles are crossing facilities, interchanges take 1.8s. Because in the intersection large cars have higher percentage, appropriate correction can be made according to proportion of large cars and large cars twice the parameters of the small cars.

(2) The average headway of turn left is 3.5-4 s.

(3) The headway of turn round is usually 3.5-4 s. When the head cars turn round and after cars turn left, there is 4 seconds time leading car effects following car, which are unaffected in the remaining time. The mixed lanes with higher percentage of turning vehicles could calculate the headway according to the proportion of the car turn round.

In jiaxing city's Zhongshan East Road – Zhonghuan West Road intersection, for example, after 4 times' adjustment, the final signal control plan was made, which is shown in the following table.

Table 4. Zhongshan east road signal timing scheme

Period of time		Phase sequence 1		Phase sequence 2		Phase sequence 3		Phase sequence 4	
	phase	Straight and right of east-west		Left of East-wes		Straight and right of south-north		Left of of south-north	
	Release direction	2，6		1,5		4,8		3,7	
	Cycle, time difference	min	max	min	max	min	max	min	max

Period of time		Phase sequence 1		Phase sequence 2		Phase sequence 3		Phase sequence 4	
Working day									
22:00—07:20	inductive control	16	40	16	24	16	40	16	26
07:20—09:00	C160，0s		48		32		45		35
09:00—16:50	C130，0s		40		24		40		26
16:50—18:30	C160，0s		48		32		45		35
18:30—22:00	C130，0s		40		24		40		26
Weekend									
22:00—07:20	inductive control	16	40	16	24	16	40	16	26
07:20—22:00	C130，0s		40		24		40		26

6. Right turn signal lamp control method

(1) At present, part of the city's right turn vehicles' releasing is following opposite direction's left turn and same direction's straight turn. Take the intersection of four entrances' south import as an example. The change of light has been shown in the figure below. In the entire process of signal transformation, the right direction indicator lights are never bright.

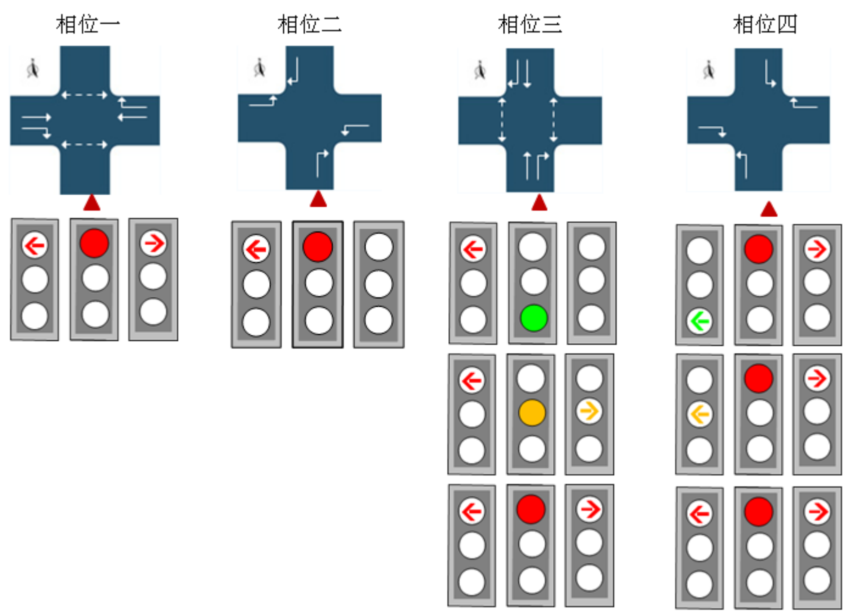


Figure 7. Traffic lights diagram of right turn vehicles release with left turn of opposite direction and straight of same direction

(2) Part of intersections with big right turn flow take a completely open right turn traffic control mode. Under the premise of avoiding pedestrian right turn vehicles run full-time. The following lights can be considered to set up. There is no need to set the right direction indicator lights.

(3) Right direction indicator's green light turned on only on the condition there is no motor vehicles and non-motor vehicles. Two kinds of circumstances are set which are setting stereoscopic pedestrians facilities or right turn vehicles release only on the left turn vehicles release.

7. Acknowledgement

This kind of signal control method is based on given the designated period of time and the arrival rate of default control period is the same. Reasonable design of signal control phase, control effect through the field observation of existing schemes and the real-time of green time adjustment, are used in several rounds of repeated optimization to get the best solution. Confirm that fully satisfy what class key constraints and form the final signal control plan. This method does not need an extensive investigation traffic data and do not need complex formula calculation. The operation method is simple, effective and easy for grassroots polices to adjust and optimize the intersection quickly.

References

C. J. Yu (2011). "Study on Evaluation Indicator Selection Method for Urban Road Traffic Management Level". *ICCTP (2011)*, Nanjing, China.

J. Lu (2013). "Study on Related Technique Standard of Road Traffic Signals". *Applied Mechanics and Materials*, 409-410(2013), 1057-1066.

J. Lu (2015). "Study on Cooperative Control Method among Large Flow and Long-distance Intersections". *Applied Mechanics and Materials*, 744-746 (2015), 2006-2011.

J. Lu (2012). "Study on Implementation Method of Left-turning Traffic Forbiddance Measure on Urban Road". *Applied Mechanics and Materials*, 178-181 (2012), 1729-1737.

J. Q. Wang (2013). "Study on Setting Method of Urban Expressway Exit Numbers". *ICTIS (2013)*, Wuhan, China.

Summarization of Analytic Studies of Bus IC Cards and GPS Data Integration

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Abstract: The analytic studies of bus IC card and GPS data integration belongs to the important part of Intelligent Transportation. It has much great development potential and brings much convenience and hitherto unknown change to transportation and planning. This paper analyses and summarizes the technical principle, the current situation of application, research status at internal and abroad of bus IC card and GPS data integration. This article points out the deficiency of the current studies and puts forward the direction of later research, application and development.
Keywords: Bus IC card; GPS; Data integration; Bus passenger information; Traffic management.

1 Introduction

Bus passenger flow information is the basis for transit planning, capacity allocation and real-time scheduling. Bus management is based on the flow information collection. The information provides reference for daily schedule and network optimization. Bus IC card records the information such as travel time and route of the passengers. Bus IC data is the analytical object, combines with other kinds of bus operation's schedule information, including routes, site layouts, bus schedules. With the help of date analysis, we can reduce complexity and improve the accuracy.

GPS data integration technology has the characteristics of all-weather, high precision and automatic measurement. As the advanced measurement method, GPS data has integrated into the national economic construction, national defense construction and social development of all application fields. GPS data integration technology in the field of traffic are mainly used in car navigation system, route planning, information search, emergency rescue, etc.

2 Analysis of Data integration principle and its merit and demerit

2.1 Bus IC card and GPS data integration principle

Bus IC card is refers to the integrated circuit card, it consists of large scale integrated circuit, and has the function of repeated access encrypted data. The Global

Positioning System uses GPS satellite, makes the real-time positioning and navigation come true.

The sites passengers get on, transfer or not and the sites passengers get off is the three key question of the IC card data analysis. We should filter and collect the raw data and set up a data storage at first, and according to the analytical content, we can extract relevant data sets to data query, analysis and data mining. The system architecture of Bus IC card data analysis platform is in the Figure 1 below.

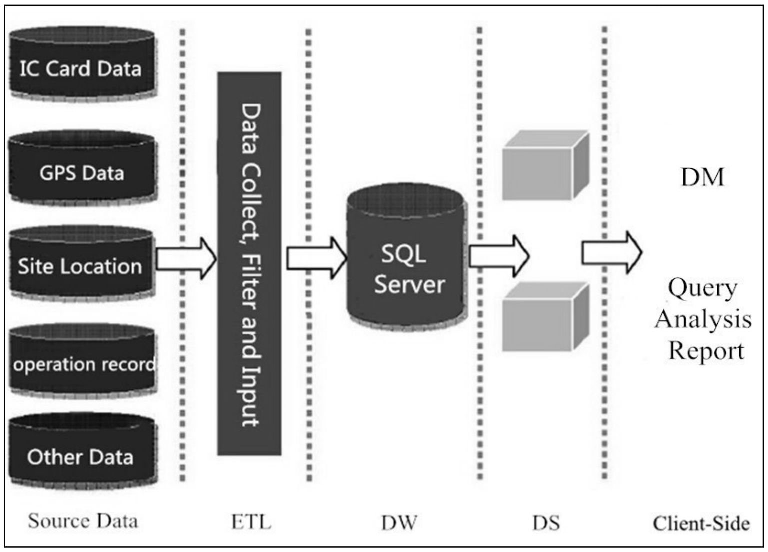

Figure 1. The system architecture of Bus IC card data analysis platform

GPS is a navigational system involves satellites and computers that can determine the latitude and longitude of a receiver on Earth by computing the time difference for signals from different satellites to reach the receiver. GPS system structure is as follows:

Space Segment: Composed of 24 GPS satellites, Each GPS satellite's signals are used for navigation and positioning, they launch navigation message constantly.

Control Segment: Consist of several tracking stations and monitoring systems in the global. According to their different roles, the tracking station is divided into the master station, monitor station and injection station.

User Segment: Consist of the GPS receiver, data processing software and the corresponding user equipment. Its function is receive GPS satellite signals, and use these signals to navigation and positioning, etc.

2.2 Merit and Demerit analysis

2.2.1 Merit and Demerit analysis of Bus IC card data integration technology

Compared with the traditional bus data investigation method, analysis method of the bus IC card data has the following advantages:

(1) Large sample size

(2) Continuous recording of samples

(3) Acquisition cost is low
(4) Data processing can realize automation

Although the method has many merit, but there are also some demerit:

(1) Due to the lack of bus passengers' personal attributes, it can't associate the travel behavior characteristics and passengers' personal attribute together.
(2) Bus IC card data can't get users' evaluation of the system service level.
(3) Bus IC card data can't fully embody all the bus passengers' characteristics
(4) IC card don't record the start sites, so the data can't show the passenger flow volume of each site directly.

2.2.2 The characteristics of GPS data integration

(1) All-weather positioning in the world
(2) High positioning accuracy
(3) Short observation time
(4) Without the visibility between stations
(5) Instrument is easy to operate
(6) Can provide three-dimensional geocentric coordinate globally
(7) Widely application
(8) Drawback of GPS system:

Some questions like the electromagnetic interference of the city, signal reflection, building block signals still need to solve. Blocking satellite signals leads to positioning misalignment, which is the GPS's deadly weakness.

3 Research Status

3.1 Overseas Research Status

Foreign study of data integration of bus IC card can be divided into the following several aspects:

3.1.1 Intelligent bus data integration

Department of Transportation of Florida set up ADAMS（APTS Data Archiving and Mining System）in 2007. It's a part of the intelligent transport system of the research plan. ADAMS use the data of AVL(Automatic vehicle location), APC(Automatic Fare Collection) and EFC(Automatic Passenger Collection). It takes the advantages of the business intelligence technology, set data warehouse and analytical model.

3.1.2 Bus transfer problem

Markus Hofmann studied transfer behavior of passengers in 2005, and he divided all the passengers into single travel and transfer travel. He used the iterative classification algorithm to judge the transfer's assumption continuously.

Ka Kee Alfred Chu took the Gatineau for example in 2008, he used the relationship of twice travels' time and space to judge travel records, and confirm the transfer records.

3.1.3 Bus transit OD prediction

Janine M.Farin took the St. Paulo's data for example in 2006, he calculate buses' OD Matrice between every traffic zone. The research uses the AVL system data to judge the site which passengers get on the bus, and make them the start point of travel. On the basis of two hypotheses below, we can calculate the origin of each trip.

(1) A travel destination is the start point for next trip.

(2) The destination of last trip always end up with the first trip on the same day.

3.2 Domestic Research Status

With the wide implementation of bus IC card system, our country also started the research of data mining. Zhang Wei proposed to use buses' GPS and passengers' IC card information to obtain the buses' OD amount.

About the data integration, Wei Yun introduced a bus regional scheduling method to solve the problem of real-time monitoring to operating vehicle With the help of GPS PPP(Precise Point Positioning), we can improve the accuracy.

4 Research Summary

4.1 Overseas Research Summary

(1) Foreign bus card develop to involve crossing transportation and other businesses. Data analysis includes four aspects: intelligent bus data integration, determine bus transfer, calculate bus OD matrices and analyze the characteristic of the bus passengers' behavior.

(2) The United States, Britain and other developed countries use the technology of traditional bus and subway site to take sampling survey for OD has been relatively mature.

4.2 Domestic Research Summary

4.2.1 Bus IC card research summary

(1) There is little research that is application of actual data in our country, we lack of deep research for intelligent transport system data storage, cleaning, mining, operation and other problem.

(2) There was some differences of internal and overseas intelligent transport system. We haven't analyzed the applicability and accuracy of clustering method of getting on site.

(3) Domestic transit OD prediction research is the OD calculation between sites on a single line. There is no related research of bus network level OD prediction problem.

(4) In the aspect of determining passengers' sites, we have the judge method based on the site which passengers get off the bus. By analyzing the individual credit data, the results are accurate, and we can get passenger's bus travel path. The analysis of characteristics of urban public transit has very important significance.

Overall, the bus IC card data analysis technology is a new research field both at home and abroad, the theory and method are still not mature.

4.2.2 GPS data integration research summary

(1) Traffic data collection and management. GPS should equipped in the City cars, the management's system can collect each hour's traffic flow of any road, and these accurate data is the basis for traffic management and planning.

(2) GPS joint map matching technology to provide real-time scheduling method for traffic controllers. Enable the regionalization of bus dispatching. But to display and map matching has larger error.

(3) Use GPS to help bus operation scheduling can solve the problem of vehicle real-time information collection. Through real-time adjust the frequency, can not only decrease operating cost, but also improve people's satisfaction.

5 Future Direction

(1) Adopt a new data fusion technology or a new model to determine the passengers' get-off site.

(2) By bus IC data analysis, we can grasp the nature of the urban land, function layout, climate characteristics, passengers' travel purpose, travel distance and social characteristics.

(3) Bus IC data analysis needs further study on the data warehouse construction method and get-on or get-off site judgment method.

(4) The combination of GPS data integration and GIS

(5) Higher levels of survey technology

(6) GPS data integration application of dynamic differential GPS.

6 Epilogue

Bus IC card record the important information of the bus passenger flow. Based on bus IC card data mining and combined with the corresponding data of the model calculation, we can get many important data from public transport planning, the capacity allocation and real-time scheduling.

GPS data has the characteristics of all-weather global positioning, higher positioning accuracy, short observation time, without the visibility between stations and widely used, which makes GPS data integration become advanced measuring method and the new productive forces.

This paper analyzes merit and demerit of the bus IC card and the GPS data integration technology, and also introduced the use in the field of transportation. This article summarizes the two kinds of data integration technology research status, research deficiency and the research direction.

References

Chen Xuewu, Dai Xiao and Chen Qian. (2004) "Bus IC card information collection, analysis and applied research.". China Civil Engineering Journal. 37(2)

Chen Qian, Chen Xuewu and Wang Wei. (2003.5) "City information collection of the urban intelligent bus.". Urban Public Transport.

Chen Shaohui. (2005) "Based on GIS platform, road vehicles' OD data analysis system.". Chang'an University."The application of IC card and international standards." http://yicard.com.

The Design of a U-Turn Lane Right Set and Its Control Mode at an Intersection

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Abstract: Aiming at the problem of low efficiency and poor security of u-turn traffic at intersection, the project carry out an analysis of operation characteristic, conflict and design on u-turn traffic, and take the u-turn traffic conflict and influence factors in consideration. For an actual signalized intersection, we design a scheme of u-turn lane right set, and give the corresponding traffic signal control mode, which effectively avoids four kinds of conflict between u-turn traffic and other traffic in time and space, and improves the efficiency and safety of u-turn traffic. Finally, operate the status quo intersection and designed intersection with VISSIM based on actual survey data of the intersection, and collect corresponding traffic data to analyze traffic evaluation. Result shows that, the implementation of u-turn lane right set and the improvement of control mode can effectively avoid conflict points between u-turn traffic and other traffic; delay time, stop time and queue length have been reduced significantly, and traffic flow capacity at intersection has also been greatly improved. In the field of traffic engineering design, it is worthy of in-depth study and innovation on right set of u-turn lane.
Keywords: U-turn lane; Right set; Control mode; VISSIM simulation.

1 Introduction

The intersection is where the bottleneck of traffic network located. According to statistics about 80% of the traffic delay and congestion occurred in the intersection. As one of the common running forms of urban vehicles, u-turn traffic at intersection is one of the influencing factors which can not be ignored.

Aiming at the design of u-turn lane, there are mainly three kinds of design patterns: u-turn in the internal intersection, u-turn in front of the stop line, u-turn at the transition section of the inlet channel. It is more based on engineering experience when setting u-turn lanes in the domestic, and there is no content about u-turn lanes setting in road design standard. In US Highway Capacity Manual in 2000, u-turn vehicles are regarded as left-turn vehicles to estimate saturation flow rate of traffic flow. However the running state of u-turn vehicles and left-turn vehicles are different. The foreign research on u-turn traffic at signalized intersection is mainly discriminated by historical accident data based on MUTCD. The related research includes the internal conflict points and what affects left-turn traffic has on u-turn traffic. But the research mode is single, at the same time it takes less pedestrians and non-motor vehicles for consideration.

As can be seen, the current design of the u-turn lane is lack of system, inefficient and poor safety.

2 The text part

2.1 Design ideas

Aiming at the problems of low efficiency and poor security of u-turn traffic at intersection, this project carry out an analysis of operation characteristic and conflict on u-turn traffic. And for an actual signalized intersection, we design a optimal design of u-turn lane right set, and give the corresponding traffic signal control mode. This design can not only increase the turning radius of the u-turn vehicles to ensure the efficiency of u-turn traffic, and also can effectively avoid conflict points between u-turn traffic and other traffic.

2.2 Design analysis

2.2.1 Analysis of operating characteristics

We analyze the characteristics of u-turn traffic at intersection from 2 aspects: traffic efficiency and security. Traffic efficiency is mainly reflected in time that u-turn traffic pass through intersection, while safety is reflected through conflict points.

At the intersection, the radius of u-turn vehicles is less than the radius of left-turn and right-turn vehicles. The vehicle speed is relatively slow, and it is vulnerable to be interfered in internal traffic at intersection. If u-turn vehicles pass through the intersection with low efficiency, it will directly reduce the efficiency of inlet and outlet channel. If u-turn vehicles and left-turn vehicles share one lane, it will cause great restrictions on left-turn vehicles that follow u-turn vehicles, and even cause serious queue in left turn road.

At general signalized intersection, u-turn vehicles usually share one lane with left-turn vehicles, and it make use of left-turn temporal gap to achieve u-turn. There are conflicts with other traffic, and the diagram of conflict analysis is as Figure 1.

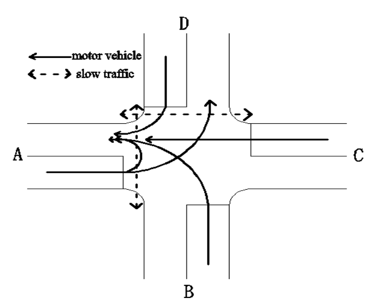

Figure 1. Conflict analysis of U-turn traffic at intersection

There are multiple conflict points in Figure 1 between an import u-turn traffic and the following traffic: (1) respectively other motor vehicles: left-turn traffic (diversion point with left-turn traffic of A and confluence point with left-turn traffic of B), straight traffic of C, and right-turn traffic of D; (2) conflict points with the bicycle, pedestrian traffic.

2.2.2 Influence factors

In the optimal design of u-turn lane at signalized intersection, we need to consider the following influence factors:

(1) Type of u-turn vehicles: The structure and operating characteristics of vehicle will affect its u-turn performance, such as turning radius and speed. So it's necessary to take the composition of traffic flow models in consideration to design.

(2) U-turn space: It refers to the space range that u-turn vehicles run. Whether there is hard isolation or green isolation in the center road has an important influence on u-turn time and space. It would obstruct the vehicles in the opposite if the exit lane were occupied. So we should try to reduce the number of occupied exit lanes.

(3) U-turn Lane sharing: It will cause a lot of restriction or queue on left-turn vehicles that follow u-turn vehicles. So if there are too many u-turn vehicles, we should try to separate out a u-turn lane.

2.3 Design scheme

According to a junction in Jin Zhong city, as shown in Figure 2 is the intersection of Zhong Du Road and Shun Cheng Street which is T type. In the status quo, there are fences on Zhong Du Road and Shun Cheng Street, and there is no u-turn opening on the road. There are many shops and offices on both sides, so it exits a lot of u-turn demand. And it has great influence on traffic efficiency of the whole intersection. So, this intersection design is optimized based on u-turn traffic, and we give the channelization design and signal control scheme.

2.3.1 Traffic channelization design

It should take the running orbit of u-turn traffic and import channel, median strip and export channel in consideration on design of u-turn traffic at intersection.

(1)Through the investigation of the status intersection, the u-turn vehicles at intersection are mostly compact cars. According to Table 1, the turning radius of the cars' axle should be no less than 6m. Because there is no hard isolation in middle of the road and the width of status lane is 3m, the u-turn lane needs to be right set at least two lanes in order to make u-turn vehicles use the inside lane of the export.

Table 1. Table of u-turn vehicles radius

Vehicle type	vehicle length /m	Wheelbase /m	Shaft radius /m	Moving radius /m
Standard car	4.9	3.35	5.8	7.3
Heavy-Duty Vehicle	12	7.32	12.4	13.7

(2)In order to reduce delay caused by shunt between u-turn vehicles and left-turn vehicles in the same direction on Zhong Du Road, we need channelize u-turn lane and left-turn lane separately, and set a u-turn lane alone.

(3)Reducing traffic conflict between u-turn traffic and left-turn traffic, right-turn traffic: In order to make the u-turn vehicles enter the inside lane of the export, we make the separately designed u-turn lane right set on Zhong Du Road.

(4) Reducing conflict between u-turn traffic and slow traffic: There are fences on pedestrian trails in the status, so pedestrian cross the road mainly through the underground passage, which can effectively avoid collisions between pedestrians and u-turn traffic. However, there are still conflicts between non-motor vehicles and u-turn traffic. This design will put the stop line in import backwards in order to avoid such conflicts. The concrete backwards distance should be no less than 7.3m according to moving radius in Table 1.

(5)In order to ensure u-turn vehicles pass the intersection orderly, we design guide line for the u-turn lane in north and east.

In accordance with the design ideas above, the design of traffic channelization is shown in Figure 3.

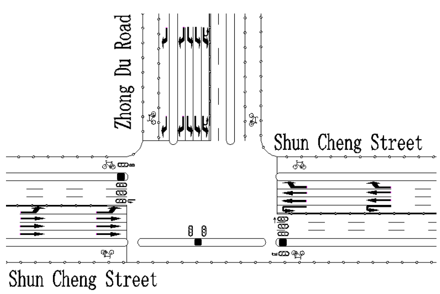

Figure 2. The T intersection of Zhong Du Road and Shun Cheng Street

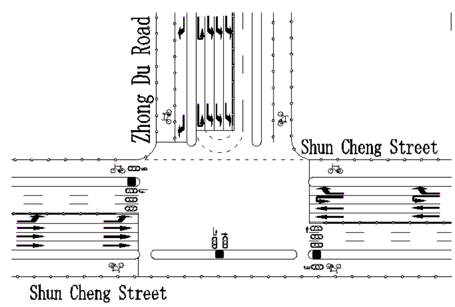

Figure 3.Optimal design of channelization at intersection

And lane channelization sign should be placed in the east side and the north side after 60-80 meters away from the stop line. The layout diagram is as follows:

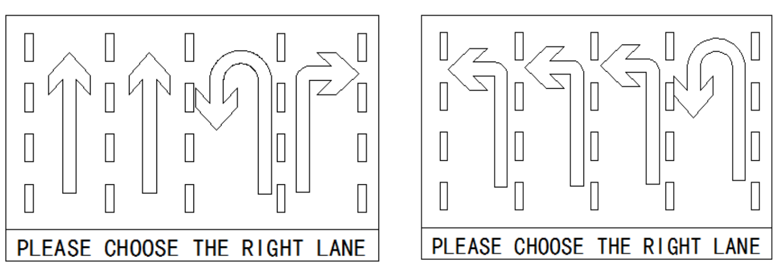

Figure 4. The lane channelization sign on east and north side

2.3.2 Design of traffic control scheme

It can effectively avoid the conflict points of traffic flow through the traffic signal scheme from the time, such as conflict between u-turn traffic on east and straight traffic on west, and conflict between u-turn traffic on north and left-turn traffic on west. The designed signal control scheme of the intersection according to status traffic flow is as follows:

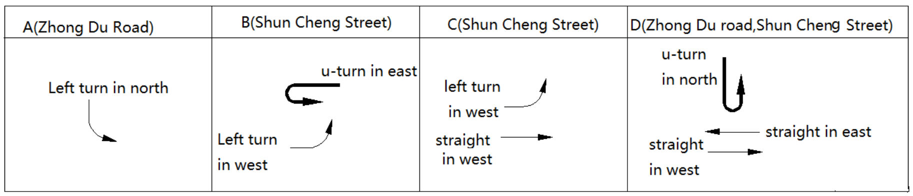

Figure 5. Diagram of intersection signal phase

2.4 VISSIM simulation

Verify the program by VISSIM: First, we should build status intersection simulation on the basis of actual survey data. Then make the simulation comparison with the designed intersection scheme, and analyze the data.

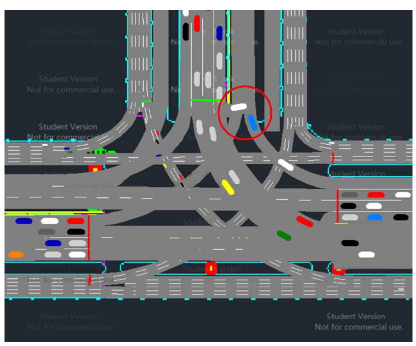

Figure 6.Status simulation

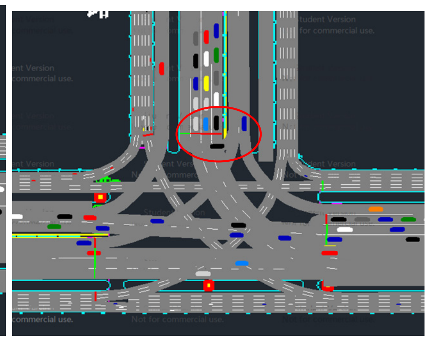

Figure 7.Optimized simulation

As can be seen in Figure 6, because the need of turning radius, the u-turn vehicles on north would access to the outermost lane of the export. And it causes great delay of right-turn vehicles on east. However after u-turn lane right set, as in Figure 7, these two kinds of traffic conflict have been well settled.

Taking advantage of designed traffic control scheme, but maintaining the same cycle of status, we respectively collect status and designed simulation data during peak period and flat period. And traffic evaluation data on u-turn lane on north, right-turn on east and left-turn on west is respectively compared as follows:

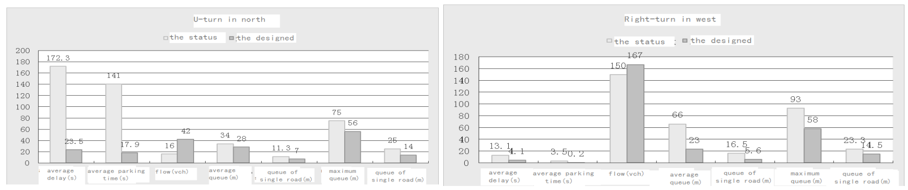

Figure 8. Traffic evaluation data under flat periods

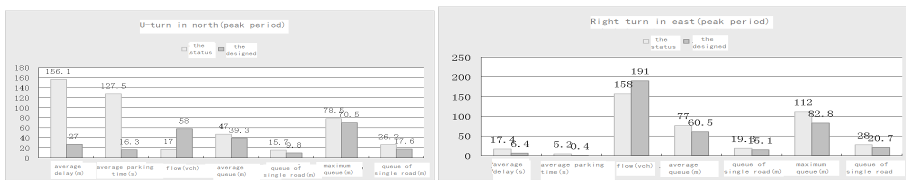

Figure 9. Traffic evaluation data under peak periods

As can be seen from the above figures:

(1)The design virtually eliminates the conflict between u-turn traffic and straight traffic, conflict between u-turn traffic and left-turn traffic (on the north and west side), conflict between u-turn traffic and slow traffic from space and time;

(2)U-turn traffic has been prevented from right-turn traffic. Compared with operating data of current situation, the delay time, stop time and queue length have been obviously reduced, and the traffic flow capacity has also been greatly improved;

(3)Comparing the data in the flat period and peak period, we can see the designed scheme can still work well, and the efficiency of current situation traffic has been greatly improved.

3 Conclusion

Aiming at the problems of low efficiency and poor security of u-turn traffic at intersection, we design a u-turn lane right set and make a simulation by VISSIM software. The result shows that the optimal design has a good sense of the promotion. It has a good reference of the intersection with a lot of u-turn demand but with no central isolation. And it also has a strong reference in the design of other type of intersection or left-turn lane right set. For example, the left-turn lane can be right set in oblique cross to increase the turning radius in order to ensure the security and efficiency of traffic. So, the research of lane right set is still worthy of further study.

Acknowledgement

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Reference

CHEN Kai, ZHANG Ning, HUANG Wei. (2006). Considering of the Application Research of Indirect Left Turn with U-turn at Intersection. *Journal of Transportation Engineering and Information*.4, 4, 82-86.

Lu, J., Dissanayake, S., Xu, L.,& Williams, K. (2001). Safety evaluation of right-turns followed by U-turns as an alternative to direct left turns: *Crash data analysis*. Florida Department of Transportation, Tallahassee.

WANG Tao.(2014).Analysis and optimization of factors affecting the U-turn intersection traffic. *Construction Science and Technology*, 14, 89-91.

ZHANG Bin, LI Wenyong, CHEN Xuewu.(2005). Analysis and Simulation of the intersection capacity after practicing one-way road traffic. *Road Traffic & Safety*, 23, 3, 52-55.

ZHANG Hailei.(2009). Study on U-turn traffic design in signalized intersection. *Road Traffic & Safety*. 6

ZONG Erkai.(2012). Research on capacity of left-turn lanes at signalized intersection. *Beijing University of Technology.*

Specification for the Construction of Traffic Information Backbone Network Interconnection

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Abstract: In this paper, study report and solutions of the interconnection and interworking of voice, video and data transmission of traffic network nodes in Jilin Province by researches on network construction of transport sectors and the visiting and investigational study of relevant network equipment manufacturers and operators in Jilin province are carried out. On this basis, technical standards of Jilin traffic information backbone network construction, traffic communication information transmission including network data, voice and video, grading protection construction of traffic information network security, construction standards of traffic information network IT room, and test standards of traffic information network acceptance have been developed. The study aims to promote the construction of Jilin traffic information network and network security level, and improve the efficiency of its transportation network interconnection, network construction and operation and maintenance from the perspective of technical support, playing an exemplary role in traffic information backbone network interlinking of other provinces and regions.
Keywords: Traffic; Network interconnection; Technical standards.

1 Significance

It aims to achieve standard system of traffic informatization according to the Five-year Development Program of Jilin highway and waterway transportation informatization. It provides a unified standard for booming construction of traffic information network of units around China nowadays, to achieve the goal of provincial bureau and city bureau proposed for the interconnection and interworking of traffic information network. Moreover, it standardizes communications of networks, and ensures effective communication among traffic backbone networks, in order to allow traffic informatization to play its due role in decision making and management at all levels of transport administrative sections.

2 Research process

(1) Survey of network construction of Jilin transport sectors

Combined with the existing network construction of all traffic departments in Jilin Province, investigation and survey has been thoroughly conducted on network construction of various sectors by the questionnaire of provincial transportation affiliated units, and site visit and study has been carried out on provincial affiliated units. Drafting group went to Jilin Province Transport Authority, the Authority of the provincial bureau, Jilin Highway Bureau, Metropolitan Transit Authority, Transit Authority and units directly under to investigate, and visited their computer rooms, toll stations, overload control stations, and passenger stations, following the presentations and recommendations of Information Centers of regional units for network construction.

(2) Research on network equipment manufacturers and ISP operators

Drafting group carried out detailed investigation on device manufacturers, operators. On one hand, they knew the most advanced communication equipments and relevant technology products from equipment manufacturers. On the other hand, they understood equipment room constructions and equipment usages from operators, providing great technical support for the establishment of this standard. Specification drafting group referred to a lot of technical information and relevant norms of our country, industries and regions, with discussion during the conference and in-depth communication with traffic information centers of other provinces, and exchanged work experience on network building mutually, to determine the framework of Jilin Province transportation information backbone network interconnection regulatory.

(3) Develop of Security Standards of Jilin transportation industry and traffic information backbone network interconnection construction

Safety standards of Jilin transportation industry have been developed through researches on units in other provinces which have undertaken informatization level safety construction of transportation departments, and reference to Jilin level security standards. According to needs and requirements of Jilin highway and waterway transportation informatization and relevant researches, specification drafting group determined a number of contents including Jilin traffic information network structure and network technology, network security, the level of information protection. By building a network simulation environment, the interconnection and interworking of voice, video and data transmission of traffic network nodes in Jilin Province have been achieved and feasible report and appropriate solutions have been proposed. After needs analysis, field research, checking and experiments, drafting group prepared rough draft of norms initially. In addition, experts were organized for consultation and demonstration, to further improve the specification, making it a formal exposure draft. The draft was sent to all levels of network nodes in provincial transport sectors for technical feedback and suggestion from various units. The technical standards after feedback were demonstrated, organized and improved again, to prepare system documentation of "construction norms of traffic information backbone network interlinking in Jilin Province".

3 Main content

The system documentation of "construction norms of traffic information backbone network interlinking in Jilin Province" is composed of five parts, involving the technical standards, construction standards and acceptance test standards, such as to form multi-level polyhedral vertical structure (see figure 1) :

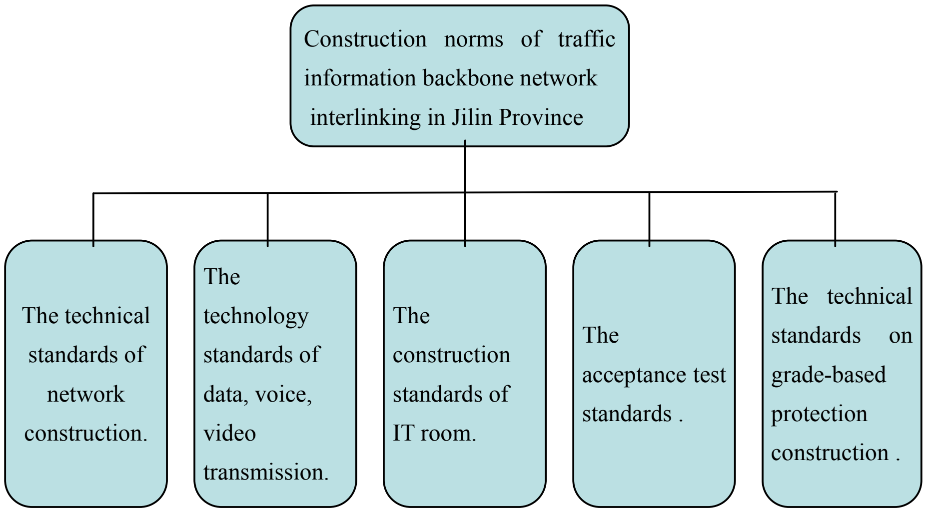

Figure 1 the structure of the system documentation of "construction norms of traffic information backbone network interlinking in Jilin Province"

(1) The development of technical standards of Jilin traffic information backbone network construction

Develop applicable scope, technical route and definition explanations of norms. Standardize guiding principles of network construction, the basic process and traffic information backbone network bandwidth and equipment standards, and prepare IP addresses and domain plans.

(2) The development of technology standards of Jilin traffic information communication network data, voice, video transmission

Data transmission technology standards standardize network selection, network interface devices, network switching equipment, and network server on network platform, with regulations on the selection of network storage devices, and specifications on network generic cabling and network security platform. Voice technology standards standardize basic technologies, protocols and standards and functions of Voice of Internet Phone (VOIP). Video technology standards standardize basic provisions and main technical indicators of video surveillance services. Transmission methods and technical standards of wired and wireless signals, construction standards of multimedia services have been also regulated.

(3) The development of construction standards of Jilin traffic information network IT room;

Formulate standards on the building, environment, UPS, air conditioning systems fire control, lightning in computer room.

(4)The Development of acceptance test standards of Jilin traffic information network;

Develop standards on test range, test methods, test items, performance testing requirements, and test documentation requirements.

(5) The development of technical standards on grade-based protection construction of traffic information network in Jilin;

Standardize security assurance level and grading methods of information system, basic requirements for all levels, basic principles and process of hierarchy protection on information system, as well as engineering management of information system security.

4 Popularization and application prospects

This standard is applicable to information network construction of Jilin Department of Transportation, city (state) Department of Transportation and ministry units directly under. Units directly under district-level or county-level transportation departments can also implement the standards. Results of this specification can guide the province's transportation and communication information network construction into normal construction, so as to improve the efficiency of interconnection, network construction and operation and maintenance of transportation departments in the province.

Results of this specification can enhance application scope of traffic information network, network construction, and ensure the scientificity and consistency of network construction, so that the interconnection and interworking of traffic information network among units in the province can be achieved, to play its role in the protection of the network infrastructure of traffic information data transmission, and a crucial role in emergency treatment and disposal of abrupt environmental accidents. At the same time, it also provides as a basic platform for unified and efficient supervisor-subordinate information sharing of transport sectors.

This specification determines the technical standards for security assurance level of Jilin traffic information systems, serving as reference bases of security assurance level construction of each network node in transport sectors of the province, to avoid the duplication of grading, high grading standards and other issues, while saving a lot of funds in safety grade construction.

Results of this specification can provide technical support to promote the Jilin traffic information communication network construction and network security level construction, making reference to interconnection construction of traffic information backbone network for other provinces and regions.

References

Acceptance specification for environmental information network (HJ 725-2014),the Ministry of environmental protection

Information security technology Classification guide for classified protection of information system (GB/T 22240 - 2008), the people's Republic of China National Quality Supervision and inspection and quarantine

Information security technology Baseline for classified protection of information system (GB/T 22239 - 2008), the people's Republic of China National Quality Supervision and inspection and quarantine

Information Security Technology Guide of Implementation for Classified Security Protection of Information System (GB/T25058-2010), the people's Republic of China National Quality Supervision and inspection and quarantine

Specification for environmental information network building (HJ460 - 2009),the Ministry of environmental protection

China Railway Special Line Information Management System Framework Design

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Abstract: This article describes the problems of railway special line management; put forward the idea of establishing an information management system to standardize the management of railway special line; analysis the demand of special line information management system in security management, operation management and other aspects of daily operations; according to the system functional demands, appropriate discussion are made to obtain the system functional framework, logical framework and physical framework.
Keywords: Special lines; Information management system; Framework design.

1. Existing problems of railway special lines management

Railway special line is designed to serve the industrial enterprises and other units of rail transport facilities. As an important part of the railway network and freight, the special lines play an important role in China's railway freight transport. However, many problems are existing in China's railway special line management, which are seriously affect the transport efficiency and safety, mainly in the following aspects.

Table 1. Existing problems of special line management

Special line management problems	The main performance of the problem
Security Management Problems	1.1 Policy cannot be executed leads to human negligence 1.2 The aging of equipment leads to overload and partial load; 1.3 The lack of on-site monitoring equipment and emergency rescue plan;
Operations Problems	2.1The truck stop time is too long to lower the work efficiency; 2.2 The lack of shunting system leads to take longer delivery vehicles work time; 2.3The loading and unloading machine is generally obsolete which leads to lower efficiency;
Property management Problems	3.1 Illegal conduct of special lines affect the safety of transportation; 3.2 The change of property right can not be recorded promptly, which resulting in unclear responsibility for the accident.
Management systems are not compatible	4.1Mutual exchange of information between special lines and local railway bureau is difficult to achieve.

Those problems mentioned above resulting in improving transportation costs and the responsibility for accident is unclear, etc. It is necessary to establish an information management system that promotes special line to rail freight yard line, standardization and institutionalization. With the application of this system the efficiency and safety of special line transportation can be improved, in which way the special lines could make its due contribution to national economic development.

2. Demand and function analysis

2.1 Special line information management demands analysis

Special Line Information Management System is a multi-system, which can complete various functions to maintain efficient operation of a special line, in general, there are daily operations management demands, operation security demands, customer management demands, property management demands. Specific demands is shown as below table 2.

Table 2. Special line information management demands analysis

Functional demands module	Demand for specific content
Daily operations management demands	1.1 The demand of vehicle arrival prediction and confirmation timely delivery; 1.2 Shunting operation demands; 1.3 Detection work demands; 1.4 Statistical operations demands; 1.5 Resource management operations demands.
security demands	2.1 Working field real-time monitoring demands; 2.2 The demand for establishment of the emergency rescue plan; 2.3 Equipment safety testing demands.
Customer management demands	3.1 Statistical and analysis of traffic volume demands; 3.2 Safety assessment demands.
Property management demands	4.1 Property right management demands; 4.2 Online processing demands.

2.2 The function analysis of dedicated line information management system

According to the above knowable, we can get design of information systems function modules as follows based on causal method.

Table 3. Special line information management functions analysis table

Modules	Functions
Operation Management Module	1.1The establishment of information exchange network; 1.2 Function of efficient organization of vehicle sheeting; 1.3 Function of uploading information for every position in each day.
	2.1 Function of Working field real-time monitoring;

Security Management Module	2.2 Function of emergency safety plan; 2.3 Function of mastering the running state of the equipment. 2.4 Function of Mastering the vehicle load
Resource Management Module	3.1Loading and unloading machine and Handling appliance management; 3.2 Function of financial managemen; 3.3 Function of HRM (human resource management).
Property Management Module	4.1 Function of online application; 4.2 Function of Property information update and record.

According to statistical data, the loading income from special lines account 30% of the whole railway freight transport income. Therefore, we must regard the special line property unit as big customer, which means customer management should be taken into consideration. With the special line information management system, we can get a variety of special line management data, and then we can accurately grasp the status and the laws of send cars, so it will be simply to comprehend the needs of special line transport.

3. Design of special line information management system function framework

Railway Special line information management system is a complex system which include resource management, security management, customer management and other business areas. Therefore, it is necessary to establish the information management system in accordance with the method designed at railway freight station. Only in this way, can we lead the special line toward to standardization, modernization.

3.1 Special Line Information Management System Framework

The functional framework of the information management system is the basis for logical framework and physical framework design, which identifies functionality required to meet the various demands of users. In the following content, we will focus on "high-quality service, high security, and high efficiency management", and then design a system function framework consists of seven sub-system as shown in Figure 1.

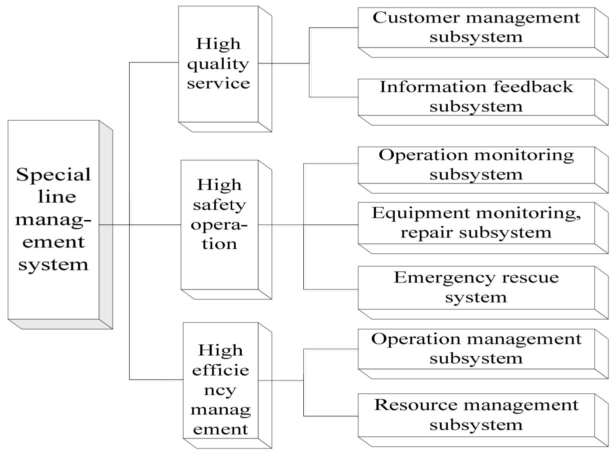

Figure 1.The system function framework

Meanwhile, the function framework can be subdivide into 20 specific subsystems as shown in Table 4.

Table 4. Subsystem functional division

Classification Subsystem	Subsystem functions
Customer management subsystem	1.1 Special line customers in volume, income statistics; 1.2 Special line station stopping statistics; 1.3 Special line in accident statistics; 1.4 Special line dedicated railway property change management.
Information feedback subsystem	2.1 Feedback the irregular operation information to the Railway Bureau; 2.2 Upload statistical data to the Railway Bureau every year; 2.3 Feedback the results of device checks to local railway bureau.
Operational monitoring subsystem	3.1Timely pick-up and recording vehicle status; 3.2 The weighing result record; 3.3 Stop line detection, vehicle stop recording time; 3.4 Safety monitoring in the workplace routinely.
Device Management Subsystem	4.1 System records the state of equipment, service life, the use of the scientific method to predict equipment failure and early warning; 4.2 System Administration and regularly reminded local railway line unit organization dedicated equipment inspection car, recording equipment status.
Emergency Rescue subsystem	5.1 Emergency rescue plan; 5.2 Traffic safety and maintenance decision support; 5.3 Security protection.
Resource management subsystem	6.1Transportation Resource Management; 6.2 Financial Management; 6.3 HRM Management.
Operations Management Subsystem	7.1 Operation management; 7.2 Operating efficiency statistics; 7.3 Employees technology assessment organizations

Logical framework mainly show the relationship between the unit system features and functions through the data stream. According to the functional demands above, the top-down model is employed to simulation the process in which the system deal with problems, and then the system logic framework map systems is established, as shown in Figure 2:

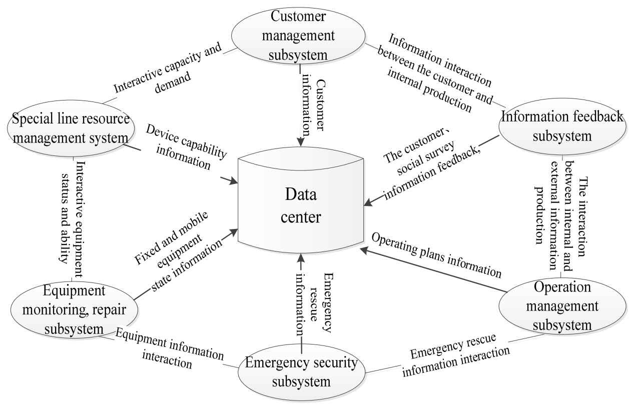

Figure 2.The system logic framework

Physical framework is the concrete embodiment of the logical framework, which describes the relationship between system functions and function and relationship of the way data transfer between divided modules by a system configuration diagram, and then we find out the realization function method through the figure. Combining the above analysis and the present situation of special line management in our country, we can establish the physical framework of the system, based on SSD (system sequence diagram) method, as shown in Figure 3.

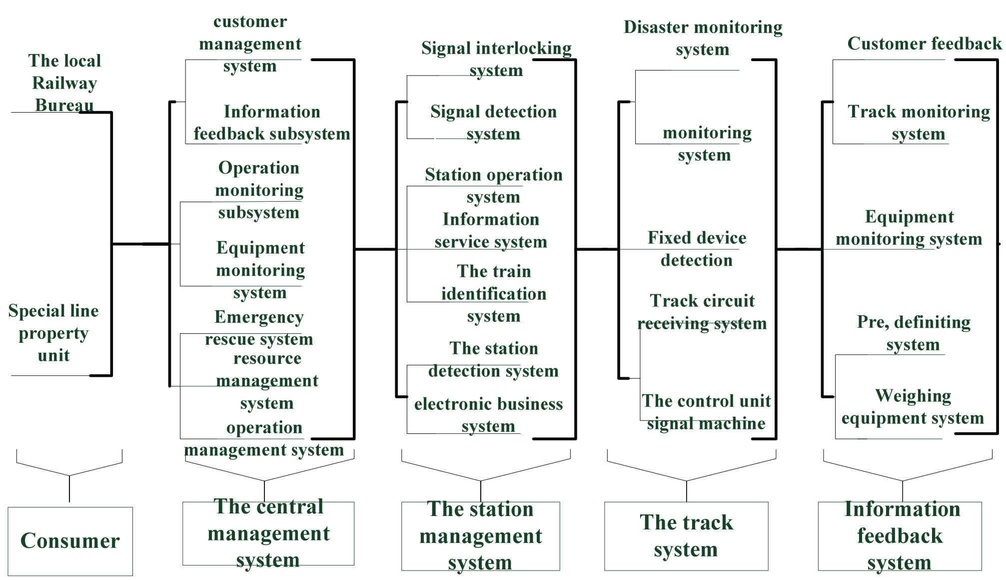

Figure 3.The system physical framework

3.2 System functional advantages

1. The system propose the reform direction of the freight yard in operation management module, establish interconnection between railways bureau Information Systems and special line information management system. In this way, we can improve the operating efficiency and safety protection in special line;

2. The system can automatically detect truck stop time, so we can accurately know the stop time, which helps us to calculate the rent from Trucks instead of warehouse;

3. The system can check the status of real-time monitoring of pounds equipment, and records data automatically, so the overload can effectively avoid;

4. The use of information systems can the scientifically guide the staff work and clarify the responsibilities of employees.

5. The system argument the online application function, which can accept the application of property change and update timely after the change of property. So we can clear responsibility and avoid unsafe factors such as overloading and irregular loading.

4 Conclusions

Firstly, this article describes the existing problems in railway special lines management, and then with the method of system engineering, the concept of information management system was put forward on account of current situation in special lines management. Finally, we establishes function framework, logic framework and physical framework. In recent years, fast freight is rapidly develop, while special lines paly a importation role in it ,so this article may has certain guiding significance to standardize the management of special lines and improve work efficiency. However, the management of railway special line is a tough task, an information management system is barely enough to solve the problems. The cooperation between special lines property units and railway bureau is the fundamental demand to promote the healthy development of special lines.

Acknowledgement

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Reference

Fan Zhiqiang., and Lin Yinjie. (2007). "Discussion on the operation and management mode of railway special line." *Agricultural Science&Technology*, 03, 14-15.

Jia Limin., and Wang Zhuo. (2006). "The theory and method of railway intelligent transportation system design optimization" *China Railway Publishing House*.

Li Wenxin., and Li Zairong. (1998). "A new mode of management of railway special line"*, China Academy of Railway Sciences*, 02, 18-20.

Ling Wei. (2009) "Study on the special railway line safety management", *China New Technologies and Product*, 20, 63.

Meng Yan. (2005). "Study on the method of structure design of Railway Intelligent Transportation Syste." *China Academy of Railway Sciences*.

Qing Feng. (2013). "Study on Discussion on the special railway transport organization and management of enterprise.*" Technology and business*, 23, 58.

Wang Dawei. (2008). "Discussion on strengthening the management of special railway lines in China." *Railway Freight*, 8, 26-27.

Dynamic OD Matrix Estimation Algorithm Based on Information Extraction

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Abstract: OD matrix is one of the most important research fields in intelligent traffic, it's the key data of microscopic traffic simulation, city traffic planning, management and control etc…In this article, through the multipath search algorithm based on point and punishment method and modified Logit model to determine the distribution of matrix, according to the structure of OD deviation state space model and combining with polynomial trend based on information fusion Kalman filtering, put forward the dynamic OD matrix estimation algorithm based on information extraction. Finally, combining with the example of analysis and calculation, verify the validity and feasibility of the presented method in this paper.
Keywords: Information extraction technologies; Dynamic OD matrix estimation; Distribution matrix; Kalman filter.

1 Introduction

The precise dynamic OD demand, accurately reflect the running status of urban road network, is the data base to develop effective traffic management measures, is important input of ATI and ATMS in ITS, directly influence ITS effectiveness of real-time system.

At present, OD matrix estimation method mainly has the maximum entropy model method, minimum model method, the method of maximum likelihood, generalized least squares method and Bayesian statistics. In recent years, through the efforts of the researchers, the dynamic OD matrix estimation research with some new results. Cascatta put forward two dynamic OD estimation models: one step and iterative method. It's lack of computational effectiveness, and without considering the inherent constraint model. Hazelton solves the problem of uncertainty of OD matrix estimation, using two order statistical information flow between sections to estimate the OD matrix, and illustrates that the model is feasible and effective combining with the example. Li Jueyou analyzed the insufficient of successive iterative algorithm for least squares model adopted to solute OD matrix estimation, proposed the filled function method to find global optimal solution of the model. With the acceleration of the information process, acquiring traffic information using mobile phone positioning information has become feasible. But the current research on the mobile phone positioning information is also limited to theoretical modeling stage, and travel recognition technology is not yet mature. Li Junwei introduced the unscented Kalman filter (UKF) algorithm for fast road network dynamic OD matrix estimation, but it needs to be calculated all the lag influence OD until the present stage, significantly improved the computing complexity. Kalman filtering algorithm can linear estimate dynamic OD based on real-time observation data, it has been widely used. Okutani will be the unknown OD flow as the state vector, using autoregressive process set up the state equation, using Kalman filtering algorithm estimate the real-time OD of a small road network. Chang introduced the advanced extended Kalman fitler (EKF) algorithm to solve the model. In addition, the scholars also studied other dynamic OD matrix estimation algorithm includes genetic algorithm.

Now, according to the traffic of multi-source data, massive, heterogeneous, time-varying, non-intuitive significant feature extraction, advanced traffic information extraction technologies including information fusion, data mining and granular computing, emerge as the times require. The excellent characteristics of the extraction technology has obvious advantages, it greatly improves the level of traffic information extraction, promote the development of ITS. So, the related research technology of information extraction, this paper puts forward the dynamic OD estimation algorithm based on information extraction.

2 Dynamic OD estimation algorithm based on information extraction

As a key parameter in the model to estimate the dynamic assignment matrix OD, reflects the dynamic relationship between OD flow and the traffic volume of time variant. The accuracy of the parameters greatly affect the dynamic OD estimation effect. Therefore, this paper was to explore distribution matrix, on the basis of research on dynamic OD estimation algorithm based on information extraction.

2.1 Extraction of assignment matrix

At present, the parameter acquisition method mainly has the dynamic traffic assignment model and traffic simulation. The dynamic traffic assignment model is a very complicated problem, and spatial and temporal complexity of city road network and the influence of travel behavior leads to traffic simulation cannot get the desired results. The model described traffic network is more complex, the sensitivity of algorithm more weaken, solving more complex, error of omission in the calculation larger. These will reduce the accuracy of the model, and if the model cannot satisfy the real-time requirements, no matter how it's effect will not be accepted. Based on the literature of the particles travel cost, by the multipath search algorithm based on point and punishment method and modified Logit model, combining $\alpha_{i,t}^{r,\tau}$ calculated $\theta_{i,t}^{r,\tau}$.

In the travel route choice, people generally do not consider all connected path, and will only consider travel cost within the scope of sustainable path. Therefore, defining the path impedance within the shortest path impedance 1+H times (H to stretch coefficient path) path and there is no loop as a valid path. Let $l_{r,j}$ be OD r article j dissimilar shortest path, length is $f_{r,j}$, V_j is the set of the through point of $l_{r,j}$, v_b^j is the j time for the shortest path time delay in point b. E_j is the set of the through path of $l_{r,j}$, w_i^j is travel cost of link i, in j-th time for the short circuit. Effective path set of OD r can be obtained, as follows:

Step 1: $v_b^l = 0, \forall b \in V; w_i^l = C_{r,\tau,j}^g; E_j = \varnothing, V_j = \varnothing; j = 1$

Step 2: Using the Dijkstra shortest path algorithm to obtain any shortest path(the path through point v_b to add the corresponding v_b^j), length is denoted by $f_{r,j}$, folding the path through edge into E_j, through point into V_j.

Step 3: Given point penalty factor α', penalty factor β', and the right side and the vertex delays in $l_{r,j}$. And use the right side of w_i^j and v_b^j to replace the corresponding time weight and vertex delay in G. The punishment function as follows:

$$v_b^{j+1} = \alpha', \forall v_b^j : v_b \in V_j \tag{1}$$

$$w_i^{j+1} = (1 + \frac{\beta'}{f_{r,j}}) w_i^j, \forall w_i^j : i \in E_j \tag{2}$$

Step 4: if $l_{r,j} \geq (1+H) l_{r,j}$, the algorithm terminates; Otherwise, $k = k+1$, go to the Step 2.Combined with the travel cost and effective path set, $\gamma_{r,\tau,j}$ can be determined using the improved Logit model. As follows:

$$\gamma_{r,\tau,j} = \frac{\exp(-\theta C_{r,t,j}^g / \bar{C}_{r,t}^g)}{\sum_k \exp(-\theta C_{r,t,k}^g / \bar{C}_{r,t}^g)} \tag{3}$$

Combined with Cascetta's "vehicle package" hypothesis and Dr. Lin Yong's improved "vehicle package" hypothesis, Assume that all vehicles traveled along j-th path composed of a package (j,τ) within the interval time τ(H in length),the headway vehicles in the package always uniform distribution, and can be stretched or squeezed with the same proportion. Making the time interval package (j,τ) through the detector of the link i is $\Delta_j = \left[\delta_{1,\tau}^{i,j}, \delta_{2,\tau}^{i,j}\right]$, $\delta_{1,\tau}^{i,j}, \delta_{2,\tau}^{i,j}$ is time the first and tail car in package (j,τ) through the detector. The duration of H accounts for the time interval $\Delta_j = \left[(h-1)H, hH\right]$, so

$$\alpha_{i,t}^{r,\tau} = \left|\Delta_j \cap \Delta h\right| / \left|\Delta_j\right| \tag{4}$$

In the formula, $|\bullet|$ is operator of interval length. Although the assumption of headway uniform distribution in a particular case may be incorrect, because we are concerned about the variation rule of large flow rate. As long as the estimated time length of H is large enough, statistically, the formula (4) still is practical value. Thus, distribution matrix unit of $\theta_{i,t}^{r,\tau}$ can be obtained by the formula (5).

$$\theta_{i,t}^{r,\tau} = \sum_j \alpha_{i,t}^{r,\tau} \gamma_{r,\tau,j} \tag{5}$$

2.2 **Dynamic OD matrix estimation algorithm based on information extraction**

According to the structure of OD deviation state space model and combining with polynomial trend based on information fusion Kalman filtering, put forward the dynamic OD matrix estimation algorithm based on information extraction, as follows:

Step 1: Initialization, $\hat{E}_{0.0} = E(E_0), P_{0.0} = Var(E_0), k = 1$.

Step 2:Toextractcongestion particles $A_{i,t}$ in link i within t, particles of traffic safety $B_{i,t}$, then extract the travel cost particles $C_{i,t}^{g}$.

Step 3:To extract distribution matrix $\theta_{i,t}^{r,\tau}$.

Step 4:Combined with the conventional Kalman filtering, forecast OD structure deviation value of k-1 to k stage and variance matrix, as follows:

$$\hat{E}_{k,k-1} = A_k \hat{E}_{k-1,k-1} \tag{6}$$

$$P_{k,k-1} = A_k P_{k-1,k-1} A_k^T + W_{k-1} \tag{7}$$

Step 5:Combined with information fusion theory, estimate filter error and estimate of k stage OD structure deviation. If $\left| \frac{\hat{E}_{k,k} - \hat{E}_{k-1,k-1}}{\hat{E}_{k-1,k-1}} \right| \le \varepsilon$ (ε is a critical value of the predetermined precision), go to the Step 4, otherwise, go to the Step 6.

$$P_{k,k}^{-1} = P_{k,k-1}^{-1} + B_k^T V_k^{-1} B_k \tag{8}$$

$$\hat{E}_{k,k} = P_{k,k} \left[P_{k,k-1}^{-1} \hat{E}_{k,k-1} + B_k^T(k) V_k^{-1} Y_k \right] \tag{9}$$

Step 6:According to the composition of OD, estimate dynamic OD matrix combined with $\hat{\mu}_{r,\tau}$, as follows

$$X_{r,\tau} = E(X_{r,\tau}^H + \mu_{r,\tau} + \eta_{r,\tau}) = X_{r,\tau}^H + \hat{\mu}_{r,\tau}, \quad \tau = k\lambda, k\lambda+1, ..., (k+1)\lambda - 1 \tag{10}$$

$$X_{\tau} = E(X_{\tau}^H + \mu_{\tau} + \eta_{\tau}) = X_{\tau}^H + \hat{\mu}_{\tau}, \quad \tau = k\lambda, k\lambda+1, ..., (k+1)\lambda - 1 \tag{11}$$

Step 7:Update database, $k = k+1$, go to the Step 6.

3 Implementation

This chapter selected part of Liuzhou-yufeng old airport road network as the research object in Guangxi autonomous region development zone, the network diagram as shown in figure 1, including 24 sections (article 17 a two-way road, 7 one-way road), 16 nodes, graph edge Numbers beside road number, which nodes are included in the 5 to hair, point 3, 5, 12, 14, 16, a total of 25 OD pairs. There're a total of nine sections of the road network device induction coil, section 5, 6, 14, 15, 16, 17, 18, 24, 25, induction coil, and the remaining sections of the devices under assumed section to install detector are located the position of the nodes in a third section length. At the same time, the actual OD demand and corresponding road traffic information have been collected from 9:00 to 14:00 on July 5, 2007.Assumes that the current maximum of the flow of time interval number is equal to 4, then the observation time interval and the departure time intervals are 10 min. Each time for 30 min, each time interval number equals 3, and each set out the observation interval time interval number n equals 1.

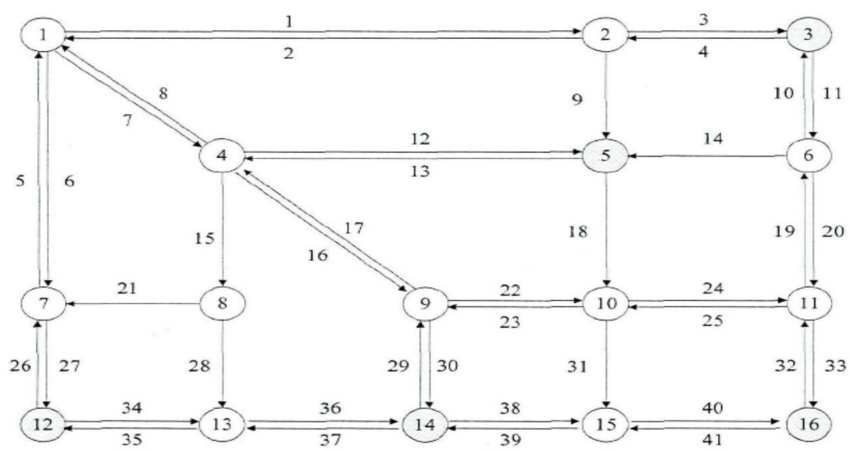

Fig.1 Network diagram

Model history needs the optimal value of OD matrix. Considering the actual system, traffic demand has a certain similarity in different day, so we adopt the method of traffic simulation under the condition of similar input to generate historical value. In practice, collect data in the same day from different weeks or different month, and get the optimal value of history.

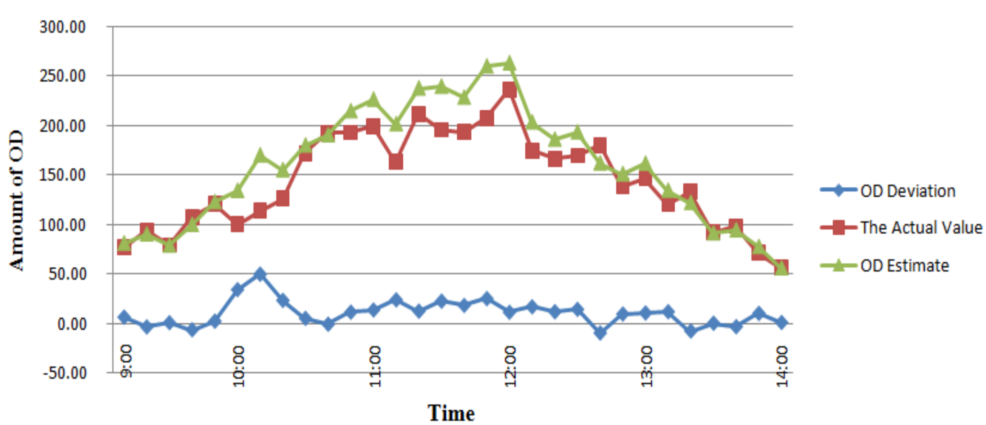

Fig.2 (3, 14) results contrast figure

We used conventional Kalman filtering method to estimate regression simulation of dynamic OD matrix by combining the method of dynamic OD matrix, and got fig.2and fig.3.From the overall, due to the good robustness of polynomial trend model, in terms of accuracy, Kalman filtering method based on the polynomial trend of information fusion is higher than conventional Kalman filtering method. Especially, when great changes have taken place in the OD matrix, polynomial trend Kaiman filtering method based on information fusion of robustness significantly is more than the conventional Kalman filter method.

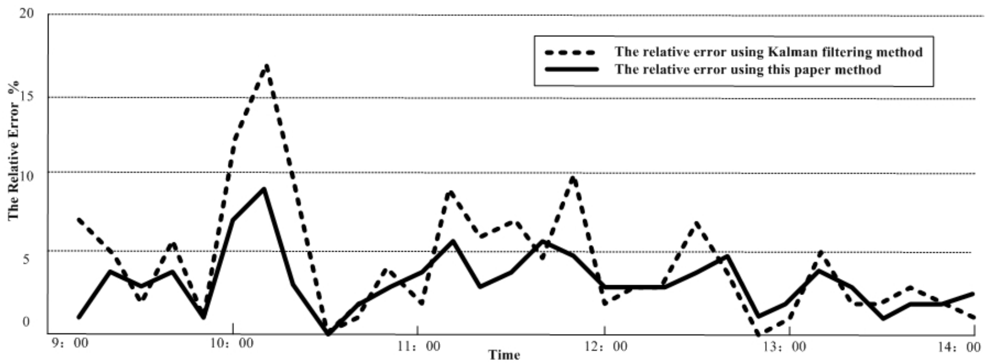

Fig.3 Relative error comparison chart in different methods

4 Conclusions

Dynamic OD matrix is indispensable information in city management, is one of the hot topics in the field of transportation research, but the calculation method of the dynamic OD matrix estimation is still in the primary stage, related research needs to be further. Distribution matrix reflects the dynamic relationship between time-variable OD flow and the traffic volume, the parameter accuracy greatly affects the dynamic OD estimation results, so this paper first puts forward the extraction algorithm of distribution matrix. On this basis, according to the OD structure deviation state space model, combined with the polynomial trend of Kalman filtering method based on information fusion algorithm, proposed dynamic OD matrix estimation based on information extraction. Finally in the instance analysis, respectively use conventional method and the presented method to estimate analysis, the results verify the effectiveness of the presented method.

References

Cascetta E. (1984)Estimation of trip matrices from traffic counts and survey data: A generalized least squares estimator. *Transportation Research Part B.* 18(4/5): 289-299.

Chang G L, Wu J.(1994)Recursive Estimation of Time-Varing Origin-Destination Flows from Traffic Counts in Freeway Corridors. *Transportation Research B*. 28(2) : 141-160.

Hazelton M L. (2003). Some comments on origin-destination matrix estimation. *Transportation Research Part A*. 37(10): 811-822.

Zhou X S, Mahmassani H S. (2007).A Structural State Space Model for Real-time Traffic Origin-destination Demand Estimation and Prediction in A Day-to-day Learning Framework.*TransportationResearchB*.41(8)：823-840.

Customized Shuttle Bus or Car? Analysis on Travel Mode Choice Behavior of Commuters

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Abstract: Customized shuttle bus is a new service pattern of public transportation which can meet the personalized travel demand. In the article, we used discrete choice model to analyze the factors affecting commuters travel mode choice, with the investigation which is about Beijing commuters' travel characteristics and transportation mode choice under different scenarios. Binomial Logit model has been built to the population characteristics and probability of commuters who chose the customized shuttle bus, thus it provides the reference to adapt to the characteristics of customized shuttle bus business strategy for the bus companies to determine.
Keywords: Commuters; Customized shuttle bus; Way to travel; Traffic model.

1 Foreword

Bus priority is one of the city's major transport development strategy. The emergence of customized shuttle bus, which is one person one, one-stop direct and personalized service to meet the commuters, adds a new attraction for the public traffic. In the past year, since Beijing took the lead after the opening line of custom bus, in a number of cities in Fujian, Tianjin, Shenzhen, Chengdu, Xiamen, etc. have been popularized. Although the response of customized shuttle bus is active in the market, but the occupancy rate is still low.

In order to attract more commuters to choose customized shuttle bus, we must deeply analyze the population characteristics and the influence factors of travel mode choice behavior of commuters who chose to take the customized shuttle bus. Current research on customized shuttle bus is still in its infancy exploration, existing research focuses on customized shuttle bus line layout, model selection and price. In this paper, we establish binomial Logit model, which is based on the travel behavior of commuters, costs and travel time, to clearly reflect the determinant of commuters' travel mode choice behavior, at the same time, this model can also provide the operator decision basis to promote the new bus service mode customized shuttle bus.

2 Commuters Travel Mode Choice Analysis

2.1 Travel mode investigation

Taking the RP/SP survey as an example, which is about car travelers' behavior in the commuting time in Beijing. The survey sites including office parking lot, large residential area, industrial area parking lots. The main content of RP survey as shown in Table 1:

Table 1. RP survey content

Property	Content
Personal characteristics	gender, age, marital status, income, occupation, driving experience, car ownership situation
Traffic Characteristics	transport, travel distance, travel time, travel costs, the number of days per week car trip, The number of trips together

In the SP survey, assuming the respondents could choose cars or customized shuttle bus to work, the time and cost required for each of the two modes of transportation as follows:

car travel time=walk to the parking lot of time + driving time + walk to the company time

car travel costs= fuel costs+ road toll+ parking fee+ impairment charges

(*fuel costs*=(trip distance* fuel consumption/ kilometer)* prices)

customized shuttle bus travel time=walk to station time + running time walk to the company time

Customized shuttle bus travel cost= trip distance* price/ kilometer

Because customized shuttle bus can use the bus lane or highway, commuting time regarded as a smooth running, so we assume the travel time is 60min, and customized shuttle bus fares can be divided into normal and preferential two cases; however, because the car may appear congestion, car travel is divided into normal and delayed for two cases. The above situation can be composed of 4 scenarios, as shown in Table 2:

Table 2. Classification of travel situation

Situational	Situational brief
1	Car travel is normal, take customized shuttle bus with no preferential
2	Car travel is normal, take customized shuttle bus with preferential
3	Car travel is delay, take customized shuttle bus with no preferential
4	Car travel is delay, take customized shuttle bus with preferential

2.2 Data Analysis

The basic situation of the respondents is shown in table 3:

Table 3. The basic situation of the survey respondents

Category	Actual situation
Gender	60% men, 40% women
Age	To the youth, middle-aged, mainly concentrated in between 26 to 42 years of age
Marital status	76% of the respondents are married
Income	Most respondents monthly income above 4000, the proportion reached 84%
Occupation	The vast majority of respondents personnel for enterprises
Driving experience	75% of respondents in six years or less driving experience
Possession of the car	78% of respondents own a car

Table 4. The results of travel mode choice

Travel situation	Car		Customized shuttle bus		Select the customized bus ratio %
	Time/min	Fee/yuan	Time/min	Fee/yuan	
Situation1	40	25	60	12	17.3
Situation2	40	25	60	10	19.6
Situation3	55	38	60	12	72.2
Situation4	55	38	60	10	75.4

We can see from Table 4: In the context 1 and 2 the respondents chose customized shuttle bus travel is only 17.3% and 19.6%; In the context 3 and 4 the respondents chose customized shuttle bus travel is 72.2% and 75.4%; Thus the difference travel time and cost between cars and customized shuttle bus is the key factor that whether commuters choose the customized shuttle bus.

3 Cars and Customized shuttle Bus Choice Relation Model

3.1 Model establishment

In recent years, There are many travel options for travelers research. For example, Cherchi E (Cherchi E.2002) according to RP / SP surveys of residents in Cagliari, Italy travel Nested Logit (NL) model. In literature (Central Transportation Planning.1997) MNL model using travelers commuting travel mode choices, focuses on the impact of the transfer amount select travelers commuting and travel mode. In Mcfadden DL (Mcfadden D L.2000) article Mixed Logit model using travel mode choice modeling and the results obtained. Yang Liya (Yang,2012) select features travelers, travel features, travel mode and level of service as a utility variable Logit model to build a hierarchical way to travel and departure times union choice. In Guan Hongzhi (Guan, 2008) article Beijing downtown area, for example, the parking fee payers are divided into individual units of payment and reimbursement categories, the establishment of private cars, buses, taxis targeted way to travel for the two types of samples and all the sample selection Logit model.

In this paper, we use binomial Logit model to quantitatively analysis travelers' choice behavior in the commuting time (Liu, 2008; Jia, 2007; Guan, 2004). Based on the principle of random effect theory and maximize effect, assumptions are as follows:

$$\mathrm{P}(i) = \frac{\exp V_i(X)}{\sum_{i=1}^{n} \exp V_i(X)} \quad (1)$$

Among them: *P (i)* as the selection probability of the i travel mode; *Vi (x)* for the selection of the utility function of the i travel mode, i=0、1,i=0, i = 0 represents select customized shuttle bus travel; i = 1 represents choose car travel; n for the number of travel mode.

In the article we regard commuter' car trip as a reference item, its utility equation is 0. The variables of the model and the way we choose its corresponding values as shown in Table 5. We use the chi square detection estimation results, with 95% confidence, the gender variable was not significant, and so it did not enter the model variables. The Nagelkerke R Square (coefficient of determination) is 0.368, more than 0.3, indicating that the accuracy of the model is high. Our model is calibrated as shown in Table 6 with the survey data and the calculated parameters.

Table 5. model variable parameters and values the way

Variable	The value of the variable		
Age(A)	A≤25：1	26≤A≤35:2	36≤A:3
Income (S)	S≤3000：1	3000＜S≤10000:2	1000≤S:3
Marital status (M)	YES：1 NO：0		
Enterprise staff (W_1)	YES：1 NO：0		
Self-employed households (W_2)	YES：1 NO：0		
Driving experience (Y)	Y≥3（年）：1 Y＜3（年）：0		
Car ownership situation (O)	YES：1 NO：0		
Take customized shuttle bus commute time≤40min(T_1)	YES：1 NO：0		
Take customized shuttle bus commute time 40~60min(T_2)	YES：1 NO：0		
Car travel days / week (D)	1、2、3、4、5		
Travel time difference (T)	Car travel time—Customized shuttle bus travel time		
Travel fee difference (F)	Car travel fee—Customized shuttle bus travel fee		
The number of peers (N)	1、2、3…		

Table 6. Model parameter calibration results

Select mode	Variable	Parameters	χ^2	Sig
Customized shuttle bus	Constant term	0.734	14.652	0.001
	A	-0.237	16.234	0.000
	M	-0.034	11.734	0.001
	S	-0.104	6.287	0.008
	W_1	0.052	9.372	0.002
	W_2	0.054	10.843	0.002
	Y	-0.024	16.528	0.000
	O	-0.095	25.753	0.000
	T_1	-0.042	17.436	0.000
	T_2	-0.046	12.264	0.001
	D	-0.005	8.114	0.005
	T	0.047	124.62	0.000
	F	0.057	76.24	0.000
	N	0.009	12.471	0.001
The coefficient of determination	Chi-square		396.000	
	-2 Log likelihood		1.692	
	Nagelkerke R Square		0.368	

According to the parameters of each of the variables in Table 6 the calibration can get utility function for customized shuttle bus ride:

V_0=0.734-0.237*A-0.034*M-0.104*S+0.052*w_1+0.054*w_2-0.024*Y-0.095*O-0.042*T1-0.046*T_2-0.005*D+0.047*T+0.057*F+0.009*N

Using the formula (1) we can be calculated for each commuter time travelers in different contexts probability of selecting a different way to travel. For example, the traveler is 37years old married with a private car. His income is 11,000 yuan a month. He rode the customized shuttle bus was 55 minutes commuting time. However, Private car commuting time is 35 minutes. Two kinds of transportation cost difference of 25 yuan. the traveler selects customized shuttle bus to travel for 2.4% probability, but he choose private car to travel for 97.6% probability.

3.2 The results of the model solution

Based model calibration parameters analyzed commuters choose the law as follows: (1) *A* parameter is negative, indicating that young people more likely to choose to customized shuttle bus travel; (2) *M* parameter is negative, indicating that a single person with respect to the married person is more likely to accept customized shuttle bus travel; (3) *S* parameter is negative, indicating that as incomes increase people more inclined to choose travel by car; (4) *Y* parameter is negative, indicating the shorter driving experience are more likely to change the habits of the past, to choose a new way to travel; (5) *O* parameter is negative, indicating that people of owned car are more willing to choose a car to travel; (6) *T1, T2* parameter is negative, and the T1 <T2 descripts commuters do not want to pay too much time to take the customized shuttle bus, and when the customized shuttle bus save more time, more and more people will choose it; (7) *D* parameter is negative, indicating that as commuters increase the number of days weekly to be more dependent on car travel, selecting the customized shuttle bus is more difficult; (8) *T* parameter is positive, indicating that is the more time cars saved, the more commuters choose using cars; （9）*F* parameter is positive, indicating that the relative cost of car is lower than the customized shuttle bus costs, commuters prefer to choose the customized shuttle bus trip; (10) *N* parameter is positive, indicating that the more people travel together, the more likely people choose the customized shuttle bus travel.

4 Conclusions

In this paper, we established a binomial Logit model based on the actual choice behavior of commuters, travel time and travel expenses. Because of we considered the personal and traffic characteristics of commuter, the model are more reasonable and more precise. The main results are as follows:

(1) Unmarried young commuters prefer customized shuttle bus as a commuter tool;

(2) Relatively low income commuters prefer to choose customized shuttle bus;

(3) The more the number of counterparts, the more commuters likely to choose customized shuttle bus.

At the same time, we can make the following suggestions for the promotion of customized shuttle bus mode through the analysis of model parameters:

(1) Customized shuttle bus mainly aimed to serve the young and middle-income people;

(2) Due to travel time for commuters is sensitive, we can attract car commuter by optimizing bus lines and reducing travel time;

(3) We can formulate preferential fares policies for those who ordered at the same time to attract more potential commuters who may take customized shuttle bus , so that to improve the occupancy rate of customized shuttle bus, let the bus service model innovation, provide more convenient and comfortable way to travel for commuters.

References

Central Transportation Planning.(1997). Transfer penalties in urban mode choice modeling (travel model improvement program). Washington D C: Travel Model Improvement Program，1997: 30-45.

Cherchi E, de D Ortúzar J.(2002). Mixed RP/SP models incorporating interaction effects. Transportation, 29(4):371-395.

Guan, H. Z.(2004). Disaggregate model - Traffic Behavior Analysis Tools. China Communications Press. 12:1-5

Guan, H. Z., Yan, H., Li, Y.(2008). Considering the parking fee payers travel mode choice model. China Civil Engineering Journal. 41(4):91-94.

Jia, H,F., Gong, B. W. and Zong, F.(2007). Transportation mode choice disaggregate model and its application. Journal of Jilin University(Science Edition). 37(6):1288-1293

Liu, B. E., Jun, Z. C. and Li, Y. L.(2008). The establishment of resident trip mode choice of disaggregate model. Journal of Highway and Transportation Research and Development. 25(5):136-141.

Mcfadden D L, Train K.(2000). Mixed MNL Models for Discrete Response. Journal of Applied Econometrics, 15(5): 447-470.

Yang, L. Y., Shao, C. F.(2012). Logit model stratified travel mode choice and departure times union. Journal of Traffic and Transportation Engineering,12(2)：76 - 83.

Field Test Research on Vehicles Crossing the Lane Lines and Lane-Changing Locations Traffic Behavior in Multi-Lane Freeway Diverging and Merging Areas

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Abstract: In order to explore the driving behavior characteristics of vehicles which across the line of multi-lane freeway diverging areas, the paper selected Hu-Ning multi-lane freeway interchange (groups) as a field observation engineering, and extracted diverging and merging locations, speed and other traffic behavior from the drivers and the vehicles. The test results showed that: a multi-lane freeway diverging area motorcycle type difference and diverging location with low correlation under free-flow condition, and the vast majority of drivers choose merging locations advance under medium and low flow conditions, the locations merging behaviors of heavy vehicles and cars are broadly similar, but when the traffic conditions change, the merging locations between the two appears discrepancy and so on.

Keywords: Multi-lane freeway; Diverging and merging areas; Locations of lane-changing; Traffic behavior; Safety design.

1 Introduction

The research on traffic behavior of multi-lane freeway diverging areas is a new content and hot. The behavior of a driver driving is a process of information exchange and control. The state of the automobile and the state information of the environment are the decision-making basis of the driver driving behavior (Guo Zhongyin, 2012). Driving behavior characteristics of diversification of multi-lane freeway interchange diverging areas directly affects road traffic safety and traffic efficiency. Researchers are working on the multi-lane freeway diverging areas' efficiency and security and exploring vehicle characteristics, in order to establish the most safe and effective design criteria (Fisher. R.L, 1948). Olsen and Hostetter found that the confluencebehavior and the length of speed change lane is related by research of three entrance ramp (Olsen, R.A., 1976). Kou and Machemehl found the unobvious statistical laws between level of traffic flow, vehicle speed near the ramp, enter and delayed into the main line's vehicle speed parameters and vehicle confluence position by collecting four entrance ramp data9 (Kou, C.C., 1997).

2Test Equipment

It can be used with three cameras to shoot sub- confluent area of the vehicle operating conditions, each shot time is 2 hours .Selected one of the 10 minutes time video to analyze, the speed was measured with radar gun . When car out of the main line of diverge spot, mainly has the following several types:

(1)In or before the gradual change section,

(2)A third stage in front of the deceleration lane,

(3)A third stage in the middle of the deceleration lane,

(4)In the final stage of the deceleration lane 1/3,

(5)Out of compositenasal discharge.

3Experimental Design and Data Collection

With Google Map view of the powerful features and full reconnaissance visits Shanghai-Nanjing Expressway road type , Suzhou north and Zhengyi interchange junction located in Kun shan City is taken as a centralized object of study.

Figure1.The map of Zhengyi Interchange

Figure2.The map of Suzhou North Interchange

Firstly specific distance marking along the deceleration lane need to be done to assess the diverge spots at site .and then these point positions of vehicles streaming Need to be statistics during 10minutes.Simultaneously, recorded on the book with classification , and drew data analysis chart, through video analysis software Corel Video Studio Pro X4 processing. vehicles speed data acquisition could be acquired with the radar gun.

4 Lane-changing Position Data Analysis

4.1 Diverging Lane-changing Position Analysis

Selecting the diverging position reflects the way the driver diverge intention to achieve. Vehicle needs a certain critical points in the diverging area before the completion of their diversion lane change behavior, but decide whether it makes the most direct factor that a person produces diversion lane change intent is the distance between the vehicle and the key point(Li Li, 2011).

Driving is a complex intelligent behavior(Li Yingfeng, 2008).For diverging area and exit ramp, vehicle is along the line the outside lane in theory .when driving a certain position in the area , between the deceleration lane and the exit ramp. Vehicles begin steering into the deceleration lane change lane and exit ramp .However, due to the mutual influence of subjective and objective factors, traffic location showed differences, in multi Lane freeway diverging areas. Based on the safety design concept of man-machine engineering, road design should be people-oriented (Zhao Cui, 2012).

Because the expressway entrance region exists straight and the confluence of the traffic flow, traffic behavior becomes more complex than other roads. When the vehicle is accelerating or decelerating to enter or leave the lane, it will produce many conflicts, easily leading to accidents(Wang Xiaofei,2011).from the respect of microscopic traffic safety research, Many scholars at home and abroad established the models by analyzing the relations among the geometric road design , operating characteristics of the vehicle , the driver of the psychological and physiological responses , environmental factors and traffic safety (Yan Ying Sheng, 2011).

All vehicles are divided into five types according to its shunt position characteristic: transition section and the upstream, the deceleration lane of 1/3 segment, deceleration lane middle 1/3 segment , the deceleration lane 1/3 segment , Painted (delta end).the way of Shunt spot collection was used of both artificial field recording and video software review combination .Ten minutes as the basic unit of time at scene, staff recorded vehicles in accordance with the above five kinds of distribution. Indoor the point information could be analyzed through Video analysis software Corel Video Studio Pro X4 diversion, with the help of the radar gun, the speed of the vehicle can also be measured .

Firstly, the analysis that different models effecting Vehicle shunt positions in multi-lane freeway diverging areas could be got. Information in figure3, the heavy duty truck shunt positions are similar to passenger cars' under the condition of free distribution, namely the shunt position mainly concentrated in the range of the gradual stage ,While the shunt degree point decreased from the deceleration lane of

1/3 segment of anterior to the middle1/3segment, the percentage is not significantly different. Due to analyze the internal mechanism of the vehicles, it could be concluded that the headway distance between vehicles are such large under free flow conditions, that mutual interference effects little, and lane changing flow behavior can be chosen arbitrarily , thus drivers usually choose to change diversion into the deceleration lane early. The behavior choice no matter from the aspects of driving safety or comfort are reasonable.In the process, because of the large degree of freedom of choice, small interference factors, the physical properties of different models of vehicles differences reduce,furthermore,under the condition of free flow,the degree of correlation between different models of vehicles and shunt position is low in multi-lane freeway diverging areas.

Secondly, it could be analyzed vehicle shunt positions in multi-lane freeway diverging areas from the point of view of traffic flow environmental differences. figure3 shows that, under restrictive conditions shunt ,there is a great differentiation phenomenon between heavy trucks and passenger cars diverge position, that the primary focus of heavy goods vehicles shunt position are lane of 1/3 segment of anterior , followed by the middle third of the deceleration lane section , However , in binding position it contains the last section of 1/3 the deceleration lane shunt , the analysis can be found in figure3 bottom bar ,diverge position with heavy goods vehicles and buses tends close to shunt nasal discharge with intention from the free flow of traffic diversion to restrictive conditions diverge.

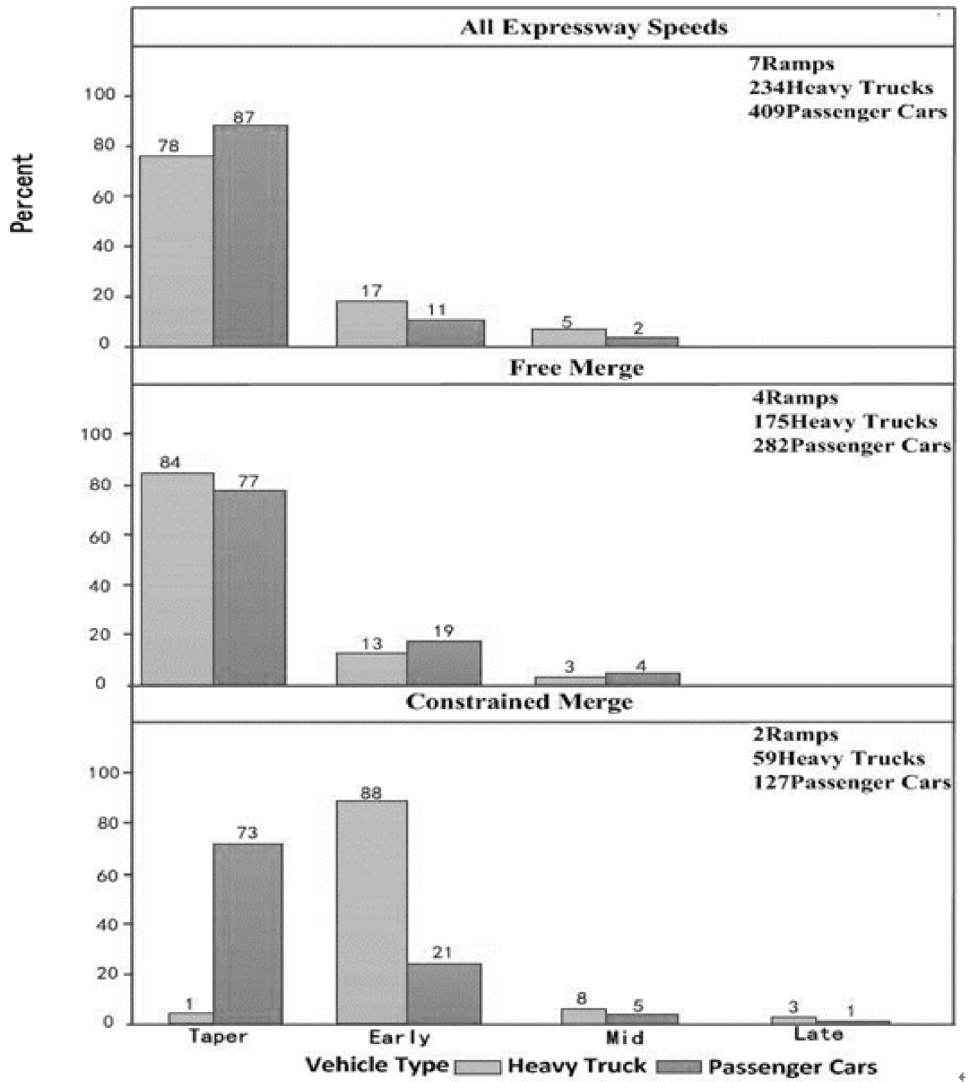

Figure2. Diverging Positions of Vehicles

4.2 Merging Lane-changing Position Analysis

For the multi-lane freeway entrance ramp, in theory, the combined vehicle should be along the confluence of the acceleration lane and in which a position change merge, that is done out of the confluence nose and before the transition section. According to the analysis of the live video and radar gun data, the combined position in figure 4 is statistical analysis in the conditions of all types of the ramp, types of the vehicle and freeway speed.

Analysis of figure4 can be obtained, for free and constrained merge conditions, most of the vehicles in the early or middle position is combined, but for forced merge conditions, most vehicles combined late even in the transition section.

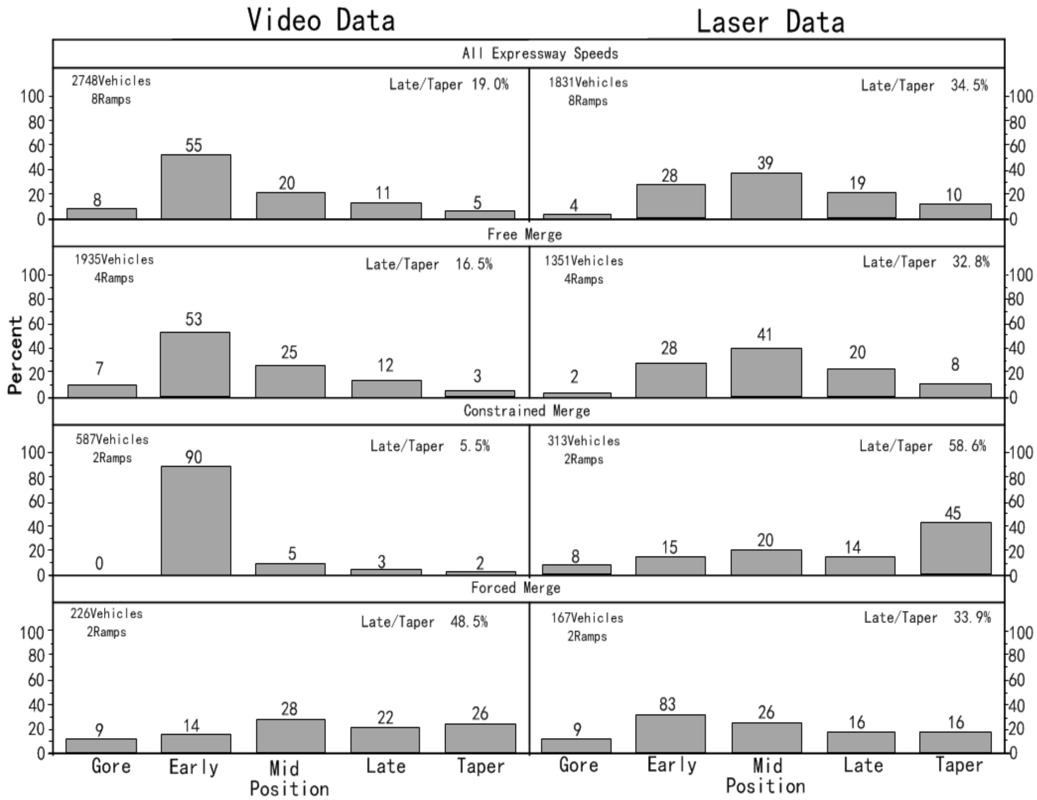

Figure3. Merging Positions of Vehicles(All ramps、Vehicle types、Speeds)

The gap acceptances did not appear frequently in the mandatory confluence condition, but the combined behavior may occur in a certain order and quantity at the same time, because the freeway operation speed is small in this condition, combined vehicle without acceleration too much can reach earlier comfortable confluence speed; in the constraint conditions of confluence, due to the insufficient clearances which can be inserted into and the of traffic flow is not sufficient to provide slow, orderly merging process, so it is difficult to find the gap acceptances.

Figure5 shows the heavy trucks and passenger cars combined driving behavior is similar, however, with the changes of the traffic flow conditions, the two combined position become differences of differentiation.

Analysis of Figure4 can be obtained, in the constraint conditions of merging, most heavy trucks merge in transition section or after transition section, but a few bus also confluence in transition section or after transition section, the situation may be caused by the following reasons, the first is the difference of dynamic characteristics between the heavy trucks and the large passenger vehicles, the second is the traffic flow density, the third is the confluence of space squeezed caused by the length of the acceleration lane restrictions.

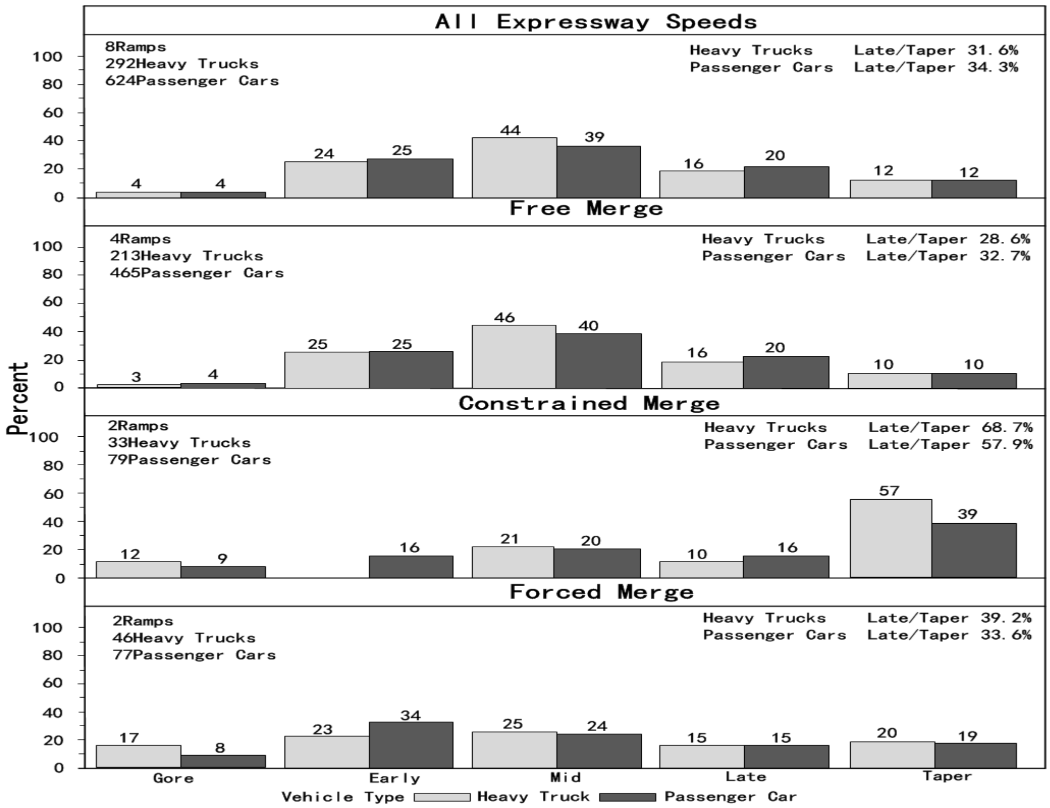

Figure4. Merging Positions of Vehicles (Heavy Trucks and Passenger Cars)

5 Conclusion

This paper get a lot of useful conclusions by far field observation experiment in the Shanghai Nanjing Freeway Interchange (Group) from the drivers and vehicle groups in divert, confluence position , speed and other traffic behaviors. The research into the behavioral characteristics of traffic conditions on multi -lane which explore the design concepts and practice of the people, vehicles and environmental harmony and adapt in the divided and confluence areas of the freeway, for (widening) the divided and confluence areas of the multi-lane freeway safety design and operation management to provide realistic basis.

References

GuoZhongyin(2012),RoadSafetyEngineering,Beijing,People'sCommunications Press,2012.

Fisher,R.L(1948).Traffic Performance on Acceleration and Deceleration Lanes. Highway Research Board, Washington, DC, Volume 18(4), 1948.

Olsen, R.A. and R.S. Hostetter(1976). Describing and Shaping Merging Behavior of Freeway Drivers. InTransportation Research Record605 , Transportation

Research Board, National Research Council, Washington, D.C., 1976, pp. 7-13.

Kou,C.C.,R.B(1997).Machemehl. Modelling Vehicle Acceleration-Deceleration Behavior during Merge Maneuvers. Canadian Journal of Civil Engineering.Vol. 24(3) , 1997, pp.350- 358.

Li Li, Jiang Rui, Jia Bin, Zhao Xiaomei, etc.(2011), Modern Traffic Flow Theory and Application, Volume I- Freeway Traffic Flow, Beijing, Tsinghua University Press, 2011.

Li Yingfeng,Shi Zhong-ke(2008).Microscopic Traffic Simulation of Random Decisions Lane-changing Dehavior , Journal of System Simulation, 2008.

Zhao Cui; MING;Zhao Nina(2012), Driving Behavior in Freeway Interchange Diverging Area, Highway and Transportation Research, 2012.

Wang Xiaofei, Fu Xinsha, Ge Ting.(2011).Traffic Risk Assessment Model of Entrance Area in Freeway Interchange. Journal of Transportation Engineering,2011.10.

Yan Ying Sheng, Yanting,Yuanhua Zhi,Liu Haoxue(2011).Traffic Risk Assessment and Speed Control in Freeway Entrance Area,.Journal of Transportation Engineering, 2011.4.

Field Test of Vehicles' Speed Driving Behavior in Multi-Lane Freeway Interchange Diverging Areas

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Abstract: In order to explore and research the characteristic of vehicles' speed driving behavior in a multi-lane freeway interchange diverging area, and provide realistic basis for safety design of diverging area, this paper choosed Hu-Ning multi-lane freeway interchange (groups) as a field observation engineering, and used MC5600 vehicle type pneumatic tube system statistics and field velocity data and SPSS Statistics software processing data. Tests showed that: the relationship between the frequency and the velocity of cars and trucks are the normal distribution. Two-lane ramp terminal average speed of cars is 75~85 km/h, and the operating speed (V85) of cars is 90~100 km/h; the single lane average speed of cars is 60~70 km/h, and the operating speed (V85) of cars is 80~95 km/h. Two-lane ramp terminal average speed of trucks is 70~80 km/h, and the operating speed (V85) of trucks is 80~90km/h; the single lane ramp terminal average speed of trucks is 60~85 km/h, and the operating speed (V85) of trucks is 65~100 km/h.
Keywords: Multi-lane freeway; Diverging areas; Driving behavior; Operating speed; Safety design.

1 Introduction

China is entering into a multi-lane freeway and the new period of expansion. Studies have shown that the freeway interchange has the highest possible area of accident frequency and severity (McCartt, A.T., 2004). Some researches of multi-lane freeway interchange diverging areas design standards shows that diverging areas is an area of high accident rates , but currently it can be hardly provided clear and updated geometric design standards to the designer (El-Basha, R.H.S., 2006). Domestic and international statistics show that accident rates of multi-lane freeway interchange diverging areas reached about 40% in the entire interchange area (Li Guang, 2012). The vehicle speed characteristics directly affect traffic safety and operational efficiency in multi-lane freeway interchange diverging areas. Reports (The First Highway Survey and Design Institute Co. Ltd.,

2012) showed two-way four lane Expressway merge area and ramp vehicle speed behavior observation test, and achieved to the vehicle running speed of V85, then analyzed The velocity gradient analysis of vehicle. AASHO recommended on an average speed of main line as interchange ramp design speed, the main line design speed of 1/2 is as minimum ramp design speed; Canadian recommendations to the main line design and left some room(Jia Li,2003).Abdel-Aty(Abdel-Aty,M.,2006) studied the road safety performance enhancement effect on different limited speed conditions in Orlando and Florida by experiment, and it was concluded the speed limit has a specific effect on freeway diverging areas upstream, downstream traffic accident.

Tennessee Department of Transportationat (TxDOT) (Fitzpatrick,K.,2006) project research provided different design standards when design speed is greater than 80mi / h freeway.

Vehicle needs a certain critical points in the diverging area before the completion of their diversion lane change behavior, but decide whether it makes the most direct factor that a person produces diversion lane change intent is the distance between the vehicle and the key point(Li Yingfeng,2008).Driving is a complex intelligent behavior. For diverging area and exit ramp, vehicle is along the line the outside lane in theory .when driving a certain position in the area , between fluence into the deceleration lane and the exit ramp. vehicles begin streaming into the deceleration lane change lane and exit ramp .However, due to the mutual influence of subjective and objective factors, traffic location showed differences in multi-lane freeway diverging areas. Based on the safety design concept of man-machine engineering, road design should be people-oriented(Zhao Cui,2012).

Because the freeway entrance region exists straight and the confluence of the traffic flow, traffic behavior becomes more complex than other roads . When the vehicle is accelerating or decelerating to enter or leave the lane, it will produce many conflicts, easily leading to accidents(Wang Xiaofei,2011).From the respect of microscopic traffic safety research. Many scholars at home and abroad established the models by analyzing the relations among the geometric road design, operating characteristics of the vehicle , the driver of the psychological and physiological responses , environmental factors and traffic safety（Yan Ying Sheng，2011）.

In summary, due to the driver's driving process is a process of information exchange and control , while vehicle status and environmental status information is a fundamental basis for the driver's decision to drive behavior（Guo Zhongyin，2012).Given the reality both of accident happening frequently and the lack and differentiation of shunt vehicle driving behavior in Multi-lane Freeway Interchange Diverging Areas , this article through technical means far-field observations triage area for multi- lane freeway vehicle speed operational phase behavior depth exploration. This paper further explores the vhicles speed driving behavior by far field observation techniques.

2 Test instruments and equipment

MC5600 vehicle type pneumatic tube can be used to text the data of two-way two-lane , and the motorcycle types are divided according to the wheel base . When the vehicles pass sensor of pneumatic tube, it can produce a signal , conduct to the unit by the side of the road , and form an axle electrical signal to collect the speeds of different motorcycle types when they pass the section . Figure 1 is MC56500 traffic data analysis and management and the schematic diagram of MC5600 is showed in the figure 2.

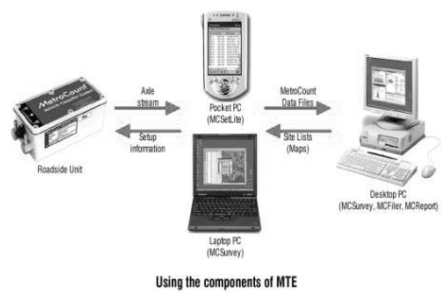

Figure1Traffic data analysis software

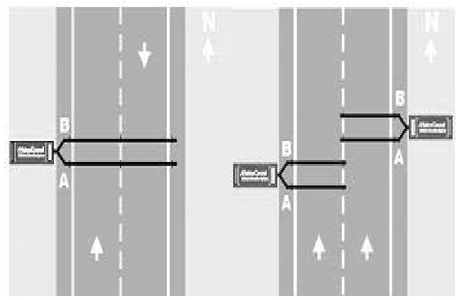

Figure2 MC5600 test equipment

3 Test Scheme Design and Data Collection

3.1 Test Scheme Design

Figure3 is the equipment schematic diagram of the field test research on driving behavior in diverging areas . Due to the limits of the large traffic flow, high speed, lane more objective reality conditions and so on , MC5600 vehicle type pneumatic tube system is only applied on the experimental research of the ramp terminal or the ramp.

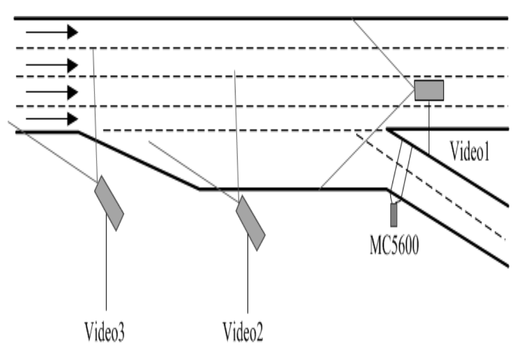

Figure3 Field test design schematic in diverging area

3.2 Data Collection and Test Process

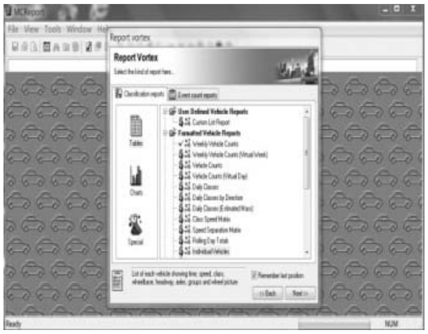

Figure4 MC5600 data acquisition platform

Figure 5 MC5600 data output

Through testing the field observations speed characteristics of different models , we Analyzes the internal mechanism and reveals the influence on road traffic safety . Figure 4 is MC5600 data acquisition platform . Figure5 is MC5600 data output.

4 Analysis of Experimental Data

4.1 The Bus Speed Analysis of Multi-lane Freeway Diverging Area terminal

4.1.1 Bus Speed Analysis of Two-lane ramp Diverging Area Terminal

Two-lane ramp is a kind of important form to be adapted to high density multi-lane freeway ramp traffic diversion,which often is applied in the junction of Interchange . Respectively, table 1and table2 are the Suzhou North and Zhengyi interchange speed statistics of bus.Figure7 and Figure 8 are buses speed chart in two-lane ramp diverging area terminal.

Table 1 shows that it has been measured the effective speed of 1166 bus as a sample which average is 86.53km/h in two-lane ramp diverging area terminal of Zhengyi interchange .In accordance with the determination of the 85th percentile speed driving speed as the operating speed (V85), its operating speed (V85) of 101.2km / h in two-lane ramp diverging area terminal of Zhengyi interchange .

Table 2 shows that it has been measured the effective speed of 982 bus as a sample which average is 75.30km / h in two-lane ramp diverging area terminal of Suzhou North interchange.According to statistical analysis of the measured data, its operating speed (V85) of 86.72km/ h in two-lane ramp diverging area terminal of Suzhou North interchange.

Contrastivly analyze the table 1 and table 2 , from the terms of the mean value, variance and the number and the maximum , Suzhou North Junction is smaller than Zhengyi Junction , but difference between them is about 10 km/h. For speed in the diverging area driving behavior are objective and representative , and can meet the requirements of analysis in the terms of ration and changing trends .We investigate its reason , analyzing the term of diverging area ramp , in the test of Suzhou North Junction , we choose the diverging area ramp of Suzhou and Hangzhou directions , while the test of Zhengyi Junction is Zhengyi diverging area , so the former traffic volume and heavy duty truck scale is larger than the latter , which is the main reason of otherness . Analyzing from the geometric forms of diverging area ramp , they both locate in the plains , but the plane curve radius of the main line in the Suzhou North Junction is obviously smaller than it in Zhengyi Junction , having effects on the sights , while Zhengyi Junction diverging area is located in the straight line and have a good sights . So the difference of geometric linear in the diverging area play a significant part in the influence of diversities in speed .

Table1. Speed statistics of bus in two-lane ramp diverging area(a)

Effective Sample	1166
Average Value(km/h)	86.53
Median(km/h)	86.30
Plural(km/h)	92
Standard Deviation	14.347
Variance(km/h)	205.831
Skewness	-0.199
Standard Error of Skewness	0.072
Kurtosis	0.619
Standard Error of Kurtosis	0.143
Full Distance(km/h)	107
Minimum(km/h)	20
Maximum(km/h)	126
Percentile 25(km/h)	77.07
50(km/h)	86.30
75(km/h)	96.10
85(km/h)	101.20

Table2. Speed statistics of bus in two-lane ramp diverging area(b)

Effective Sample	982
Average Value(km/h)	75.30
Median(km/h)	75.70
Plural(km/h)	69
Standard Deviation	11.772
Variance(km/h)	138.574
Skewness	-0.681
Standard Error of Skewness	0.078
Kurtosis	3.370
Standard Error of Kurtosis	0.156
Full Distance(km/h)	95

Minimum(km/h)	15
Maximum(km/h)	110
Percentile 25(km/h)	68.65
50(km/h)	75.70
75(km/h)	82.20
85(km/h)	86.70

From the analysis of the table, bus speed and frequency can be adopted between the normal distribution curve fitting, in which average speed is among 75~85km/h and operating speed (V85) is 90~100km/h in two-lane ramp diverging area terminal.

4.1.2 Speed Statistics of Bus in Single-lane Ramp Terminal

Table 3 described the speed statistics of bus in single-lane ramp terminal of Suzhou North junction in the direction of Hangzhou.And table 4 is the speed statistics of bus in single-lane ramp terminal of Suzhou North junction in the direction of Suzhou.

Table 3 Speed statistics of bus in single-lane ramp terminal（a）

Effective Sample	291
Average Value(km/h)	69.50
Median(km/h)	66.70
Plural(km/h)	52
Standard Deviation	24.765
Variance(km/h)	613.320
Skewness	-0.078
Standard Error of Skewness	0.143
Kurtosis	-0.430
Standard Error of Kurtosis	0.285
Full Distance(km/h)	104
Minimum(km/h)	12
Maximum(km/h)	116
Percentile 25(km/h)	52.00
50(km/h)	66.70
75(km/h)	91.50
Effective Sample	95.80

From the analysis of the table, bus speed and frequency could also be adopted between the normal distribution curve fitting,in which average speed is among 60~70km/h and operating speed (V85) is 80~95km/h in single-lane ramp diverging area terminal.

Table 4 Speed statistics of bus in single-lane ramp terminal(b)

Effective Sample	112
Average Value(km/h)	63.30
Median(km/h)	64.40
Plural(km/h)	80
Standard Deviation	14.471
Variance(km/h)	209.418
Skewness	-0.387
Standard Error of Skewness	0.228
Kurtosis	0.145
Standard Error of Kurtosis	0.453
Full Distance(km/h)	72
Minimum(km/h)	28
Maximum(km/h)	100
Percentile 25(km/h)	56.15
50(km/h)	64.40
75(km/h)	72.80
Effective Sample	78.91

4.2TheTrucksSpeedAnalysisofMulti-lane Freeway Diverging Area Terminal

4.2.1 The Speed of Trucks in Two-lane Ramp Terminal

Two-lane ramp is a kind of important form to be adapted to high density multi-lane freeway ramp traffic diversion ,which Often is applied in the junction of Interchange . Respectively, table 5and table 6 are the Suzhou North and Zhengyi interchange speed statistics of trucks at Hu-Ning multi-lane freeway ,which was analyzed with the software of SPSS Statistics.

Table 5 Speed analysis of trucks in Zhengyi interchange diverging area

Effective Sample	525
Average Value(km/h)	77.73
Median(km/h)	76.40
Plural(km/h)	65
Standard Deviation	13.354
Variance(km/h)	178.340
Skewness	0.458
Standard Error of Skewness	0.107
Kurtosis	0.230
Standard Error of Kurtosis	0.213
Full Distance(km/h)	84

Minimum(km/h)	43
Maximum(km/h)	126
Percentile 25(km/h)	67.80
50(km/h)	76.40
75(km/h)	86.30
85(km/h)	91.91

Table 6.Speed analysis of trucks in Suzhou North interchange diverging area

Effective Sample	181
Average Value(km/h)	68.41
Median(km/h)	68.70
Plural(km/h)	71
Standard Deviation	10.410
Variance(km/h)	108.377
Full Distance(km/h)	66
Minimum(km/h)	35
Maximum(km/h)	101
Percentile 25(km/h)	62.00
50(km/h)	68.70
75(km/h)	74.80
85(km/h)	79.62

Table 5 shows that it has been measured the effective speed of 525 trucks as a sample which average is 77.73km / h in two-lane ramp diverging area terminal of Zhengyi interchange .In accordance with the determination of the 85th percentile speed driving speed as the operating speed (V85), its operating speed (V85) of 91.91km/ h in two-lane ramp diverging area terminal of Zhengyi interchange .Table 6 shows that it has been measured the effective speed of 181 trucks as a sample which average is 68.41km / h in two-lane ramp diverging area terminal of Suzhou North interchange.According to statistical analysis of the measured data, its operating speed (V85) of 79.62km / h in two-lane ramp diverging area terminal of Suzhou North interchange.

The buses' speed and frequency can be adopted between the normal distribution curve fitting,in which average speed is among 70~80km/h and operating speed (V85) is 80~90km/h in two-lane ramp diverging area terminal.

4.2.2 Speed Statistics of Trucks in Single-lane RampTerminal

Table7 described the speed statistics of trucks in single-lane ramp terminal of Suzhou North junction in the direction of Hangzhou.And table 8 is the speed statistics of trucks in single-lane ramp terminal of Suzhou North junction in the direction of Su zhou.

Table 7 shows that it has been measured the effective speed of 141 trucks as a sample which average is 85.01km / h in single-lane ramp diverging area terminal of Suzhou North interchange . its operating speed (V85) of 91.91km / h in single-lane ramp diverging area terminal of Suzhou North interchange .Table 8 shows that it has been measured the effective speed of 40 trucks as a sample which average is 58.47km/h in single-lane ramp diverging area of Suzhou North interchange.According to statistical analysis of the measured data, its operating speed (V85) of 64.96km/ h in single-lane ramp diverging area terminal of Suzhou North interchange.

Table 7. Speed analysis of trucks in single lane ramp diverging area(a)

Effective Sample	141
Average Value(km/h)	85.01
Median(km/h)	84.90
Plural(km/h)	102
Standard Deviation	17.943
Variance(km/h)	321.937
Skewness	0.048
Standard Error of Skewness	0.204
Kurtosis	-0.912
Standard Error of Kurtosis	0.406
Full Distance(km/h)	76
Minimum(km/h)	48
Maximum(km/h)	124
Percentile 25(km/h)	70.25
50(km/h)	84.90
75(km/h)	101.80
85(km/h)	104.58

From the result ,bus speed and frequency can be adopted between the normal distribution curve fitting,in which average speed is among 60~85km/h and operating speed (V85) is 65~100km/h in single-lane ramp diverging area terminal.

Table 8 Speed analysis of trucks in single lane ramp diverging area(b)

Effective Sample	40
Average Value(km/h)	58.47
Median(km/h)	59.50
Plural(km/h)	50
Standard Deviation	9.175
Variance(km/h)	84.180
Skewness	-0.250

Standard Error of Skewness	0.374
Kurtosis	1.253
Standard Error of Kurtosis	0.733
Full Distance(km/h)	47
Minimum(km/h)	35
Maximum(km/h)	81
Percentile25(km/h)	54.33
50(km/h)	59.50
75(km/h)	62.83
85(km/h)	64.96

5 Conclusion

This paper choosed Hu-Ning multi-lane freeway interchange (groups) as a field observation engineering , used MC5600 vehicle type pneumatic tube system statistics and field velocity data and SPSS Statistics software processing data , combined with the current confluence area security advanced design concept for safety design index analysis speed and obtained by statistical analysis methods autostrada triage area end vehicle speed traffic behavior characteristics , provide realistic basis for Multiple lanes freeway main design speed, the triage area variable lane length of geometric design and ramp design speed , determination of technical indicators.

References

McCartt,A.T.,V.S.Northrup,and R.A(2004).Retting. Types and Characteristics of Ramp Related Motor Vehicle Crashes on Urban Interstate Roadways in Northern Virginia. Journal of Safety Research, Elsevier Ltd., Volume 35, pp.107-114, 2004.

El-Basha, R.H.S(2006). Driver Speed Behavior on Freeway Deceleration Speed-Change Lanes. M.A.Sc. Thesis, Department of Civil and Environmental Engineering, Carleton University, Ottawa, 2006.

Li Guang, Li Zhiyong, Yuan Jie, Xu Ying(2012).Safety Evaluation of Freeway Interchange in Ramp Diverging Area, Highway Engineering, 2012.

Mountains Highway Network Security Technology System Research and Demonstration Project, The First Highway Survey and Design Institute Co., Ltd., 2012.

Jia Li, Fang Xia(2003). Design and Safety Studies of Freeway Merging Areas, Central South Highway Engineering, 2003.

Abdel-Aty,M.,Dilmore, J.,and Dhindsa,A.(2006),Evaluation of variable speed limits for real-time freeway safety improvement, Accident Analysis and Prevention, 2006, vol38, p335-345.

Fitzpatrick,K., K.Zimmerman,R.Bligh,S.Chrysler, and B. Blaschke (2006). Criteria for High Design Speed Facilities. FHWA/TX-07/0-5544-1.

Li Li, Jiang Rui, Jia Bin, Zhao Xiaomei, etc.(2011), Modern Traffic Flow Theory and Application, Volume I- Freeway Traffic Flow, Beijing, Tsinghua University Press, 2011.

Li Yingfeng,Shi Zhong-ke(2008).Microscopic Traffic Simulation of Random Decisions Lane-changing Dehavior, Journal of System Simulation, 2008.

Zhao Cui; MING;Zhao Nina(2012), Driving Behavior in Freeway Interchange Diverging Area, Freeway and Transportation Research, 2012.

Wang Xiaofei, Fu Xinsha, Ge Ting(2011). Traffic Risk Assessment Model of Entrance Area in Freeway Interchange, Journal of Transportation Engineering,2011.10.

Yan Ying Sheng, Yanting,Yuanhua Zhi,Liu Haoxue(2011).Traffic Risk Assessment and Speed Control in Freeway Entrance Area,Journal of Transportation Engineering, 2011.4.

Guo Zhongyin(2012), Road Safety Engineering, Beijing,People's Communications Press,2012.

Urban Traveler Travel Mode Choice Equilibrium Model under the Condition of Bus Lanes

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Abstract: Considering urban residents in peak period, the residents can choose by way of car, bus, subway travel network composition of three kinds of travel way to travel. There are bus lanes in the urban road, constitute the travel cost function with urban residents by considering the main factors in the process of travel mode choice. The travel mode choice equilibrium model was established that the bus lane conditions in the peak travel period, on the basis of the User equilibrium theory. Obtain the maximum delay time, the number of trips and travel costs in travel costs equilibrium state. The rationality of the model was verified by a simple numerical example, the next was further discussed that subway fares impact on travel division of three ways. The results showed that: On the one hand, the Subway travel mode by most people's choice, because this way is travel time stability, this is also consistent with the actual situation. But also be launched from the side to avoid the uncertainty of residents during the trip. On the other hand, the subway fares effects of urban travelers' travel mode choice.

Keywords: Bus lane; Rush hour; Travel mode; Travel cost equilibrium.

1 Introduction

In 1952, the famous scholar Wardrop proposed user equilibrium (UE) principle and system optimization (SO) theory (Shao Chunfu, 2004). User equilibrium principle can be described as: road traffic distributes in such a way that travel costs are the same in the path actually used and less than any unused path.

This paper analyzes the problems of travel mode choice equilibrium in the rush hour. This problem can be simply described as follows: Suppose there are N residents travel from living areas to workspaces every morning, in relatively stable travel process, N can be regarded as constant. Every morning peak, N_1 residents choose cars, N_2 residents choose buses, N_3 residents choose subways, the number of each travel mode is unknown. Assuming cars and buses share a road, buses drive on the bus lanes on the very outside, there is a bottleneck at the end of the road. The capacity of the bottleneck is s, when the road vehicles exceeds s, people have to queue up and wait to pass the neck.

The author in the process of establishing processing on the bottlenecks problem and model also draw on research results related to traffic bottleneck theory (Vickrey, 1969; Arnott et al, 1988, 1990, 1993, 1998; Tabuchi, 1993; Lin Zhen, Yang Hao, 2003, 2004). In the condition of bus lanes, travel mode of buses will not affected by the bottleneck. Travel time of buses can be regarded as a definite value. Of course, due to the decline of capacity in the bottleneck, cars have to queue up and wait to pass the neck. Travel mode choice equilibrium is the balance of residents' travel costs, this paper will establish equilibrium model of travel mode choice, focus on the connection of subway fares, travel cost and the number distribution of residents.

2 Symbol definition

Symbols are defined as follows:

t ——Departure time of car mode and the time that arrive at the pick-up point of bus and subway;

t^* ——The time of arriving destination on time;

$C_j(t)$ ——The cost of mode j;

T_j^c ——General time of travel mode j in off-peak;

$T_j^e(t)$、$T_j^p(t)$、$T_j^l(t)$ ——When being early, on time or late, queue waiting time at the bottleneck of mode j;

T_2^o、T_3^o ——The time of walking to the bus and subway, assuming constant;

$T_2^d(t)$、$T_3^d(t)$ ——The time of residents waiting at bus station and subway station;

t_j^e、t_j^p、t_j^l ——For cars, they refer to earliest departure time, departure time when arrive on time and latest departure time; For buses and subways, they refer to earliest arriving time, arriving time when arrive on time and latest arriving time at bus station or subway station;

θ_1、θ_2、θ_3 ——Residents travel cost per unit time, the unit cost of penalty for early and late;

P_j ——The fare of mode j;

π_j ——uncomfortable cost function produced by crowded inside of mode j;

α、β——uncomfortable cost coefficient produced by crowded outside in the rush hours of bus and subway;

Among them： $j = 1,2,3$; represent cars mode, buses mode and subways mode.

3 Establishing equilibrium models

3.1 Equilibrium of cars travel cost

N_1 residents travel by cars in the rush hour. Cost for car mode: travel time cost (off-peak time, bottleneck delay time), penalty cost for early or late, fixed monetary cost (mainly refers to the fuel surcharge, parking fees, etc.). Residents can be divided into three categories respectively: early, on time and late. Residents bear the penalty cost for early or late.

Therefore, the cost of all residents that choose car mode can be expressed as:

$$C_1(t)=\begin{cases}\theta_1[T_1^c+T_1^e(t)]+\theta_2[t^*-t-T_1^c-T_1^e(t)]+P_1 & t\in[t_1^e,t_1^p)\\ \theta_1[T_1^c+T_1^p(t)]+P_1 & t=t_1^p\\ \theta_1[T_1^c+T_1^l(t)]+\theta_3[T_1^c+T_1^l(t)+t-t^*]+P_1 & t\in(t_1^p,t_1^l]\end{cases} \quad (1)$$

When car mode is at equilibrium, whether residents arrive early, on time or late, their travel costs are the same. Suppose in the earliest and latest departure time, there is no delay time at bottleneck. It means residents set out at $t\in(t^e,t^l)$ that have to queue up and wait. So in the station of equilibrium, the expected travel costs of residents that set out at $t=t_1^e$, $t=t_1^p$, $t=t_1^l$ are the same. Therefore, following is the equation:

$$E[C_1(t)]=\begin{cases}\theta_1 E[T_1^c]+\theta_2 E[t^*-t_1^e-T_1^c]+P_1 & t=t_1^e\\ \theta_1 E[T_1^c+T_1^p(t_1^p)]+P_1 & t=t_1^p\\ \theta_1 E[T_1^c]+\theta_3 E[T_1^c+t_1^l-t^*]+P_1 & t=t_1^l\end{cases} \quad (2)$$

Rush hours at the bottleneck starts at t_1^e and ends at t_1^l, so queue waiting duration in the rush hours is $T=t_1^l-t_1^e$. The capacity of a path is determined by the bottleneck, so based on the related theory of traffic engineering （Wang wei, 2000） ,we know $T = nN_1/(n-1)S$, therefore：

$$t_1^l = t_1^e + N_1 / \frac{(n-1)S}{n} \quad (3)$$

When cars travel cost is at equilibrium, according to equation (4) and (5),we can get：

$$\begin{cases} t_1^e = t^* - T_1^c - \frac{\theta_3}{\theta_2+\theta_3} \cdot \frac{nN_1}{(n-1)S} \\ t_1^l = t^* - T_1^c + \frac{\theta_2}{\theta_2+\theta_3} \cdot \frac{nN_1}{(n-1)S} \\ t_1^p = t^* - T_1^c - \frac{\theta_2\theta_3}{\theta_1(\theta_2+\theta_3)} \cdot \frac{nN_1}{(n-1)S} \end{cases} \quad (4)$$

$$T_1^p = \frac{\theta_2\theta_3}{\theta_1(\theta_2+\theta_3)} \cdot \frac{nN_1}{(n-1)S} \quad (5)$$

$$C_1(t) = \theta_1 T_1^c + \frac{\theta_2\theta_3}{\theta_2+\theta_3} \cdot \frac{nN_1}{(n-1)S} + P_1, \quad t \in [t_1^e, t_1^l] \quad (6)$$

3.2 Equilibrium of buses travel cost

Under the condition of bus lanes, there are N_2 residents that choose to travel by buses, cost for bus mode include: travel time cost (including walking time, queue waiting time and bus travel time), penalty cost for early or late, uncomfortable cost produced by crowded inside and bus fare. Uncomfortable cost produced by crowded inside is associated with travel time and number of passengers, the coefficient associated with number of passengers is α, so uncomfortable cost produced by crowded is $\pi_2[\alpha T_2^c(t)]$.

Same to the cars mode, the expected travel costs of residents are the same in the station of equilibrium.

So, we can get:

$$\begin{cases} t_2^e = t^* - T_2^c - \frac{\theta_3}{\theta_2+\theta_3} \cdot \frac{N_2}{S_2} \\ t_2^l = t^* - T_2^c + \frac{\theta_2}{\theta_2+\theta_3} \cdot \frac{N_2}{S_2} \\ t_2^p = t^* - T_2^c - \frac{\theta_2\theta_3}{\theta_1(\theta_2+\theta_3)} \cdot \frac{N_2}{S_2} \end{cases} \quad (7)$$

$$T_2^d = \frac{\theta_2\theta_3}{\theta_1(\theta_2+\theta_3)} \cdot \frac{N_2}{S_2} \qquad (8)$$

$$C_2(t) = \theta_1(T_2^o + T_2^c) + \frac{\theta_2\theta_3}{\theta_2+\theta_3} \cdot \frac{N_2}{S_2} + \pi_2(\alpha T_2^c) + P_2, \quad t \in [t_2^e, t_2^l] \qquad (9)$$

3.3 Equilibrium of subways travel cost

Similar with buses, we can get:

$$\begin{cases} t_3^e = t^* - T_3^c - \dfrac{\theta_3}{\theta_2+\theta_3} \cdot \dfrac{N_3}{S_3} \\ t_3^l = t^* - T_3^c + \dfrac{\theta_2}{\theta_2+\theta_3} \cdot \dfrac{N_3}{S_3} \\ t_3^p = t^* - T_3^c - \dfrac{\theta_2\theta_3}{\theta_1(\theta_2+\theta_3)} \cdot \dfrac{N_3}{S_3} \end{cases} \qquad (10)$$

$$T_3^d = \frac{\theta_2\theta_3}{\theta_1(\theta_2+\theta_3)} \cdot \frac{N_3}{S_3} \qquad (11)$$

$$C_3(t) = \theta_1(T_3^o + T_3^c) + \frac{\theta_2\theta_3}{\theta_2+\theta_3} \cdot \frac{N_3}{S_3} + \pi_3(\beta T_3^c) + P_3, \quad t \in [t_3^e, t_3^l] \qquad (12)$$

3.4 Equilibrium model of travel mode

When travel mode reaching equilibrium station, residents set out in rush hours have same travel cost no matter which mode they choose. A resident cannot reduce his cost by unilaterally changing his travel time or mode. That is to say, in the equilibrium condition of travel modes, meet the formula (13):

$$\begin{cases} C(t) = C_j(t) & N_i > 0 \\ C(t) \le C_j(t) & N_i = 0 \quad i = 1、2、3; j = 1,2,3; \\ N = \sum N_i \end{cases} \qquad (13)$$

$C(t)$ is the travel cost in the equilibrium condition of travel modes.

In practical situation, it is impossible that any travel mode is not selected in rush hours. So, formula (13) can be converted into formula (14):

$$\begin{cases} C(t) = C_1(t) = C_2(t) = C_3(t) \\ N = N_1 + N_2 + N_3 \end{cases} \qquad (14)$$

Total number of residents N is known already, $C_1(t)$、$C_2(t)$ and $C_3(t)$ have been calculated respectively. Bringing formula (6),(9) and (12) into（14）:

$$\begin{cases} C(t)=C_1(t)=\theta_1 T_1^c+\dfrac{\theta_2\theta_3}{\theta_2+\theta_3}\cdot\dfrac{nN_1}{(n-1)S}+P_1 \\ C(t)=C_2(t)=\theta_1(T_2^o+T_2^c)+\dfrac{\theta_2\theta_3}{\theta_2+\theta_3}\cdot\dfrac{N_2}{S_2}+\pi_2(\alpha T_2^c)+P_2 \\ C(t)=C_3(t)=\theta_1(T_3^o+T_3^c)+\dfrac{\theta_2\theta_3}{\theta_2+\theta_3}\cdot\dfrac{N_3}{S_3}+\pi_3(\beta T_3^c)+P_3 \\ N=N_1+N_2+N_3 \end{cases} \quad (15)$$

We can get C and [N_1, N_2, N_3] by solving formu la (15):

$$\begin{cases} N_1=\dfrac{(n-1)(A^1+B^1+SN)}{[nS_2+nS_3+Sn-S]} \\ N_2=\dfrac{nS_2(B^1+SN)-A^1[nS_3+nS-S]}{S[nS_2+nS_3+nS-S]} \\ N_3=N-N_1^1-N_2^1 \end{cases} \quad (16)$$

$$C=\theta_1(T_2^o+T_2^c)+\frac{\theta_2\theta_3}{\theta_2+\theta_3}\cdot\frac{nS_2(B^1+SN)-A^1[nS_3+nS-S]}{SS_2[nS_2+nS_3+nS-S]}+\pi_2(\alpha T_2^c)+P_2 \quad (17)$$

In formula(16)and(17):

$$\begin{cases} A^1=\dfrac{SS_2(\theta_2+\theta_3)}{\theta_2\theta_3}[\theta_1(T_2^o+T_2^c-T_1^c)+\pi_2(\alpha T_2^c)+P_2-P_1] \\ B^1=\dfrac{SS_3(\theta_2+\theta_3)}{\theta_2\theta_3}[\theta_1(T_3^o+T_3^c-T_1^c)+\pi_3(\beta T_3^c)+P_3-P_1] \end{cases} \quad (18)$$

4 Example analysis

According to the equilibrium model of travel mode, set up relevant numerical parameters, assuming the subway fare (P_3) is variable. A numerical example set parameters are shown in table 1 and table 2.

Table 1. parameters 1

Parameters	N	T_1^c	T_2^c	T_3^c	T_2^o	T_3^o	P_1	P_2	q
Value	20000	1.0	1.5	1.2	0.1	0.15	12	2	0.025

Table 2. parameters 2

Parameters	θ_1	θ_2	θ_3	α	β	S	S_2	S_3	n
Value	15	10	20	0.8	1.2	6000	4000	10000	4

When travel cost is under equilibrium condition, assuming $\pi_2(\alpha T_2^c) = \alpha T_2^c, \pi_3(\beta T_2^c) = \beta T_3^c$, fitting formula of P_3 about residents travel distribution and travel cost can be solved as follows by formula (16), (17) and (18):

$$\begin{cases} N_1 = 2956.6216 + 364.8648 * P_3 \\ N_2 = 2508.1081 + 324.3243 * P_3 \\ N_3 = 14535.2707 - 689.1891 * P_3 \\ C = 31.3802 + 0.5405 * P_3 \end{cases} \quad (19)$$

According to formula(19), $P_3 \in [0, 21.09]$.

Draw formula (19) in the reasonable range of P_3 by Matlab, the result is as follows:

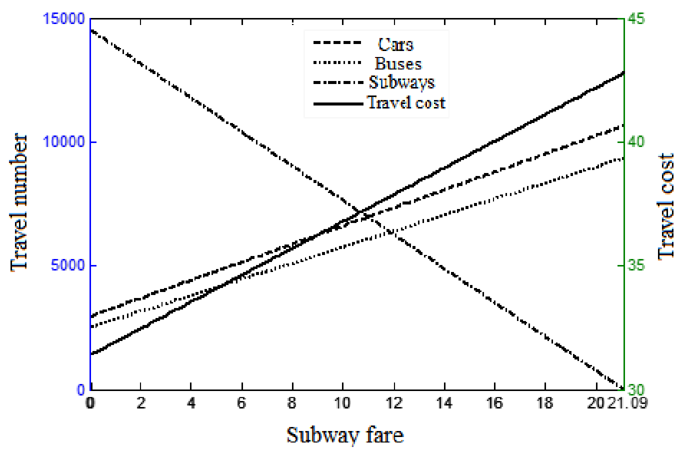

Figure 1. Subway fares relationship with travel number distribution and travel costs under the condition of bus lane

We can get following conclusions through above chart:

(1) When the city subway fare is lower than 11, subway is most popular.

(2) The relationship between subway fares and the number of residents is negative, when fare tends to 0, the number of residents choose subways reaches the maximum value of 14535, when the number tends to 0, subway fare reached the maximum value of 21.09.

5 Conclusion

In order to study the macro situation of urban residents travel mode choice in the rush hour, this paper consulted user equilibrium thought and bottleneck theory, establishing equilibrium model of travel mode choice under the condition of bus lane, the example analyzed the relationship between subway fare, distribution of residents and travel cost. The results show that: (1) subway is most popular because of its stability, large volume and relatively fast speed; (2) the example analysis indicates the applicability and rationality; (3) starting from the subway fare setting angle, equilibrium model of travel mode choice can provide relevant reference for the formulation of subway fare, and put forward a new theory and research method for the relationship between subway fares and the number of residents take subways.

References

Arnott R, Depalma A, Lindsey R. (1990).Economics of a bottleneck. *Journal of Urban Economics*, 27(1):111-130.

Arnott R, Depalma A, Lindsey R. (1993). A structural model of peak-period congestion: A traffic bottleneck with elastic demand. *The American Economic Review*, 83(1):161-179.

Arnott R, Depalma A, Lindsey R. (1988).Schedule delay and departure time decisions with heterogeneous commuters.*Transportation Research Record*, 1197:56-67.

Arnott R, Depalma A, Lindsey R. (1998.)Recent development in the bottleneck .In: Button K J, Verhoef E T, Road Pricing, Traffic congestion and environment. *USA: Edward Elgar Publishing*, 79-110.

Lin Zhen, Yang Hao.(2003).Modal split based on bottleneck model of public transport. *China Civil Engineering Journal*, .36(7)：1-6.

Lin Zhen, Yang Hao.(2004).Characteristics of trip modal equilibria under different conditions. *Journal of Industrial Engineering Management,* 18(2)：30-34.

Shao ChunFu.(2004).Traffic Planning. *China Railway Publishing House*, 151-161.

Tabuchi T.(1993).Bottleneck congestion and modal split. *Journal of Urban Economics*. 34(3):414-431.

Vickrey W S.(1969).Congestion theory and transport investment. *The American Economic Review*. 59(2):251-260.

Wang Wei, Guo XiuCheng. (2000). Traffic Engineering. *Southeast University Press*, 125-169.

Forecast Model of Conventional Public Transit Passenger Volume in Small- and Medium-Sized Cities Based on the IHGA-LS-SVM with Grey Correlation Analysis

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Abstract: Based on the principal factor analysis of conventional public transit passengers' volume in small and medium-sized cities, the forecast model of passengers' volume on the basis of IHGA-LS-SVM with Grey Correlation Analysis is proposed. By applying Grey Correlation Analysis between the influencing factors of passenger' volume, the input variables of LS-SVM were screened. Then an Improved Hybrid Genetic Algorithm (IHGA) is applied to optimize the selection of model parameters. When applied to forecast the conventional public transit passengers' volume in a city of Sichuan from 1999 to 2011, the results shows that compared to other forecast methods this model improves forecast accuracy, shorten the convergence, is a feasible and effective forecast model of conventional public transit passenger' volume in small and medium-sized cities.
Keywords: Urban traffic; Forecast model of passengers' volume; Grey correlation analysis; Least squares support vector machine; Improved Hybrid Genetic algorithm.

1 Introduction

With the accelerated process of urbanization in China, the total economy and the size of the population continues to expand in recent years, and development of public transit in small and medium-sized cities is closely related to the economy and convenience of residents' trips. So scientific and accurate forecast of public transit passengers' volume is an important reference to planning and management of urban public transport. However, the traditional statistical analysis and forecast methods that predict public transit passengers' volume are mostly based on large sample data which due to various limits in actual circumstances, are quite difficult to be collected. So for solving this problem, the least squares support vector machine (LS-SVM) (J. A. K. Suykens, J. Vandewalle, 1999), which is a reformulation to SVM (V. Vapnik, 1999) and suited for small sample data, is adopted to build the model to forecast public transit passengers' volume in small and medium-sized cities. For the regression accuracy and generalization ability of LS-SVM are extremely dependent on two hyper-parameters, the regularization parameter C and the kernel parameter σ, advanced meta-heuristic approaches are necessary to be used for optimization.

Based on the principal factor analysis of conventional public transit passengers' volume in small and medium-sized cities, the forecast model of passengers' volume on the basis of IHGA-LS-SVM with Grey Correlation Analysis is proposed. By applying GCA between the influencing factors of passenger' volume, the input variables of LS-SVM were screened, then an improved hybrid genetic algorithm (IHGA) is applied to optimize the selection of model parameters. When the model is applied to forecast the conventional public transit passengers' volume in a city of Sichuan, the results shows that compared to other forecast methods this model can effectively improve forecast accuracy, shorten the convergence. It's a feasible and effective forecast model of conventional public transit passenger' volume in small and medium-sized cities.

2 IHGA-LS-SVM Model with Grey Correlation Analysis

2.1 Grey Correlation Analysis

With Grey Correlation Analysis, the uncertain relative situation during objects or the relative situation of system factors can be explained quantitatively(Deng Julong,2002).GCA can analyzes and confirms the influence degree of factors according to the geometry approach degree of behavior factor list and data list, so taking the similar degree of curves as the weigh yardstick of correlation degree(Luo Youxin,Zhang Longting,Li Min,2001).There are many factors which influence the result of public transit passengers'volume forecast, and these factors have different influence degree to volume forecast, so the grey correlation among these factors must be analyzed with qualitative analysis(Chiang YuMin,Hsieh HsinHsien,2009). And initial value processing(Yao Tao,Wang Pengcheng,2004)is adopted to make the equal weight among factors(Zhang Yongjuan,Zhang Xiong,2007).Then setting the factors corresponding numbers as the original data series, which is presented by $x^0(k)$ ($k=1,2,\cdots,n$). The initial value processing is as below:

$$x(k)=x^0(k)/x^0(1)\,(k=1,2,\cdots,n) \qquad (1)$$

Then isopolarity processing of data series obtained from formula (1) can delete the negatives and reserve positive numbers of the data series. Isometric processing can transform the initial data, which makes the new variation tendency reflect the interaction levels of each factor, and moderate-effect measurement is adopted in this paper. The system takes factor sequences screened out as the element points of factors space, and takes those numbers of influencing factors as the part coordinate of this point(S.W.Zhang,T.X.Lan,etc,2010). So the factor sequence can be shown as follows:

$$x_i = [x_i(1), x_i(2), \cdots, x_i(k)] \tag{2}$$

Setting x_0 as the element points of reference factor, and $\eta_{0,i}$ as the grey correlation degree of factor sequence i ($i = 1,2,\cdots,N$) to the reference sequence:

$$\eta_{0,i} = \eta(x_0, x_i) = 1/n \sum_{k=1}^{n} \eta[x_0(k), x_i(k)] \tag{3}$$

The correlation coefficient of factor k on sequence i to the factor of reference sequence, which is denoted by $\mu_i(k)$, is calculated as follows:

$$\mu_i(k) = \eta(x_0(k), x_i(k)) = \frac{\min_{i\in N}\min_{k\in n}|x_0(k) - x_i(k)| + \mu \max_{i\in N}\max_{k\in n}|x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \mu \max_{i\in N}\max_{k\in n}|x_0(k) - x_i(k)|} \tag{4}$$

Where μ ($0 < \mu < 1$)represents resolution coefficient. By replacing $\eta[x_0(k), x_i(k)]$ of formula (3) with $\mu_i(k)$, a new formula of correlation degree is obtained as below:

$$\eta_i = 1/n \sum_{k=1}^{n} \mu_i(k) \tag{5}$$

The weight value of each factor sequence will be obtained after the normalization processing of μ_i, and the main factors can be sorted out.

2.2 IHGA-LS-SVM Model

2.2.1 LS-SVM Model

Compared with SVM which is a machine learning algorithm (J.A.K.Suykens, etc,2002)providing better generational ability than the empirical risk minimization used by traditional methods, the least squares support vector machine(LS-SVM) applies linear least squares criteria to the loss function to replace the inequality constraints with equality constraints. The optimization problem is defined as follows(J.A.K.Suykens,J.Vandewalle,1999):

$$\min_{\omega,\theta,\gamma} J(\omega,\gamma)=\frac{1}{2}\omega^T\omega+\frac{1}{2}C\sum_{i=1}^{N}\gamma_i^2 \tag{6}$$

Subject to $S_i=\omega^T\varphi(a_i)+\theta+\gamma_i$, $C>0$, $i=1,2,\cdots,N$.

The Lagrangian function can be set up by the formula below:

$$L(\omega,\theta,\gamma_i,\lambda_i)=J(\omega,\gamma)-\sum_{i=1}^{N}\lambda_i\left(\omega^T\varphi(a_i)+\theta+\gamma_i-S_i\right) \tag{7}$$

where λ_i is the i th Lagrange multiplier. The Karush–Kuhn–Tucker (KKT) conditions for optimality are described as follows(Fletcher R,1987):

$$\begin{cases} \dfrac{\partial L}{\partial \omega}=0\rightarrow\omega=\sum_{i=1}^{N}\lambda_i\varphi(a_i) \\ \dfrac{\partial L}{\partial \theta}=0\rightarrow\sum_{i=1}^{N}\lambda_i=0 \\ \dfrac{\partial L}{\partial \gamma_i}=0\rightarrow\lambda_i=C\gamma_i, i=1,2,\cdots,N \\ \dfrac{\partial L}{\partial \lambda_i}=0\rightarrow\omega^T\varphi(a_i)+\theta+\gamma_i=S_i \end{cases} \tag{8}$$

After eliminating variables ω and γ_i, the optimization problem could be transformed into the following form:

$$\begin{bmatrix} 0 & \vec{1}^T \\ \vec{1} & \varphi^T\varphi+C^{-1}I \end{bmatrix}\begin{bmatrix} \theta \\ \lambda \end{bmatrix}=\begin{bmatrix} 0 \\ S \end{bmatrix} \tag{9}$$

Where $S=[S_1,\cdots,S_N]^T$, $\lambda=[\lambda_1,\cdots,\lambda_N]^T$, $\varphi=[\varphi(a_1),\cdots,\varphi(a_N)]$, $\vec{1}=[1,\cdots,1]^T$,and I is the identity matrix. The solution of λ and θ can be obtained by solving Eq.(9). Then according to Mercer's theorem, the output result could be calculated as follow:

$$S_i=\sum_{i,j=1}^{M}\lambda_i K(a_i,a_j)+\theta \tag{10}$$

$$K(a_i, a_j) = \exp\left(-\|a_i - a_j\|^2 / 2\sigma^2\right) \tag{11}$$

where σ is the Gaussian kernel, and the kernel function $K(a_i, a_j)$ which is widely adopted is selected as the radial basis function (RBF) (J.A.K.Suykens,J.Vandewalle, 2000)in this paper for less numerical difficulties when implementing nonlinear mapping.

2.2.2 IHGA optimization

After the structure of LS-SVM is determined, the optimal penalty factor C and kernel parameter σ need to be searched while the appropriate selection of these two parameters will affect the learning performance of LS-SVM.In this paper, an improved hybrid genetic algorithm (IHGA) with better convergence speed and accuracy is proposed for parameter optimization. Its basic thought is taking the Levenberg-Marquardt optimization algorithm as an operation operator of GA. So IHGA which consists of four basic operators as selection, crossover, mutation and Levenberg-Marquardt optimization has both advantages of global searching of GA and local optimization ability of Levenberg-Marquardt optimization algorithm.The optimization process of LSSVM by IHGA is shown as follows:

(1)Coding mode. Initialize the population size and maximum iteration. The real coding method is selected to code C and σ to generate initial population.

(2)Fitness function. IHGA is introduced to search the optimal parameters so as to improve the classification precision. And the reciprocal value of root-mean-square error is chosen as the fitness which evaluates the performance of individuals.

(3)Selection. Based on the fitness, the roulette method and the optimal individual preservation strategy are adopted to ensure IHGA converging to the global solution.

(4)Adaptive crossover. Improved arithmetic crossover is proposed to generate new individuals.And the adaptive adjustment of p_c (Srinivas M,Patnaik L M,1994)is illustrated to improve the global search capability as follows:

$$p_c = \begin{cases} p_{c1} - (p_{c1} - p_{c2})(f_a - f_{avg}) / (f_{max} - f_{avg}), & f_a \geq f_{avg} \\ p_{c1}, & f_a < f_{avg} \end{cases} \tag{12}$$

$$p_c' = \begin{cases} p_{c1} - (p_{c1} - p_{c2})(f_b - f_{avg}) / (f_{max} - f_{avg}), & f_b \geq f_{avg} \\ p_{c1}, & f_b < f_{avg} \end{cases} \tag{13}$$

$$a_1' = (1 - P_c)a + P_c b, f_a < f_{avg}$$
$$a_2' = (1 - P_c)b + P_c a, f_a \geq f_{avg} \tag{14}$$

$$b_1' = (1 - P_c')b + P_c' a, f_b < f_{avg}$$
$$b_2' = (1 - P_c')a + P_c' b, f_b \geq f_{avg} \tag{15}$$

where $p_{c1} = 0.9$, $p_{c2} = 0.6$.

(5)Adaptive mutation. Nonuniform mutation is chosen in the paper. And the mutation probability p_m is also adaptively selected according to population fitness:

$$p_m = \begin{cases} p_{m1} - (p_{m1} - p_{m2})(f - f_{avg})/(f_{\max} - f_{avg}), & f \geq f_{avg} \\ p_{m1}, & f < f_{avg} \end{cases} \tag{16}$$

where $p_{m1} = 0.1$, $p_{m2} = 0.001$ .Set $x_{k,i}$ as the value of individual x_k corresponding to i th individual population, $\Delta x_{k,i+1}$ as the changing quantity of x_k when updating to $i+1$ th individual population, $x_{k,i+1}$ as the updating value of x_k , $x_{\max,k}$ as the optimal value of x_k , $x_{\max}$ as the known optimal value of all the populations, $r_1, r_2 \in [0,1]$.Then updating process of mutation operator is as below:

$$\Delta x_{k,i+1} = r_1(x_{\max,k} - x_{k,i}) + r_2(x_{\max} - x_{k,i}) \tag{17}$$

$$x_{k,i+1} = x_{k,i} + \Delta x_{k,i+1} \tag{18}$$

(6)Levenberg-Marquardt optimization(D.W.Marquardt,1963).After the updating operations above, Levenberg-Marquardt algorithm(Guo Xianghong,Sun Xihuan,Ma Juanjuan,2009) is applied as an operator to optimize the value of individuals.

(7)When the optimization process is finished, the global optimal solutions of C and σ are assigned to LS-SVM for the training and testing of sample data.

3 Analysis of case and validation

3.1 Data collection and variables selection

To testify the validation of IHGA-LS-SVM model with Grey Correlation Analysis, the relevant data of a city in Sichuan from 1999 to 2011 are collected to forecast the conventional public transit passengers' volume. Ten items of data as GDP, permanent resident population, urban built-up area, annual per capita disposable income of urban households, bicycle&electric bicycle ownership, motorcycle ownership, bus amount, total mileage of bus lines, total coverage area of bus stops (300m radius), conventional public transit passengers' volume are illustrated in table 1 (from Sichuan Statistical Yearbooks 1999-2011 and actual traffic surveys).

Table 1 Relevant data of a city in Sichuan from 1999 to 2011

Year	GDP (100 million Yuan)	PRP (every 10,000 people)	UBA (sq.km.)	AIH (Yuan)	BEO (10,000 units)	MO (10,000 units)	BA (standard transit bus)	TML (km)	CAS (sq.km.)	PV (10,000 person-time)
1999	63.4	20.2	18.0	3776	4.03	1.01	45	45.9	3.42	464.4
2000	71.6	21.5	18.8	3991	4.44	1.25	45	47.5	3.57	487.7
2001	82.8	22.7	19.7	4280	4.82	1.61	63	57.8	3.94	703.2
2002	95.9	23.6	21.0	4644	5.31	1.97	63	59.6	4.41	735.9
2003	111.8	24.9	22.3	5159	6.03	2.35	90	70.1	5.05	1081.8
2004	130.4	26.3	23.9	5716	6.56	2.68	97	81.3	5.85	1216.3
2005	156.1	28.2	25.6	6371	7.43	3.18	109	93.4	6.72	1427.8
2006	187.0	30.0	27.1	7415	8.43	3.61	123	108.9	8.09	1679.5
2007	227.3	31.9	28.3	8714	9.65	4.33	138	126.4	9.20	1962.8
2008	281.8	33.7	31.5	10125	10.74	5.06	145	128.8	10.44	2164.1
2009	349.0	35.3	36.0	11620	11.58	5.70	162	136.7	12.32	2398.3
2010	418.2	36.6	38.0	12977	11.65	6.00	175	150.0	14.82	2658.1
2011	492.4	38.2	41.2	14495	11.83	6.37	195	164.4	17.30	2892.5

For the selection of main variables, GCA is adopted to verify the correlations between passengers' volume and other influencing factors. By formula (1) and (2), the results of correlations are illustrated in table 2.

Table 2 Correlation analysis results

forecast index	GDP (100 million Yuan)	PRP (every 10,000 people)	UBA (sq.km.)	AIH (Yuan)	BEO (10,000 units)	MO (10,000 units)	BA (standard transit bus)	TML (km)	CAS (sq.km.)
correlation	0.76	0.60	0.64	0.81	0.77	0.75	0.82	0.82	0.80

We can see that four index as annual per capita disposable income of urban households,bus amount,total mileage of bus lines, total coverage area of bus stops (300m radius) exceed 0.8. So, the four corresponding influencing factors are chosen.

3.2 Parameters selection optimization

IHGA is applied to optimize the hyper-parameters selection. The overall process of optimized hyper-parameters is illustrated in Fig.1. The root-mean-square error of the training samples and the fitness function is defined as follows:

$$RMSE = \sqrt{1/N \sum_{i=1}^{N} \left(S_i - \hat{S}_i \right)^2} \tag{19}$$

$$Fitness\ (i) = 1/\left(RMSE\ (i) + 0.00001\ \right) \tag{20}$$

Where $RMSE(i)$ is RMSE of fast leave-one-out of i th individual population, 0.00001 on denominator is empirical value for avoiding $RMSE(i) = 0$.

3.3 Simulation result

The data set is split into training and testing sets. The training set includes 9 groups of data(1999-2007), and the testing set includes 4 groups of data(2008-2011).

The training set is used to establish LS-SVM model for forecasting volume ,and the testing set is used for checking the performance of LS-SVM. After ten times of data simulation with IHGA to get optimal value of C and σ, two LS-SVM models are validated by respectively choosing the four influencing factors with correlations exceeding 0.8 and all nine influencing factors. And, to further test the reliability of the IHGA-LS-SVM model, two methods as multiple regression model and BP-neural networks model are built based on the four influencing factors to carry out the forecast results comparation with LS-SVM.When applying the four models to forecast passenger' volume from 2008 to 2011, the comparation result is illustrated in table 3.

From the results illustrated above, first we can see that the maximum&minimum relative error of forecast values of LS-SVM I is 1.891% and 0.938%, and the maximum&minimum relative error of LS-SVM II is 3.017% and 1.486%. Meanwhile, the modeling speed of LS-SVM I is less than LS-SVM II. So, LS-SVM model with Grey Correlation Analysis is more effective than normal LS-SVM.And the average relative errors of the four models are 1.318%,2.254%,3.081% and 2.523%,the relative errors of LS-SVM I is obviously less than the other models. So, it proves that IHGA-LS-SVM model with GCA has high feasibility, effectiveness and precision when forecasting public transit passenger' volume in small and medium-sized cities.

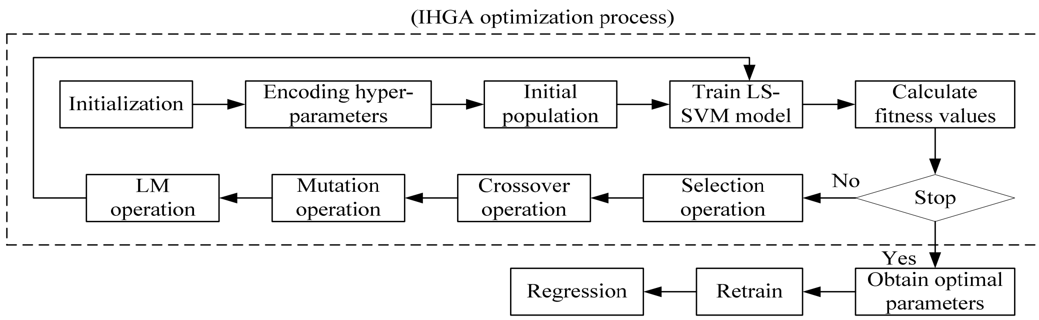

Figure1. Flowchart of IHGA-based hyper- parameter algorithm

Table 3 Forecast results confrontation based on different variables and models

Year	PV(10,000 person-time)	LS-SVM I(four factors)		LS-SVM II(all nine factors)		multiple regression model		BP-neural networks model	
		Forecast value	relative error	Forecast value	relative error	Forecast value	relative error	Forecast value	relative error
2008	2164.1	2195.3	1.442	2229.4	3.017	2219.6	2.565	2236.6	3.350
2009	2398.3	2420.8	0.938	2456.1	2.410	2346.4	-2.164	2464.2	2.748
2010	2658.1	2631.5	-1.001	2618.6	-1.486	2611.7	-1.746	2704.3	1.738
2011	2892.5	2947.2	1.891	2953.3	2.102	2985.1	3.201	2957.8	2.258

4 Conclusion

In this paper, LS-SVM model with Grey Correlation Analysis based on IHGA hyper-parameter selection is established to forecast conventional public transit passenger' volume in small and medium-sized cities. And the proposed IHGA has not only the advantage of global searching of GA, but also the advantage of local optimization ability of Levenberg-Marquardt optimization algorithm.When using the relevant data of a city in Sichuan from 1999 to 2011 to verify the IHGA-LS-SVM model with Grey Correlation Analysis, after comparing the forecast results of four models as LS-SVM I,LS-SVM II,multiple regression model and BP-neural networks model,the analysis of the results indicates that IHGA-LS-SVM model with Grey Correlation Analysis is a more feasible, effective and accurate forecast method for conventional public transit passenger' volume in small and medium-sized cities.

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References

J.A.K.Suykens, J.Vandewalle (1999). "Least squares support vector machine classifiers." *Neural Processing Letters,* 9(3), 293-300.

J.A.K.Suykens, J.Vandewalle (2000). "Recurrent least squares support vector machines." *IEEE Transactions on Circuits and Systems-I,* 47(7),1109-1114.

J.A.K. Suykens, T. Van Gestel, J. De Brabanter,B. De Moor,J. Vandewalle (2002)."Least Squares Support Vector Machines." *World Scientific Publications*, Singapore.

V. Vapnik (1999). "The Nature of Statistical Learning Theory."*Springer-Verlag*, New York.

Deng Julong (2002). "Basic theory of Grey Theory." Wuhan,Huazhong University of Science and Technology Publications, China.

Luo Youxin, Zhang Longting, Li Min (2001). "Grey System Theory and Its Application to Mechanical Engineering." Changsha, National University of Defense and Technology Publications,China.

Chiang YuMin, Hsieh HsinHsien (2009). "The use of the Taguchi method with grey relational analysis to optimize the thin-film sputtering process with multiple quality characteristic in color filter manufacturing." *Computers & Industrial Engineering,* 56, 648-661.

Zhang Yongjuan, Zhang Xiong (2007). "Grey correlation analysis between strength of slag cement and particle fractions of slag powder." *Cement & Concrete Composites ,*29(6),498-504.

Yao Tao, Wang Pengcheng (2004)."Optimized Design of Injection-Moldling Process Parameters Based on Grey Relational Analysis." *Journal of Inner Mongolia University of Technology (Natural Science),*23(4),274-278.

S.W. Zhang, T.X.Lan, X.F. Fang, etc (2010). "Application of Grey Correlation Analysis on Tool Selection. *Advanced Materials Research,* 97-101,2485-2488.

Srinivas M, Patnaik L M (1994). "Adaptive probabilities of crossover and mutation in genetic algorithm." *IEEE Transactions on Systems Man and Cybernetics,* 24 (4),656-667.

Guo Xianghong, Sun Xihuan, Ma Juanjuan(2009). "Parametric estimation of the van Genuchten's equation based on hybrid genetic algorithm." *Advances in Water Science*, 20(6),677-682.

D.W. Marquardt (1963). "An algorithm for least squares estimation of nonlinear parameters." *J.Soc.Indust.Appl.Math*,11(2),431-441.

Fletcher, R (1987). "Practical Methods of Optimization". Chichester: John Wiley and Sons.

Technical Methods and Application Modes of Lancang River Waterway Modern Management

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Abstract: Lancang River is an important navigable river in Yunnan province, at the same time it is a cross-border international river in southwest China, however, compared to other rivers such as Yangtze River, the waterway management and maintenance level is relatively backward, and modernization and information lever is lower. Therefore, according to the characteristics of the Lancang River, we need to achieve the modernization and efficient of Lancang River waterway management by means of information, so that the Lancang River waterway management and maintenance can reflect the unique pattern of the Lancang River shipping, and promote the development of the Lancang River shipping.

Based on analysis of the current situation and needs of the Lancang River waterway management, the article put forward the suitable advanced, modern management and maintenance mode for Lancang River, which is based on the building principles of conducting top-level design, constructing the overall framework, improving infrastructure, achieving breakthroughs in key business systems by small strides.

This study is an important foundation of constructing the Lancang River intelligent waterway, and realizing full coverage, all-weather operation and rapid response modern waterway management system. It is helpful to improve the management and maintenance level of the Lancang River waterway, and promote the shipping economic development and international shipping Exchanges development of the Lancang - Mekong River. It can accelerate the Lancang - Mekong international shipping development and construction, improve the status of the Lancang River shipping, and have important significance in promoting economic and social development in Yunnan Province, developing international trade, establishing a good international environment on the neighboring countries.

Keywords: Lancang river waterway management; Means of information; Application modes; Intelligent waterway.

1 Introduction

1.1 Background and Significance

Lancang River is an important navigable river in Yunnan Province and also a cross-border international river in southwest China (Wangtao, 2009). During the "Eleventh Five-Year" period, the first phase of Grade V waterway project was put into operation in 2007. The 71 km long navigable waterway from King Hung to the 243th Sino Burmese Boundary landmark of China and Burma reached the goal of perennial navigation for 300-ton ships. The domestic waterway infrastructure construction tends to be perfect, which laid a foundation for its further development in "the 12th Five Year Plan" period.

In recent years, the Lancang River waterway management and maintenance has gotten high attention of Yunnan government and its transportation department. Thus, the related study is pushing forward gradually. However, compared with other rivers such as Yangtze River, the overall technical level of the waterway management and maintenance is relatively weak. Especially, in comparison to the waterway infrastructure, modern management system in Lancang River and even in Yunnan has not been built, information technology supporting is obviously inadequate, information system construction such as integrated waterway management and public service are lagging behind, which are limiting Lancang River shipping development. If we want to give full play to the ability of Lancang River waterway infrastructure, we need to improve the level of informatization and modernization according to the characteristics of Lancang River, so that the system can reflect the unique pattern of Lancang River shipping, and promote the development of the Lancang River shipping.

This study will improve systematization, scientificalness and effectiveness of waterway management, and improve the efficiency of waterway management, and ultimately promote the overall modernization of Yunnan transportation.

1.2 Overview of domestic and foreign research

The waterway is an important part of the national transportation infrastructure, is the basis for the existence of water transportation. To improve the navigation conditions, and ensure the smooth and safe navigation play an important role in national economy and national defense construction (Ren Bobu, 2007). The main way to achieve modernization of waterway management is informatization construction.

In recent years, with the development of computer technology, network technology, database technology, geographic information system technology and so on, a variety of management systems have been appeared in different countries, the waterway informatization construction improve rapidly. Such as electronic navigational chart (ENC), automatic identification system (AIS), SOA architecture application system, these systems solve some resource integration problems to a certain extent, also improve the efficiency of waterway management, and make the waterway management modernization having technical support.

2 Lancang River Waterway Management Situation and Needs Analysis

2.1 Lancang River Waterway Construction Situation

Lancang River is a 1289.5 kilometers long, typical mountain river in Yunnan

Province, which has been covered by a 40 percent valley area. Most of the river valley has a poor navigation condition. Since 1975, the river has been constructed as national defense waterway, in which 191 km from Nandeba to Jinghong reaches the sixth waterway standard and 100-ton ship is allowed to pass by; 71km from Jinghong to the China-Burma border pillar No. 243 reaches the fifth waterway standard, and 300-ton ship is allowed to pass by; 64km from Nandeba to Jinghong bridge is substandard without renovation, which has not yet been opened officially.

Lancang River's open waters area is 293 kilometers with 290 navigation marks along this area. One of the waterway regulation projects was completed in 2007, which has been equipped with 657 navigational aids and 2 signal stations. Currently, the waterway has not been equipped with night flight navigation aids. Thus, the night flight is not allowed.

Generally speaking, the Lancang waterway construction starts relatively late, investment is inadequate and shipping facilities construction lags behind. To get full play to Lancang River shipping advantage, we must further increase the intensity of waterway regulation and navigation facilities construction to achieve connection of the Lancang - Mekong River shipping.

2.2 Present waterway management situation

In recent years, with the development of computer technology, network technology, database technology and GIS technology, Yunnan Province navigation administration have built electronic navigational chart (ENC))system, network system, Yunnan shipping and Maritime integrated service platform, data storage system, hydrological system and navigation mark remote sensing and control system. The ECN system refers to the Yangtze River ENC production standards, which covers 360km and 5km on both sides from Jinghong Port to Chiang Saen port. China Maritime Safety Administration, provincial maritime bureau and 16 states (city) local maritime bureau are connected through intranet, extranet, private network, cable, wireless, etc. Yunnan Province Harbor Marine Integrated Service Platform enables document exchange, coordination office, daily communication and online communication by the private network for the province 16 states (city) local maritime bureau. The data storage system stores data in a single unified management for several servers. There are 10 hydrological ruler enables remote hydrology report, while navigation mark remote sensing and control system has have pilot.

Although these systems solve some Lancang River management problems to a certain extent and improve the efficiency of waterway management, they still cannot meet the needs of modernization and informatization.

Therefore, studying technical methods and application mode of Lancang River waterway modern management to construct the Lancang River waterway management information, has an important significance to enhance the quality and overall ability of waterway management, improve the electronic navigational chart comprehensive service level, and better serve the coastal economy and the shipping industry .

3 Suitable technical methods analysis for Lancang River waterway management information construction

3.1 Technologies for Digital Waterway

Digital waterway system based on inland electronic navigational chart (IENC) is an excellent platform to implement navigation mark monitoring, spatial query, simulation navigation and other functions. Multiple techniques including IENC, GIS, GPS, database, information transmission, RS and so on will be applied to waterway management in this system. The system will be the major trend of domestic and international waterway management, and also it will be an important mean of information construction of Lancang River waterway management.

3.2 Realize the comprehensive management of waterway by SOA system frame

Lancang River digital waterway should be based on IENC to realize the functions such as navigation mark remote sensing and control, waterway maintenance and management, dynamic management of working ships. It should provide efficient, stable, configurable coordination and linkage among systems based on the requirement of waterway comprehensive management.

According to difficult coordination across multi-system, unease process extension, and difficult coupling across traditional integrated middle ware,the large information construction projects which involve multi-department and multi-domain must rely on good design framework. Currently, there are two methods to achieve system integration including EAI (Enterprise Application Integration) and SOA (Service Oriented Architecture).Essentially, EAI is a message-based integration, having a bad expansion and reusability. SOA is independent of operation system, programming language and hardware platform. Actually, SOA is a flow-based integration and has good expansion, reusability and compatibility. So, SOA will be used as the whole frame of this system.

4 Informatization construction and application mode analysis for Lancang River waterway management

4.1 System construction model

Based on the analysis of the Lancang River management requirements, applicable technology, and the specific characteristics and information construction situation of Lancang River waterway, we suggest that the construction should take the waterway management objectives proposed in Yunnan waterway transportation "Twelfth Five Year Plan" as the overall direction, the management needs of Lancang River waterway management needs as the basis, , "top leading, framework supporting, urgent need building first, breakthrough at key points " as the overall construction principle to carry out the construction work . It can be specifically divided into:

1. Top-level design

According to the overall needs and development goals of informatization, use a systematic approach to do the top-level design to meet the integration and automation demands of shipping informatization, and realize unified planning, unified architecture, unified standards and integrated management.

2. Construct overall framework

The overall framework is the specific implementation of collaboration and data integrated application in top-level design. For the basin which information construction carried out earlier, the initial construction is lack of top-level design and supporting frame, which results in difficulties in the latter integration between systems. Lancang River waterway information construction should take this as a lesson. It is recommended to take the general framework as support, and realize system bus, unified portal based on single sign-on, security, data exchange, business management and integration of public service.

3. Improve infrastructure

Communication, network, computing and data storage infrastructure are the foundation of information construction. Based on making full use of the province's transportation network construction, we should extend the core network and strengthen the wireless network, and improve network and data security system to provide a safe, stable operating environment for the application system.

4. Achieve breakthroughs in key business systems

Individual business system is the basis of the Lancang digital waterway. Each individual application system can be developed in parallel and debugged simultaneous under the guidance of top-level and the requirements of the overall framework , which can be specifically constructed by the following aspects: inland electronic navigational chart(IENC) production (IENC is the basis for achieving digital waterway, should be constructed first), IENC analysis system, waterway maintenance management system, ship dynamic management systems, navigation mark remote sensing and control system, water level remote sensing and report system, waterway integrated management and information service platform.

5. Use small strides in building mode

It is recommended to take better information supporting regions as pilot area when constructing individual business system. The construction should always keep pace with the frame construction with small steps, establish milestones, build and integrate synchronously. The process quality management should be guaranteed to ensure congruence of goals and integrated approaches in the process of development at the same time.

4.2 System application mode

Lancang River waterway management can use three modes: decentralized management, centralized management, combination of decentralized management and centralized management.

1. Decentralized management

Management departments work independently using their existing office system.

2. Centralized management

When an emergency occurs, waterway management department draw staff from the corresponding departments according to the management needs, and carry out emergency work.

3. Combination of decentralized management and centralized management

These two modes have their own advantages. Decentralized management can play advantage in the daily supervision and management. It reflects staff efficiency better compared to centralized management. Centralized management can reflect the collaboration of different departments in an emergency event. It can eliminate the intermediate links, and greatly improve the rescue efficiency.

After the waterway information system construction is completed, it can achieve the function of online collaborative management and work using a variety of information and communication tools based on network platform construction and SOA architecture. It can achieve a unity of centralized management and decentralized management, and reflect data sharing and data integration, in order to get a "peacetime" and improve the efficiency of emergency rescue without affecting the daily management efficiency.

5 Conclusion

Based on the Lancang River waterway for modernization and development of information technology needs, this paper summarizes the results of the current study, integrates a number of representative application technologies such as digital waterway technology, geographic information technology and so on, and carries out with a strong targeted information technology management methods and application mode of research.

This is the first systematic research on the overall structure and construction mode of Lancang River waterway construction. It reveals the specific characteristics and construction ideas for Lancang River waterway management information, having important significance for “Twelfth Five-year” and even “Thirteen Five-year” Lancang River waterway management modernization and information.

References

Wangtao (2009). “Research on Lancang River shipping development in Yunnan.” *DaLian Maritime university*.

Ren bobu (2007). “Research on waterway information management platform.” *Nanjing university of science&Technology.*

Li tianbi (2004). “Study on Construction of Digital Navigation Channel of

Ganjiang River." *Hohai university.*

Linqiang, Xufeng (2011). "Application of digital waterway's comprehensive monitoring system in maintenance and management of waterway." *Port&Waterway Engineering*, 51(3), 126-130.

Fan xiaofeng (2007). "Research on the general framework of digital waterway." *Science and Technology Consulting Herald.*

GIS, GPS, and BIM-Based Risk Control of Subway Station Construction

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Abstract: In the process of subway station construction, many large construction equipments are placed in a narrow area where the operations are highly dense and the equipments have to carry heavy load and move or rotate in a broader space. In addition, there are tall equipments carrying out aerial operation. Some construction equipments are placed in limited underground space. These special conditions bring extremely high risks to subway station construction. This paper probes into (1) the application of BIM in summarizing and dynamically managing all the information and data in the process of construction; and (2) the installation of GPS receiver OEM board on large, high-risk construction equipments, the utilization of GIS and GPS data in dynamic management of three-dimensional geographic spatial location information of machineries and the visualized management of all data and information. In addition, this paper analyzes the risks related to large construction equipments and neighboring buildings and controlling methods. In this paper, the author suggests to integrate GIS, GPS and BIM to develop construction early warning and risk management systems so as to dynamically monitor the conflict risks among cranes, drilling machines, excavators, loaders and dumpers, the risks of collision between equipments and neighboring buildings and the risks of deformation and structure damage of foundation pits and retaining walls. Lastly, this paper analyzes the functional needs of the early warning and management system, which provides a theoretical reference for the development and implementation of this system.

Keywords: GIS; GPS; BIM; Subway station; Construction risk.

1 Research Background

The subway stations are always located at places where there are numerous high-rise buildings and complicated underground utilities. Various equipments are placed in one limited space and a number of workers carry out construction operations both on the ground and underground. On the construction site, it is likely that the large equipments collide with other equipments, or the equipments collide with the neighboring buildings or temporary facilities or the ground bearing pressure is insufficient. All these are potential risks.

At present, the method of artificial control of video monitoring are generally used to monitor the construction risk in the world. From the literature review of the situation, the intelligent control is not a security risk.

Given the characteristics of construction and surrounding conditions, delicacy construction, informatization management and visual dynamic monitoring will be out of question if we can develop the early warning and risk management system using GPS, BIM and WebGIS. This will put the risk under control and speed up the construction.

2 Program of GPS Setting on Construction Equipments

The GPS receiver and OEM board, installed on the tall equipments and fixed on the ground, can identify the real-time accurate spatial location of construction equipments. In order to simplify the motion model building of construction equipments, the OEM board can adopt the following programs: (1) For the self-propelled equipments like excavators and cranes with rotation mechanism, the OEM board can be installed at the middle of the swivel joint, so as to pick up real-time information of the equipments; (2) for the large parallel-movement equipments like gantry crane, the OEM board can be installed in the driving room to collect real-time information; (3) for the equipments with rotating mechanism like tower crane, the OEM board can be mounted on the end of the suspension arm; and (4) the OEM board can be mounted in a fixed location, so it can be used to collect data of pseudo-range difference.

The GPS signal on the moving station is transmitted to the base station via wireless network. After that, the signal goes through universal serial server and the multiport serial card of host computer and then it is connected via serial cable and the serial port of base server. At last, a multi-channel GPS signal acquisition system is set up, just as shown in Figure 1.

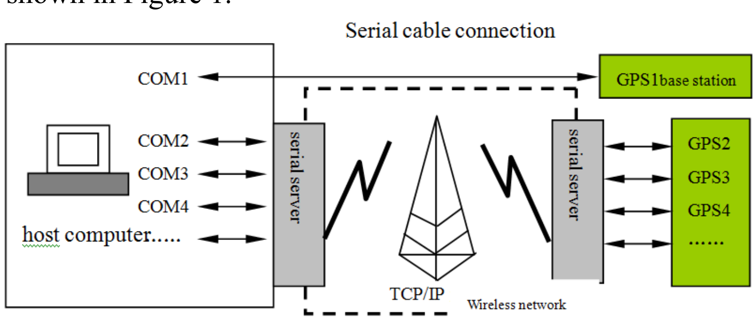

Figure 1. multi-channel GPS signal acquisition system

3 Building of Risk Data Model

3.1 Building-related Information Model

Building-related information model should involve information of (1) line grid and elevation positioning; (2) the spatial position and size of the foundation pit, space enclosing structure, steel shotcrete, pile body and top beam; (3) the main part of the station: floor, column, roof, walls, soil mass and the separated layer; (4) the spatial location and dimensions of adjacent existing architectural complex, structures, civil pipeline facilities; (5) work yard model includes traffic facilities, traffic signs and markings and urban greening. The construction structural element involves attribute parameter of layered soil mass and steel shotcrete, concrete strength, steel strength and the location and load of the steel. These will help to calculate the structural safety and research the load-carrying capability at different stages.

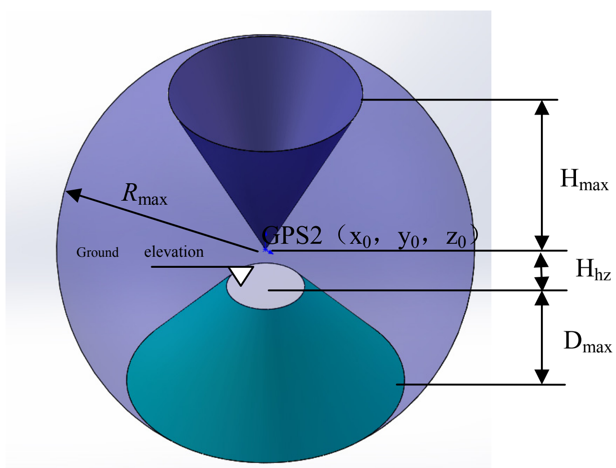

Figure 2. Simplified

3.2 Spatial Data Model of Construction Equipments

The authors of this paper take excavator and truck crane as example and introduce the modeling method of construction equipments (suppose we install the GPS receiver and OEM board at the center of the central swivel joint). (1) We build a simplified spatial model of excavator: namely simplify the activity space of the excavator, just as the spherical body shown in Figure 2. Above the ground, the activity space is a hemispherical space, the center of which is the three-dimensional position of GPS (x0, y0, z0). The three-dimensional position of GPS may change as the excavator moves; the radius of this hemisphere space is maximum radius of the excavator's digging area (one of excavator's parameter). The activity space of the excavator excludes a cone whose height is H_{max} and a circular truncated cone whose height is D_{max}. In the figure 2, R_{max} is the maximum radius of the excavator's digging area, D_{max} is the excavator's maximum digging depth, and H_{max} is the excavator's maximum digging height.

In the process of operation, the excavator may shake. In addition, there is time lag when the OEM board receives data. Therefore, for the sake of safety, the radius of the spherical space should be increased. There is no other equipment under the excavator. Thus, the spatial model can be expressed by parameter equation (1):

$$\begin{cases} x = x_0 + (R_{\max} + C_{\mathrm{V}}) \sin\varphi \cos\theta \\ y = y_0 + (R_{\max} + C_{\mathrm{V}}) \sin\varphi \sin\theta \\ z = z_0 + (R_{\max} + C_{\mathrm{V}}) \cos\varphi \end{cases} \quad (1)$$

In this formula:

x, y, z ——the coordinates of X, Y and Z representing the most farthest points the excavator can reach.

x_0, y_0, z_0 ——the coordinates of X, Y and Z of center of gyration.

R_{max} ——the maximum radius of the excavator's digging area.

C_V ——modification value of radius of the excavator's digging area.

D_{max} ——the excavator's maximum digging depth.

H_{max} ——the excavator's maximum digging height.

H_{hz} ——the height of the center of gyration (in this paper, it represents the height of the GPS).

φ ——elevation (angle of depression) of the excavator's main arm, $\arcsin((-H_{hz} - D_{max})/R_{max}) \le \varphi \le \arcsin((H_{max} - H_{hz})/R_{max})$;

θ ——rotation angle of the excavator, $0 \le \theta \le 2\pi$.

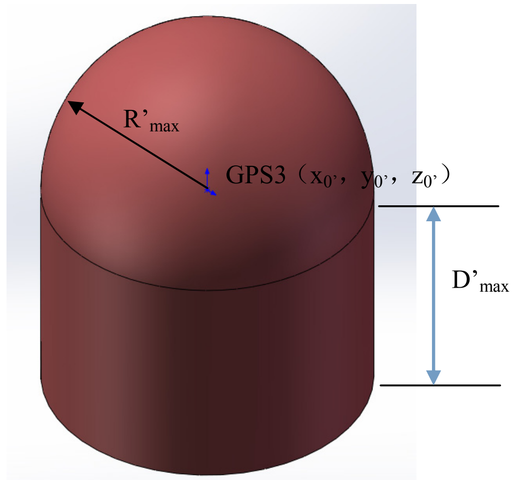

Figure 3. Simplified

(2) The simplified spatial model of truck crane is as shown in Figure 3. The activity space above the swing mechanism is simplified to a hemispherical space, the center of which is the three-dimensional position of GPS (x0 ', y0', z0 '). The radius of this hemispherical space equals to maximum working radius (one of the truck crane's parameters) plus the long side of the hanging object (the centre distance between the object and the steel wire rope); the activity space under the truck crane is a cylinder.

When the object is higher than the center of gyration, the spatial model can be expressed b parameter equation (2):

$$\begin{cases} x = x_0' + (R'_{\max} + C_V')\sin\varphi\cos\theta \\ y = y_0' + (R'_{\max} + C_V')\sin\varphi\sin\theta \\ z = z_0' + (R'_{\max} + C_V')\cos\varphi \end{cases} \qquad (2)$$

In this formula :

x, y, z	---the coordinate of x, y and z of the point that the truck crane (and the object) can reach.
x_0', y_0', z_0'	---the coordinates of x, y and z of the center of gyration.
R'_{max}	---the crane' maximum working radius and the long side of the lifted object.
C_V	---correct value of the crane's radius (the safety stock added due to the shake of crane and lifted object is taken into consideration.)
φ	---the elevation of main arm, $0 \le \varphi \le \pi$.

θ ---the rotation angle of the main arm, $0 \le \theta \le 2\pi$.

When the lifted object is lower than the center of the swing mechanism, the spatial model can be expressed by parameter equation (3):

$$\begin{cases} x = x_0' + (R'_{\max} + C_V')\cos\theta \\ y = y_0' + (R'_{\max} + C_V')\sin\theta \\ z = z_0' - D'_{\max} \end{cases} \quad (3)$$

In this formula :

D'_{max}---the vertical distance between the lifted object's undersurface and the top surface of the swing mechanism.

Meanings of the rest symbols are the same as that of the symbols in parameter equation (2).

4 Analysis and Control of Conflict Risk

4.1 Analysis of Conflict Risk

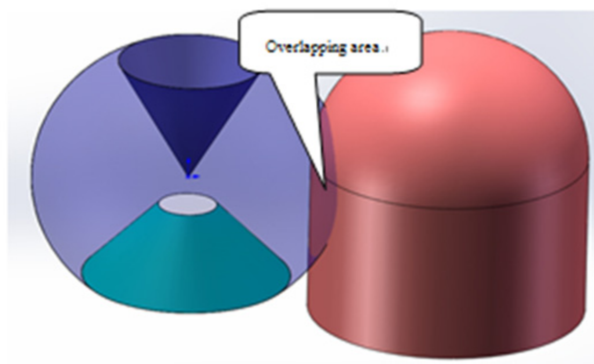

Figure 4.Dynamic space overlapping area

The conflicts in the process of construction may cause decline of productivity and property damage or personal injury. BIM technique can be used to analyze the hazardous area, conflicts between large equipments, collision between equipments and neighboring buildings (temporary facilities), topple of tall equipments, the conflicts between equipments and the pedestrians and the conflicts between equipments and passing-by vehicles.

We also analyze the spatial overlap of some factors that lead to conflicts and the obtained public areas should be the collision risk space. We take excavator and truck crane as an example and overlay the activity spaces of excavator and truck crane.

Just as shown in Figure 4, the overlapped public area is the space where collision may occur.

4.2 Control of Conflict Risk

Controlling methods of conflict risks:

(1) All large equipments are armed with GPS receiver and OEM board, so the system server can identify the location information of each large construction equipment, integrate each equipment' attribute information (various mechanical parameters). In this way, the dynamic real-time analysis of whether there can be a collision area is carried out. In case of any collision, the system automatically and immediately notified the drivers to pay attention to the collision area.

(2) Large equipments may enter the area where the bearing capacity is weaker (for example, the top edge of the pit), which is a collision in the broad sense. Once the mass of a large construction equipment (including loaded or lifted objects) is greater than the carrying capacity (considering the safety factor) of the neighboring building (temporary facilities) (safety factor), the system automatically and immediately notified the drivers to pay attention to the possible collision.

(3) Before the construction starts every day, the security personnel will print the pre-analyzed risk lists and send them to the large equipment drivers, reminding them of the risks of potential collision risk and insufficient bearing capacity.

5 Risk Early Warning of Subway Station Construction and Functional Requirement Analysis of Management System

The field investigation shows that the system should have the following functions: (1) 4D simulation preview and dynamic management of the construction process, equipment installation, existing neighboring buildings, civil pipe network, security facilities (fender post, support and bounding wall); (2) 4D simulation and dynamic management of materials processing, stacking and transportation; (3) real-time tracking simulation and dynamic management of the equipments' 3 D location; (4) 4D simulation rehearsal and analysis of safety conflicts between two construction equipments, staff and construction equipments, construction equipments and engineering structures, and construction equipments and the ground traffic; (5) monitoring information management and feedback; (6) risk analysis and forecasting, risk identification management and accident early warning; (7) emergency plan simulation and visualization selection; and (8) simulation preview of emergency evacuation and emergency rescue visualization.

From the current research and application of early warning system has been similar to the situation, the development of Risk Early Warning and Management System of Subway Station Construction is feasible, and it is very urgent.

6 Conclusions

This paper presents a program to use GPS, BIM and GIS to dynamically monitor the risks in the process of subway station construction, probes into the construction equipment modeling and discusses conflict risk analysis and controlling method. The author's limited ability and shallow knowledge have limited the study, so the author expect more colleagues to spare no efforts to the system development.

References

He Yueguang, Du Nianchun, Li Zhiwei(2009). A Study of Monitoring Inforamiton Management System of Metro Contruction Based on Web GIS. *Rock and Soil Mechanics*.

Wang Shu Qiang, Wang Qiankun, He ChenChen(2012).GIS-based Subway Construction Emergency Management System Design. *Modern Buiness Trade Industry.*

Zhang Youhui, Qiao Qinghe(2007). Crashworthiness Control of Large-scale Construction Machinery. *Construction Mechanization*.

Site Optimization for Entrances and Exits of Underground Roads

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Abstract: Constructing underground roads has been important to alleviating traffic pressure. Site selecting of entrances and exits scientifically is significant to controlling the construction scale of underground roads and making it develop rapidly. First, the primary index system was established based on analyzing the factors that affect entrances and exits site of underground roads. The important factors, which include the distribution capacity of entrances and exits, travel costs of the area, construction costs and operation-maintenance costs, were determined after analyzing the primary index system by using ISM and Matlab. Second, the bi-level programming model to optimize the site of entrances and exits was set up. The objective function of the upper level was to minimize the land cost, construction cost, operation cost, maintenance cost of underground roads, the reconstruction cost of the ground transport network, and the travel cost in the area. The objective function of the lower level was to assign the traffic flow equilibrately in the transport network. Then, the iterative optimization algorithm (IOA) was used to solve the bi-level programming model. Finally, an example was employed to prove the feasibility of the model. The results show that the land use scale and the construction costs can be controlled by optimizing the entrances and exits site of the underground roads.
Keywords: Underground roads; Site selection of entrance and exit; ISM system; Matlab; Bi-level programming model.

1 Introduction

With the acceleration of urbanization and the rapid growth of the traffic demand, the contradiction between high motorization and the capacity of roads has become increasingly serious because of the limitation of the land resources and environmental protection (HAN J W, 2010). As a result, the city has experienced from the surface roads to the large-scale development of the elevated roads, which still can't solve the contradiction. The cities both at home and abroad put more effort to the underground road's building to alleviate the traffic pressure, and a few theories and practice achievements have been made (CHEN Z L, ZHANG P, 2009). In foreign countries, the studies about underground roads have been concentrated on the traffic capacity, the traffic management during the construction and operation (Hirata T, Tetsuo Y A I, Mahara T, 2006), and the environmental impact assessment (Thalheimer, Erich S, 2004). In China, researchers focus on how to alleviate the heavy traffic pressure of fast lanes and main roads by building underground roads or underwater tunnels (HU Y C, SIMA B Q, JIN W Z, 2009). These researches are mainly conducted by qualitative analysis, and lack of achievements which can guide the network planning of underground roads. In practice, however, site selection of network nodes, especially entrances and exits is critical which will directly affect the ability of underground roads that attract traffic, guide the needs and connect with other traffic facilities.

In this paper, site selection of entrances and exits of underground roads was taken as the center point, an ISM system was established and the factors affecting the site selection were analyzed. Eventually, a bi-level programming model was set up to optimize the site of entrances and exits.

2 Analyses on ISM System about Site Optimization for Entrances and Exits of Underground Roads

Through analysis, 12 factors that directly affect entrances and exits site of underground roads were divided into four categories, namely:

1) technical standards, including : distribution ability of entrances and exits $A1$, support capabilities of the underground road network $A2$, and connecting effectiveness with the ground road network $A3$, linear indicators $A4$;

2) natural conditions, including : geological conditions $A5$, topographic conditions $A6$, land use conditions $A7$;

3) environmental factors, including: environmental coordination $A8$, transportation environmental impact factors $A9$;

4) economic factors, including: regional travel costs $A10$, construction costs $A11$, operation and maintenance costs $A12$. The factors set is indicated by A, $A=\{A1, A2, A3\cdots, A12\}$, as shown in Table 1.

Above factors include both qualitative and quantitative factors, and they are not important equally. So it’s necessary to select the most important factors and find the optimum proposal by using quantitative methods. The ISM and Matlab will be used to determine the most important factors. Specific steps are as follows:

1) Establish the adjacency matrix. 12 factors in the system relate and influence each other, the relationship among these factors are direct or indirect. Adjacency matrix is used to show the direct relationship. If Ai has direct influence on Aj, then $aij=1$, otherwise $aij=0$.The adjacency matrix is shown in table 2.

2) Obtain reachability matrix by using Matlab. Adjacency matrix in Table 2 reflects the direct relationship between factors, but there are significant indirect

relationships among them. If Ai have direct influence on Aj and Aj have direct influence on Ak at the same time, Ai would have indirect influence on Ak . This influence may be shown through one or more in-between factors. Reachability matrix R will be used to represent these direct or indirect relationships. When Ai has direct or indirect influence on Aj , $aij=1$, otherwise $aij=0$,as shown in Figure 1 .

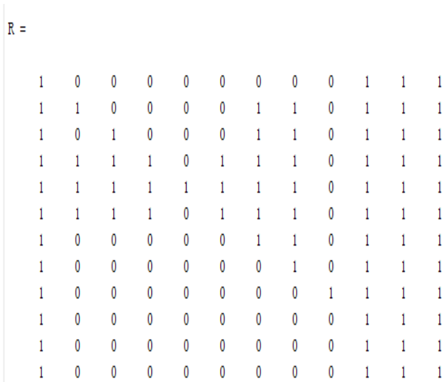
Table 1. System factors

Element Number	Name of the Elements	Meaning of the Elements
$A1$	distribution ability of entrances and exits	the efficiency of vehicle traveling in and out
$A2$	support capabilities of underground road network	coordination with underground road itself
$A3$	connecting effectiveness with the ground road network	the ability that coordinate with road network
$A4$	linear indicators	the radius of longitudinal slope and curvature
$A5$	geological conditions	engineering geologic conditions, hydro geological conditions
$A6$	topographic conditions	buildings and structures
$A7$	land use conditions	vegetation conditions, land use area
$A8$	environmental coordination	coordination between entrances & exits and their surrounding environment
$A9$	transportation environmental impact factors	traffic impact factors such as noise and exhaust gas
$A10$	regional travel costs	vehicle travel cost in a region
$A11$	construction costs	construction costs
$A12$	operation and maintenance costs	operation and maintenance costs

Table 2. Adjacency matrix A

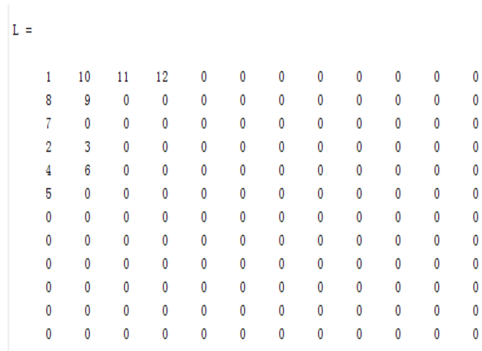
	$A1$	$A2$	$A3$	$A4$	$A5$	$A6$	$A7$	$A8$	$A9$	$A10$	$A11$	$A12$
$A1$	1	0	0	0	0	0	0	0	0	1	0	1
$A2$	1	1	0	0	0	0	1	1	0	0	1	0
$A3$	1	0	1	0	0	0	1	1	0	0	1	0
$A4$	1	1	1	1	0	0	1	1	0	0	1	0
$A5$	0	0	0	1	1	1	1	1	0	0	1	1
$A6$	1	0	0	1	0	1	1	1	0	0	1	0
$A7$	0	0	0	0	0	0	1	1	0	0	1	1
$A8$	0	0	0	0	0	0	0	1	0	0	1	1
$A9$	0	0	0	0	0	0	0	0	1	1	1	1

$A10$	0	0	0	0	0	0	0	0	0	1	1	1
$A11$	1	0	0	0	0	0	0	0	0	0	1	0
$A12$	1	0	0	0	0	0	0	0	0	0	0	1


R =

1	0	0	0	0	0	0	0	0	1	1	1
1	1	0	0	0	0	1	1	0	1	1	1
1	0	1	0	0	0	1	1	0	1	1	1
1	1	1	1	0	1	1	1	0	1	1	1
1	1	1	1	1	1	1	1	0	1	1	1
1	1	1	1	0	1	1	1	0	1	1	1
1	0	0	0	0	0	1	1	0	1	1	1
1	0	0	0	0	0	0	1	0	1	1	1
1	0	0	0	0	0	0	0	1	1	1	1
1	0	0	0	0	0	0	0	0	1	1	1
1	0	0	0	0	0	0	0	0	1	1	1
1	0	0	0	0	0	0	0	0	1	1	1

Fig.1 Reachability matrix


L =

1	10	11	12	0	0	0	0	0	0	0	0
8	9	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0
2	3	0	0	0	0	0	0	0	0	0	0
4	6	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0

Fig.2 Caculated results

3) Obtain the antecedent set, outcome set and the intersection of system factors, as well as the layer classification by using the reachability matrix;

According the reachability matrix, we can find all factors affected by Ai to form the set $R(Ai)$ and all factors affected Ai to form the antecedent set $\mathrm{A}(Ai)$. Then we can obtain all factors that not only affect Ai but also are affected by Ai, which form the intersection $\mathrm{S}(Ai)$. As shown in table 3.

The layer classification is a process to determine every factor's level. The basic approach is to identify the factors that have no relation with any other factors, they are senior factors, remove them, and seeking more senior ones from remaining factors, and so on, until determine the lowest level of the collection. The senior factors are defined as following: $L1=\{Ai|Ai\in A, R0(\mathrm{Ai})\cap \mathrm{A}\,0(\mathrm{Ai})=R0(\mathrm{Ai}), \mathrm{i}=1,2,\cdots,\mathrm{n}\}$.

4) Calculated Result by Matlab, as shown in Figure 2.

We can get the conclusions from the result: the first layer factors are $A1$, $A10$, $A11$ and $A12$; the second layer factors are $A8$ and $A9$; the third layer factor is $A7$; the fourth layer factors are $A2$ and $A3$; the fifth layer factors are $A4$ and $A6$; the sixth layer factor is $A5$.

The interpretative structural model is established, as shown in Figure 3.

Table 3. antecedent and reachability sets

element	Accessible sets $R(Ai)$	Antecedent sets $A(Ai)$	Intersection sets $S(Ai)$
A1	A1, A10, A11	A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12	A1, A10, A11
A2	A1, A2, A7, A8, A10, A11, A12	A2, A4, A5, A6	A2
A3	A1, A3, A7, A8, A10, A11, A12	A3, A4, A5, A6	A3
A4	A1, A2, A3, A4, A6, A7, A8, A10, A11, A12	A4, A5, A6	A4
A5	A1, A2, A3, A4, A5, A6, A7, A8, A10, A11, A12	A5	A5
A6	A1, A2, A3, A4, A6, A7, A8, A10, A11, A12	A4, A5, A6	A4, A6
A7	A1, A7, A8, A10, A11, A12	A2, A3, A4, A5, A6, A7	A7
A8	A1, A8, A10, A11, A12	A2, A3, A4, A5, A6, A7, A8	A8
A9	A1, A9, A10, A11, A12	A9	A9
A10	A1, A10, A11, A12	A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12	A1, A10, A11, A12
A11	A1, A10, A11, A12	A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12	A1, A10, A11, A12
A12	A1, A10, A11, A12	A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12	A1, A10, A11, A12

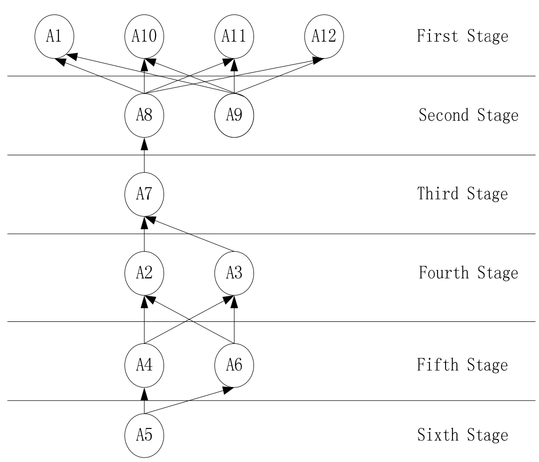


Fig.3 The interpretative structural model

3 Site selection model and algorithm

3.1 Problem description

The site–selecting problem of the underground road entrance-exits can be described as: M entrance-exits of the underground roads are selected within the regional traffic network, the selected ones should have enough traffic capacity and the function of distributing the traffic flow; the land cost, construction cost, traffic network improving cost, and the vehicle operation cost are minimum; the operation and maintenance cost is minimum and the traffic flow of underground roads should be correspond to the capacity of entrance-exits; the traffic flow assigned to the ground road network should be appropriate to the capacity of existing sections. The adverse effect of building the underground road network should be taken into account, in other words, the newly-built underground road entrance-exits will attract a lot of traffic, which may lead to the traffic congestion near the entrance-exits, thus the ground roads in the influence area should be widen or built, the construction cost will rise and the traffic flow of the network will also be redistributed. Based on the traffic equilibrium, the paper set up the bi-level programming model of site selection for entrances and exits of underground roads.

3.2 Mathematic model

The notations used in the model are defined as follows:

L is the nodes number of the traffic network; D is the number of traffic zones; K is the number of traffic zone being suitable for the underground entrance-exits; M is the number of underground road entrance-exits needed to be selected; A is the set of ground road sections in the traffic network; H is the set of underground road sections in the traffic network; A_1 is the number of ground road sections which are planned to be widened or built ; λ is the conversion Coefficient between travel cost and currency; r,s are the start and stop nodes of each section in the traffic network; d is the traffic zone; k is the traffic zone being suitable for underground road entrance-exits; m,m' are the entrances and exits of the underground road; a is the ground road section; h is the underground road sections.

The studied traffic network is divided into D zones, and M underground road entrance-exits will be selected. For convenience, the traffic zone is expressed with its geometric center, and then each traffic zone is a node in the traffic network. In addition, assume only one entrance or exit can be placed in each traffic zone. Actually, some traffic zones are not suitable for placing transport hub due to the geographical position and other reasons, so assume that only K zones are suitable to place entrance/exits of the underground roads, then the inclusion relation can be concluded: $M \in K \in D \in L$.

Set $Z=[z_{md}]_{M\times D}$, where z_{md} is variable of 0-1, $z_{md}=1$ represents placing entrance-exit m in the zone d, otherwise $z_{md}=0$. Matrix Z represents site- selection project of entrance-exit m; Set $P=[c_{md}]_{M\times D}$, where c_{md} is the cost of the land use and construction that placing entrance-exit m in the zone d; Set $G=[c_{mm'}]_{MM'}$, where $c_{mm'}$ is the cost of constructing, operating and maintaining the underground road between entrance-exit m and entrance-exit m' ; $Q=[q_{rs}]_{D\times D}$ represents vehicle-travel-distribution matrix of initial D zones (before underground roads are built); Set $E=[e_{md}]_{M\times D}$, where e_{md} is the vehicle volume from entrance-exit m to zone d and $b_{mm'}$ is the vehicle volume between entrance-exit m and entrance-exit m' in the underground road system.

3.2.1 Upper programming model

According to the above definition of variables, the total of land use and construction cost of M underground road entrance-exits can be expressed as $F_2(Z)=\sum_{m=1}^{M}\sum_{m'=1}^{M}\sum_{d=1}^{D}c_{mm'}z_{md}z_{m'd}$; the total of the construction, operation and maintenance cost of the underground roads can be described as $F_2(Z)=\sum_{m=1}^{M}\sum_{m'=1}^{M}\sum_{d=1}^{D}c_{mm'}z_{md}z_{m'd}$. Considering built entrance-exits, the vehicle-travel-distribution matrix will be expressed with $Q'=[q'_{rs}]_{D\times D}$, where $q'_{rs}=q_{rs}+\sum_{m=1}^{M}z_{md}\,e_{md}+\sum_{m=1}^{M}\sum_{m'=1}^{M}z_{md}z_{m'd}\,b_{mm'}$.

The whole travel cost of the region is expressed by $F_2=\sum_{a\in A}x_at_a+\sum_{h\in H}x_ht_h$, actually, the newly-built underground road entrance-exits will attract a lot of traffic, which may lead to the traffic congestion near the entrance-exits, thus the ground roads in the influence area should be widen or built, the construction cost will rise and the traffic flow of the network will also be redistributed. Then the travel cost and the reconstructive cost would be

$F_3(Z)=\lambda\sum_{a\in A}x_at_a(x_a,y_a)+\lambda\sum_{h\in H}x_ht_h+\sum_{a}^{A_1}G_a(y_a)$, $s.t.$ $y_a\geq 0,(1\leq a\leq A_1)$, of which, y_a is the extension variable of ground section a, Y is the extension vector, $G_a(y_a)$ represents reconstruction cost of section a.

The objective function of the upper model was to minimize the land use cost, construction cost, operation cost, maintenance cost of underground roads, and the reconstruction cost of the ground transport network, as well as the travel cost in the area.

$$\min F(Y,Z)=\sum_{m=1}^{M}\sum_{d=1}^{D}c_{md}z_{md}+\sum_{m=1}^{M}\sum_{m'=1}^{M}\sum_{d=1}^{D}c_{mm'}z_{md}z_{m'd}+\lambda\sum_{a\in A}x_a t_a(x_a,y_a)$$
$$+\lambda\sum_{h\in H}x_h t_h+\sum_{a}^{A_1}G_a(y_a)$$

$s.t.$

$$q'_{rs}=q_{rs}+\sum_{m=1}^{M}z_{md}\,\mathrm{e}_{md}+\sum_{m=1}^{M}\sum_{m'=1}^{M}z_{md}z_{m'd}\,\mathrm{b}_{mm'} \quad (1)$$

$$\mathrm{y}_a\geq 0,(1\leq \mathrm{a}\leq \mathrm{A}_1) \quad (2)$$

In the objective function, the first algebraic term represents the land use and construction cost of building M underground road entrance-exits in the D zones; the second represents the sum of construction, operation, and maintenance cost of underground roads; the third and forth is the total cost of the vehicle trip; the fifth is the charge of the sections extension. The first constraint condition shows when the underground entrance-exits are planned to be constructed, the traffic distribution of the region will be considered, the last one shows that the expanding capacity vectors are negative.

3.2.2 The lower programming model

In the lower level, the section flow vector $X=(\cdots \mathrm{x}_a\cdots \mathrm{x}_h\cdots)$ and the vehicle flow vector $Q'=(\cdots \mathrm{q}'_{rs}\cdots)$ are obtained by using the theory of user equilibrium with elastic demand assignment.

$$\min W(\mathrm{X},\mathrm{Q}')=\sum_{a\in A}\int_0^{x_a}t_a(\omega,y_a)d_\omega+\sum_{h\in H}\int_0^{x_h}t_h(\omega)d_\omega-\sum_{rs}\int_0^{q_{rs}}D_{rs}^{-1}(\omega)d_\omega$$

s.t.

$$\sum_k f_k^{rs}=q'_{rs},\forall r,s \quad (3)$$

$$x_a=\sum_{r,s}\sum_k f_k^{rs}\delta_{a,k}^{rs},\forall a \quad (4)$$

$$x_h=\sum_{r,s}\sum_k f_k^{rs}\delta_{\mathrm{h},k}^{rs},\forall \mathrm{h} \quad (5)$$

$$f_k^{rs}\geq 0,\forall r,s,k \quad (6)$$

$$q'_{rs}\geq 0 \quad (7)$$

Where x_h is the inverse function of demand function correspond to $r-s$ of $O-D$,

t_a is the traffic impedance function of ground road sections, which is related to the extension variable y_a of section a and defined as $t_a(x_a, y_a) = t_0[1+\alpha_a(\frac{x_a}{c_a+y_a})^{\beta_a}]$, α_a, β_a represent the parameters of section a, t_h is the traffic impedance function of underground road section h, which is defined as $t_h(x_h) = t_0[1+x_h\gamma_h]$, γ_h represents the parameters of section h; t_0 represents the travel time while the flow of sections is 0; c_a is the traffic capacity of section a; x_k represents the flow of route k from r to s in $O-D$; $\delta^{rs}_{a,k}$ and $\delta^{rs}_{h,k}$ are 0-1 variables; when route k of $O-D$ from r to s pass section a (or h), $\delta^{rs}_{a,k}=1$ (or $\delta^{rs}_{h,k}=1$) ,otherwise $\delta^{rs}_{a,k}=0$ (or $\delta^{rs}_{h,k}=0$). The five constraint conditions of equation (3), (4), (5), (6), (7) represent the flow within the regional network is conserved.

3.2.3 Algorithm

Using iterative optimization algorithm to solve the bi-level programming model, the basic steps are as follows:

Step1: Set the initial solution $Y^0=(0,\cdots,0), k=0$, Y^0 is the improved variable, the initial network is the present one.

Step2: Plug Y^k into the upper objective function, the third item of it will be a constant term, and then the model will become a simple problem of entrance-exit site selection, which can be solved by the general algorithm, the solution of the objective function is Z^{k+1}.

Step3: Plug Z^{k+1} into the upper objective function, the first item of it will be a constant term and the model will turn into a traffic network equilibrium assignment problem, the related algorithms in the literature (GAO Z Y, ZHANG H Z, SUN H J, 2004) can be used to solve the model, we can obtain the solution of the objective function is Y^{k+1}.

Step4: Conduct significant difference tests on Y^k and Y^{k+1}, if there is a significant difference, then set $k=k+1$, and return to the step 2, if not, Y^{k+1} and Z^{k+1} are the solution.

4 The example

The underground road network is described as figure 4. Assumed: there are 10 nodes, 4 zones: 1, 3, 8, 10; 3 underground entrance-exits:1, 4, 10. L=10，D=4，M=3.

O-D Matrix $[q_{rs}]_{D\times D}$, $[e_{md}]_{M\times D}$, $[b_{mm'}]_{M\times M}$ Can be predicted by the data in table 4.The traffic capacity of each section is $c_a = 2000$, the extension charge of the section is $G_a(y_a) = 0.0002\gamma_a y_a$,parameter $\lambda = 0.00002$.

Table 4. O-D Flow of zones

OD	1	3	4	8	10
1	-	500	600	600	1200
3	300	-	600	540	600
4	330	600	-	540	700
8	400	200	540	-	650
10	1000	600	450	250	-

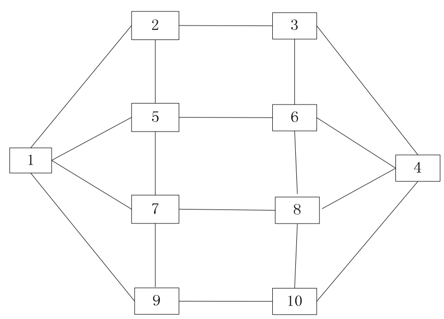


Fig.4 Underground Road Network

Table 5. Optimal Location of Entrance/Exit

Z(m,d)	1	3	8	10
1	1	0	0	0
4	0	1	0	0
10	0	0	0	1

According to the table 5, place entrance-exit 1 into section 1, entrance-exit 4 into section 3, and entrance-exit 10 into section10. The minimum objective function value has been obtained after iterations, which is the optimal scheme.

5 Summary

Entrances-exit site selection of underground roads was studied in this paper. Four important quantitative factors were confirmed by ISM, according to which, a bi-level programming model was established. The objective function of the upper level is to minimize the land use cost, construction and reconstruction cost of the ground transport network, etc. The objective function of the lower level is to assign the traffic flow equilibrately in the transport network. The iterative optimization algorithm (IOA) was used to solve the bi-level programming model. And an example was employed to prove the feasibility of the model. The results show that it is effective in controlling land use and construction cost to optimize the entrance-exit location.

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References

CHEN Z L, ZHANG P. (2009). Research of Chinese Underground Road Construction . Chinese Journal of Underground Space and Engineering, (2):1-12.

GAO Z Y, ZHANG H Z, SUN H J. (2004).Bi-level Programming Model of Urban Traffic Network Design Problem and Application.Journal of Transportation Systems Engineering and Information Technology, 4(1):35-44.

HAN J W. (2010). The Underground Road Entrance Location Model Based on Analytic Hierarchy Process (ahp).Journal of Rail-way Survey, (5):75-77.

Hirata T, Tetsuo Y A I, Mahara T. (2006).Traffic safety analysis in underground urban expressway using driving simulation system MOVIC-T4 Transportation Research Board 85th Annual Meeting.Washington D C: TRB.

HU Y C, SIMA B Q, JIN W Z. (2009) Underground Rapid Road Network Planning Based on The Hubs Choice Model.Journal of South China University of Technology: Natural Science Edition, 37(2): 65-69.

Thalheimer, Erich S. (2004).Reduction in city background noise due to relocation of artery traffic into underground tunnels, The 2004 National Conference on Noise Control Engineering. Baltimore: Institute of Noise Control Engineering: 406-416.

Attribute Mathematical Recognition Model of the Congestion Level of Urban Traffic

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Abstract: Because of the urban road space is relatively limited and the growth of traffic demand is approximately infinite, the phenomenon of traffic congestion is becoming even more serious. According to the attribute mathematical theory, the evaluation index system of traffic congestion was put forward, and the urban traffic congestion evaluation model was set up. The evaluation indexes of urban traffic conditions weights are determined by variation coefficient method. The state of traffic congestion can be recognized by the method of confidence criterion. The final evaluation results can be obtained by calculating the investigation results. Finally, the model can be used to sort the result of traffic congestion evaluation for each road and each intersection. The results show that the method is feasible to solve such problem.
Keywords: Traffic congestion; Attribute mathematical; Coefficient method; Confidence criterion.

1 Introduction

The problem of urban city traffic congestion is becoming even more serious because the continuous expansion of city size and the sustained growth of vehicle possession. At present, there is still no unique definition for the classification criterion of city traffic congestion How to identify the congestion state effectively has aroused a lot of attention from scholars in the field of traffic engineering The independent research of intersections and roads can't reflect the real status of regional traffic network because the urban road expressed in the form of network performance. Aiming at these problems, in recent years, many scholars did a lot of research and achieved some results. Fahmy M. F. and Ranasinghe D. N. (Thajchayapong, S., Pattara-Atikom, W., Chadil, N., & Mitrpant, C., 2006) use the queuing model to discriminate the congestion state. The reference (YANG, Z. Y, 2008)proposed a novel traffic interval programming method based on SFLA and FCM. The reference(Li-chunying, 2010) considered the influence of traffic flow parameters and some related environmental factors of the city traffic condition. However, above methods usually based on the way of single index evaluation or rely on subjective judgment matrix. In order to identify the urban traffic congestion state scientifically and effectively, an investment method based on the model of attribute mathematical has been proposed.

2 The evaluation index system of traffic congestion state

The reference (Qiliang R, 2008) has been cited in order to reflect the traffic congestion state objectively and accurately. The levels of traffic congestion can be divided into four tiers. The four states are unblocked (the first level), relatively smooth(the second level), low-congestion(the third level),congestion(the forth level), Block(the fifth level), the definition of different levels of traffic state, as in table 1 below.

Table 1. The classification of traffic congestion

The level of traffic congestion	Remarks
Unblocked	Free form flow ; No interfering by external environment; No time loss
Relatively smooth	Blocking is weak; Little interference by external environment; Less time loss
Low-congestion	Slightly blocked; Serious interference by external environment; Much time loss
Congestion	Congested traffic flow; Close to saturation; Vehicles hardly leave the intersection for once
Blocked	Blocking; Saturated or overload; Vehicles can not leave the intersection for once

Urban road traffic is composed of roads and intersections from microcosmic angle. Therefore, the state of regional traffic congestion is determined by the congestion status of each intersection and each road. The principle of selecting indicators abide by independence, comparability and representative. Evaluation index refer to the HCM(the level classification of road service), HCM85(the level classification of signal intersection service), the level classification of signal intersection service proposed by Beijing Municipal Engineering Design Institute and other relevant literature. The evaluation index system and grading standards, as shown in Table 2.

Table 2. Evaluation index system and grading standards

The total index	The first indicators	The secondary indicators	Grading standards				
			C_1	C_2	C_3	C_4	C_5
The state of traffic congestion I	Road I_1	Velocity/km•h^{-1} (u_1)	≥40	[35,40)	[28,35)	[20,28)	<20
		Density/pcu•km^{-1}•ln^{-1}(u_2)	<12	[12,25)	[25,45)	[45,70)	≥70
		Saturation(u_3)	<0.35	[0.35,0.65)	[0.65,0.85)	[0.85,1.0)	≥1.0
		Flow rate/pcu•h^{-1}•ln^{-1}(u_4)	<500	[500,950)	[950,1150)	[1150,1950)	≥1950
	Intersection I_2	Delay/s(u_5)	<15	[15,25)	[25,40)	[40,60)	≥60
		Saturation(u_6)	<0.6	[0.6,0.7)	[0.7,0.8)	[0.8,0.9)	≥0.9
		Length of the queue/m(u_7)	<30	[30,40)	[40,50)	[50,60)	≥60
		Parking twice(u_8)	0	0	[0,0.2)	[0.2,0.5)	≥0.5

3 Attribute Mathematical recognition model of the congestion

3.1 The establishment of classification matrix

Urban traffic congestion state needs to measure both the state of roads congestion(I_1) and the state of intersections congestion(I_2). Subjects $X=\{$The state of traffic congestion$\}$, several states of traffic congestion can be taken out from X(x_1 , x_2 , x_3 , $\cdots x_n$).The state of traffic congestion is based on the actual situation and the value of n can not affect the final result of congestion evaluation. Take F as the attribute space, the grading standards are $C=\{c_1, c_2, c_3, c_4, c_5\}$ ={Unblocked, Relatively smooth, Low-congestion, Congestion, Blocked}.Classification standard matrix ,shown as follows.

$$A=\begin{matrix} & c_1 & c_2 & \cdots & c_5 \\ I_1 & [a_{11},b_{11}] & [a_{12},b_{12}] & \cdots & [a_{15},b_{15}] \\ I_2 & [a_{21},b_{21}] & [a_{22},b_{22}] & \cdots & [a_{25},b_{25}] \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ I_4 & [a_{81},b_{81}] & [a_{82},b_{82}] & \cdots & [a_{85},b_{85}] \end{matrix} \tag{1}$$

The benefit index: u_1 (larger means better); The cost index: u_2, u_3, u_4, u_5, u_6, u_7, u_8 (smaller means better).

(1) $a_{j1}>a_{j2}>a_{j3}>a_{j4}>a_{j5}$, $b_{j1}>b_{j2}>b_{j3}>b_{j4}>b_{j5}$, $j=1$.

(2) $a_{j1}<a_{j2}<a_{j3}<a_{j4}<a_{j5}$, $b_{j1}<b_{j2}<b_{j3}<b_{j4}<b_{j5}$, $j=2,3,4,5,6,7,8$.

3.2 Attribute measure space

Attribute measure space means that a method of quantitative analysis to describe the actual survey data which belong to a section in different degrees. The evaluation index system of traffic congestion state has some(j) evaluation index. The actual survey data of I_j (t_1 , t_2 , t_3 , $\cdots$, t_8). The attribute measure spaces of each evaluation index(c_1, c_2, c_3, c_4, c_5) are [u_{jg}]

$$[u_{jg}]=[\underline{u}_{jg},\overline{u}_{jg}] \tag{2}$$

If $a_{j1}<a_{j2}<a_{j3}<a_{j4}<a_{j5}, b_{j1}<b_{j2}<b_{j3}<b_{j4}<b_{j5}$,

When $t_j<a_{j1}$, $\underline{u}_{j1}=1$, $\overline{u}_{j2}=\overline{u}_{j3}=\cdots,\overline{u}_{j5}=0$.

When $t_j<b_{j1}$, $\overline{u}_{j1}=1$, $\underline{u}_{j2}=\underline{u}_{j3}=\cdots,\underline{u}_{j5}=0$.

When $t_j\geq a_{j5}$, $\underline{u}_{j5}=1$, $\overline{u}_{j1}=\overline{u}_{j2}=\cdots,\overline{u}_{j4}=0$.

When $t_j\geq b_{j5}$, $\overline{u}_{j5}=1$, $\underline{u}_{j1}=\underline{u}_{j2}=\cdots,\underline{u}_{j4}=0$.

When $a_{jl}\leq t_j\leq a_{j(l+1)}$, then

$$\begin{cases} \underline{u}_{jl} = \dfrac{|t_j - a_{j(l+1)}|}{|a_{jl} - a_{j(l+1)}|} \\ \underline{u}_{jk} = 0 \quad (k < l \; or \; k > l+1) \\ \underline{u}_{j(l+1)} = \dfrac{|t_j - a_{jl}|}{|a_{jl} - a_{j(l+1)}|} \end{cases} \text{ and } \begin{cases} \overline{u}_{jl} = \dfrac{|t_j - b_{j(l+1)}|}{|b_{jl} - b_{j(l+1)}|} \\ \overline{u}_{jk} = 0 \quad (k < l \; or \; k > l+1) \\ \overline{u}_{j(l+1)} = \dfrac{|t_j - b_{jl}|}{|b_{jl} - b_{j(l+1)}|} \end{cases}$$

3.3 Index weight

The evaluation indexes of urban traffic conditions weights are determined by variation coefficient method in order to avoid the subjective qualitative evaluation. The calculation method of coefficient method shown as follows.

$$C.V_j = \sqrt{1/5 \cdot \sum_{g=1}^{5} (d_{jg} - \overline{d}_j)} \Big/ \overline{d}_j \tag{3}$$

$$\overline{d}_{jg} = 1/2 \cdot (\underline{u}_{jg} + \overline{u}_{jg}) \tag{4}$$

$$\overline{d}_j = 1/5 \cdot \sum_{g=1}^{5} d_{jg} \tag{5}$$

For equations in the text, $C.V_j$ means the coefficient of the evaluation index j.

The coefficient of evaluation index were processed by using the normalization method. The calculation method of the index weight shown as follows.

$$w_j = C.V_j \Big/ \sum_{j=1}^{8} C.V_j \tag{6}$$

For equations in the text, w_j means the weight of the secondary indicators.

3.4 Comprehensive evaluation

The state of traffic congestion can be recognized by the method of confidence criterion.

$$[u_g] = [\underline{u}_g, \overline{u}_g], (1 \leqslant g \leqslant 5)$$

$$\underline{u}_g = \sum_{j=1}^{8} w_j \cdot \underline{u}_{jg}, \; \overline{u}_g = \sum_{j=1}^{8} w_j \cdot \overline{u}_{jg} \tag{7}$$

$$[u_g'] = 1/2 \cdot (\underline{u}_g + \overline{u}_g) \tag{8}$$

$$k = \min\left\{ g : \sum_{i=1}^{g} u(c_i) \geq \lambda, 1 \leq g \leq 5 \right\} \tag{9}$$

For equations in the text, k means the grade of traffic congestion state.

$$q_{xi} = \sum_{i=1}^{n} n_i u_{xi}(c_i) \tag{10}$$

For equations in the text, q_{xi} reflect the situations of different regional traffic network congestion.

4 Empirical study

This paper selected the roads of a city as the research object. The traffic network which selected mainly consists of 6 sections and 5 intersections(see figure 1). The heavy lines represent the roads and the circles represent the intersections. The fine lines represent side-roads.

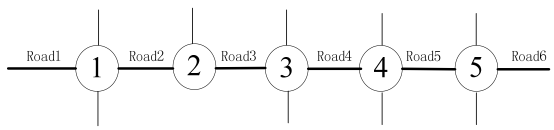

Fig.1 The diagram of the roads and the intersections

Through the actual traffic survey, the data shows as follows.

Table 3. The index value of each road

The label of the road	Velocity	Density	Saturation	Flow rate
r_1	37	32	0.64	873
r_2	35	33	0.65	894
r_3	34	36	0.71	973
r_4	32	39	0.82	1122
r_5	28	43	0.85	1161
r_6	26	51	0.87	1199

Table 4. The index value of each intersection

The label of the intersection	Delay	Saturation	Length of the queue	Parking twice
cr_1	37.7	0.73	49	0.11
cr_2	39.7	0.68	49	0.09
cr_3	43.9	0.76	56	0.13
cr_4	48.8	0.8	57	0.17
cr_5	51.4	0.81	59	0.2
cr_6	37.7	0.73	49	0.11

Refer to equations in the text by (1) and (2), the classification standard matrix and the attribute measure space can be acquired. According to Eq. (3) , (4) and (5), the index weights of each section and each intersection shown as follows.

$W_{r1}=\{0.2272,02311,0.2853,0.2563\}$, $W_{r2}=\{0.2718,0.2105,0.2717,0.2459\}$, $W_{r3}=\{0.2543,0.2300,0.2420,0.2735\}$, $W_{r4}=\{0.2075,0.2469,0.2717,0.2738\}$, $W_{r5}=\{0.2709,0.2318,0.2508,0.2469\}$, $W_{r6}=\{0.2501,0.2349,0.2488,0.2661\}$.

$W_{cr1}=\{0.2380,0.2581,0.2351,0.2688\}$, $W_{cr2}=\{0.2281,0.2748,0.2393,0.2576\}$, $W_{cr3}=\{0.2347,0.2411,0.2227,0.3015\}$, $W_{cr4}=\{0.2101,0.2272,0.2573,0.3054\}$, $W_{cr5}=\{0.1928,0.2388,0.2122,0.3561\}$.

According to Eq. (7) , (8) and (9), the attribute measure spaces of each section and each intersection shown as follows.

$u_{r1}'=\{0.7212,0.4596,0.4279,0.0404\}$, $u_{r2}'=\{0.0153,0.4578,0.4847,0.0421\}$, $u_{r3'}=\{0,0.3665,0.5,0.1335,0\}$, $u_{r4}'=\{0,0.1358,0.5,0.3641,0\}$, $u_{r5}'=\{0,0.0116,0.4983,0.4884,0.0017\}$, $u_{r6}'=\{0,0,0.4158,0.5,0.0842\}$, $uc_{r1}'=\{0,0.1262,0.4415,0.3631,0.1399\}$, $uc_{r2}'=\{0,0.1140,0.4393,0.3780,0.1655\}$, $u_{cr3}'=\{0,0.0768,0.3434,0.4117,0.2370\}$, $u_{cr4}'=\{0,0.0456,0.2872,0.4449,0.3092\}$, $u_{cr5'}=\{0,0.0239,0.2631,0.4699,0.3665\}$.

With reference to score criterion, ranking the state of traffic congestion.

Section(6)>section(5)>section(4)>section(3)>section(2)>section(1),intersection(5)>intersection(4)>intersection(3)>intersection(1)>intersection(2).

5 Conclusions

The method of attribute mathematical was used to recognize the state of urban traffic congestion on the basis of the influence factor index system. On the one hand, the result shows that this method can solve such problems effectively. On the other hand, the model can be used to sort the result of traffic congestion evaluation for each road and each intersection.

At a macroeconomic level the model can be used for the urban traffic management in order to compare different parts of the traffic states. On the micro level, the model can analysis the states of each section and each intersection independently.

Reference

Thajchayapong, S., Pattara-Atikom, W., Chadil, N., & Mitrpant, C. (2006, September). Enhanced detection of road traffic congestion areas using cell dwell times. In Intelligent Transportation Systems Conference, 2006. ITSC'06. IEEE(pp. 1084-1089). IEEE.

YANG, Z. Y., HUANG, X. Y., DU, C. H., & Tang, M. X. (2008). Study of urban traffic congestion judgment based on FFCM clustering.Application Research of Computers,25(9), 2768-2770.

Li-chunying. (2010). Study on traffic congestion prediction model of multiple classifier combination.Computer Engineering and Design.(23):5088-5091.

Qiliang R. (2008) "Research on H-Fuzzy Evaluation Method for Traffic Congestion of City Road-Network." Journal of Chongqing Jiaotong University(Natural Science),41 - 44.

Hai-qing L, Li-cai Y, Lei W, et al. (2012) "Regional traffic congestion evaluation based on Fuzzy-PCA". Journal of Shandong University(Engineering Science).

Engineering, L. X. W. H. L. Y. W. L. Z. Y. O. M. A. E.. (2011). "Study on city traffic state recognition based on extension decision theory." Journal of Wuhan University of Technology(Transportation Science & Engineering).

Xiu-liang, W. (2010). "Comprehensive evaluation method of urban traffic system based on attribute mathematical model." Journal of Chongqing University of Technology(Natural Science).

Traffic Volume Prediction Algorithm Based on Traffic Flow Sequence Partition and a Neural Network

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Abstract: It is an important premise to identify and predict traffic flow instantly and accurately in ITS. Therefore, it is of great significance to realize the control and induction of ITS. Aiming at the intersection short-term traffic volume forecasting problem, we proposed the combined model prediction algorithm based on the analysis of traffic flow sequence partition and neural network model. This algorithm divides the traffic volume into different patterns along the time and volume dimension by clustering analysis, and then describes and predicts traffic flow value according to different patterns. The experiment results on real data set demonstrate that our algorithm based on the combination model is more accurate.

Keywords: Intelligent transportation system; Traffic flow prediction; Clustering analysis; Neural network.

1 Introduction

So far, researchers have proposed many short-term traffic flow prediction models. In 1981, Stephanedes put forward History Average Model to predict short-term traffic flow; In 1991, Davis utilized K neighbor weight function nonparametric regression model based on Euclidean distance to predict short-term traffic flow value; In 1993, Kim put forward highway traffic flow forecasting method based on ARIMA model; In 1999, Williams applied ARIMA model to predict sections of single point traffic flow; In 2002, Smith compared parameters regression and nonparametric regression model, pointing out that with the data' amount increasing, better nearest neighbor value can be obtained, different state classification definition and distance function had a promoting effect on prediction effect. Yin proposed a fuzzy neural network model to predict urban traffic network flow. Fuzzy clustering was used to analysis on the input data. Building relationships between the clustering and prediction value by using neural network, so as to achieve the result and reduce the complexity of prediction (LU, 2009).

For short-term traffic flow prediction problem in intersection, this paper proposed traffic volume prediction algorithm based on traffic flow sequence partition and neural network. The algorithm firstly uses the clustering method to divide traffic flow mode in time and space dimensions, then adopts the neural network method to model and forecast each traffic flow mode.

2 Traffic Flow Sequence Partition

Traffic flow data are time series, and are segmented according to the characteristics of time series data change. The most commonly used time series partition method is piecewise linear description (LI, 2002). Choosing K - means clustering algorithm as the basis of sequence partition algorithm (YU, 2012), the basic idea of K-means clustering algorithm is as follows:

(1) All the traffic flow data is sorted according to the size of flow rate value. Choose K - means clustering algorithm as the basis of clustering partition algorithm, using Euclidean distance as the clustering distance unit.

(2) Generate three clusters: C_1、C_2、C_3 according to previous step. C_1 is clustered into 2 clusters, C_2 into 3 clusters, C_3 into 2 clusters according to the size of $C_1 > C_2 > C_3$, but the size of each cluster is ordered based on time, so poly C_1 and C_2 into 5 clusters.

(3) After two steps' clustering, poly a day's flow values into 7 clusters. Although there are overlaps between clusters, distinguish their order from time series.

(4) Calculate mass's center and each cluster's quality. The abscissa of mass's center is for time, ordinate of mass's center is for the average of flow. The quality of cluster is the number of objects in each cluster according to the abscissa of mass's center , donated by t_1、t_2、t_3、t_4、t_5、t_6、t_7, the corresponding qualities are m_1、m_2、m_3、m_4、m_5、m_6、m_7.

(5) Calculate according to the formula (1).

$$t_1^* = t_1 + \left|\frac{m_1}{m_2 - m_1}\right| \times (t_2 - t_1) \qquad (1)$$

3 The BP Neural Network Prediction Model

BP neural network in traffic prediction research has made some achievements. Its prediction accuracy is superior to traditional ARIMA model, but inferior to the nonparametric regression method (HAN, 2004). Therefore the BP neural network is chosen as the intersection of short-term traffic flow prediction model. The BP algorithm is one of the most commonly used feed-forward neural network learning algorithm. In the practical application of artificial neural network, there are a lot of artificial neural networks adopting BP network or its changed form, figure 1 is the framework of the BP neural network diagram and the single neuron model.

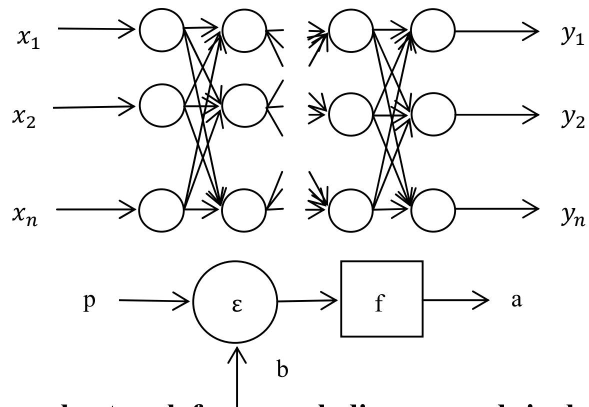

Figure1. BP neural network framework diagram and single neuron model

The characteristics of BP neural network model are: neurons in each layer only have connections with adjacent layer neurons; neurons in the same layer have no connections with each other; neurons in each layer have no feedback connections. BP neural network can be divided into three layers: input layer, hidden layer and output layer. Original weight value and threshold value are given arbitrarily. The two values need to be adjusted to make network's actual output and desired output consistent gradually.

The BP neural network learning is based on samples, including input part and output part. The input layer plays a role of buffer and storage. Data source can be put into neural network directly or after process, and neural network input node depends on the dimensions of input data. Therefore, node number of input layer mainly revolves around the actual demand; neurons number in output layer depends on the result of model dealing.

The basic idea of BP algorithm is through continuous processing of training sample set, calculate the result of output layer and the expected results error. For each training sample, change the weight so as to make the square error between network output and actual category with minimum mean constantly. Reverse is transmitted to the input layer node. In turn, reference error is calculated for each link node, connection weights are adjusted accordingly. Namely, the network learning process can be divided into two propagations: the forward propagation and the error back propagation (SONG, 2009).

The forward propagation: calculate each unit's input and output value in hidden layer and output layer;

The error back propagation: reflect network prediction error and back propagation error by updating weights and bias.

Specific steps are as follows:

① Initialize weights: the adjustable parameters are initialized to smaller random numbers.

② Make following calculation for each input sample:

a. Forward propagation input：calculate net output and net input of each unit in hidden layer and output layer. Net input of each unit in hidden layer and output layer is calculated by linear combination of its input, as shown in figure 2.

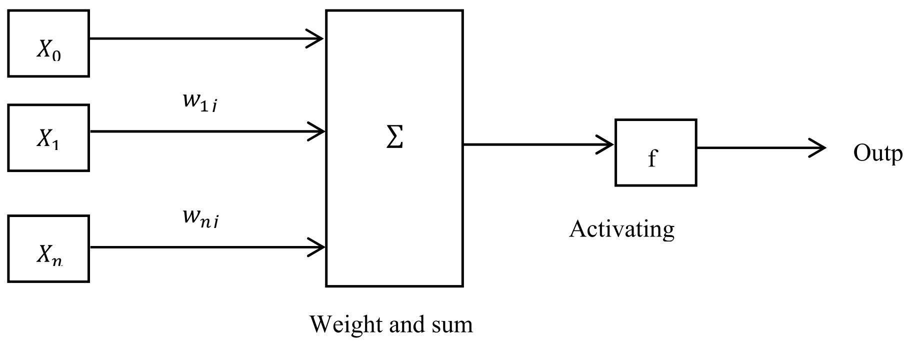

Figure 2. Linear combination process

For a given unit j in hidden layer or output layer, the net input I_j to unit j equals each output connected with this unit multiplies its corresponding wrights, then sum:

$$I_j = \sum_i w_{ij} O_i + \theta_j \tag{2}$$

where w_{ij} the connecting weight from unit *i* in last layer to unit j; O_i is the output of unit i in last layer; θ_j is the deviation value of unit j.

b. Calculate transmission error: reflect network prediction deviation by updating weight and bias, propagate errors backward.

c. Weight correction: the purpose is to reflect error in propagation. The correction formula is as follows:

$$\Delta w_{ij} = (l) Err_j O_i \tag{3}$$

$$w_{ij} = w_{ij} + \Delta w_{ij} \tag{4}$$

where Δw_{ij} is changing value of w_{ij}; l is learning rate, ranging from 0 to 1.

③Judge whether the error converges to required precision. If so, it's over; or input the next round of samples and turn to step ②.

4 Traffic Flow Prediction Portfolio Model

The current limitations of neural network reflect on the following several aspects. First of all, because the neural network model is almost made up by multiple sets of section function, the input and output data between prior knowledge are difficult to integrate into the model and have a certain influence on identification accuracy; Second, a lot of original cleaning data is needed in the process of training, making it difficult to establish the model. Therefore, the BP neural network method has some deficiencies from practical engineering application. In short-term traffic flow prediction, when the road network condition and traffic condition are changed, the trained network is properly updated so as to forecast better. At the same time, the current network type selection and determination of the network structure still lack of guidance in theory, so we need to match experience with theory. In addition, the neural network framework is complex. Precision and approximation ability are relatively high, so the calculation and training time is quite long. There is difficulty in real-time prediction, but the network framework is simple. It is also difficult to guarantee accuracy requirement and solve the problem that the each model has its applicability. Because the complexity of the road is different from other road traffic and particularity, the BP neural network forecasting accuracy of short-term traffic flow has to be improved.

Traffic flow portfolio model is the combination of traffic flow sequence partition and BP neural network model. The specific idea is: on the basis of using traffic flow sequence partition algorithm, use the BP neural network as prediction algorithm for modeling and predict with session data.

5 The Experiment and Analysis

Use a week's traffic flow data of intersection between People's South Road and one ring road in Chengdu City as training samples of BP neural network. Establish BP neural network for each split range. In the prediction of traffic direction, regard the first five time unit value as the input of BP neural network, the next unit of time value as output. Namely, input variables are five, and output variable is one. The BP neural network chooses a three-layer neural network framework, including input layer, hidden layer and output layer. Unit number in hidden layer is seven. Traffic flow prediction result is shown in figure 3:

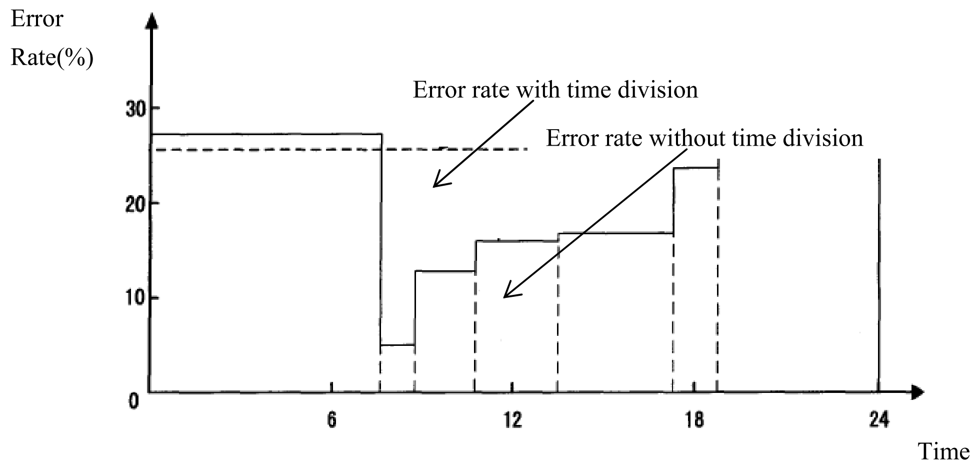

Figure 3. Traffic flow prediction based on traffic flow sequence partition

Prediction error rate above the dotted line in figure 3 is 25.78% without using quadratic clustering algorithm. Seven phase functions in solid line show the forecasting accuracy after a separate modeling with time division. Table 1 shows the detailed instructions.

Table 1. Traffic prediction accuracy based on traffic flow sequence partition

Period of time	0：00-7:30	7:30-8:50	8:50-10:50	10:50-14:00
Error rate（%）	28.22	4.45	13.15	18.08
Period of time	14:00-17:30	17:30-18:50	18:50-24:00	
Error rate（%）	18.95	25.57	28.22	

Through the combination of sequence partition algorithm and BP neural network model to predict traffic flow, we find that two dimensional clustering algorithm of traffic flow model depends on the traffic flow distribution according to flow rate and time. It is easy to draw traffic bimodal shaped by observing: one is early peak, another is late peak. Traffic flow value size clustering can be divided into several classes, so as to distinguish peak flow, largest flow of traffic information, especially for the city's main road. General speaking, traffic signal timing plans are not set fixedly, it can be adjusted in all directions automatically. This state change can be reflected by the size of the traffic flow change indirectly. Secondly, the clustering partition on the time dimension can clearly be divided by the data of early peak and late peak.

6 Conclusions

The experimental result shows there is little difference between two kinds of forecasting methods in low flow period. In other times, traffic flow prediction method's error rate based on combination model is greatly reduced, especially in the early peak, so that the traffic flow prediction accuracy in rush hour can reach to 85%. Therefore, traffic volume prediction algorithm based on traffic flow sequence partition and neural network can meet the needs of the traffic management and forecasting effectively.

Reference:

DOU Huili, LIU Haode, WU Zhizhou, YANG Xiaoguang(2009). "Study of Traffic Flow Prediction Based on wavelet Analysis and Autoregressive Intergrated Moving Average Model."*Journal of Tongji University(Natural Science)*, 37(4), 486-489.

HAN Chao, SONG Su, WANG Chenghong(2004). "A Real-time Short-term Traffic Flow Adaptive Forecasting Method Based on ARIMA Model."*Journal of System Simulation*, 16(7), 1530-1535.

LI Bin, TAN Lixiang, JIE Guangjun, LI Haiying, ZHUANG Zhenquan(2002). *"Asynchronous more frequent pattern discovery algorithm in time series."* Journal of software, 13(03), 410-416.

LU Haiting, ZHANG Ning, HUANG Wei, XIA Jingxin(2009)."Research Progress of Short Term Traffic Flow Prediction Methods."*Journal of Transportation on Engineering and Information*, 7(4), 84-91.

SONG Guojie, HU Cheng, XIE Kunqing, PENG Rui(2009). "Process neural network modeling for real time short-term traffic flow prediction." *Journal of Traffic and Transportation Engineering*, 9(5), 73-77.

TAN Manchun, FENG Luobin, XU Jianmin(2007). "Traffic Flow Prediction Based on Hybrid ARIMA and ANN Model."*China Journal of Highway and Transport*, 20(4), 119-121.

YU Bin, WU Shanhua, WANG Minghua, ZHAO Zhihong(2012). " K-nearest neighbor model of short-term traffic flow forecast."*Journal of Traffic and Transportation Engineering*, 12(2), 105-111.

Dynamic Response of the Track Irregularity State in a Subway Turnout Zone

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Abstract: Aiming at the environmental vibration problems of turnout zone, the vibration equations for vehicle and turnout system are developed respectively by means of finite element method and Lagrange equation. According to irregularities characteristics of turnout structure, the wheel/rail contact geometry is introduced to the vehicle-turnout coupling system. Then the computational software is coded with Matlab. Dynamic responses of the irregularities state are analyzed. The calculation results show that large impact of vehicle-turnout system is produced when vehicle passing through the switch area and frog area. The vertical geometric irregularity of turnout has significant influence on wheel/rail interaction force, where turnout wear aggravates this dynamic action. To improve the turnout working state and reduce the maintenance cost, the occurrence and development of wear in frog area should be controlled strictly.
Keywords: Turnout; Irregularity state; Dynamic response; Wheel/rail interaction force.

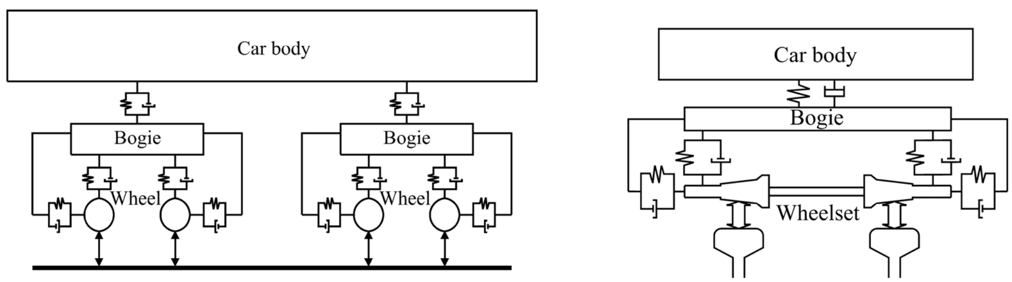
1 Introduction

Turnouts are an important part of the subway track system. Due to the use of high frequency and complex structure, turnout life is shortened greatly, which has a major influence on the maintenance costs of the tracks. Additionally, there are often only small time intervals available for service of turnouts in the track during the night. In turnout zone, a vertical impact of the wheel on the switch area and frog area occurs. The subway company's goal is to optimize the impacts to minimize the dynamic effects. The objectives of operations management have been paid widely attention to by researchers at home and abroad. More recently, the dynamic interaction between train and turnout was simulated by comparison of simulations performed using multi-body software GENSYS and FEM software DIFF3D (Kassa, 2006). The behavior of a vehicle passing a turnout to determine the influence of gauge-widen design on wheel/rail contact relationship was studied (Cao, 2011).

However, for a complex system such as Hadfield steel frog it is a daunting task to develop realistic numerical model. Dynamic vehicle-track interaction in turnout is far more complex than on ordinary tangent or curved track. To further understand the impact damage, a simulation model of the China No.12 turnout is developed to predict magnitude of impact force in this paper. Finally, several advices are advanced for maintenance in subway turnout zone.

2 Vehicle Model

Vehicle system is assumed to be a multi-body dynamic model with primary and secondary suspensions, where mainly references B-type metro vehicle in the process of establishing the model. It contains three components: car body, bogies and wheel sets. The car body and two bogies are both modeled with consideration of swinging, floating-sinking, side rolling, nodding and yawing. The wheel sets are modeled with consideration except nodding. That is, 6-degrees of freedom of the car body, bogie frame and 5-degrees of freedom of the wheel set are included in the model, for a total of 31. The dynamic analysis model of vehicle is shown in Figure 1.



(a) Elevation view (b) Side view

Figure 1. Vehicle model

3 Turnout Model

When dealing with vehicle-turnout interaction, rail profile variation along the track has to be considered. The wheel sets generate vertical movement while passing through the turnout, due to the transition from stock rail to blade rail and from wing rail to nose rail. That way, the rail profile sudden variation leads to high wheel/rail contact force, where wear of turnout tends to exacerbate the effect.

Rail profiles of No.12 turnout are measured by Calipri device. With this device, at some 100 positions on the left and right rails in the main route have been measured, including both new profiles and worn profiles. Track gauge is also measured at these positions. The sampling positions are shown in Figure 2. Figure 3 shows the measured rail profiles on the right rail (facing move) in the switch and frog area of the main route. Then, the rail profiles are represented by cubic parametric B-splines. Besides that, in order to obtain arbitrary section profiles along the track, an interpolation method is used, where its strategy is to interpolate the rail profile between two measured cross-sections. The rail profiles of switch area are plotted in Figure 4.

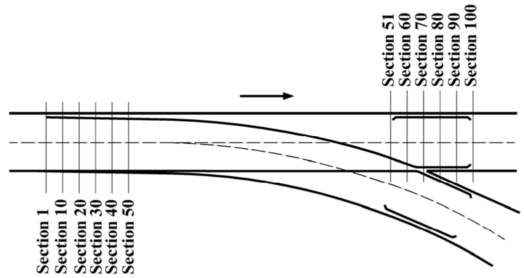


Figure 2. Sampling positions along the track

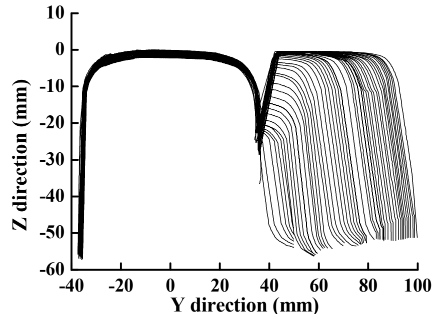


Figure 3. Measured rail profiles

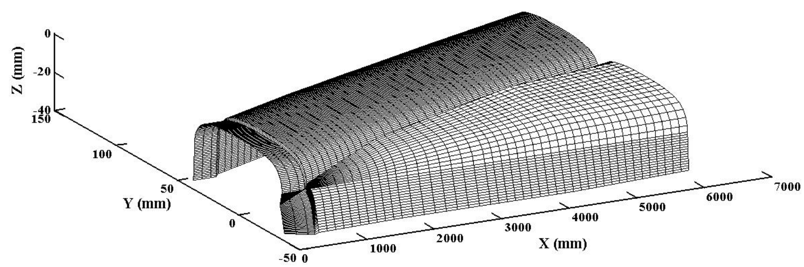


Figure 4. Rail profiles of switch area

Rail structures of the turnout, including stock rail, blade rail, nose and wing rails, and check rails, are discretized by neighbor fasteners on sleepers. Then, they are modeled by Euler beam elements, where one element has 4-DOFs, vertical displacement and slope, lateral displacement and slope. Turnout sleeper is viewed as rigid mass block in horizontal direction with 1-DOF of lateral displacement, and divided into finite beam elements in vertical direction with 2-DOFs of vertical displacement and slope.

4 Numerical Solution of Equations

As previously discussed, the dynamic interaction of vehicle-turnout coupling system is highly influenced by the rail profile variation, where it has significant implications on wheel/rail contact geometry. The contact parameters between wheel and turnout rails can be obtained by the wheel/rail contact point trace method (Ren, 2010), where the contact points are determined by a spatial curve.

According to the principle of Hamilton, finite element equation for vehicle system can be obtained,

$$\boldsymbol{M}_V \ddot{\boldsymbol{a}}_V + \boldsymbol{C}_V \dot{\boldsymbol{a}}_V + \boldsymbol{K}_V \boldsymbol{a}_V = \boldsymbol{Q}_V + \boldsymbol{F}_{VT} \tag{1}$$

Where, $\boldsymbol{M}_V$, $\boldsymbol{C}_V$ and $\boldsymbol{K}_V$ is the corresponding mass matrix, damping matrix and stiffness matrix for vehicle model; $\ddot{\boldsymbol{a}}_V$, $\dot{\boldsymbol{a}}_V$ and $\boldsymbol{a}_V$ is the acceleration vector, speed vector and displacement vector; $\boldsymbol{Q}_V$ is the gravity vector for vehicle model; $\boldsymbol{F}_{VT}$ is the interaction force between vehicle and track.

The finite element dynamic equation for the turnout system can be written as

$$\boldsymbol{M}_T\ddot{\boldsymbol{a}}_T + \boldsymbol{C}_T\dot{\boldsymbol{a}}_T + \boldsymbol{K}_T\boldsymbol{a}_T = \boldsymbol{F}_{TV} \tag{2}$$

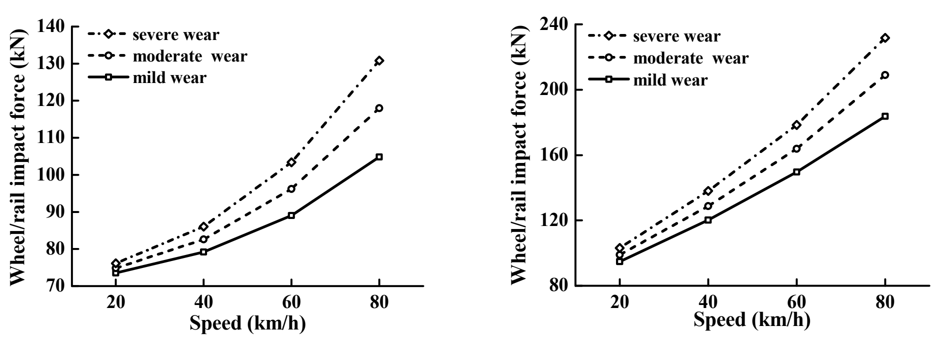
Where, $\boldsymbol{M}_T$, $\boldsymbol{C}_T$, $\boldsymbol{K}_T$ and $\boldsymbol{F}_{TV}$ is the global mass, damping, stiffness, load matrices of turnout subsystem, which is assembled by each element matrices of mass, damping, stiffness and load.

The model of vehicle-turnout coupling system is defined in time domain. The equations of motion for these two subsystems are written separately, where it can solve them independently with an iterative scheme. The vertical wheel/rail contact is coupled by non-linear Hertz contact force, and the lateral is coupled by tread creep force. A rapid method for solving the coupling system vibration response with the improvement of Newmark-β integration can be adopted (Yang, 1996).

5 Examples of Simulation Results

As an application example of the results provided by the modeling method proposed in the paper, vertical impact is considered for No.12 turnout from a subway line negotiated by a B-type vehicle. To comprehensively understand dynamic responses of the vehicle and track coupling system in turnout zone, the following influence factors will be studied: 1) average driving speed, V=20, 40, 60, 80 km/h; 2) the level of wear, mild wear, moderate wear and severe wear, in switch area and frog area respectively; 3) passenger weigh criteria, considering AW2 condition (full load, the vehicle axle load is 14.15 ton) and AW3 condition (crush load, the vehicle axle load is 15.98 ton). The different calculation conditions depicted above will be considered in the analysis of the simulation results presented below.

Results of the computation for the influence of wear under different average driving speed on the wheel/rail impact force in switch area and frog area are shown in Figure 5.

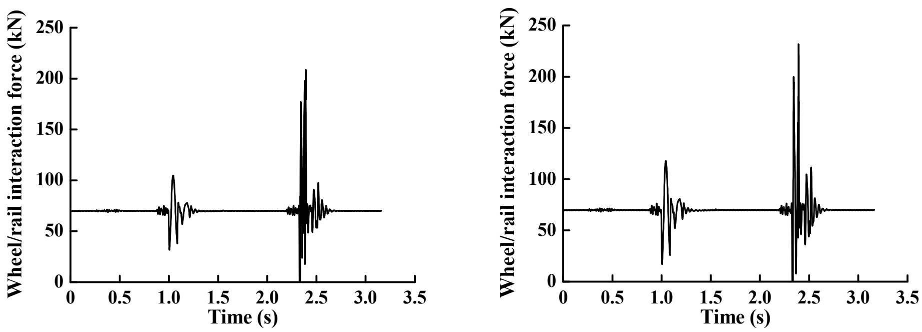


(a) Wheel/rail impact force in switch area (b) Wheel/rail impact force in frog area

Figure 5. Influences of wear and speed on the wheel/rail impact force

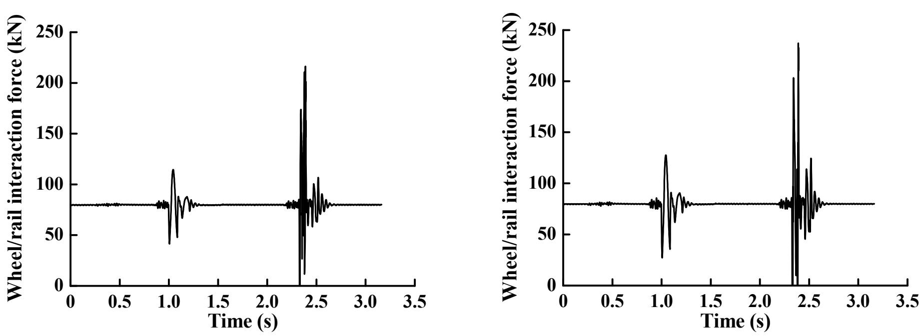
Figure 5 shows that the abrupt change of the rail profiles in two areas has significant influences on the wheel/rail impact force. Severe impact occurs during the vehicle passing over the turnout, which may produce damage of the contact surfaces. Rail profile variation is relatively shorter length of the frog area than the switch area, which will lead to sudden transfer of the contact points and cause higher wheel/rail impact force. Additionally, the level of wear tends to exacerbate the effect, but the influences increase dramatically as the average driving speed increases.

Based on long-term observations in the field, two calculation conditions are discussed with the different passenger weigh criteria. Case 1 is mild wear in both switch area and frog area; Case 2 is moderate wear in switch area and severe wear in frog area. The constant speed of the vehicle V=80 km/h is specified for these simulations. The results computed by varying passenger weigh criteria on the dynamic response of the wheel/rail interaction force have been plotted in Figure 6 and Figure 7.



(a) Calculation condition of Case 1 (b) Calculation condition of Case 2

Figure 6. Influence of AW2 condition on wheel/rail interaction force



(a) Calculation condition of Case 1 (b) Calculation condition of Case 2

Figure 7. Influence of AW3 condition on wheel/rail interaction force

As shown in Figures 6 and 7, two peak values can be observed in the positions of the abrupt change of the rail profiles and hence impact will be induced there. A large impact occurs between the vehicle and the frog, even in presence of an ideal geometry, producing high dynamic loading of the wheel and track in the vertical direction. Increasing the vehicle axle load will significantly strengthen external shocks, where the wheel/rail interaction force will reach 0kN in transient time duration. Meanwhile the level of wear has a certain influence on the magnitude of wheel/rail interaction force. The vehicle axle load, by contrast, is the main factor of further damage. From reducing impact and improving traffic operation's point of view, it should be paid attention to the relationship between the vehicle axle load and the evolution of rail wear.

6 Conclusions

With the aim of increasing the understanding of the complex interaction between vehicle and turnout, two models for dynamic analysis of vehicle-turnout coupling system are developed. As application examples, vertical impact of No.12 turnout from a subway line is investigated. The numerical results demonstrate that the rail profiles variation has significant influence on impact force between vehicle and turnout. In the meantime, operational system parameters, such as average driving speed, wear level, passenger weigh criteria, may accelerate the process of turnout damage. Further, it is expected that the vehicle-turnout coupling model can be applied to guide maintenance in turnout zone, and that the maintenance cost will then reduce.

Acknowledgement

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References

Cao, Y., Wang, P., and Zhao, W. H. (2011). "Dynamic responses due to irregularity of NO.38 turnout for high-speed railway." *Proceedings of the 3rd International Conference on Transportation Engineering*, 2544-2549.

Kassa, E., Andersson, C., and Nielson, J. (2006). "Simulation of dynamics interaction between train and railway turnout." *Vehicle System Dynamics: International Journal of Vehicle Mechanics and Mobility*, 44(30), 247-258.

Ren, Z. S., Sun, S. G., and Xie, G. (2010). "A method to determine the two-point contact zone and transfer of wheel–rail forces in a turnout." *Vehicle System Dynamics: International Journal of Vehicle Mechanics and Mobility*, 48(10), 1115-1133.

Wang, P. (1997). "Research on wheel/rail System dynamics on turnout." *PhD thesis*, Southwest Jiaotong University of China.

Yang, F., and Fonder, G. A. (1996). “An iterative solution method for dynamic response of bridge-vehicles systems.” *Journal of Earthquake Engineering and Structural Dynamics*, 25(2), 195-215.
Zhai, W. M. (2007). “Vehicle–railway coupling dynamics and application.” *China Science Publishing House*, Beijing.

Data Model of 3D Geological Modeling and Realization

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Abstract: The displaying of three-dimensional geological body can describe the complex subsurface geological structure visually, improve the engineer's space imagination effectively, understand the geological spatial relationship more intuitive and design more reasonable. The paper analyzed the three-dimensional geological data model usually used, established a Generalized Triangular Prism (GTP) element model and considered the impact of faults, Set up a three-dimensional geological modeling method based on GTP. Achieved a three-dimensional geological drilling, borehole cross-section and other information visualization inquiry and geological cutting, excavation, hierarchical display and other visualization techniques based on three-dimensional spatial analysis techniques and graphics.

Keywords: Geological; Three-dimensional modeling; Visualization; Generalized triangular prism; Spatial analysis.

1 Introduction

Design and construction of railway engineering generally face complex geological condition, traditional analysis and interpretation of engineering geological data is generally restricted to two-dimensional and static expression, the visibility of description of spatial geological structure fluctuation is poor, usually cannot fully reveal the law of spatial changes, and it is difficult to understand the geological environment directly, completely and accurately. So it cannot meet the demand of engineering design personnel for spatial analysis (LI Mingchao, 2007). Building of three-dimensional geological model can directly describe the complex underground geological tectonic situation. enhance maximize the visibility and the accuracy of geological analysis allows the designer to make engineering design and construction scheme in line with the actual geological phenomena in the distribution and the change rule, reduce the project risk.

2 Engineering geological 3D data model

Due to the complexity of geological body itself and multiplicity of description, thus formed a variety of spatial modeling methods and a variety of data model. At present, the 3D geological data model is mainly including three kinds: based on face expression (Surface-based), based on the body (Voxel-based) expression and mixed structure data model(XIONG Zuqiang, 2007).

2.1 The overview of 3D data model

The 3D data model is directly related to the functionality of three-dimensional geological modeling and the possibility spatial analysis, and provides the basic support for visual expression and analysis of 3D geological modeling and 3D geological data. A good 3D geological data model, must meet the following conditions(XIONG Zuqiang, 2007): ① can correctly, accurately express the geological body, including geological semantics (Geological semantics); ② ensure operational efficiency and robustness ; ③ can express the geometry and topology of 3D geological model construction.

2.2 The data model based on surface representation

Data model based on surface representation that is based on boundary of object to define and describe the spatial entities, mainly through the approach of simulation of geological interface, and then combined into a body, focusing on the three-dimensional surface representation. As grid structure, facets model (such as TIN), boundary representation model, wire frame model, a multi-layer DEM model (Lemon A M, 2003; WANG Chunxiang, 2003; LI Shaojun, 2008). The data model based on surface representation is able to display and data update, and the advantages can be realized conveniently strata visualization and model updating, but also has the defect of being not able to describe the 3D topological relation, it is difficult to analyze spatial (A.A.G. Requicha, 1983). Figure 1 and figure 2 are the 3D geological modeling results using the wire frame model and the multilayer DEM model.

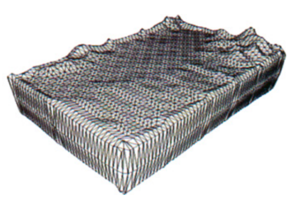

Figure 1. geological body Wire frame model

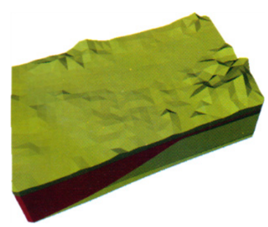

Figure 2. geological body of multilayer DEM model

2.3 The data model based on body representation

The data model based on body representation use the body information instead of surface information to describe the object inside, described the object inside through the body information, focused on the representation of body 3D space. The body element is the most basic unit of composition. According to difference of the body element, it can set up different data model. Mainly includes the 3D grid model, octree model, Constructive Solid Geometry, Tetrahedron Network(Victor J D ,1993; Lemon A M, 2003; CHENG Penggen, GONG Jianya, 2004). Body model with a simple data structure, advantages for space operations and analysis, but the storage space was large; the computing speed is also slow. Figure 3 was mainly several body data structure model of the schematic diagram.

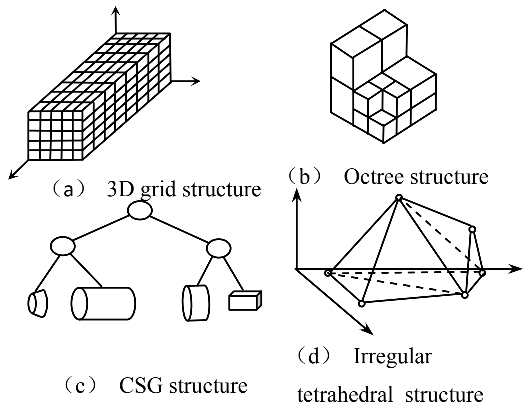

Figure 3. Several body data structure model

2.4 Data model based on the hybrid structure

The Hybrid structure data model comprehensive two or more data models to form an integrated structure data model, such as TIN-CSG,TIN-Octree, TEN-OCtree and Wireframe-Block mixed models and so on (LI Changling，2013). When representing different spatial entity used different data models, advantage of Hybrid model based on the data structure can be effectively complete description of the phenomenon of three-dimensional space. However, due to the complexity and unpredictability of geological spatial objects in practice, it is difficult to make the right choice about the extent of binding of surface and voxel representation. Moreover no good solution in computer, and the excessive stress of complete expression in theoretical dose not conducive to achieving the modeling. Figure 4 is schematic of a hybrid data structure of Octree-TEN.

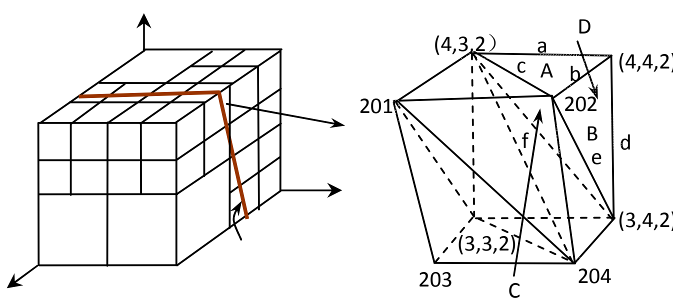

Figure 4. schematic of a hybrid data structure of Octree-TEN

2.5 Analysis of data model

It is obvious that each data model has its own advantages and disadvantages, andifferent applicable scope. Thus the construction of three-dimensional geological model, considering its own characteristics and modeling purposes, should choose a reasonable 3D Spatial Data Model. For example, basing on the long ribbon model of railway lines, the data and methods to build the model should meet the need of space ribbon model characteristics. Therefore, it is particular important to learn how to design three-dimensional data model and structure, which is more easy to implement and suitable for the expression and analysis of circuit.

Because it is geared to the needs of geological modeling, the model can deal with complex geological structure by using the surface, but it is difficult to solve internal properties showing , such as cutting and mining. As well as the surface and body hybrid model just stop at the theoretical level, So the modeling method based on voxel has been more and more adopted. Especially in order to adapt to complex geological model, the improved model based on triangular prism has became the main model of 3D geological modeling. Through exchanged the standard three prism (TP) to meet the needs of the various circumstances of modeling, it named the generalized Tri-Prism.

3 The modeling based on generalized triangular prism model

3.1 GTP model

When used GTP conducted geological modeling, it used the different stratification of borehole data to simulate stratum's hierarchical entity and express stratum form, guaranteed 3D geological modeling accuracy maximize. The GTP model adopt GTP as basic voxel, included six Vertices, edges, TIN triangle, side quadrilateral and triangular prism. The triangle set of GTP bottom surface can express different geological interface, The GTP Side can describe geological spatial adjacencies, morphology and characteristic attributes between ground level. As shown in Figure 5a. Meanwhile for the geological pinch, dislocation and other complex geological modeling, GTP voxels can be deformed, shown in Figure 5 (b) and Figure 5 (c).

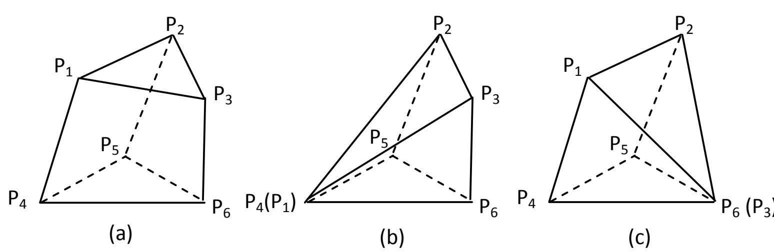

Figure 5. GTP model

Figure 6 shows the GTP-Voxel drawn renderings.

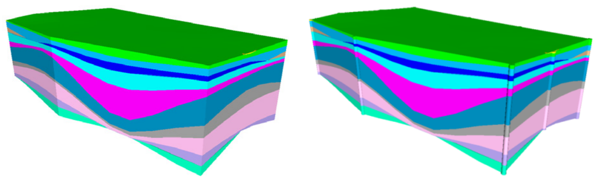

Figure 6. GTP-Voxel drawn renderings

3.2 Three-dimensional geological modeling based GTP

GTP obtained by TIN processing extensions .TIN as constraints controlled the generation process of GTP, expressed the topological relations between voxels and can express the internal structure and properties of three-dimensional geological body . GTP model based on the original borehole data Modeling directly, Make the model more meet with actual geological conditions and ensured modeling accuracy. The three-dimensional geological modeling process based on GTP as shown in Figure 7.

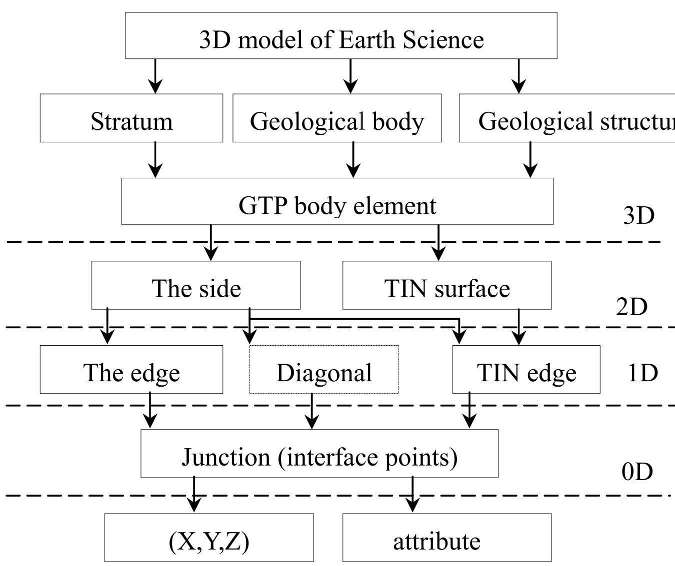

Figure 7. The 3D geological modeling process based on GTP

The thesis adopt GTP-voxel model, achieved the drilling and drilling profile queries shown in Figure 8 and Figure 9, polygon cutting and splitting visualization of model shown in Figure 10 and figure 11 and excavation effect of three-dimensional geological model shown in Figure 12.

Figure 8. 3D drilling map search

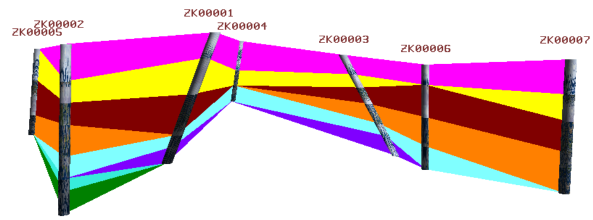

Figure 9. Drilling profile inquiry

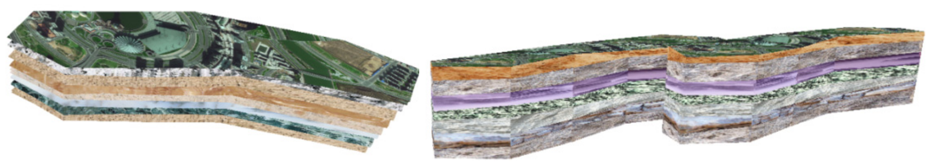

Figure 10. Polygon cutting renderings

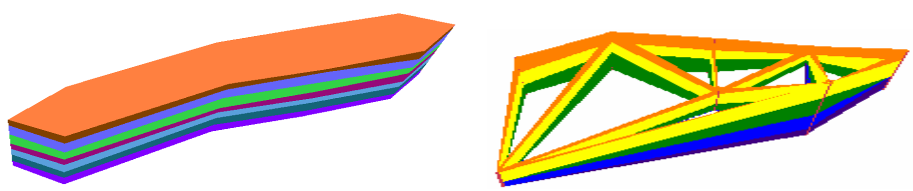

Figure 11. Polygon splitting renderings

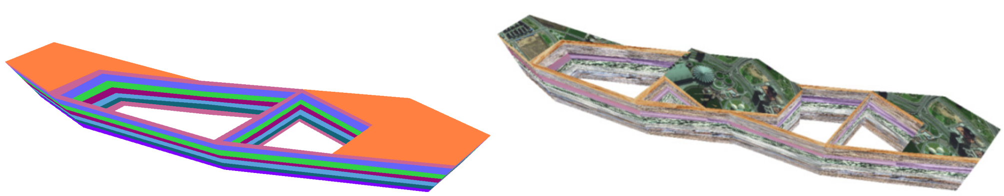

Figure 12. Excavation effect of 3D geological model

4 Conclusions

The theses analyzed the three-dimensional geological modeling features, adopt drilling data as the main data source and achieved a three-dimensional geological modeling method based on GTP. It established the three-dimensional banding geological model which meet the design requirements of railway line, achieved a variety of three-dimensional visualization of the model. The research result opened up an effective way for rapid and real-time reproduction of 3D geology information and visualization comprehensive analysis.

Acknowledgement

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References

LI Mingchao (2007). "Refined Modeling for Numerical Simulation of Engineering Rock Mass Structures Based on 3D Geological Model." *Chinese Journal of Rock Mechanics and Engineering,* 26(9), 1893-1898.

XIONG Zuqiang (2007). "Study on technology of 3D stratum modeling and visualization based on TIN." Rock and Soil Mechanics, 28(9), 1954-1958.

Lemon A M, Jones N L (2003). "Building solid models from boreholes and user-defined cross-section." Computers and Geosciences, 29(3):547-555.

WANG Chunxiang, BAI Shiwei (2003). "Study on application of 3DSIS to geotechnical engineering." Rock and Soil Mechanics, 24(4), 614-617.

LI Shao-jun, FENG Xiating, WANG Wei (2008). "Integrated technology of visualizing simulation for three-dimensional underground cavern based on geotechnical strata information." Rock and Soil Mechanics, 29(1), 235-239.

A.A.G. Requicha, H.B.Voelcker (1983). "Solid Modeling: Current Status and Research Directions."IEEE Computer Graphics and Application, 3(7), 25-37.

Victor J D (1993). "Delaunay Triangulations in TIN Creation: An Overview and a Linear Time Algorithm."Int.J. Geographical Information System, 7(6), 501-524.

Lemon A M, Jones N L (2003). "Building solid models from boreholes and user-defined cross-section." Computers and Geosciences, 29 (3), 547-555.

CHENG Penggen, GONG Jianya, SHI Wenzhong (2004). "Geological Object Modeling Based on QuasiTri-prism Volume and Its Application." Geometrics and Information Science of Wuhan University, 29 (7), 602-607.

LI Changling，ZHANG Hong，ZHU Liangfeng(2013). "Algorithm for true-3D modeling of geological body with single-fault." Computer Engineering and design, 34 (10), 3590-3594.

Simulation of Pedestrian Evacuation Flow Based on Crowd Space

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Abstract: Simulation of pedestrian evacuation flow is based on cellular automata model, which defines personal space and information processing space within the field of pedestrian's movement. It uses the pedestrian density to descript evacuation characteristics in the condition of the different environments, in order to determine pedestrian's behavior choice. Furthermore, it analyses system scale, exit's width, pedestrian density and selection strategies on the effect of evacuation time, and observes the self-organization phenomena in the process of simulation. It is shown that the evacuation time is not only influenced by the scale of the system, but also directly with the exit width and selection strategy.
Keywords: Personal space; Information processing space; Cellular automata; Evacuation time; Selection strategy.

1 Introduction

In recent years, there has been a steady growth of interest in concern about pedestrian flow in order to aid the design of pedestrian's evacuation strategy and to optimize the allocation of resources. Helbing (1998, 2000) revealed that a pedestrian could be influenced by three kinds of social forces in the process of movement: (a) repulsive interaction forces between pedestrians, (b) self-driving forces for pedestrians, and (c) attractive forces from collective herding instinct. Based on Helbing's work, Nishihara (2006) took these three kinds of social forces synthesized to two kinds of interaction force field in the process of pedestrian's movement: personal space and information processing space. Yet there have been few studies how to define personal space and information processing space. Consequently, how to present this difference is a subject of much concern.

In studies of pedestrian flow simulation, the model of cellular automata (CA) has widely been used in different kinds of fields, such as pedestrian walkways, traffic intersections, transportation facilities, and other public buildings pedestrian flow. Burstedde (2001) and Schadschneider (2002) proposed a floor field model to describe pedestrian's behavior and self-organization phenomena. Based on their work, Kirchner (2002) modified the transition probability and found a non-monotonic dependence of the evacuation times on the coupling constants. Huang (2008) proposed a floor field model based on the discrete choice model. Peng (2011) presented a multi-floor field to simulate pedestrian flow through a "T" intersection. The essence of these CA models is to study the probability of pedestrians moving to the next target, namely the transition probability.

Based on the basic CA model, this paper aims to define the personal space and information processing space to describe pedestrian's movement in crowd space, and expresses the difference of pedestrian's behavior in the condition of the different environments.

2 Model

The model is described in the $N \times N$ two-dimensional discrete cellular grids system Ω^2, where N is the system scale, Ω^2 is the two-dimensional system. Based on empirical statistics, the size of a cellular grid corresponds to approximately 0.4m×0.4m (Fang, 2003), the average speed of a pedestrian is about 1.00m/s in normal circumstances (Yang, 2008). Therefore, one time-step is approximately 0.4s in this model. In the process of simulation, every pedestrian can wait or move to 8 directions around his neighbors in each time-step of the model's evolution. Therefore, the field of pedestrian's movement is displayed in Figure 1.

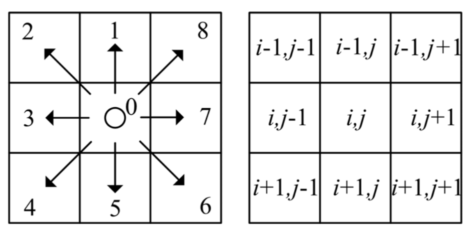
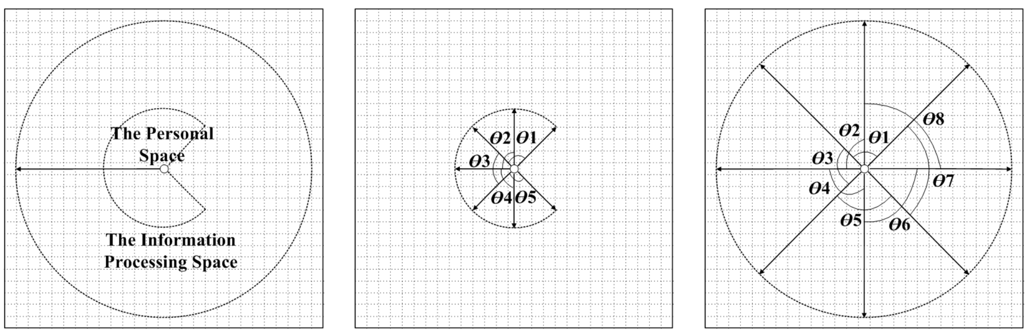


Figure 1. The field of pedestrian's movement

2.1 Crowd Space

Pedestrian's movement is a complex dynamic process. A pedestrian will not only appear to be imitating others moving, but also trying to keep a certain distance with others in the process of movement. This means that there are two forces in the process of pedestrian's movement: (a) a repulsive force field defined as personal space, (b) an attractive force field named as information processing space. In order to define personal space and information processing space in CA, we assume that personal space and information processing space are composed of cellular grids. Supposing the system has enough cellular grids, a pedestrian's personal space is composed of the cellular grids oriented by the shortest distance of exit, which distance is within 2m from his position (Nishihara, 2006). And the cellular grids, which distance from his position is between 0m and 5m, constitute his information processing space (Nishihara, 2006). If a pedestrian is near the wall, we assume that there is a non-existent cellular grid occupied by a virtual pedestrian. In personal space, we assume that there are non-existent cellular grids occupied by pedestrians, this hypothesis demonstrates that walls have repulsive force to pedestrians, and pedestrians do not like to crowd near the wall. In information processing space, we assume that there are non-existent cellular grids occupied by pedestrians, this assumption shows that walls have attractive force to pedestrians, and pedestrians think they will effectively reach an exit along walls. Therefore, there also has two kinds of interaction force fields to influence on pedestrian's movement. In empirical statistics, the maximum angle of vision range on each direction is roughly 90 degrees. Therefore, the crowd space are shown in Figure 2 when the shortest distance of exit is in the left side.



(a) (b) (c)

Figure2. The crowd space in CA. (a) the personal space and the information processing space; (b) the personal space; (c) the information processing space

In personal space, we define the void density of every 8 direction's corresponding cellular grids in personal space to describe this repulsive force. If P is $\forall$ a pedestrian, these densities are expressed as $\dot{\rho}_d^P$, $d\,(d=0,1,\cdots,8)$ is a optional direction as shown in Figure 1. Thereinto, $\dot{\rho}_0^P$ is set zero. When the shortest distance of exit is in the left side, $\dot{\rho}_6^P=\dot{\rho}_7^P=\dot{\rho}_8^P=0$. When the shortest distance of exit is in the right side, $\dot{\rho}_2^P=\dot{\rho}_3^P=\dot{\rho}_4^P=0$. When the shortest distance of exit is in the upper side, $\dot{\rho}_4^P=\dot{\rho}_5^P=\dot{\rho}_6^P=0$. When the shortest distance of exit is in the lower side, $\dot{\rho}_1^P=\dot{\rho}_2^P=\dot{\rho}_8^P=0$. Because these direction's corresponding cellular grids are not in the pedestrian's vision range.

In information processing space, we define the same direction's pedestrian density of every 8 direction's corresponding cellular grids in information processing space to demonstrate this attractive force. If P is $\forall$ a pedestrian, these densities are expressed as $\ddot{\rho}_d^P$. And $\ddot{\rho}_0^P$ is set zero.

2.2 Direction Force Parameter

In order to synthesize a repulsive force of personal space and an attractive force of information processing space, we assume that P is $\forall$ a pedestrian in Ω^2, (i,j)

is his current position's coordinate, his 9 optional position's coordinate is $(x, y) \in \{i-1, i, i+1\} \times \{j-1, j, j+1\}$. Then we have

$$F_d^P = \begin{cases} 0, & d = 0 \\ \omega\xi\dot{\rho}_d^P + (1-\omega)\eta\ddot{\rho}_d^P, & d = 1, \cdots, 8 \end{cases} \quad (1)$$

It is called the direction force parameter of P on direction d. Thereinto, $\{i-1, i, i+1\} \times \{j-1, j, j+1\}$ is shown the set of Cartesian product between $\{i-1, i, i+1\}$ and $\{j-1, j, j+1\}$, ω $(0 \le \omega \le 1)$ is the inertia weight, ξ and η are the random numbers extracted evenly in the range of [0, 1].

2.3 Distance Parameter

This paper calculates the Euclidean distances from every cellular to the exits in the calculation of distance parameter. This calculation process is shown in Eq. (2), where (x, y) is $\forall$ a cellule's coordinate in the system, D_{xy} is the shortest distance from a cellular (x, y) to the exits, (x_w^e, y_w^e) is coordinate of the cellular w in the exit e.

$$D_{xy} = \min_e(\min_w(\sqrt{(x - x_w^e)^2 + (y - y_w^e)^2})) \quad (2)$$

If P is $\forall$ a pedestrian, (i, j) is the current position's coordinate, his 9 optional position's coordinate is $(x, y) \in \{i-1, i, i+1\} \times \{j-1, j, j+1\}$. The shortest distances of P moving to 9 optional positions are shown in Eq. (3), where S_d^P is the shortest distance from the cellular (i, j) to a cellular (x, y) in the process of P moving to 9 optional positions.

$$S_d^P = \begin{cases} 0, & d = 0 \\ \dfrac{\left|D_{ij} - D_{x,y}\right|}{1}, & d = 1,3,5,7 \\ \dfrac{\left|D_{ij} - D_{x,y}\right|}{\sqrt{2}}, & d = 2,4,6,8 \end{cases} \quad (3)$$

2.4 Moving Profit

The model calculates direction force parameter F_d^P and distance parameter S_d^P of 9 optional positions in every pedestrian's neighbors. Furthermore, it obtains moving profit E_d^P of every cellular grid as shown in Eq. (4).

$$E_d^P = F_d^P + S_d^P \quad (4)$$

2.5 Selection Strategy

When multiple pedestrians simultaneous choose a void cellular grid to access, there is conflict among these pedestrians. In the real world, there are mainly two kinds of selection strategy.

(1) The competitive strategy: it will randomly select a pedestrian based on the same probability to access this void cellular grid, while not having selected

pedestrians will hold their positions in the next time-step.

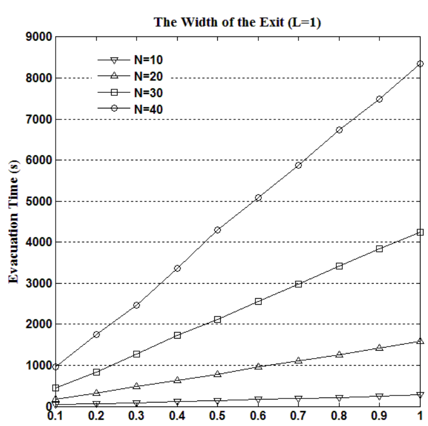
(2) The concessional strategy: it will select a pedestrian, who has the maximum direction force parameter, to access this void cellular grid.

3 Simulation and Analysis

In the process of simulation, the model assumes that there are not have obstacles in the system and every pedestrian sight is not affected. Pedestrian density K is defined as the value of the total number of pedestrians divided by the total number of cellular grids $N \times N$. Pedestrian evacuation time T is described as the required time of all pedestrians leaving the system. L is expressed as the width of the exit. In process of the simulation, we take the average value of operated 20 results as statistical index in order to reduce the effect of initial condition on the statistical indexes.

3.1 Experiment 1

When the simulation chooses the competitive strategy, this paper studies the curves of pedestrian evacuation time T changing with pedestrian density K as demonstrated in Figure 3, based on $N = 10,20,30,40$, only one exit from the system, and $L = 1,10$. In the case of fixed the exit's width from the system, there is an increasing trend in the process of pedestrian evacuation time changing with pedestrian density. This increasing trend approximately obeys the linear function. The pedestrian's evacuation time has significant difference in the condition of different system scale. It is shown that the system scale is a key factor on pedestrian evacuation time.



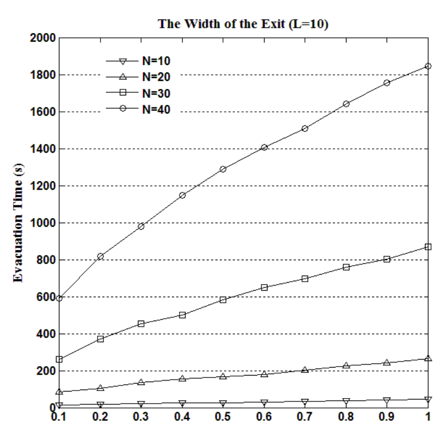


Figure 3. The curves of pedestrian evacuation time changing with pedestrian density based on different system scale

3.2 Experiment 2

When the simulation chooses the competitive strategy, we study the curves of pedestrian evacuation time T changing with the width of the exit L as demonstrated in Figure 4, based on $N = 10,20,30,40$, only one exit, and $K = 0.4,0.6$. In the case of fixed the pedestrian density, pedestrian evacuation time is approximately negative exponential decreasing trend changing with the width of exit. The pedestrian evacuation time has significant difference in the condition of different system scale. It expressed that expanding the width of the exit is the effective way to control pedestrian evacuation time in the case of big gatherings.

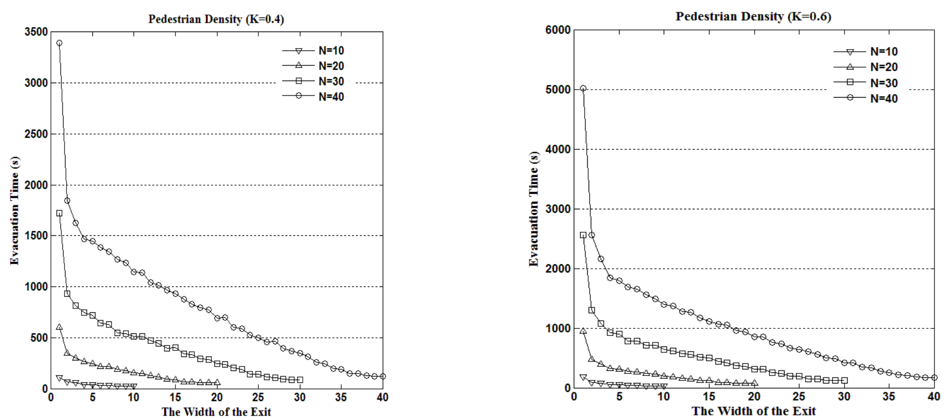


Figure 4. The curves of pedestrian evacuation time changing with the width of the exit based on different system scale.

3.3 Experiment 3

In the case of only one exit from the system, this paper studies the curves of pedestrian evacuation time T changing with the width of the exit L as demonstrated in Figure 5, based on $N = 20$, $K = 0.4,0.6$, and different selection strategies. Selection strategy has critical effects on pedestrian evacuation time. When the exit is narrow, the concessional strategy is better than the competitive strategy in the process of evacuation. With the increase of the width of the exit, the competitive strategy will gradually better than the concessional strategy. When the width of the exit is large enough, there is not a significant difference between the competitive strategy and the concessional strategy.

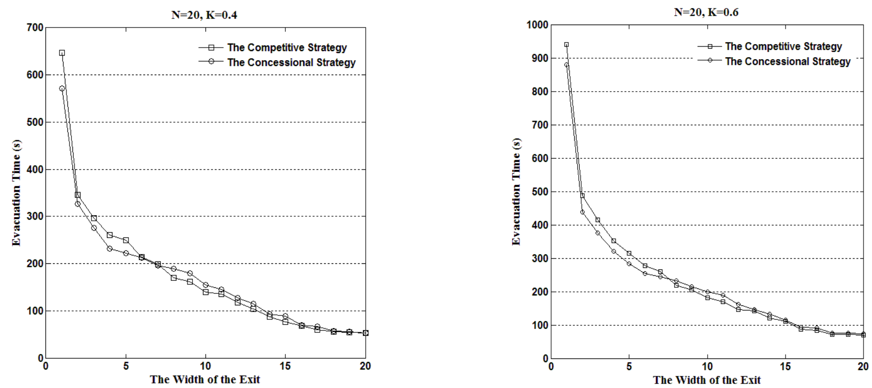


Figure 5. The curves of pedestrian evacuation time changing with the width of the exit in the condition of different selection strategies.

4 Conclusions

Based on the model of CA, this paper defines personal space and information processing space on direction of 9 optional positions to describe pedestrian's behavior in the condition of different environments. Afterwards, it simulates pedestrian's movement in the condition of only one exit from system. The conclusion indicates that evacuation time is approximately a linear increasing trend changing with pedestrian density, the system scale is a key factor on evacuation time, and expanding the width of exit is a effective way to control evacuation time. Selection strategy has critical effects on pedestrian evacuation time. With the increase of the width of the exit, there is a reversal point, which shows the competitive strategy better than the concessional strategy. Some related themes worth further studying are listed as follows: how to determine this reversal point, and how to discover this evolution mechanism.

Acknowledgement

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References

Burstedde, C., Klauck, K., Schadschneider, A., and Zittartz, J. (2001). "Simulation of pedestrian dynamics using a two-dimensional cellular automaton." *Physica A*, 295(3) 507-525.

Fang, W. F., Yang, L. Z., and Fan, W. C. (2003). "Simulation of bi-directional pedestrian movement using a cellular automata model." *Physica A*, 321(3), 633-640.

Helbing, D. (1998). "A fluid-dynamic model for the movement of pedestrians." *Complex Systems*, 6, 391-415.

Helbing, D., Farkas, I., and Vicsek, T. (2000). “Simulating dynamical features of escape panic.” *Nature*, 470, 487-490.

Huang, H. J., and Guo R. Y. (2008). “Static floor field and exit choice for pedestrian evacuation in rooms with internal obstacles and multiple exits.” *Physical Review E*, 78(2), 021131.

Kirchner, A., and Schadschneider, A. (2002). “Simulation of evacuation processes using a bionics inspired cellular automaton model for pedestrian dynamics.” *Physica A*, 312(1), 260-276.

Nishihara, K. (2006). “Section 3: The congestion of people.” *Congestion Theory*, SHINCHOSHA, Tokyo, 76-108.

Peng, Y. C., and Chou, C. I. (2011). “Simulation of pedestrian flow through a "T" intersection: A multi-floor field cellular automata approach.” *Computer Physics Communications*, 182(1), 205-208.

Schadschneider, A. (2002). “Traffic flow: A statistical physics point of view.” *Physica A*, 313(1), 153-187.

Yang,L. Z., Li, J., and Liu, S. B. (2008). “Simulation of pedestrian counter-flow with right-moving preference.” *Physica A*, 387(13) 3281-3289.

Evaluation Methods of the Chengdu Expressway's Traffic Congestion

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Abstract: Taking necessary measures to counter the traffic block problem is urgent. First of all, through the investigation and analysis, this article summarizes the congestion causes of Chengdu. And then set the evaluation index such as speed, delay in time, the frequency of parking, parking time and the road load degrees of the sections. Through analysis of the statistics, this paper provided a comprehensive evaluation model and the severity of congestion index concept which used to evaluate the rode congestion degree in the situation. Through the acquisition of data, the results model can be carried out on sections of qualitative and quantitative analysis. By calculating, use the serious traffic congestion index to determine the extent section of the serious congestion. The results in the paper can be used for the Chengdu traffic management departments to provide a scientific and rational evaluation system.
Keywords: Urban traffic; Traffic congestion; Evaluation index; Evaluation model.

1 Introduction

After years of city development, urban area of Chengdu has formed a circular radial road network. Ring and radial road network is the old city center area gradually outward development, reflected by outward radiation with loop and the formation of ring and radial urban road network. At present, the original of road network structure, has been more and more not adapt to the development of the city. The disadvantages of Chengdu city ring radial road network traffic: intersection is not enough rules, does not favor the traffic organization; Easy to form "booth pie" urban layout, in the center of the city land use is too high, the central area of the road network cannot meet the traffic demand. Causing the traffic pressure in the central area increase, bring the urban center traffic congestion problem. The phenomenon of traffic congestion in downtown Chengdu mainly concentrated in commute, holiday peak, and narrow roads. Congestion area mainly is the second ring road peripheral and central urban area within the second ring road.

2 The establishment of traffic congestion evaluation index

2.1 traffic congestion evaluation index

According to the domestic and foreign research results on the problem of traffic congestion and the analysis of current situation of Chengdu traffic congestion causes, based on the basic principles of evaluation for road section, the establishment of evaluation index system of congestion as shown in table 2-1.

Table2- 1. The traffic congestion index system

Index	The meaning of indicators	Formula
The average travel speed	By the time the vehicle total travel length and evaluation section through the sections of consuming ratio	$V = (L\times N) \Big/ \left(\sum_{i=1}^{N} t_i\right)$
Unit mileage average stops	Sections on the comment on every vehicle in the unit operation process occurs within the parking number length	$C = \left(\sum_{i=1}^{N} C_i\right) \Big/ (L\times N)$
Unit mileage average parking time	In the evaluation section ,comment on every vehicle in the unit during operation mileage in parking time	$T = \left(\sum_{i=1}^{N}\sum_{j=1}^{k_j} t_{ij}\right) \Big/ (L\times N)$
Unit mileage average travel delay time	In the evaluation of road vehicle in running process, because of the loss by the driver cannot control the situation of the time	$T = L/V - L/V$
Road load degree	The ratio of link traffic volume and road traffic capacity	$M = N/N'$

Congestion evaluation at home and abroad at present, most research is road congestion index of single factor evaluations, two evaluation indexes were taken into account in the minority. In this paper, the congestion index considering comprehensive, involves the speed, time, service level, traffic flow, road load degree, and can be used to judge the intensity of congestion, the range of congestion, traffic time.

2.2Traffic congestion index reference standard

To evaluate whether sections need to congestion and congestion degree to estimate the range of each evaluation index, so as to carry out the single factor evaluation on different parameters. The road congestion can be divided into 5 levels, respectively is very smooth, smooth, mild congestion, congestion and severe congestion. Through the time of Chengdu City statistics obtained 2013 survey data to carry on the research analysis, can determine the maximum, minimum value range is five kinds of assessment indexes for different level of congestion belongs, determine the evaluation criterion.

2.2.1Average travel speed evaluation standard

This paper mainly uses the installed detector and 2000 vehicles to install GPS positioning system through the road taxi to directly measure the road in different periods of traffic speed, and by using the method of artificial investigation to obtain the road time. Screening of the calculation based on the data from investigation, and based on the survey of related theory and traffic flow speed of the relations among the parameters, given the average travel speed of the expressway section of the reference standard table, as shown in table 2-2.

Table 2-2. Expressway review travel speed evaluation index reference table (unit: km / h)

The average travel speed	The average speed of evaluation grade	The road traffic conditions
[0,20]	severe congestion	The average traffic speed is low, the road traffic movement condition is very poor
(20,35]	congestion	The average speed of road traffic is low, poor traffic conditions
(35,50]	mild congestion	The average speed of traffic, road traffic status in general
(50,65]	smooth	The average traffic speed is higher, the road traffic running state is better
(65,∞)	very smooth	The average traffic speed is high, the road traffic movement condition good

2.2.2 Unit mileage average stops evaluation standard

Unit mileage parking number divided by the velocity in the index definition level is defined as the basis, the use of artificial research data will review the speed and the number of stops for regression analysis fitting, which according to the partition speed range, determine the congestion level corresponding to different parking times per unit mileage, as shown in table 2-3.

Table 2-3. unit mileage average stops evaluation standard reference table [unit: time/(km · a)]

Road service level	very smooth	smooth	mild congestion	congestion	severe congestion
expressway	0	（0,0.5]	(0.5,1.1]	(1.1,2.0]	(2.0,∞)

2.2.3Unit mileage average parking time evaluation standard

Average parking time by using the data of actual unit mileage and average travel speed are fitted, so as to determine the evaluation unit mileage average parking time reference standard. As shown in table 2-4.

Table 2-4.Unit mileage average parking time evaluation standard reference table[(unit: second/(km · a)]

Road service level	very smooth	smooth	mild congestion	congestion	severe congestion
expressway	0	（0,9]	(9,20]	(20,35]	(35,∞)

2.2.4 Unit mileage average trip delay time evaluation standard

According to statistical data of the taxi driver and car drivers, the expressway delay time and the running speed of the size of the corresponding comparative analysis, draw the dividing standard of the time delay as shown in table 2-5.

Table 2-5. Unit mileage average delay time evaluation standard reference table [(unit: second/(km · a)]

Road service level	very smooth	smooth	mild congestion	congestion	severe congestion
expressway	0	（0,17]	(17,48]	(48,125]	(125,∞)

2.2.5 Road load degree evaluation standard

Road load degree has close relationship with traffic running state. Table 2-6 for the road load evaluation grade standard of reference table.

Table 2-6. Road load degree evaluation standard reference table

Road load degree evaluation level	very smooth	smooth	mild congestion	congestion	severe congestion
M	[0,0.4]	（0.4,0.6]	(0.6,0.7]	(0.7,0.8]	(0.8,∞)

3 Road traffic congestion evaluation model

3.1Fuzzy mathematical evaluation model steps

Fuzzy comprehensive evaluation is the application of the theory of fuzzy mathematics object comprehensive variety of features, which will sort these objects, according to one way or select the optimal object from the domain theory. The establishment of fuzzy mathematical evaluation model mainly includes the following steps.

(1) Factors that determine the evaluation object set $U=\{x_1,x_2\ldots\ldots x_n\}$;

(2)Given the object evaluation set $V=\{y_1,y_2,\ldots\ldots y_m\}$;

(3)Determine the single factor discriminant matrix R = $(r_{ij})_{m\times m}$

where

$r_{ij}=(r_{i1},r_{i2},\ldots\ldots,r_{im}\}$,corresponding determination is made when U_i considerations;

(4)Given the factors set weight distribution, where w_i is the weight factor of the *i-th* degree;

(5)Evaluation results by Y=W∘R=（y_1,y_2,……y_m）, respectively, where "∘" is defined as a synthetic operation;

(6)Maximum possible judgment: if max{ y_1,y_2,……y_m}=y_p then the judge considers the greatest possible result for y_p

3.2 Road traffic congestion fuzzy mathematical evaluation model

This article will focus on research in Chengdu Second Ring Road Elevated Expressway, take one of three sections: Southwest Jiaotong University to the North Railway Station, North Railway Station to Sanyou Road, Sanyou Road to Jianshe Road to analyze the operation of its various sections, by actual survey data the process to determine the extent of congestion in various sections.

According to the three sections of the survey and collection of data, get the value list second ring road of each factor of peak hour, as shown in Table 3-1. 1 for Southwest Jiaotong University to the North Railway Station, 2 for North Railway Station to Sanyou Road, 3 for Sanyou Road to Jianshe Road.

Table 3-1.sections of each factor peak hour value list

section	V	C	T	t	M
1	34.8	0.2	7.5	46.0	0.6
2	28.7	0.4	9.0	18.0	0.8
3	23.0	3.0	34.5	187.9	0.9

3.2.1 Determine the index weight

Because of the error, we use a large number of samples for analysis and statistics. First, taxi drivers and other vehicle drivers sample survey, then the statistical results with the combination of expert advice, the final calculation of the overall arithmetic mean, the right to determine the weight of each factor, as shown in Table 3-2.

Table 3-2. Evaluation index weights

Weights	The average travel speed w_1	Unit mileage average stops w_2	Unit mileage average parking time w_3	Unit mileage average travel delay time w_4	Road load degree w_5
	0.212	0.203	0.201	0.195	0.189

3.2.2 Determine the development of evaluation index function

(1) The average travel speed V^i and Unit mileage average stops C^i

$$V^i = \begin{cases} 1 & 65 < V_1 \\ \frac{V_2 - 50}{15} & 50 < V_2 \leq 65 \\ \frac{V_3 - 35}{15} & 35 < V_3 \leq 50 \\ \frac{V_4 - 20}{15} & 20 < V_4 \leq 35 \\ 0 & V_5 \leq 20 \end{cases} \qquad C^i = \begin{cases} 1 & C_1 = 0 \\ \frac{0.5 - C_2}{0.5} & 0 < C_2 < 0.5 \\ \frac{1.1 - C_3}{0.6} & 0.5 \leq C_3 < 1.1 \\ \frac{2.0 - C_4}{0.9} & 1.1 \leq C_4 < 2.0 \\ 0 & 2.0 \leq C_5 \end{cases}$$

(2) Unit mileage average parking time T^i and Unit mileage average travel delay time t^i

$$T^i = \begin{cases} 1 & T_1 = 0 \\ \frac{9 - T_2}{9} & 0 < T_2 < 9 \\ \frac{20 - T_3}{11} & 9 \leq T_3 < 20 \\ \frac{35 - T_4}{15} & 20 \leq T_4 < 35 \\ 0 & 35 \leq T_5 \end{cases} \qquad t^i = \begin{cases} 1 & t_1 = 0 \\ \frac{17 - t_2}{17} & 0 < t_2 < 17 \\ \frac{48 - t_3}{31} & 17 \leq t_3 < 48 \\ \frac{125 - t_4}{77} & 48 \leq t_4 < 125 \\ 0 & 125 \leq t_5 \end{cases}$$

(3) Road load degree M^i

$$M^i = \begin{cases} 1 & M_1 \leq 0.4 \\ \frac{0.6 - M_2}{0.2} & 0.4 < M_2 < 0.6 \\ \frac{0.7 - M_3}{0.1} & 0.6 \leq M_3 < 0.7 \\ \frac{0.8 - M_4}{0.1} & 0.7 \leq M_4 < 0.8 \\ 0 & 0.8 \leq M_5 \end{cases}$$

3.2.3 Determine the degree of congestion

In section 1, for example, to calculate the matrix :

$$D = \begin{bmatrix} 0 & 0 & 0 & 0.987 & 0 \\ 0 & 0.600 & 0 & 0 & 0 \\ 0 & 0.167 & 0 & 0 & 0 \\ 0 & 0 & 0.065 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix}$$

$Y = W \circ R = \{0, 0.155, 0.202, 0.209, 0\}$， $\max\{y_1, y_2, y_3, y_4, y_5\} = y_4 = 0.209$

As a result, Southwest Jiaotong University to North Railway Station during peak hours in the moderate congestion state, so you can get: section 2 is slightly congested state; 3 is moderate road congestion state.

References

Bull Alberto (2005)Traffic congestion the problem and how to deal with it .*Mary* *land*; *Lexis Nexis*.

Hiller Bar-Gera (2007) Evaluation of a cellular phone-based system for measurements of traffic speeds and travel times .*The case study from Israel*.12.380-391

Jiuh- Biing she, Yi- Hwa Chou(2001) Stochastic modeling and real-time estimation of incident effects on surface street traffic congestion .*Intelligent Transportation Systems*. 8.669-674

Kay, J.L. Eva (1980) signal control systems, *Vehicular Technology Conferenee*. 355-360

Technol. Dev. Agency (2006) Estimating Road Traffic Congestion using Vehicle Velocity .*ITS Telecommunications Proceedings*.7.1001-1004

Community Bus Demand Characteristics Analysis Based on Smart Card Data and GPS Data

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Abstract: In recent years, the Community bus that plays an essential role in public transit system in metropolises has achieved rapid development domestically. It is on the premise that the temporal-spatial distribution characteristics of passenger-flow are confirmed, a proper network planning and operation program is about to make. In this paper, an analytical method for Community bus demand is put forward based on Smart-card data and GPS data of public transit. The index of passenger-flow could be calculated, including passenger-flow volume of line section and station through correlation analysis of data. Through data mining of passengers' records, the difference of passengers demand is analyzed between Community bus and Conventional bus. Also, taking the Community bus data in Chengdu as example, this paper has verified the rationality and applicability of this method.
Keywords: Community bus; Data mining; Smart-card; Travel behavior.

1 Introduction

Currently, the Community bus has been gradually promoted in metropolises, yet the relevant study should be conducted on its planning and operation program since great differences can be seen in such aspects as function orientation, operation mode, arrange location and development goals between Community bus and common public transit. In urban transportation network, the demand of public transit network changes overtime in temporal-spatial dimension. For public transit operators, the matching supply and demand will enable them to lower the operation cost and optimize the online vehicles allocation, yet it is quite hard to realize. In the process, the most difficult part is to accurately measure the demand changes and completely comprehend the rules of dynamic changes.

This paper aims to analyze the temporal-spatial characteristics of passengers travel in Community bus system through analysis of Smart-card data and GPS data of public transit. Comparing with traditional methods, the data mining method to collect and process data features such advantages as comprehensiveness of study subject (most of the passengers in Community bus lines are local citizens with the Smart-card ratio more than 90%), convenience of data acquisition, and the longer data span, etc. Thus, it is feasible to make detailed analysis on the passenger transit index and citizen travel characteristics.

2 Field Data

In this paper, the data base offered by Chengdu Public Transport Group Co., Ltd. derives from Smart-card data and GPS data of Community bus within a week (from November 10th to 16th, 2014) in Chengdu.

Smart-card record includes such information as Smart-card number, expenditure, the remaining number of times to be redeemed, balance, consume date, consumption type, specific travel line, and vehicle number, etc. The information is contained in a table, a complete card record is shown in a row, and the nature of different information in a column. Table 1 contains a part of Smart-card record of Community bus on November 10th, 2014 in Chengdu.

Table 1. Smart-card Data in Chengdu

CARDNO	CONSUME	REMAINTIMES	BALANCE	CONSUMEDATE	CONSUMETYPE	LINENO	BUSNO
112251029	1.8		11.5	2014/11/2 12:00	1	1075	24034
104341926	1.8		7.9	2014/11/2 14:48	1	1075	24034
104497530	0	10		2014/11/2 7:04	15	1075	24034

GPS data record includes such information as recording time, serial number of vehicle-mounted receiver (corresponding to the vehicle number of Smart-card data), GPS speed, number of line, longitude and latitude, and serial number of station, etc. The information is also contained in a table, a GPS record is shown in a row, and the nature of different information in a column. Table 2 contains a part of GPS data of Community bus on November 10th, 2014 in Chengdu.

Table 2. GPS Data of Vehicles in Chengdu

RECDATETIME	PRODUCTID	GPSSPEED	ROUTEID	SUBROUTEID	LONGITUDE	LATITUDE	STATIONNUM	DATATYPE
2014/11/10 13:59	21014010		1077	1077	104.123281	30.60486	31398	55
2014/11/10 17:21	21014137	0	1048	10480415	104.176316	30.69181	41564	3
2014/11/10 16:03	21034710	6.19	1055	10550320	104.065268	30.60489	30976	4

3 Data Analysis

In this paper, the two data sources are inseparable and comprehensively analyzed by the means of data fusion and data mining. Through analysis of Smart-card data and GPS data of Community bus, the two data sources are found fundamentally linked via the consume date and GPS recording time. No matter a vehicle is moving or stopping, its real-time position data will be uploaded via the running vehicle-mounted GPS receiver. Thereby, while the card data of passengers who just gets on the bus is recorded, the spatial position is also recorded via GPS. Based on the relevance of two records' time, it is preliminary ascertained the time, location and travel line of a passenger who gets on a bus.

The two data sources should be processed before putting them into use. The processing procedure is shown as follows.

(1) Data reduction

Among a variety of natures of Smart-card data and GPS data, a considerate part is independent of this study. Therefore, it is necessary to reduce duplicate information and delete negligible fields.

(2) Unified coding form

Since the coding forms of the same kind of data nature in the two data sources varies from each other, the coding forms need to be unified. Otherwise, an error will occur in the process of conducting a data correlated query.

(3) Selecting correlated information, setting up a database

After selecting the correlated information between the two data sources, a database is set up based on the basic data offered by Chengdu Public Transport Group Co., Ltd., and then the corresponding query work is proceeded.

4 Discussion of the Results

The major achievements of data analysis of Smart-card and GPS is passengers' behavior characteristics, which includes passenger-flow of the whole system, passenger-flow of certain line, passenger-flow of stations and variability in temporal –spatial. Once grasp the variability discipline, managers and planners can formulate reasonable bus network and operation scheme that cohere with demand based on the analysis results. Hence, system costs will decline while residents' trips are sufficiently met.

4.1 Temporal distribution

Generally speaking, passenger-flow of urban public transportation will presents regular variability. In weekdays, commuting travel occupies the main segment, while leisure travel takes over on the weekend. The two figures below are passenger-flow's statistical results of Community bus and Conventional bus in one week.

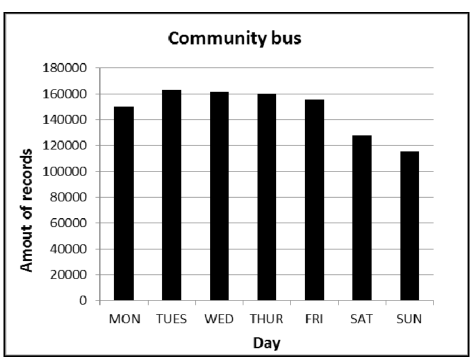

Fig 3. Community bus in one week

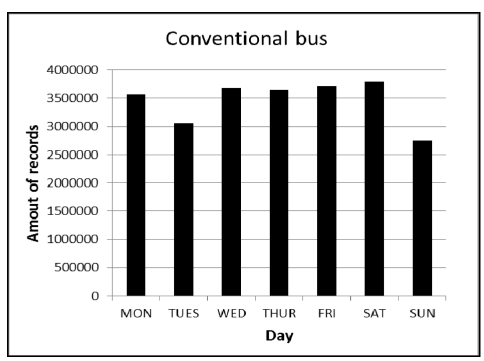

Fig 4. Conventional bus in one week

Two conclusions can received by means of comparison the two figures:

(1)Passenger-flow remain steady

Passenger-flow of the two systems merely show a little bit fluctuate in weekdays. From Saturday Community bus's Passenger-flow begins to slump and reach the minimum on Sunday. In Conventional bus system, Passenger-flow remains equal in Saturday, but decline on Sunday.

(2)Passenger-flow in Community bus system is very low

In Community bus system 1.03 million Smart-card data records are detected compare with 24.21 million records in Conventional bus system. Feeder and collector-distributor service of Community bus system didn't bring into fully play.

The variation of passenger-flow within one day belongs to temporal distribution also. Community bus in Chengdu operates from 6:00 to 21:00, then passenger-flow within every hour is displayed in Fig.5. In weekdays the distribution appears to be double peak phenomenon. The morning and evening peak time are 6:30-7:30 and 16:30-17:30, then passenger-flow will slumps at noon. In weekends, there's no remarkable peak time but a decline also shows at noon.

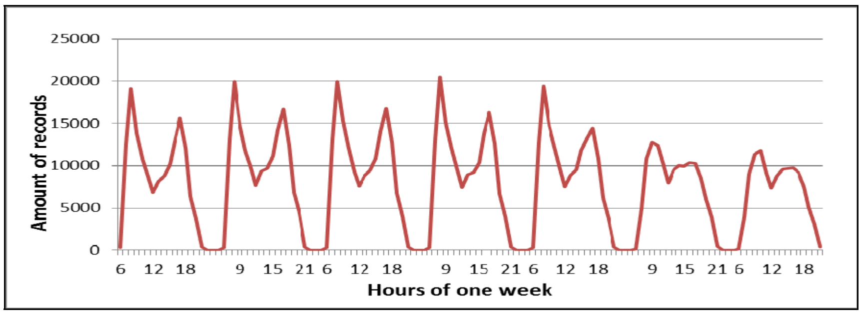

Fig 5. Temporal distribution of Passenger-flow in one week

4.2 Spatial distribution

The Spatial distribution of Passenger-flow can be divide into two aspects: on the one hand, discrepancy among lines; on the other hand, discrepancy among stations that pertain to the same line.

The 82 Community bus lines scatter on different regions of the whole city subdivision. Passenger-flow in different regions may emerge large diversity due to many reasons such as economic land-use population traffic conditions and so on. Passenger-flow of Wed and Sat are showed as Fig.6. We can see that most lines gain 600-2400 boarding transections on weekdays, while 0-2000 at weekends. Moreover, boarding transections within different lines vary considerably.

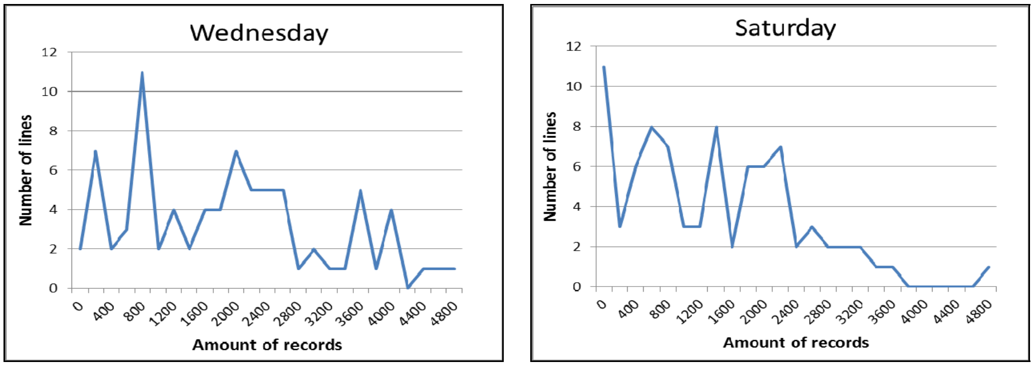

Fig 6. Passenger-flow of Wed and Sat within every line

The discrepancy among stations that pertain to the same line can also demonstrate the spatial distribution of Passenger-flow. We choose route 1030 as example because it received the most Smart-card records. The distribution among stations presents to be triple peak pattern, namely most passengers get on bus at the three main stations. Although the total quantities of two days differ greatly, the variation tendencies are the same in basically.

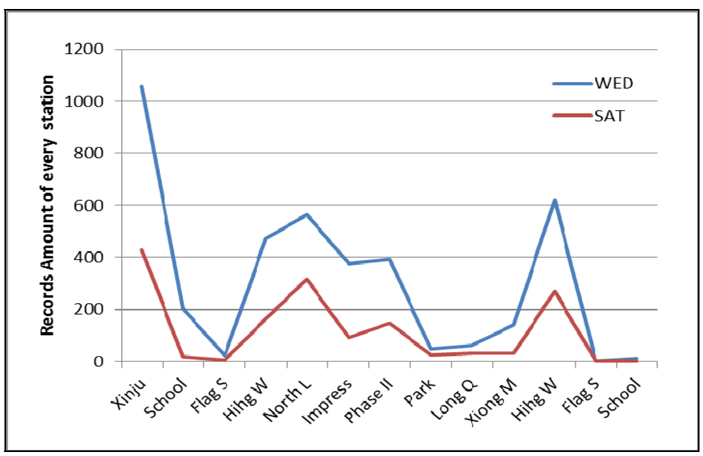

Fig 7. Passenger-flow of Wed and Sat within route 1030

4.3 Dependence degree

Passengers' travel behavior can be formulated by the dependence degree on Community bus service. The degree can be illustrated by two indicators in temporal scale.

(1) Active days in one week

If the system detects a record of one card, then we define the day as active-day. Statistical data of different passengers' active-days will reveal passengers' dependency on Community bus system.

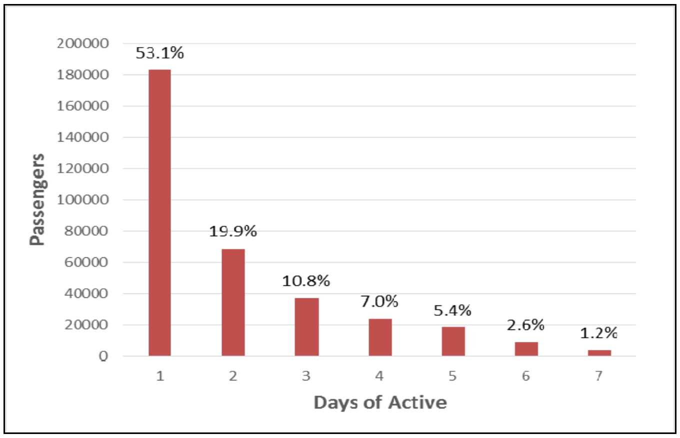

Fig 8. Passengers' active-days in one week

We can deduce from the figure over 70% passengers' active-days are less than three times, and most Smart-card just appears once. This declares that residents hadn't be accustomed to use Community bus, therefore the dependency on the system is extremely low.

(2) Average trips one day

This indicator means the average trips of all active passengers in the system. It can be calculated via dividing records amount by active cards' number. A high level denotes passengers use Community bus for round-tripping issues, nevertheless a low level denotes they use Community bus for chance merely.

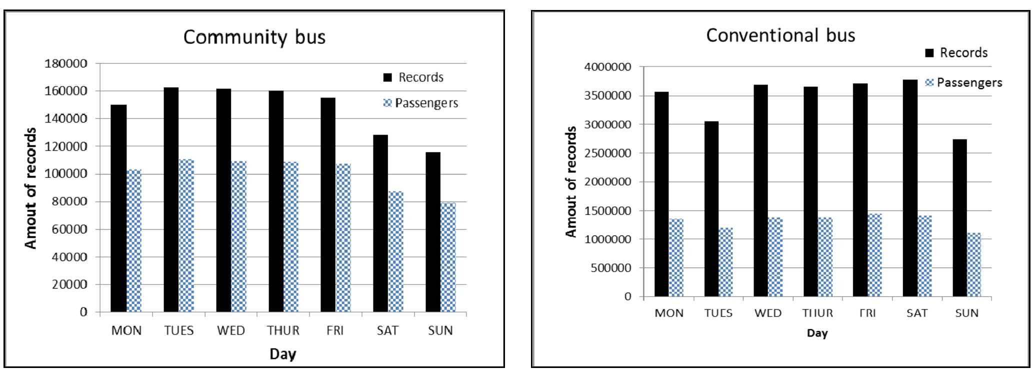

Fig 9. Average trips one day

Table 4. Comparision of average trips in two systems

Systems	MON	YUES	WED	THUR	FRI	SAT	SUN	Average
Community bus	1.461	1.475	1.474	1.469	1.450	1.464	1.465	1.466
Conventional bus	2.630	2.550	2.657	2.645	2.566	2.669	2.464	2.597

We can infer from figure 9 that the gap between records and passengers in

Conventional bus system is quite large, however the one in Community bus system is much small. In another word, the average trips in Community bus is very low.

Table 4 lists average trips in two systems every day in a week. The two average values are 1.466 and 2.597, the big disparity between the two values show that a majority of active passengers use Conventional bus repeatedly, while Community bus is just an alternative set.

5 Conclusions

As the Smart-card system and GPS recording system have been widely used in most of domestic cities, a large amount of historical data has been obtained to powerfully support our study. Comparing with traditional methods, the research methods -- data fusion and data mining in this paper features such advantages as comprehensiveness of study subject, convenience of data acquisition, and the longer data span, etc.

The Smart-card data and GPS data fusion and mining can be used to track the travel of citizens, and analyze the temporal-spatial variation rules, thus finally obtaining the available information about citizens' travel characteristics. This information mainly consists of passenger-flow volume in the whole network, the 24-hour distribution of passenger-flow everyday of a week, differences in passenger-flow and degree of dependence on Community bus of various lines and stations, etc. These data can be used for making public transit decisions, optimizing layout and adjusting operation plans in the entire network.

6 Recommendations for Future Research

The most bus lines of Community bus line in Chengdu is one-way circular, then a majority of trip stages cannot be linked into integrated trips. So this paper merely studies the temporal-spatial distribution and variation rules of passengers' travel behaviors based on boarding transactions without matching the alighting transactions. Some foreign scholars have made related researches on the alighting stations of normal bus transit. The next step for us is to focus on how to infer the alighting stations of Community bus, thus forming a complete OD matrix of citizen travel.

Acknowledgement

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References

Agard, B., Morency, C., Trepanier, M., 2006. Mining public transport user behavior from smart card data In: The 12th IFAC Symposium on Information Control Problems in Manufacturing (INCOM), Saint Etienne, France, May 17–19..

Morency, C., Tre´panier, M, Agard, B., 2006. Analysing the variability of transit users behavior with smart card data. In: The Ninth International IEEE Conference on Intelligent Transportation Systems, Toronto, Canada, September.

Bagchi, M., White, P.R., 2005. The potential of public transport smart card data. Transport Policy 12, 464–474.

Bagchi, M., White, P.R., 2004. What role for Smart-card data from a bus system? Municipal Engineer 157, 39–46.

Chen Jun, Yang Dong-yuan. Identifying Boarding Stops of Passengers with Smart Cards Based on Intelligent Dispatching Data. Journal of Transportation Systems Engineering and Information Technology. 2013(13):76--80.

Dai Xiao, Chen Xue-wu, Li Wen-yong. Study on data mining technique for bus intelligent card data processing. Traffic and Computer,2006,24(1):40-42.

Shi Fu-min, The Research of the Method of Generating the Public Transport Travel OD Matrix Based on the Data of Smart-card. ChangChun, College of traffic, Jilin University.

Zhou Tao, Zhai Chang-xu, Gao Zhi-gang. Approaching Bus OD Matrices Based on Data Reduced from Bus Smart-cards. Urban Transport of China. 2007(3):48-52.

Key Problems of Urban Rail Transit CBTC Simulation Laboratory Construction

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Abstract: The article proposes several key problems about CBTC simulation implementation on the sandbox, researches some problems such as signal equipment detection, train location and wireless communication, and proposes some corresponding solutions. In the process of the research, at first, the article comes up with the reasonable methods by comparing the several techniques; and then designs the circuits to conduct the corresponding experiments. The final solution is applied to the practical simulation sandbox. The solution is verified correctly by combining with the CBTC simulation software which is running for a long period of time on the upper computer. The solution of these key problems can make the CBTC function be simulated and implemented accurately on the sandbox, at the same time; it also provides some service for teaching and training.
Keywords: CBTC; Simulation; Location; Detection.

1 Introduction

ATC is Automatic Train Control, and it consists of three subsystems which are Automatic Train Protection (ATP), Automatic Train Supervision (ATS) and Automatic Train Operation (ATO). At the same time, it is a key system which ensures the operation security and reliability of Urban Rail Transit. Communication Based Train Control (CBTC) system is a continuous, automatic train control system utilizing high-resolution train location, independent of track circuits; high-capacity, continuous, bidirectional train-to-wayside data communications. When the CBTC runs simulation on the sandbox, it can calculate the running direction and speed of the next step according to the feedback location information, but it places a greater demand on the current location information of the train and the real-time of wireless communication. Interlock function can guarantee that the train operate safely. And to ensure the reliable running of the interlock function, the interlock host not only controls the signal equipment on the sandbox, but also reads back the signal equipment states on the sandbox accurately. At present, the domestic railway simulation sandboxes mainly base on the operation simulation which is existing already, and its location accuracy, wireless transmission real-time and data quantity can't meet the need of the simulation of Urban Rail Transit CBTC system. The article refers to many successful experiences of the railway simulation sandbox; but when the CBTC simulation system simulates on the sandbox. the key problems are to solve wireless communication, train location and signal equipment detection.

2 Wireless Communication Problems

At present, the wireless communication technologies which can be used on the sandbox include Bluetooth, zigbee, wifi and RF wireless. The Bluetooth and zigbee transmit fast, but they have shorter communication distance, so they can meet the need of multiple trains communication simultaneously. However, the communication qualities will get bad if there are many obstacles on the sandbox, so the Bluetooth and zigbee are suitable for small-sized sandbox only. The 433MHz RF wireless communication has better penetration and farther transmission distance though, the wireless data take up too much time in the air, and there will take place a phenomenon of the data loss when the multiple points carry out data communications simultaneously, so the RF wireless is suitable for the situation which is long distance and few trains. The wifi possesses some characteristics such as high-speed communication and farther transmission distance, and can support that multiple trains run simultaneously. And its network covers a larger area, so the wifi communication is suitable for medium-sized sandbox. The simulation sandbox of Southwest Jiaotong University-E'mei Campus is 35 meters long, 5 meters wide, and is divided into two layers, so it belongs to large-sized sandbox. The wireless communication modes above are difficult to be adapted to completely. Owing to the convenience of the setting up the wifi network, and it's close to the existed wireless communication mode of Urban Rail Transit, so multiple wireless APs can be used to set up the wireless wifi network. When the simulation train runs on the line, it logs on the corresponding wireless APs according to the detected location.

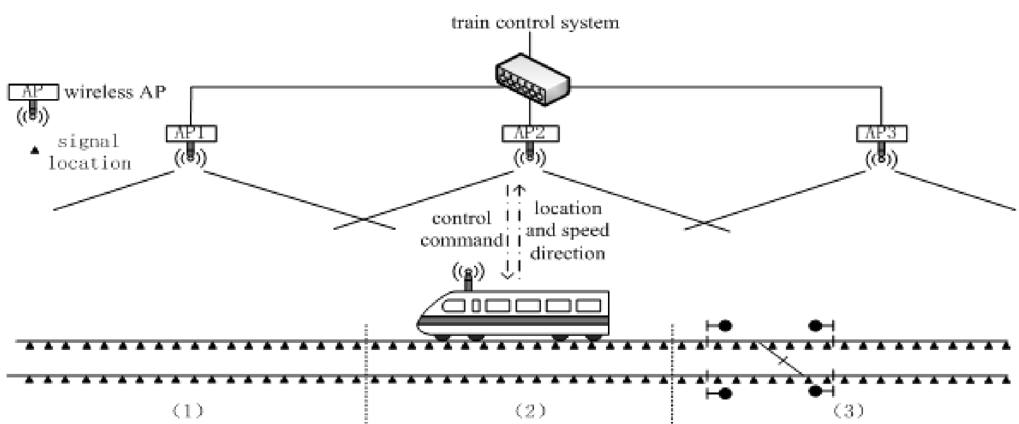


Figure 1. CBTC wireless network schematic diagram

The CBTC wireless network schematic diagram is shown in Figure 1. The line is divided into three regions, and each region uses one AP, in addition, the obducent areas of two adjacent AP wireless have partial overlaps. Because the train will store all the AP ID numbers in advance, the train can log on to the corresponding APs quickly after entering a new region. And all the AP points access to the train control system with the Ethernet.

3 Train Location Problems

At present, the indoor location modes have zigbee network location, ultrasonic location, RFID location, infrared detection and location. The zigbee network location is mainly used to the personnel location of the regions such as mines, prisons, and so on. The location accuracy of mature products could reach about 3 meters, and the accuracy could reach about 25 centimeters after optimizing the location. However, the location accuracy still can't ensure which track the train is running, so it can't be used to the sandbox. The ultrasonic location is influenced by temperature, humidity, and the sandbox's building block, so it's difficult to use on the sandbox. The infrared detection is to lay a lot of infrared emission points on the track, and each emission point will transmit the infrared lights with location code, at the same time, the train has some infrared receivers. When the train read the infrared code data for locating, due to the high location accuracy and a number of signal locations on the sandbox, using infrared detection and location will lead to the increase of the sandbox cables, and decrease the reliability of the sandbox running. The RFID location is to lay a lot of the IC card of 13.156MHz on the track, and some card readers are installed on the trains. The energies are transferred to IC cards by the inductance coupling mode, and then the card readers will carry out data transmissions with IC cards, and the speed is more faster. Because the IC card is passive and without additional wiring. Each fixed address of IC card will write the information such as track location number, track grade, line state, and so on previously. When passing, the train reads the data and adjusts the speed, at the same time, the data will be sent back to the train control system. Each IC card is 8 centimeters long, and lays continuously under the sandbox track. First of all, the trains read the IC data, and then the data will be sent back to the train control center. According to practice, one operation will spend around 40 millisecond, and 25 signal marker points can be read per second. So it can be calculated that the train's maximum operation speed is 2m/s, and the requirements of the CBTC simulation could be satisfied.

When the train card readers aims at the connective places of the two IC cards, so the train could be located accurately by reading back an error number. In the actual measurement, the error of the parking the train is in the range of 2 centimeters when we use this method.

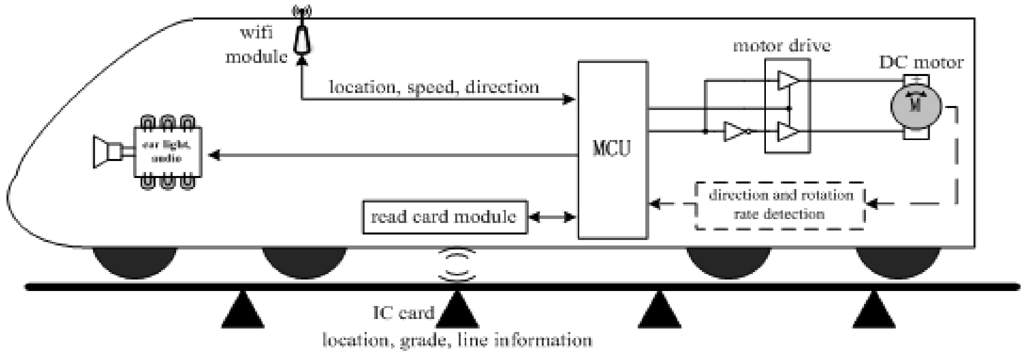
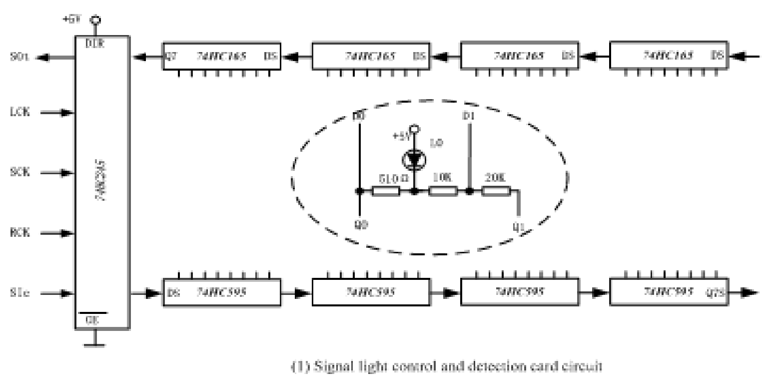


Figure 2. Train location method

4 Signal Equipment Detection

The main signal equipment of the sandbox is signal light and switch machine, and the detection of departure indicator and emergency stop button is same as the detection of signal light. On the sandbox, there are many signal lights, and there is 1.8V~3.3V voltage drop when the signal light is on. For COMS gate circuit, the reverse input level threshold is always being half of the total power, and according to the feature of the power fluctuation, the judgment of the signal light voltage drop can convert to the judgment of logic value, as shown in Figure 3(1). The control data are sent out by serial-in, parallel-out shift register 74HC595, and the detection data are sent back by parallel-in, serial-out shift register 74HC165. The shift register uses the CMOS craft manufacture, and one signal light is managed by every two bits.



state	input		output		[illegible]
	Q0	Q1	D0	D1	
normal	0	0	0	0	[illegible]
	0	1	0	1	
	1	0	1	1	
	1	1	1	1	
short circuit	0	0	0	1	[illegible]
	0	1	0	1	
	1	0	1	1	
	1	1	1	1	
broken circuit	0	0	0	0	[illegible]
	0	1	0	0	
	1	0	1	1	
	1	1	1	1	
ground	0	0	0	0	[illegible]
	0	1	0	0	
	1	0	1	0	
	1	1	1	0	

Figure 3. Signal light control and detection circuit

When we want to control signal light L0, the control data need be sent to Q0 port of the 74HC595, and the high or low level signal of output port Q0 can turn off or turn on the signal light L0. When detecting the signal light L0, the port Q0 and port Q1 input separately four logical values which are 00B, 01B, 10B and 11B, and then read back logical values of output port D0, D1. The four logical values of port D0, D1 combine into one byte from low bit to high bit, and form the state values of the equipment. As shown in Figure 3(2), the state values of signal light are different in each state, so the fault states of signal light could be judged. The control method of the other signal lights is similar to the method above, the signal light which is numbered x is managed by *Q2x, Q2x+1, D2x, D2x+1.*

The switch machine uses the push-pull solenoid, and the turnout drive data will be outputted by the parallel port of the 74HC595, and the collected data and the fault data are sent to the parallel port of the 74HC165. Figure 4 is the control and detection circuits of a group of turnout, and the detection of the turnout adopts non-contact photoelectric switch, and the positive or negative location both install one separately. When the turnout is moved, it will drive the turnout linkage mechanism. And when the turnout linkage mechanism reach one side of location (anti-location) detector reliably, the detector will output location (anti-location) pulse signal. At first, the location (anti-location) detection circuit uses the inverter 40106, resistors and capacitors to constitute TTL inverter and RC oscillator, and the output square-wave signal drives the infrared light-emitting diodes. To generate different frequency pulses, the resistors of the location (anti-location) detection circuit set different values, therefore, the input pulse of location and anti-location can be distinguished by the frequency. After the infrared receiver diodes receive the signals, the signals are modulated and outputted to the MCU to identify, and then the identified turnout states are sent back to the main control card by the port D0 of the 74HC165.

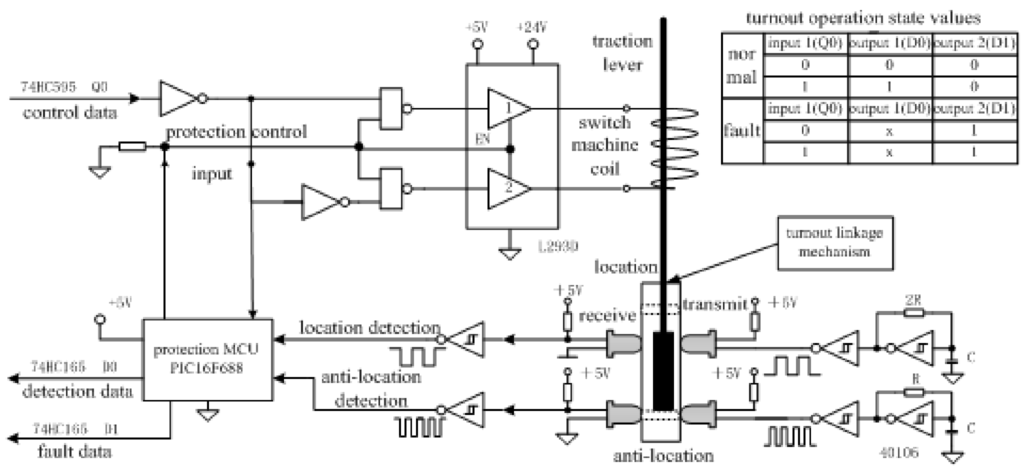


Figure 4. Turnout control and detection circuit

5 Running Test

The control system design of the CBTC simulation sandbox has a set of control system which includes multiple control boxes, and they are connected to the interlock host by RS-485 bus. One control box includes main control card, signal machine driving and detecting card, turnout driving and detecting card, so it can manage one or more intermediate stations. Each control system includes main control card, signal machine driving and detecting card, turnout driving and detecting card, and they are cascaded by SPI bus. The main control card is responsible for communication, outputting the control signals and reading back the detected data. The signal machine driving and detecting card manages the signal machine, departure indicator and emergency stop button. The turnout driving and detecting card are responsible for managing the turnout. The physical diagram of control system is shown in Figure 5.

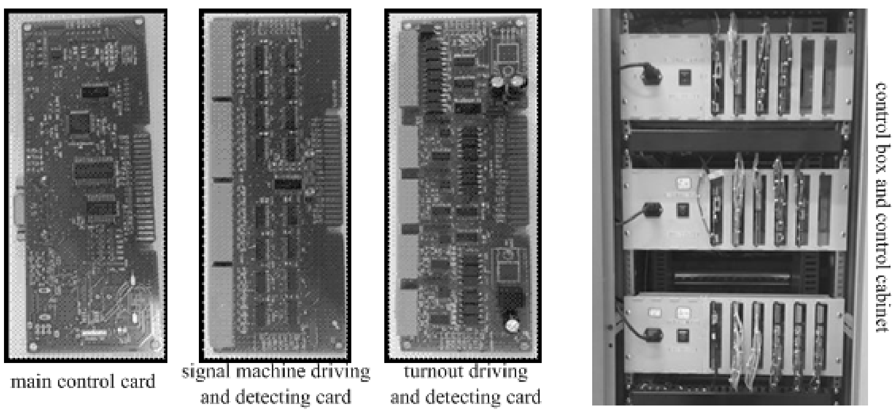


Figure 5. Physical diagram of control system

The wireless wifi is used for the train to communicate with the control center. The data will be sent back quickly to the control center after collecting new location information. The control center combines the distance of the front train to calculate the current train's speed, and then it informs the train of new commands such as direction and speed. When several trains run on the line simultaneously, the control center controls the sandbox's signal equipment with the interlock host, and detects whether the control action is accurate.

The Urban Rail Transit simulation sandbox of Southwest Jiaotong University-E'mei Campus belongs to large-sized sandbox, and it uses 10 wireless APs and 20 control boxes. According to several tests, the sandbox can meet the need of the CBTC simulation adequately. The simulation results of CBTC system is shown in Figure 6.

Figure 6. Simulation results of CBTC system

6 Conclusions

The CBTC simulation laboratory could provide specific practices for all major students. For the students of signal profession, it could train the students' abilities such as interlock logic relationship, system signal control, communication, and so on. For the students of operation management profession, it could provide vertical and horizontal linkage training based on various normal and abnormal situations in the positions such as operation coordination, emergency command center, control center, station, train, and so on. With reference to many relevant experiences how to manufacture the sandboxes, to improve it gradually and make it meet the need of the CBTC simulation, the Urban Rail Transit control sandbox of the Southwest Jiaotong University-E'mei Campus explores and researches step by step. Finally, it provides important references for the same laboratory.

Acknowledgement

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References

Citing SONG,Bingjun HAN,Hai YU,Xin ZHANG. STUDY ON COEXISTENCE AND ANTI-INTERFERENCE SOLUTION FOR SUBWAY CBTC SYSTEM AND MIFI DEVICES. IEEE Beijing Section.Proceedings of 2013 5th IEEE International Conference On Broadband Network & Multimedia Technology.IEEE Beijing Section:,2013:7.

Long Chen and Liqun Li School of Automobile and Traffic Engineering University of Jiangsu Zhenjiang,Jiangsu Province,China Daxing Huang Department of Automobile University of Shaoguan Shaoguan,Guangdong Province,China. Study on Optimization Strategy of Resources Operational Management for Urban Rail Transit. Intelligent Information Technology Application Research Association (IITA Association), Hong Kong, Shenzhen University, China.Proceedings of 2010 The 3rd International Conference on Power Electronics and Intelligent Transportation System(Volume 2).Intelligent Information Technology Application Research Association (IITA Association), Hong Kong, Shenzhen University, China:,2010:4.

LI TIAN. Current Situation Analysis of Urban Rail Transportation Equipment Manufacturing Industry in China. DEStech Publications Inc、Engineering and Industry Technology Institute(EITI)、East China University of Science and Technology, Northeastern University, Shanghai University of Engineering Science.Proceedings of the International Conference on Management and Engineering（CME 2014）.DEStech Publications Inc, Engineering and Industry Technology Institute(EITI), East China University of Science and Technology, Northeastern University, Shanghai University of Engineering Science:,2014:7.

Yu Hai,Chen Yuetan,Wang Hongyu,Zhang Xin,Yang Dacheng. COEXISTENCE STUDIES ON THE INTERFERENCE PERFORMANCE BETWEEN SUBWAY CBTC SYSTEM AND PORTABLE WI-FI DEVICES. IEEE Beijing Section.Proceedings of 2014 4th IEEE International Conference on Network Infrastructure and Digital Content.IEEE Beijing Section:,2014:5.

Full-Induction Control Method of Urban Arterial Highway Intersections

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Abstract: Operation of vehicles in urban arterial highway directly affects traffic of entire city. With large traffic volume and too many conflicts in urban arterial highway intersections, congestion problem is particularly prominent. Therefore, rational management of urban arterial highway intersections can effectively alleviate traffic congestion. Choosing the Renmin Street and Jiefang Avenue intersection of Changchun city as the research object, it aims to explore a full-induction control method for urban arterial highway intersection. The full-induction control method is explored with VISVAP to compile VAP (Vehicle Actuated Programming) and the calculation model of detector installation position is modeled. Comparing values of delay and queue length of current signal control with those of full-induction control method, the full-induction control method effectively alleviates congestion.
Keywords: Intersection management; Induction control; VAP; VISSIM.

1 Introduction

With the rapid development of Chinese economy and level of urban, vehicle population is significantly increasing and becomes populated in inner cities, which makes urban traffic congestion persistently deteriorate, especially in intersection. The experience of traffic management in intersection is that the most effective method of traffic management is signal control. Signal control can be divided into timing control, induction control and adaptive control.

Operation of induction control is based on installing detectors under the ground of intersection entrance lane. The most general detector is inductive-loop detector which is used to detect vehicles across or stop at it. Induction control can be divided into half-induction control, which only installs detectors at some entrance lanes, and full-induction, which installs detectors at every entrance lane. This kind of signal is controlled by intelligent controller that can timely detect the information of vehicle flow.

If it cannot achieve desired objectives, economic and social costs will waste. Module VAP of microscopic traffic simulation software VISSIM can realize simulation of traffic situation that around the position of detector. Using VISVAP to draw logic flow chart of VAP, transferring method of signal control to VAP, and simulating with VISSIM, delay and queue length are compared to ensure that whether the method is feasible. Many Chinese experts researched signal control method with VAP. Shao Jinjin(2011)provided a multi-phase induction control method of dynamic phase sequence; Xiu Weijie(2014)proposed an improved induction control method of bicyclic phase by research of characteristic of phase structure in standard of USA NEMA TS2; Wang Yupeng(2009)presented a new induction control method, and improved method of one intersection; He Bisheng(2011)provided a pre-signal induction control method of bus priority, and obtained optimal ahead of light time of pre-signal green and red light; Jing Tai(2014)proposed an induction control method based on probabilistic model; Xie Fei(2014)presented an induction control method based on traffic priority.

Induction control is generally applied at intersections that traffic varies considerably with time or the disparity of primary and secondary highway is distinct. It researches installing position model of detectors and aims to explore a full-induction control method to effectively alleviate urban congestion at arterial highway intersection during peak periods and fully satisfy the control of intersection during common periods.

2 Installing position model of detector

Urban arterial highway intersections are generally controlled by four phases. Detectors should be installed to detect whether there are vehicles across or stop at the entrance lane. Location of detectors should be clear to ensure vehicles that lose right-of-way at the maximum speed and minimum deceleration pass stop line or safely stop at it. Because of driving characteristics of through vehicles and left-turning vehicles, distance from detectors to stop lane should be calculated respectively.

$$S_l = \frac{-v_{0l}^2}{2a_{il}} \tag{1}$$

$$S_t = \frac{-v_{0t}^2}{2a_{it}} \tag{2}$$

S_l---Distance from detectors to left-turning stop lane;
S_t---Distance from detectors to through stop lane;
v_0---Maximum speed when vehicles pass the detector;
a_i---Minimum acceleration when vehicles pass the detector.

Right-of-way of all arterial highway intersection directions is coordinate. As urban highway intersections are close, queue length cannot affect normal pass of abutting intersections, otherwise, congestion would be worse. Therefore, other group of detectors should be installed at exit lane of abutting intersections. Distance from detectors to intersection is shown in Figure 1. When vehicles leave point C2 and drive to intersection A from B, it considers that the queue length does not affect abutting intersection B when vehicle drives from point C2 to C1 at the speed of point C2. S_2 is the distance from other group of detectors to the abutting intersection.

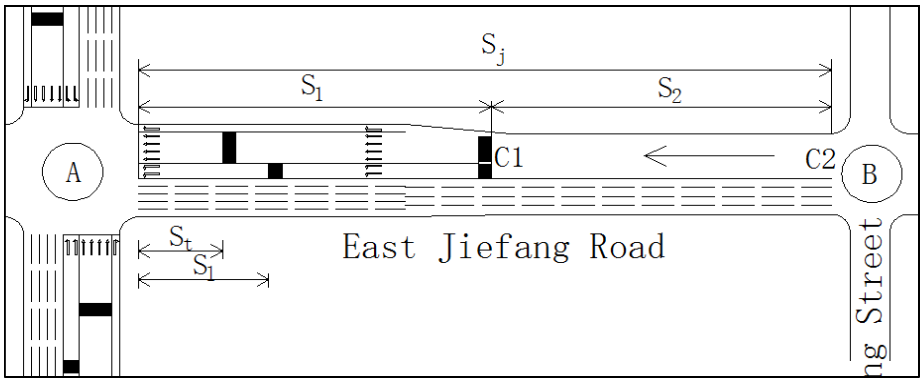

Figure 1. Distance from detectors to intersection

$$\begin{cases} S_1+S_2=S_j \\ S_1=(n-1).d_s+d \\ S_2= v_0.t \\ t=d_t .n \end{cases} \quad (3)$$

S_j---The shortest length from intersection to abutting intersections;
n---Quantity of queuing vehicles;
d_s---Space headway;
d---Average length from vehicles;
v_0---Average speed at exit lane of abutting intersections;
t---Firing time difference between the first vehicle at stop lane and the vehicle at C1, which is also the time vehicles travel from point C2 to C1;
d_t---Average firing time.

Finishing the formula, the distance model of detectors to abutting intersection can be obtained.

$$S_2= v_0 \cdot d_t \cdot \frac{S_j-d+d_s}{d_s+v_0 \cdot d_t} \quad (4)$$

3 Exploration of full-induction control method

Renmin Street and Jiefang Avenue intersection of Changchun city is selected as research object. As these highways are designed with side highway, highway and intersection have been standardized to simplify the exploration in VISSIM. Besides, influence of pedestrians is ignored.

3.1 Determination of detector installing position

With the tool of DETECTORS in VISSIM, the data have been measured in sections as follows: v_{0l} =60.7km/h=16.86m/s, a_{il} =-2.9m/s^2, v_{0t} =59.4km/h=16.5m/s, a_{it} =-4.3 m/s^2, obtained by calculation, S_l =49.01m,S_t =31.66m.The distance from detectors to left-turning stop lane is 49.01m and the detectors to through stop lane is 31.66m.

Direction of the shortest length from intersection to other abutting intersections is the east one, S_j=260m, v_0=20km/h=5.6m/s, d_t=1.1s, d=4.43m, d_s=6m, obtained by calculation, S_2=132.51m. So, detectors should be laid at 132.51m to the abutting intersection, which is shown in Figure 2.

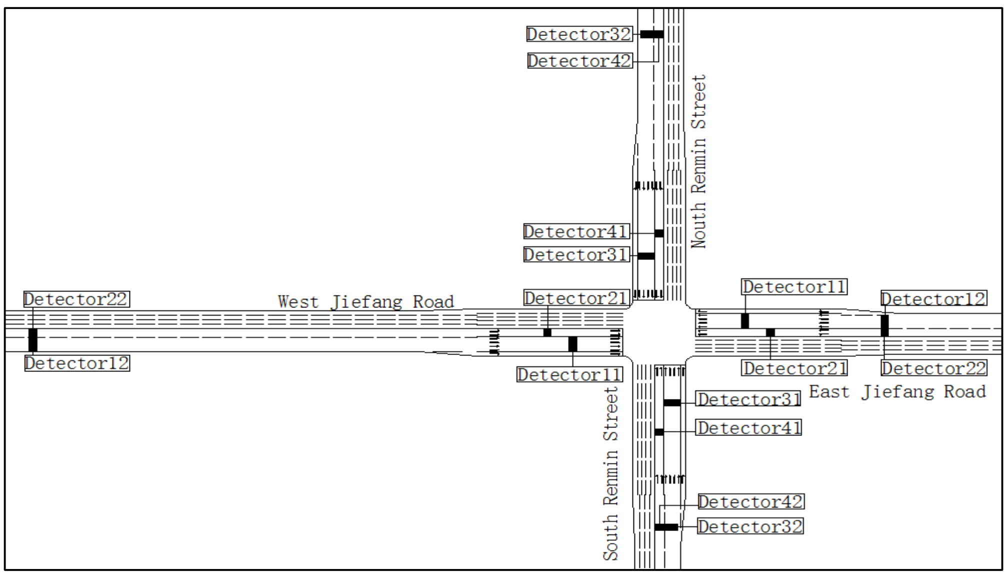

Figure 2. Position of detectors

3.2 Flowchart of VAP

It mainly uses vehicle data acquisition functions with “Occupancy” and “Headway”. Expression definition of VAP is shown in Table 1, and flowchart of VAP is in Figure 3.

Table 1. Expression definition of VAP

EXPRESSIONS	Contents
Queue	(Occupancy(12)>5)OR(Occupancy(22)>5)OR(Occupancy(32)>5)OR(Occupancy(42)>5)
Extend_Stg1	Headway(11)<=MAX_GAP

Extend_Stg2	Headway(21)<=MAX_GAP
Extend_Stg3	Headway(31)<=MAX_GAP
Extend_Stg4	Headway(41)<=MAX_GAP

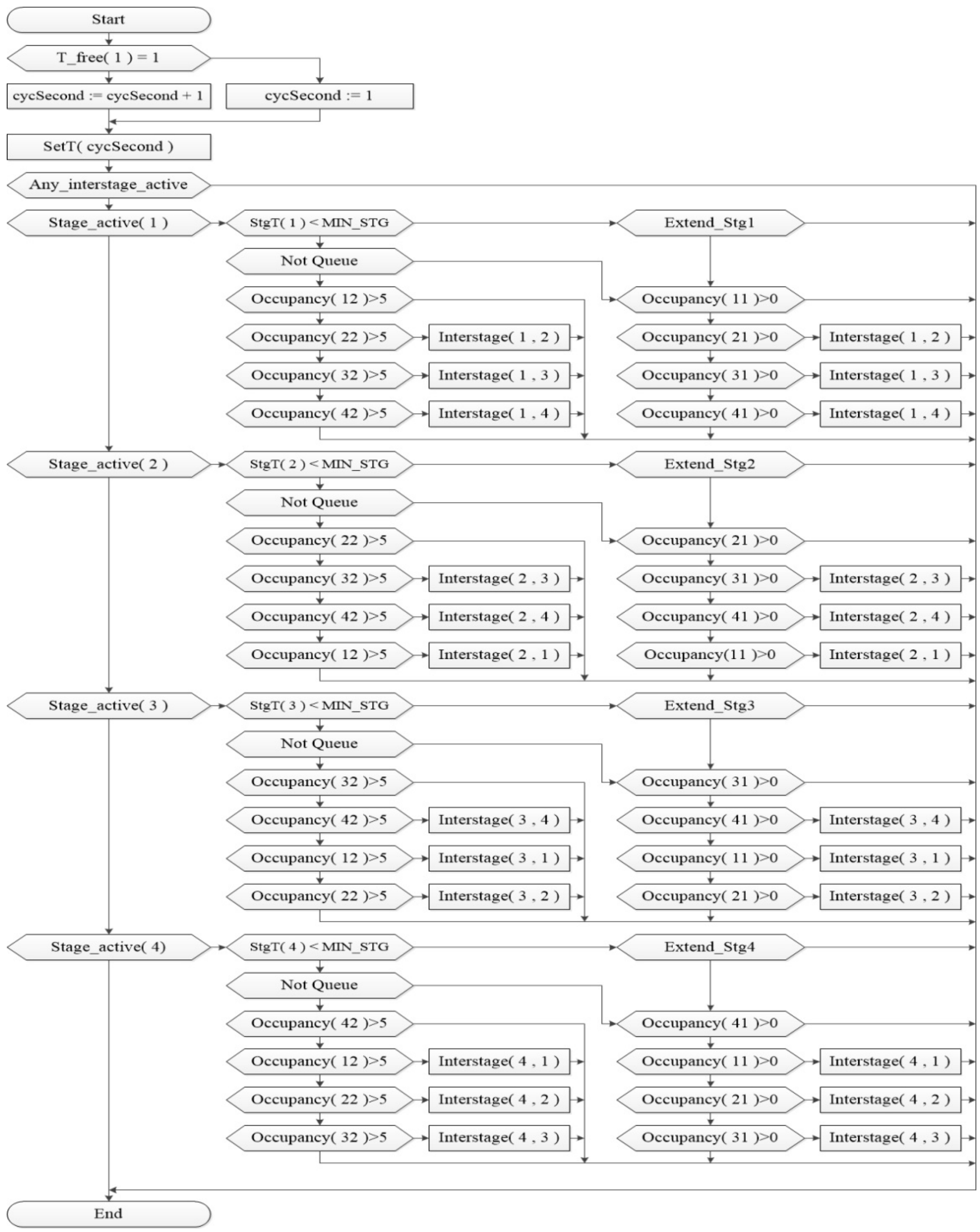

Figure 3. Flowchart of VAP

When current phase is stage 1, east-west through light is green, judging whether it reaches minimum green time. When it reaches, VAP will judge whether queues exist, otherwise, VAP will judge whether it reaches maximum time interval. If queues exist, VAP will check which direction is queuing and give right-of-way to it. If there is no queue, VAP will check detectors near to stop line whether there are vehicles crossing or stopping at detectors. If there are some vehicles crossing or stopping at detectors, VAP will give the right-of-way to it. If headway is greater than the maximum interval time, detectors near to stop line will check whether there are vehicles arriving at it. If headway is less than maximum interval time, this direction will maintain the right-of-way. VAP involves two variables, MAX_GAP is set at 3s, but the MIN_STG is needed to set according to concrete intersection.

Infinite traffic and different green time have been set to determine minimum green time of crowded intersection in VISSIM. Delay comparison of different green times is shown in Figure 4.（etw---east-west through, stn---south-north through）

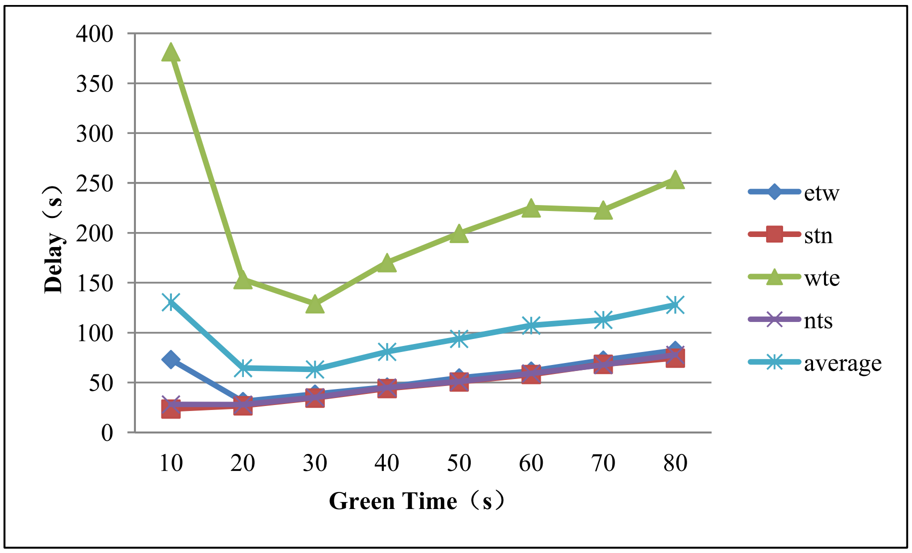

Figure 4. Delay comparison of different green time

When green time of crowded intersection is set at 10s, the numerical value of delay is relatively large; when 20s later, the delay fluctuation is relatively small. So, the MIN_STG is identified as 20s.

4 Comparison of simulation results

The current peak period signal timing of this intersection is that green time of through direction is 105s and left-turning is 45s, peak hour traffic of all directions is shown in Table 2.

Table 2. Peak hour traffic of all directions (veh/h)

	East	South	West	North
Left-turning	360	460	572	496

Straight	1832	1784	2344	1912
Right-turning	276	368	168	288
Total	2468	2612	3084	2696

The simulation effect of current signal control method is shown in Figure 4. There is no vehicle in south-north left-turning, but it does not arrive at the fixed 45s green time, part of time has been wasted. What's worse, other entrance lanes are seriously congesting.

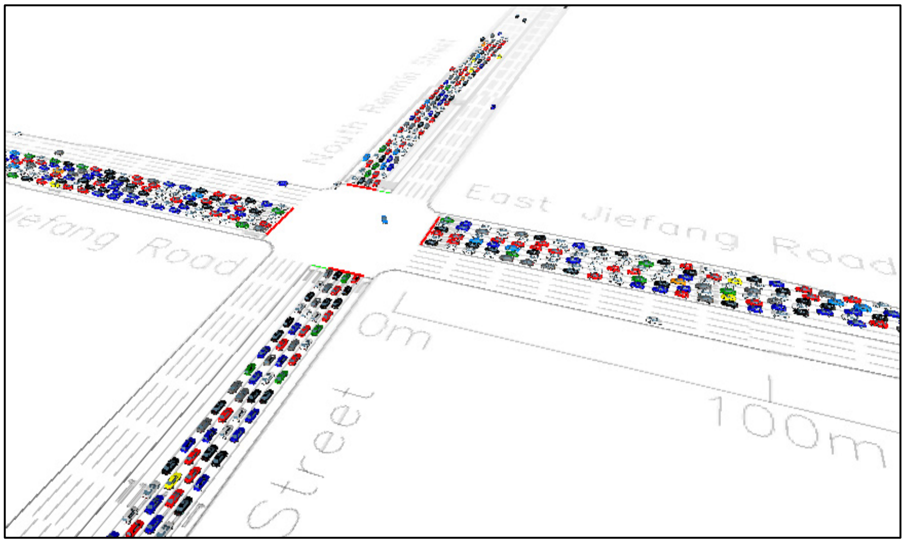

Figure 5. Simulation effect of current signal control method

Transferring control method to VAP, editing the "*.pua" file that contains signal phase, signal groups, starting stage and stage length. Simulation effect of VAP control method is shown in Figure 6. There is no congestion with the control of VAP in an hour. It concludes that the full-induction control method effectively alleviates congestion.

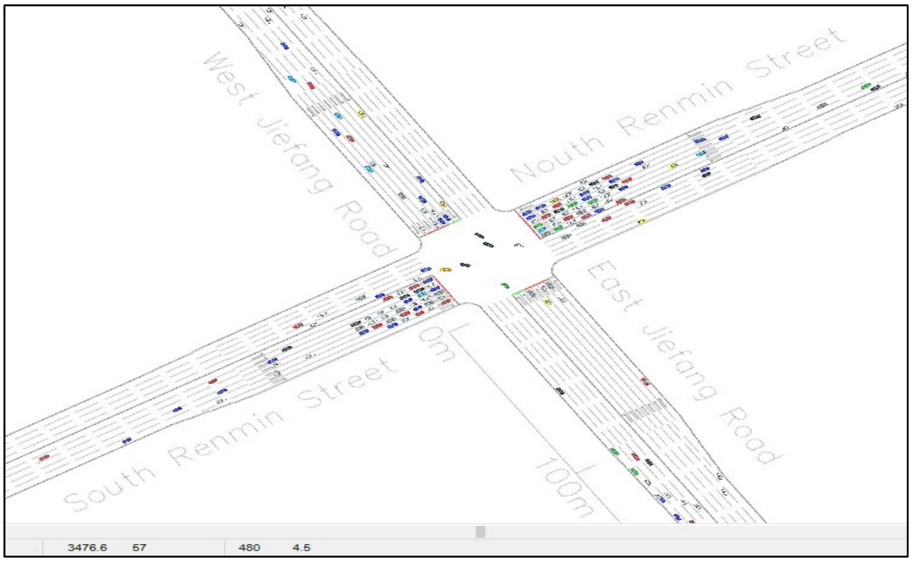

Figure 6. Simulation effect of VAP control method

Contrast diagram of delay is shown in Figure 7, and queue length is in Figure 8. 63.83% and 67.09% are the average reduction of delay and queue length respectively.

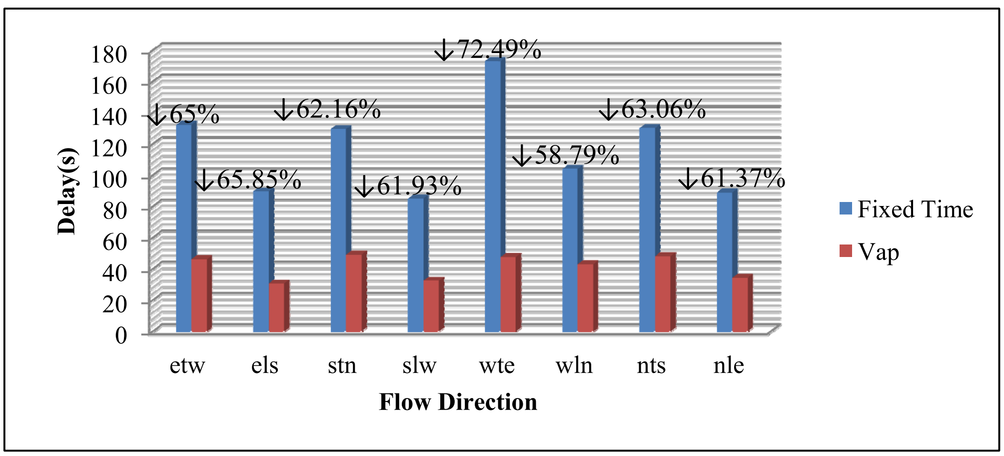

Figure 7. Contrast diagram of delay

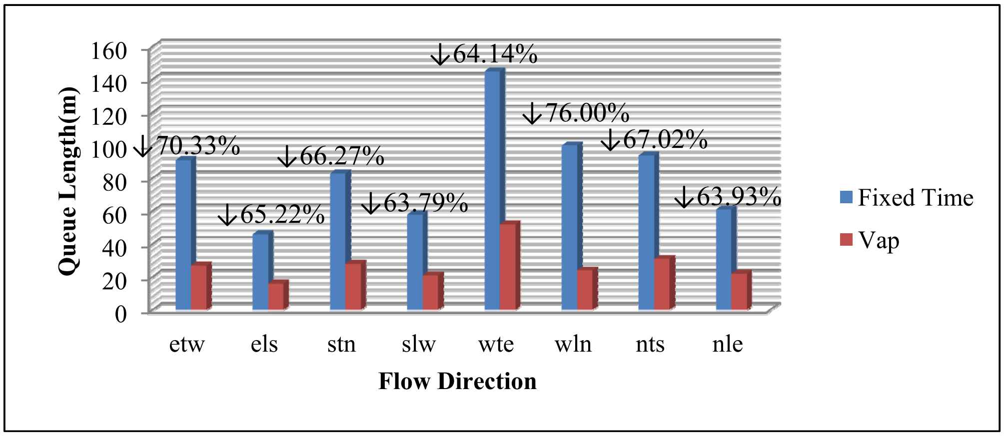

Figure 8. Contrast diagram of queue length

5 Conclusion

It researches calculation model of detectors installing position according to the driving features and explores a full-induction control method of urban arterial highway intersection. In addition, the method has been proved that it effectively alleviates congestion by VAP control in VISSIM.

References

Chen Fukun, Wu Zhong. The Research on the Induction Control Method Based on VISSIM. *Chinese Scientific Papers Online.*

He Bisheng, Song Rui. (2011) Simulation Realization of the BUS Pre-signal Induction Control. *Journal of System Smulation,* p.1909-1914.

Jing Tai, Lu Bing. (2014) The Induction Control Research Based on Probabilistic Model. *Traffic information and safety,* p.16-20.

Li Zhenlong, Zhang Jiankun. The Influence of the Traffic Signal Countdown to the Driver's Reaction Time, p.77-81.

PTV Planung Transport Verkehr AG VISSIM4.30 User Manual. PTV Corporation,2007.

PTV Planung Transport Verkehr AG VISVAP2.14 User Manual. PTV Corporation,2003.

PTV Planung Transport Verkehr AG VAP2.14 User Manual. PTV Corporation,2003.

Wang Yupeng. (2009) The Optimization Design and Simulation of Induction Control. *Modern Transportation Technology*, p.67-70.

Wu Bing, Yang Peikun. (2008) Traffic Management and Control. p. 138-148.

Xie Fei, Sun Yaojie. (2014) The Induction Control Based on Travel Priority. *Modern Electronic Technology*, p.145-151.

Xiu Weijie, Zhang Lili. (2014) The Improved Double Phase Induction Control Method Based on VISSIM. *Traffic Standardization*, p.115-121.

Zhang Zhiyong, Ren Futian. (2009) The Research on the Car-state Headway. *Beijing University of Technology Journal*, p.775-779.

Potential Conflict Number Prediction of an Intersection's Mixed Traffic Flow

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Abstract: In order to reduce the observation time of the intersection traffic conflict and decrease the difficulty of observation, meanwhile achieve the effect of actual measurement, so based on the relevant information, the objective can be realized through the method of predicted the number of potential conflicts. The paper mainly demonstrated the conflict point of mixed traffic flow and predicted the probability of potential conflict about the non-signal intersection in the view of the method of probability statistics, random process, regression analysis and two-dimension table, the theory of traffic flow and traffic conflict. The paper observed the typical intersection in Xi'an so as to test the reliability of the prediction model. The number of prediction conflicts contrasted with the representative predicted value in china, the number of actual conflicts and simulation result. The result shows that the predicted value is a little more than actual value, but contrast with other prediction model, the predicted result is more closer the actual value, so the prediction model can be used to evaluated the traffic safety of intersection instead of the number of actual conflicts.
Keywords: Intersection; Mixed traffic; Traffic conflict; Statistical test; Safety evaluation.

1 Induction

The number of traffic conflict is an important parameter for the analysis of traffic safety of intersection, and also a major evidence for the control of intersection. At the time of observation for traffic conflict, it needs too much time to assure the number of conflicts at the place of intersection (LIU Xiaoming, 1997). And when the traffic volume becomes larger and the traffic order becomes chaotic, some of conflicts are difficult to observe. However, through the method of direct observation, it is difficult to acquire the number of traffic conflicts. So it is necessary to seek other effective methods which can save the observation time of traffic conflict and reduce the difficulty of observation, and also can reach the practical effect. In order to realize this objective, it can based on sectional information predicted the number of potential conflicts that the estimated value of the number of actual conflict.

2 Non-signal intersection motor-motor conflict

2.1 The analysis of non-signal intersection motor-motor conflict

At the situation of non-signal control, as shown in the table 2-1, in the case of three or four roads intersection, the distribution condition of the number of conflict points are different. And figure 2-1and figure2-2 are the distribution condition of the conflict number of the typical T-model crossing and intersection respectively.

Table2-1. The distribution of the conflict point numbers

The types of conflict point	The number of crossing roads	
	3	4
Confluence conflict points	3	8
Split conflict points	3	8
Crossing conflict points	3	16
The total number of conflict points	9	32

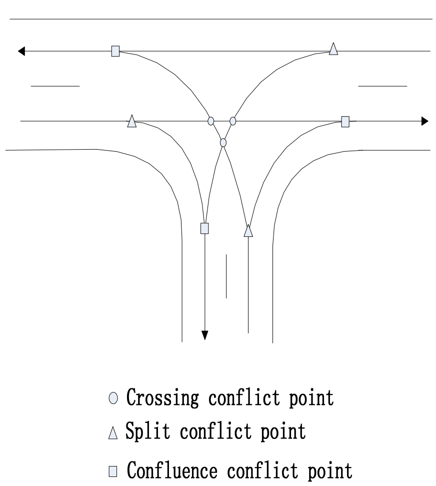

Figure 2-1. non-signal T-model crossing

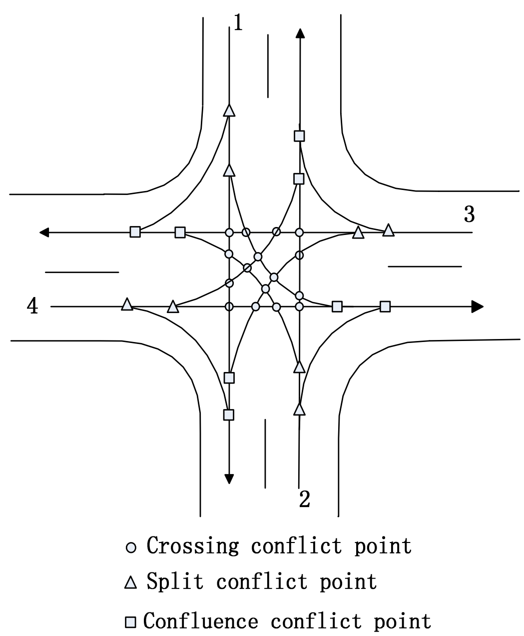

Figure 2-2. non-signal intersection

As shown in the Figures, at the non-signal intersection, the number of crossing, split and confluence conflict points between vehicles will be increased with the increase of the number of crossing roads (ZHANG Su, 1998; Hyden C, 2001).

2.2 Motor-Motor potential conflict model of non-signal intersection

2.2.1 The definition of potential conflict

Conflict is the event that the traveling vehicles slow down or braking when encountered with other vehicles. This two traffic flows are called conflict traffic flow. At intersection, necessary and sufficient condition of conflict shows that two traffic flows are conflict flows and time difference that two traffic flows arrived at conflict point is lesser. Usually, the maximum time difference that happened traffic conflict is called critical interval. It is also the minimum gap that the vehicles of minor road waiting for pass through traffic flow of main road. Call the minimum gap Δt.

According to related research, the value range of Δt is about 6~9s, foreigner experts thought that Δt is about 6~7s(Crowe E C,1989),however, according to actual measurement in china, Δt is about 7~9s(HAN Zhi, 1989).In actual application, it can according to above results to choose appropriated value.

2.2.2The calculation of the potential conflict number

1. The conflict probability of single traffic flow

Assuming all of the vehicles which arrived at the intersection are random, and all kinds of traffic flows which in the area of conflict are independence respectively, meanwhile are follow Poisson distribution. So in the critical gap Δt , the conflicted probability of traffic flow A and B is:

$$p(con)=p_a(k\geq 1)\cdot p_b(k\geq 1) \quad 2\text{-}1$$

p(con): Conflict probability of traffic flow A and B.

$p_a(k\geq 1)$,$p_b(k\geq 1)$: In the times of Δt, the probability of traffic flow A and B arrive at conflict point respectively, and the k is the number of vehicles which arrived at the conflict point.

Because of the traffic volume of the non-signal intersection are not large, so the conflict probability $p(k>1)$ that two or more vehicles arrived at the conflict point simultaneously in the times of Δt is little, so it can ignore $p(k>1)$,and 2-1 can be written as:

$$p(con)=p_a(k=1)\cdot p_b(k=1) \quad 2\text{-}2$$

According to the formula of Poisson distribution:

$$P(\mathrm{x}=\mathrm{k})=\frac{(\lambda t)^k}{k!}e^{-\lambda t},$$

the result is: $p_a(k=1)=\Delta t\cdot\lambda_A e^{-\Delta t\lambda_A}$, $p_b(k=1)=\Delta t\cdot\lambda_B e^{-\Delta t\lambda_B}$,so the 2-2 can be written as :

$$p(\text{con}) = (\Delta t)^2 \cdot \lambda_A e^{-\Delta t \lambda_A} \cdot \lambda_B e^{-\Delta t \lambda_B} \quad 2\text{-}3$$

λ_B: average arrival rate of traffic flow B in unit-time (pcu/s).
λ_A: average arrival rate of traffic flow A in unit-time (pcu/s).

2. The conflict probability of more traffic flows

In the intersection, the traffic flow A not only conflicted with traffic flow B but also conflicted with other traffic flows, at this time, in the times of Δt, the conflict probability of traffic flow A are the sum of the conflict probability that traffic flow from different directions conflicted with traffic flow A respectively. As shown in the figure2-2, meanwhile, i=1,2,3,4 respectively stand for four entrances of intersection, and j=1,2,3 respectively stand for the direction of traffic flows such as left turning, straight and right turning. So:

$$p_{ij} = \sum_k \sum_l q_{ij-kl} \quad 2\text{-}4$$

Combination 2-2 with 2-3, so the 2-4 can be written as:

$$p_{ij} = (\Delta t)^2 \lambda_{ij} e^{-\Delta t \lambda ij} \cdot \sum_k \sum_l \lambda_{kl} e^{-\Delta t \lambda_{kl}} \quad 2\text{-}5$$

p_{ij}:In the times of Δt, the probability of the vehicles of i entrance and j traffic flow conflicted with the vehicles of other traffic flow .

q_{ij-kl}:In the times of Δt, the probability of the vehicles of i entrance and j traffic flow conflicted with the vehicles of k entrance and l traffic flow.

λ_{ij}: average arrival rate of i entrance and j traffic flow vehicle in unit-time(pcu/s).

Assuming $b\,ij = \lambda_{ij} e^{-\Delta t \lambda_{ij}}$,and then 2-5 can be written as:

$$p_{ij} = (\Delta t)^2 \cdot b_{ij} \cdot \sum_k \sum_l b_{kl} \quad 2\text{-}6$$

2.2.3 The calculation of the number of intersection potential conflict per hour

According to formula 2-6, the number of potential conflicts per hour of i entrance and j traffic flow can be calculated. It is shown as below:

$$N_{ij} = \frac{3600}{\Delta t} \cdot (\Delta t)^2 \cdot b_{ij} \cdot \sum_k \sum_l b_{kl} = 3600\Delta t \cdot b_{ij} \cdot \sum_k \sum_l b_{kl} \qquad 2\text{-}7$$

The distributed condition of the conflict point of figure 2-2 can be showed through the two-dimensional table. The table2-2 shows the types of conflict that different traffic flows conflicted with each other. It covered 32 conflict points that included 16 crossing conflict points, 8 confluence conflict points and 8 split conflict points. The detailed condition is shown as below.

Table 2-2. The calculation of different forms of conflict number

	b_{11}	b_{12}	b_{13}	b_{21}	b_{22}	b_{23}	b_{31}	b_{32}	b_{33}	b_{41}	b_{42}	b_{43}
b_{11}		D		A	C			A		A	A	
b_{12}			D	A	A	C	A			C	A	
b_{13}											C	
b_{21}											A	
b_{22}						D	A	A	C	A		
b_{23}												
b_{31}								D		A	C	
b_{32}									D	A	A	C
b_{33}												
b_{41}											D	
b_{42}												D
b_{43}												

A-crossing conflict point, C-confluence conflict point, D-split conflict point.

$$N_A=3600\Delta t[b_{11}(b_{21}+b_{32}+b_{41}+b_{42})+...+b_{32}(b_{41}+b_{42})] \qquad 2\text{-}8$$

$$N_C=3600\Delta t(b_{11}b_{22}+\cdots+b_{32}b_{43}) \qquad 2\text{-}9$$

$$N_D=3600\Delta t(b_{11}b_{12}+\cdots+b_{42}b_{43}) \qquad 2\text{-}10$$

N_A: The number of crossing conflicts per hour.
N_C: The number of confluence conflicts per hour.
N_D: The number of split conflicts per hour.

3 Model validation and results analysis

It takes a typical non-signal intersection of Xi’an to verify the reliability of the prediction model. It spends two hours to observe the entrances of straight and left turning. Regard six minutes as an interval to record the traffic volume and the number of traffic conflicts. And the range of date in this paper basically meet the assumption condition, it means that the arriving rules of vehicles of two entrances basically follow Poisson distribution(the detailed dates are shown as figure 3-1, 3-3 and 3-4) .When the average speed is about 20km/h, according to some suggested values of studies to assure Δ t of straight-left turning conflict is about 7.6s (HAN Zhi 1989,Zegeer J D 1986).So as to calculate the number of the potential conflicts which come from straight-left turning, meanwhile, acquired 20 groups expected value. As shown as figure 3-1, Compared the result of prediction with the representative value in china, the value of SAMM simulation and the result of actual measurement. From figure 3-1 we can see that the prediction value is more closer to the actual value. In the actual, because of the factor of traffic condition, the reaction of drivers and the psychological condition of drivers, most of the drivers will slow down ahead to avoid the traffic conflict, so, It will lead to the observed number are less than the predicted number. From figure 3-2 we can see that the number of traffic conflicts will be increased with the traffic volume. But, in actual observation, when the traffic volume increased to a definite value, the number of traffic conflicts will be decreased. Because of the increased traffic volume will make the speed of vehicles slower, so, the number of traffic conflicts will be decreased. Furthermore, the predicted model based on Poisson distribution just applied to the condition of the arriving characteristics of vehicles follow Poisson distribution. When the traffic volume is larger, the arriving characteristics of vehicles are not follow Poisson distribution, it will needs other model to predict the traffic conflict.

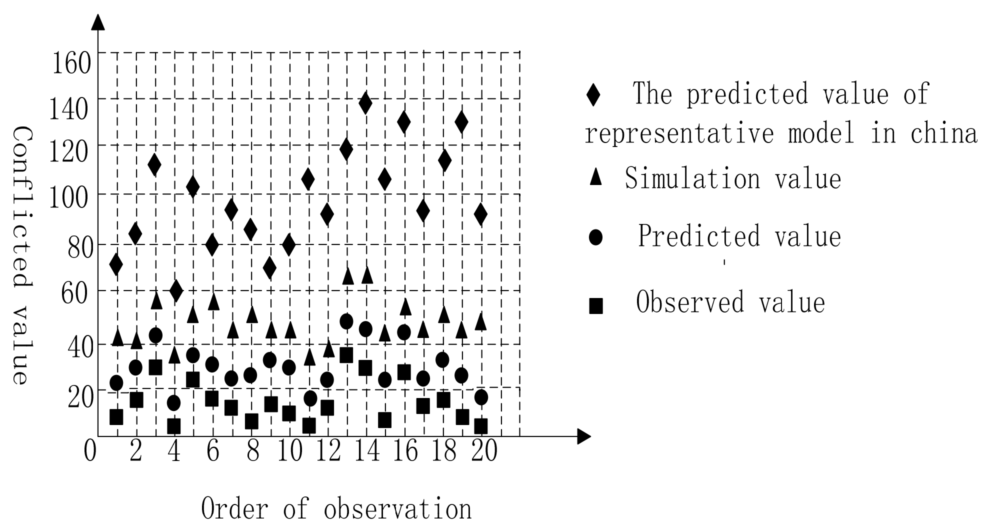

Figure 3-1. Comparison of predicted results

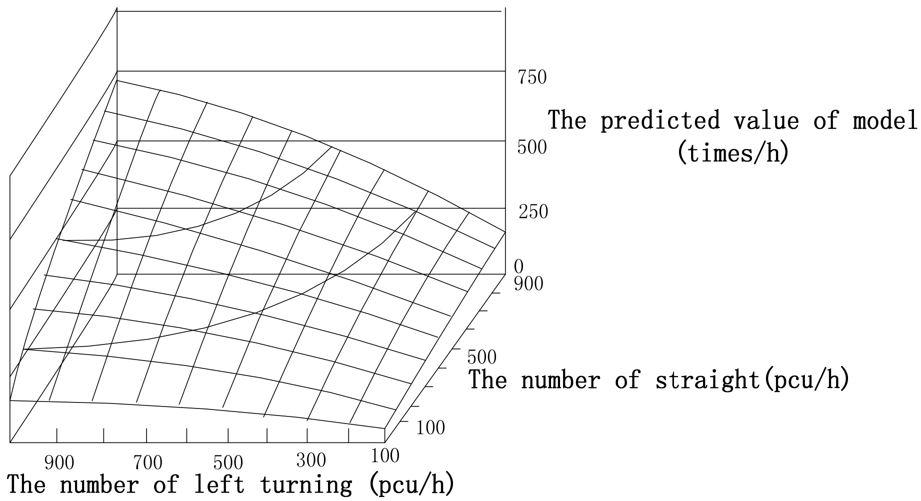

Figure 3-2. Relation of the number of conflicts and traffic flow

It is important to noted that the assumption of the arriving and depart rules of vehicles follow Poisson distribution is basically meet the parameter range of this paper. （The specific parameters are shown as figure 3-3 and figure 3-4） Abroad is generally believed that 600 pcu/h is the critical flow of Poisson distribution. And domestic study shows that when the single lane flow less than 350pcu/h, the arriving rules of vehicles follow Poisson distribution, and when the traffic flow between 350 pcu/h and 400pcu/h, the arriving rules of vehicles basically follow Poisson distribution, but sometimes follow binomial distribution (because of the affect of upstream intersection), when the traffic flow between 400pcu/h and 500pch/h(the maximum value of observation), with the larger counting interval, the arriving rules of vehicles also follow Poisson distribution.(WANG Haixing,2004)

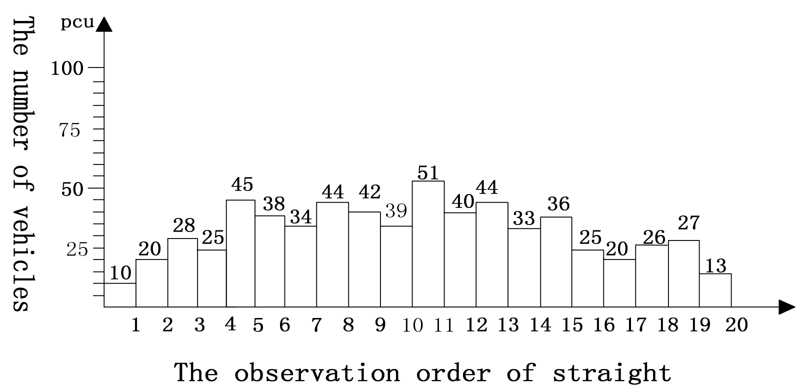

Figure 3-3. The number of vehicles from straight direction

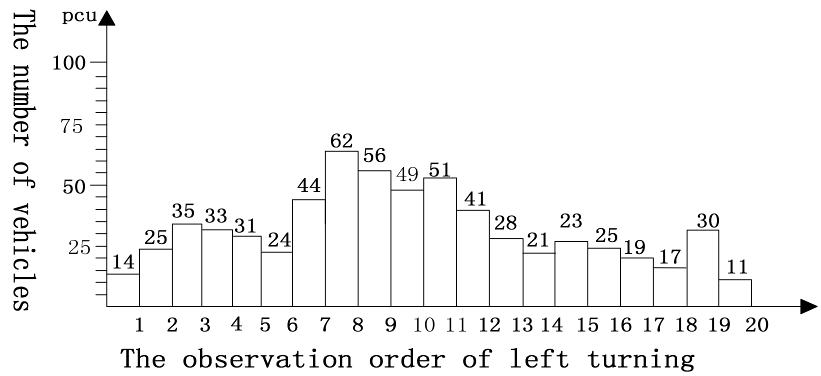

Figure 3-4. The number of vehicles from left turning direction

4 Conclusions

The paper based on the analysis of traffic volume discussed the calculated method of traffic conflict number of non-signal intersection. The results of calculation show that with the increased of traffic volume, the average number of traffic conflict and the severity of traffic conflict will be increased, furthermore, the growth speed will be more and more faster.

In the actual road condition, it is easy to see the multiple lanes of main road (two-lane or more), when the traffic volume of main road is not large, the number of lanes has a little effect on traffic conflict. But, when the traffic volume are more than a certain quantity(350pcu/h), With the increased of the lanes, it will be increase the difficulty of the minor road vehicles pass through the main road vehicles and also increase the average number of traffic conflict. Because of limited by conditions, the paper mainly discussed the calculation of traffic conflict of simply single lane, and the condition of multi-lane and the factors of vehicle speed, the range visibility and coefficient of road adhesion will also have an important effect on traffic conflict, and it will need next step study.

Acknowledgments

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References

Crowe E C.(1989). “Traffic conflict values for three-leg, un-signalized intersections” Transportation Research Record, (1287):185-194.

Hyden C, translated by ZHANG Su.(1998) .“Traffic conflict technique” Southwest

Jiaotong University Press.
Hyden, C. (2001).“The Development of Method for Traffic Safety Evaluation” The Swedish Traffic Conflict Technique, 19(6)75~78.
HAN Zhi.(1989). “The method of calculation of non-signal intersection conflict” Journal of Chongqing Jiaotong Institute, 8(4):68~77.
LIU Xiaoming, DUAN Hailin.(1997).“Research on Standard Program of Traffic Conflict Techniques at Intersections” Journal of Highway and Transportation Research and Development,14 (3): 29-34.
WANG Haixing.(2004).“Traffic conflict simulation of signal-controlled cross road based on traffic volume” China Safety Science Journal,14(3):21~24.
Zegeer J D. (1986).“Field validation of intersection capacity factors” Transportation Research Record, (1091):67-77.

Improving Measures for Transition Sections of Barriers at Tunnel Entrances in Expressways

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Abstract: The semi-rigid barriers were generally used in tunnel entrance. When impact occurred, some deformation of facilities could cause vehicles' rolling or impacting on tunnel wall, effective protection would not be provided. New transition structures combining connection sections with strengthen lap beams between standard barriers and tunnel were set to solve the above problems. According to new standards, crash simulation tests were analyzed, which small passenger car, medium truck and bus with impact angle (20°) and impact velocity on transition structures. By analyzing vehicle tracks, the buffering and redirective performances, maximum dynamic lateral deflection (D) , the maximum dynamic widening distance of lateral deflection (W), and maximum dynamic vehicle incline-out distance (VI), the results showed that the improved barriers with transition structures met the anti-collision requirements.
Keywords: Expressway; Tunnel entrance transition; Protection facilities; Simulation.

1 Introduction

From the statistics (H • Mashimo, 2012; FHAmundsen, G.Ranes, 2000), accident rates in highway tunnels, especially relatively long tunnels, were significantly less than the open sections. However, for different drivers' quality, operations management and traffic composition, driving safety of highway tunnel in China was significantly different with abroad.

Domestic highway tunnel accident investigations (Li Xinwei, 2014) indicated that the accidents mainly concentrated in the front section out of the tunnel entrance, were far higher than their proportions in highways, while the rear-end collision tunnel walls, rollover accidents accounted about 96.49% of the total accidents; the proportion of accidents caused by fire or other causes were lower; and the large trucks, passenger cars accounted about 89.85% of vehicle accidents.

In China, lacking of relevant norms of tunnel safety aspects of facility design, tunnel safety designs in expressways primarily focused on active protection measures to tunnel alignment, pavement, lighting, etc. When the accident occurred, effective passive protection facilities to vehicles were few. Generally, no protection facilities were set in tunnels, the ordinary crash barrier facilities were set outside of tunnels, and therefore serious security vulnerability leading to frequent accidents were existed at the transition section of tunnel entrances (Meng Guangcheng, Tai Yonggang, 2011).

For no protective measures, approach of fundamental shape of the concrete barrier fence or bridge extends to the tunnel and energy absorbing crash cushions were currently used, but there still had different security risks.

To improve operation safety and reduce the severity of accidents in highway tunnel entrance transition, the protection facilities with double transitions in stiffness and height need be set between the general sections and tunnels. Based on the requirements (Ministry of Transport of the People's Republic of China, 2013), existing protection facilities were improved, and collision simulations on passenger car, medium bus and truck were analyzed. By the analysis on passenger car, the buffering and redirective performances, maximum dynamic lateral deflection (D) and the maximum dynamic widening distance of lateral deflection (W) of highway barriers were tested. By the analyses of medium bus and truck, containment and redirective performances, maximum dynamic lateral deflection (D), the maximum dynamic widening distance of lateral deflection (W), and maximum dynamic vehicle incline-out distance (VI) were detected.

2 Structure design of protection facilities in highway tunnel entrance transition

According to the analysis of the accident cause in tunnel entrance transition, double transitions in stiffness and height on protection facilities and guardrail landscape change effects on traffic generation should be considered. The structure should be optimized as Figure 1.

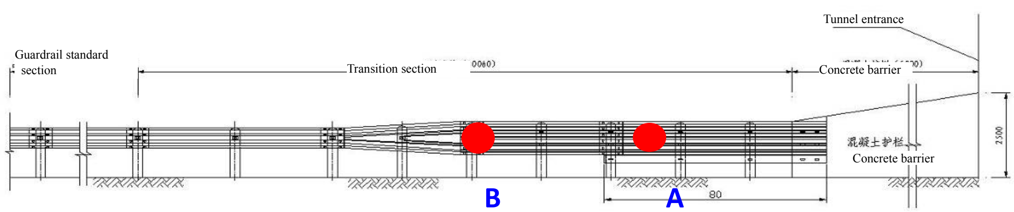

Fig 1. Design of protection facility in tunnel entrance transition

Between the normal and tunnel, the transition section was set, which was composed with stiffness and height transition. For the stiffness transition, enhanced double wave beam guardrail with column spacing 2m, three wave beam guardrail with column spacing 1m, and the strengthen lap beam were set. The length of above stiffness transition section was 10m. In order to realize the height transition, reinforced concrete guardrail was set to connect with the tunnel wall, that the length was 5m and the maximum height was 2.5 m.

The above structure scheme with 3 anti-collision level, local reinforcement could be improved to other anti-collision level when the normal section guardrail with higher protection grade.

3 Collision condition and evaluation standard

According the requirements (Ministry of Transport of the People's Republic of China, 2013), the collision condition and evaluation standard on protection facility in highway tunnel entrance transition should meet the requirements of table 1 and table 2.

Tab 1. Collision condition for transition sections of barriers

Impact Vehicle	Vehicle quality(t)	Impact velocity(km/h)	Impact angle（°）
passenger car	1.5	100	20
medium bus	10	60	20
medium truck	10	60	20

Table 2. Evaluation standard for transition sections of barriers

Evaluation Contents			**Standard**
containment performance	Whether the test cushion or divorced parts enter vehicle crew capsule		No.
	Whether the scattered location of divorced parts(≥2kg) from test cushion met the requirement		No.
redirective performance	whether the vehicle overturned after collision		No.
	Whether the wheel track met required redirective ranges after collision		Yes.
buffering performance	Occupant Impact velocity(OIV)（m/s）	longitudinal	≤12
		horizontal	≤12
	Occupant Ridedown Acceleration(ORA)（m/s^2）	longitudinal	≤200
		horizontal	≤200

4 Simulation of improved protection facility in tunnel entrance transition

According to the collision conditions, establishing full-size finite element models (XIE Suchao, 2008), impact simulations were analyzed, and results were evaluated whether meet the requirements of evaluation standards. According the requirements on collision point of transition section (Ministry of Transport of the People's Republic of China, 2013), the collision point of passenger car was point A, and that of medium bus or truck was point B in figure 2.

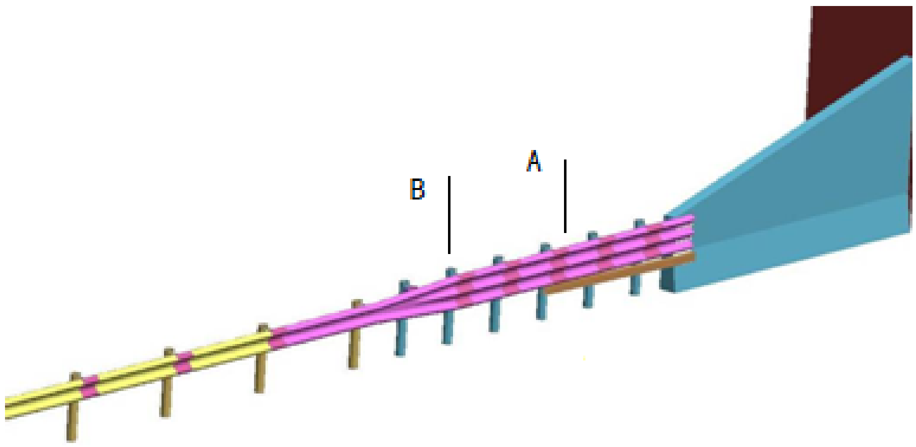

Fig 2. model of improved protection facility for tunnel entrance transition

4.1 Simulation of passenger car

Impact processing of small car and improved protection facility was showed in figure 3, the acceleration time curves of vehicle's gravity center were showed in figure 4, and the impact velocity curves of occupant after collision were showed in figure 5.

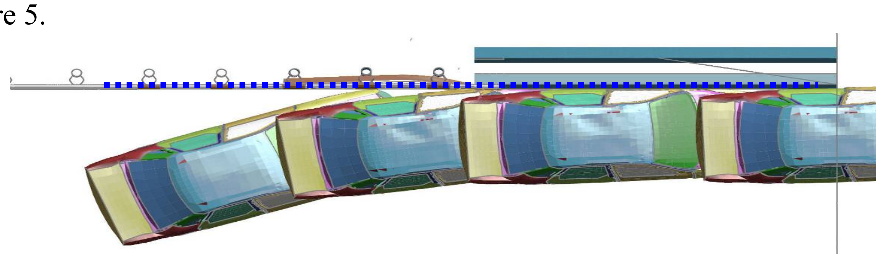

Fig 3. Impact processing of small car and improved protection facility

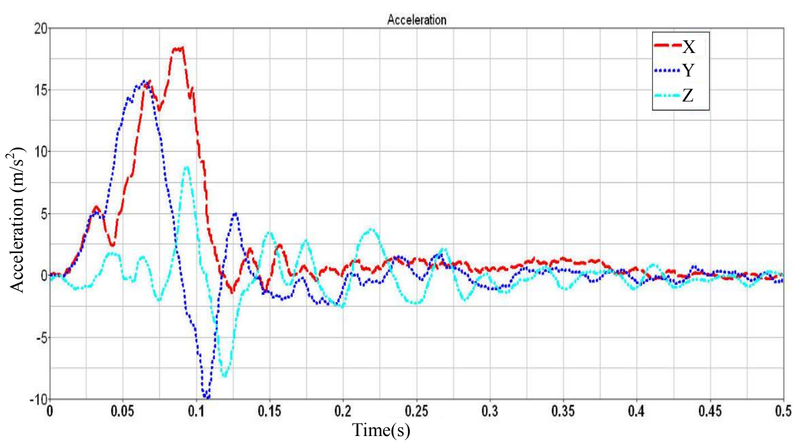

Fig 4. The acceleration time curves of vehicle's gravity center

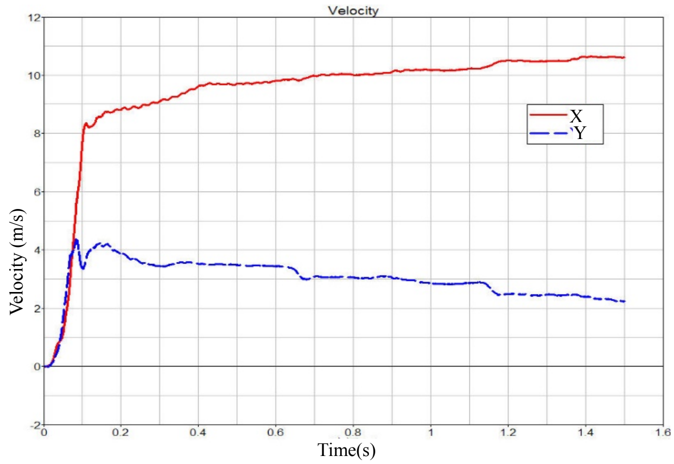

Fig 5. the curves of occupant impact velocity (OIV)

After passenger car impacted on improved protection facility, the vehicle's attitude was normal. Vehicle's Roll-over, Lateral turn and U-turn did not take place, and the Running track was still in redirective exit box. The longitudinal and lateral accelerations of maximum passenger car center were 186m/s^2 and 157 m/s^2, the longitudinal and lateral occupant impact velocity (OIV) were 9.6m/s and 4.4m/s, which meet the requirements of evaluation standards.

4.2 Simulation of medium bus

Impact processing of medium bus and improved protection facility was showed in figure 6.

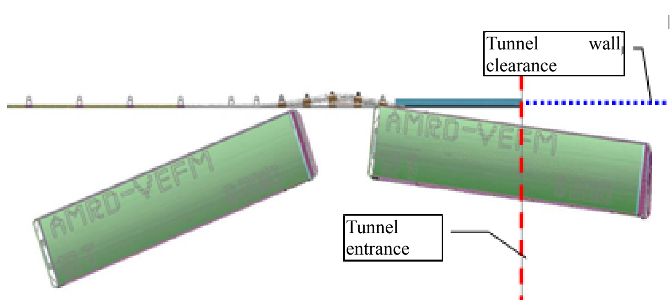

Fig 6. Impact processing of medium bus and improved protection facility

According to the simulation results, during the impact processing, the Driving state of medium bus was normal. Vehicle's Roll-over, Lateral turn and U-turn did not take place, and the Running track was still in redirective exit box. The maximum dynamic lateral deflection of transition sections of highway barriers was 408mm.

4.3 Simulation of medium truck

Impact processing of medium truck and improved protection facility was showed in figure 7.

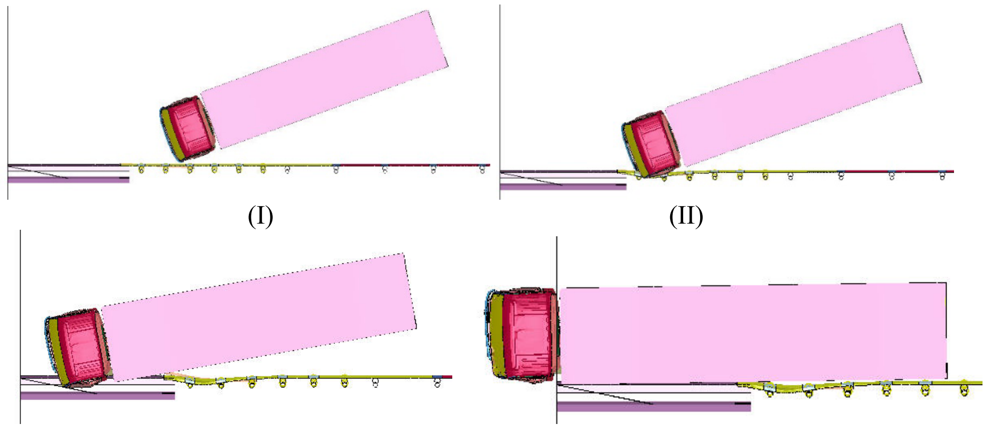

Fig 7. Impact processing of medium truck and improved protection facility

According to the simulation results, during the impact processing, the Driving state of medium truck was normal. Vehicle's Roll-over, Lateral turn and U-turn did not take place, and the Running track was still in redirective exit box. The maximum dynamic lateral deflection of transition sections of highway barriers was 343mm.

4.4 The evaluation of simulation results

The simulation results showed that the indicators of safety performance of barriers in transition sections of tunnels in expressways meet the requirements of the evaluation criteria under different impact conditions, and the improved transition section of barriers could provide protection degree of A-level.

Table 3. the evaluation of simulation results

	Evaluation criteria		Simulation results			Whether the results meet the criteria(Yes/No)
			Passenger car	Medium bus	Medium truck	
1	Whether the vehicle crossing, over ,or straddle the test barriers		No	No	No	Yes
2	Whether the test cushion or divorced parts enter vehicle crew capsule		No	No	No	Yes
3	Whether the vehicle rollover after impact		No	No	No	Yes
4	Whether the vehicle Running track beyond redirective exit box		No	No	No	Yes
5	OIV（m/s）	Longitudinal(≤12)	9.6	/	/	Yes
		Horizontal(≤12)	4.4	/	/	Yes
6	ORA（m/s2）	Longitudinal(≤200)	186	/	/	Yes
		Horizontal(≤200)	157	/	/	Yes

5 CONCLUSIONS

(1) By numerical simulation, an improved transition sections of barriers for tunnel entrance and standard section in expressway was analyzed. With the help of the barriers, the protection level can be greatly improved, and the impact risk could

be greatly reduced. According the landscape of tunnel entrances, the transition sections of barriers can be adjusted to maintain visual continuity.

(2) In application, the construction quality inspection of improved transition sections of barriers for tunnel entrance must be conducted to prevent bolt looseness.

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References

F.H.Amundsen, G.Ranes（2000）. “Studies on Traffic Accidents in Norwegian Road Tunnels”, *underground space technology*, 15 (1), 3-12.

H·Mashimo(2012). “State of the Road Tunnel Safety Technology in Japan”. *Tunneling and Underground Space Technology*, 17(2), 145-152.

Li Xinwei(2014),Crash Prediction Models and Application for Expressway, *PhD thesis*, Shanghai.

Meng Guangcheng, Tai Yonggang(2011). “Research on Road tunnel safety hazards solutions”, *Journal of Highway and Transportation Research and development (Application edition)*, 12(84), 289-292.

Ministry of Transport of the People's Republic of China (2013). “Highway guardrail safety performance evaluation standard (JTG B05-01- 2013)”, Beijing.

XIE Suchao, TIAN Hongqi, YAO Song (2008). “Impacting experiment and numerical simulation of energy absorbing component of vehicles”. *Journal of Traffic and Transportation Engineering*, 8 (3), 1-5.

Acceleration Length Model of an Eight-Lane Freeway with a Two-Lane Ramp Based on Driving Behavior

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Abstract: The current guidelines in China are mainly based on four-lane freeway, which do not fit eight-lane freeway well. Therefore, this paper researched traffic stream characteristics of the on-ramp region of Zhengyi interchange. As a result, the acceleration lane is divided into three regions—the region marked with entrance markings, the region where lane 1 connected with the inside lane of the ramp and the region where lane 1 connected with the outside lane, among which, the minimum length of merging length is calculated as a non-linear integer programming (NLIP) based on the gap acceptance theory and traffic volume. The trial results of the models above show that the present recommended value of acceleration lane length and cannot meet the vehicles' merging demand under secondary serve level when the freeway is eight-lane with two-lane ramp.

Keywords: Eight-lane freeway; Two-lane ramp; Gap acceptance theory; NLIP.

1 Introduction

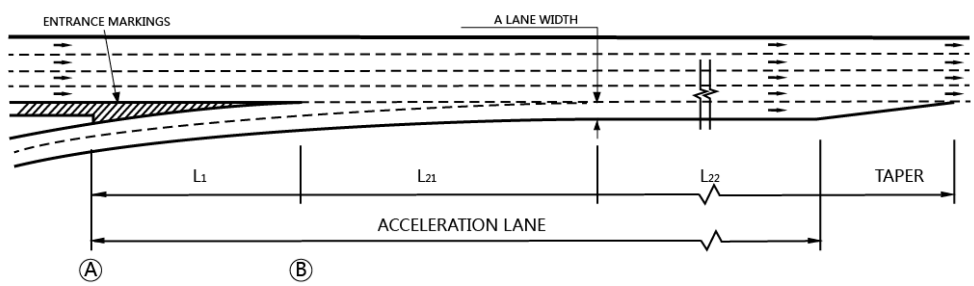
Current national standards and design specifications primarily are based on four-lane freeway. With growing number of eight-lane freeway, its design standard and management cannot meet the requirement of multi-lane freeway to some extent. This paper focuses on acceleration lane length of eight-lane freeway with two-lane ramp.

There are many studies about accelerate length calculation model. In Xu's research (Xu et al. 2007), the recommended acceleration lane length in Chinese design specification have not considered the traffic volume, and is shorter than the length needed as well. According to the traffic volume and the minimal acceptable headway in the mainline and acceleration lane, a new optimal design method of the acceleration lane length was presented in Zhi's study (Zhi et al. 2009). However, the merging model is on the assumption that vehicles search for a gap with uniform acceleration at the same time which doesn't fit the actual driving behaviors well. LI Shuo's study (Li et al. 2000) presents a new design philosophy on acceleration lane that the traffic volumes on mainline of freeway and on-ramp are considered in the computation of the acceleration lane length, which is significant to the engineering practice in the design of on-ramp especially when the mainline is in congestion.

Lane management to separate passenger car and truck is quite common in China, which may cause changes about speed and traffic flow distribution on each lane. Meanwhile, the drivers' behavior on two-lane ramp merging area have changed as well. Considering all the above, an acceleration length calculation model of eight-lane freeway with two-lane ramp is developed in this paper, with attention to the influence of drivers' behavior, eight-lane freeway traffic volume, and two-lane ramp as well.

2 Field Data Analysis of Influencing Factors

The acceleration lane is set to provide vehicles on ramp a considerable distance to accelerate to freeway speed and merge opportunities on the mainline. It is classified as either a taper or parallel type, according to the configuration of the ramp terminals and as either single or multilane, according to the number of the lanes on the ramp. In China, the most widely used type of the two-lane entrance ramp is the taper type, thus this paper focuses on the length of the two-lane entrance ramp in the taper type (Figure 1).



NOTES:
1. SPEED AT POINT A IS THE INITIAL SPEED OF THE ACCELERATION LANE
2. THE TOTAL LENGTH OF L21 AND L22 IS REQUIRED GAP ACCEPTANCE LENGTH.

Figure 1. Tapered design for entrance ramp

Constraints and decisions of the acceleration lane length diverse. Many factors should be considered, such as speeds, traffic volumes, percentage of trucks, capacity, lane management and so on. In order to provide scientific basis for modeling, headway distribution of the on-ramp merging region, speed at the ramp nose, driving characteristics were analyzed emphatically.

(1) Headway distribution of the on-ramp merging region

Based on investigation of a number of on-ramp merging region on the freeways in China, Li Wen-quan from Southeast University (Li et al. 2000) found that Erlang distribution can fit the headway data on lane 1 of on-ramp merging region through adopting suitable K values. The probability density function of Erlang distribution is written as:

$$f(t) = (\lambda K)^K t^{K-1} e^{(-\lambda K t)/(K-1)!} \quad (1)$$

Where K and λ are parameters of the probability density function and K is a positive integer which is decided by traffic volume.

In this paper, the Zhengyi Entrance of Freeway G42 is investigated, and the headway data on lane 1 at point B has been recorded. Chi-square test was applied at 5% level for 2° of freedom to see how closely the frequencies of the observed sample values agree with the expected Erlang distribution frequencies. As a result, the Chi-square test result suggested that there is no significant difference between the observed and negative exponentially distribution at 5% significance level.

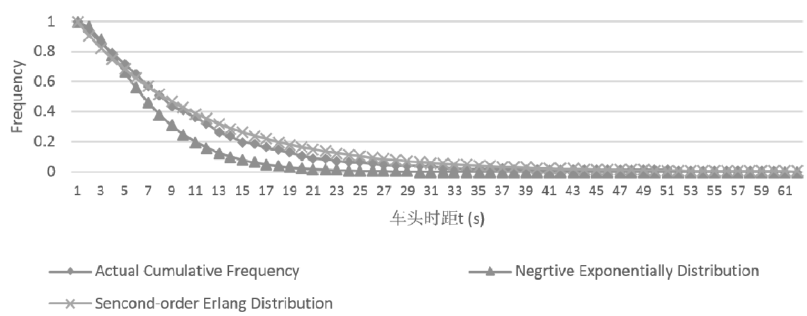


Figure 2. The Headway Frequency of lane 1 at Point B

(2) Initial Speed

In normal conditions, the noes is set as starting point of the acceleration lane, so we take the speed at the nose as initial speed. In the investigation, the actual measurement data of vehicles' speed (such as average speed, operating speed) is higher than the ramp design speed 60km/h, while the trucks' speed data is located around 60 km/h. Therefore, the design speed of ramp could be used as the initial speed of acceleration lane.

(3) Driving Behavior

Acceleration lane is divided into--accelerating, gap acceptance and triangle transition, three regions in most surveys in China. The research surveyed the on-ramp region of Zhengyi interchange (eight-lane freeway with two-lane ramp) to find which region the drivers would choose to merge. Investigation results show that the driving behavior is also affected by the entrance markings. Only 2.46% of drivers merge into the mainline crossing the entrance markings,compared with 81.57% for

L_{21} and 15.97% for L_{22}, which means that the drivers do not start to merge into the mainline traffic flow until the acceleration process is finished, but choose the proper gap to merge and adjust their speed at the same time when the entrance markings ends.

As a result, the on-ramp region is divided into three regions—the region marked with entrance markings (in length of L_1), the region where lane 1 connected with the inside lane of the ramp (in length of L_{21}) and the region where lane 1 connected with the outside lane (in length of L_{22}).

Furthermore, through the statistical analysis of the headway, the following conclusions have been drawn: (1) Drivers tend to merge after the painted nose. (2) When there is no acceptable gap to merge in L_{21}, drivers will go further to search. (3) More than 99% drivers will choose the headway more than 2.5 seconds (Figure 3). "Drivers(L21)" are the drivers whose merge point is on L_{21}, and Drivers(L22) are the drivers whose merge point is on L_{22} in figure 3.

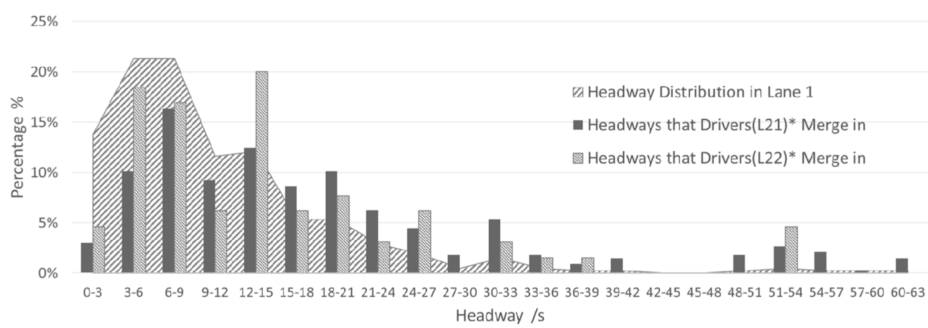


Figure 3.Frequency of headways that drivers merge in

3. Acceleration lane length calculation model

The analysis divided the acceleration lane into two parts:

- Entrance marking segment (Most of the drivers speed up only)
- Merging segment (Drivers may vary their acceleration behavior, slowing down to wait for a gap or speeding up to catch a gap)

3.1 Entrance marking segment

The minimum length of entrance marking segment is based on a combination of the following assumption:

- The drivers will enter the merging region at the ramp design speed.
- Drivers will accelerate with a constant comfortable rate.
- Because of the limitation of ramp grade, the minimum entrance marking length doesn't consider the longitudinal slope effect on acceleration.

Based on the assumptions described above, the following equation to determine the minimum length of entrance marking segment is put forward.

$$L_1 = \frac{V_1^2 - V_0^2}{2a} \tag{2}$$

Where, L_1——Entrance marking segment length, m

V_1 ——Merge speed, m/s

V_0——Initial speed on ramp， m/s

a——Acceleration rate， m/s^2

3.2 Minimum length of merging segment

The model to calculate the minimum length of merging segment is based on the gap acceptance theory. According to the results of the above, as well as the conclusion of research both in China and abroad (Torbic et al. 2012), this paper assign the critical headway (t_a) the value of 2.5 seconds, and makes the following assumptions to simplify the problem:

- Drivers will merge into the mainline when there is one or more acceptable gap on lane 1.
- Drivers will merge once there is an acceptable gap forward which means the headway is more than 2.5s.

The headway of vehicles on lane 1 is subjected to Erlang distribution. So that the probability of any gap is more than t_a is as follows.

$$p_c = f(Q_1, K) = P(h \geq t) = e^{-\frac{Q_1}{3600}t} \quad \text{（K=1）}$$

$$p_c = f(Q_1, K) = P(h \geq t) = \left(1 + \frac{Q_1}{900}t\right) e^{-\frac{Q_1}{900}t} \quad \text{（K=2）} \tag{3}$$

This research assumes that slower entry is unavoidable and is generally accepted by the public, so the probability that a vehicle could merge is set to be 0.95. Let e be the percentage of the vehicles which merge in through L_{21} and keep running on lane 1 at L_{22} region.

The probability of there are more than m headways longer than t_a in n headways could be expressed as: $p = \sum_{i=1}^{n} C_n^i p_c{}^i (1-p_c)^{n-i}$. When m=1, $p = 1-(1-p_c)^n$. The formula is the probability vehicles merge in is p. Furthermore, the length of n headways is

$$L = n \cdot h \cdot v_{85} = \frac{1000 v_{85}}{Q} n \tag{4}$$

Therefore, the model of minimum length (total length of the two ramp lanes) of merging segment could be expressed as a non-linear integer programming (NLIP).

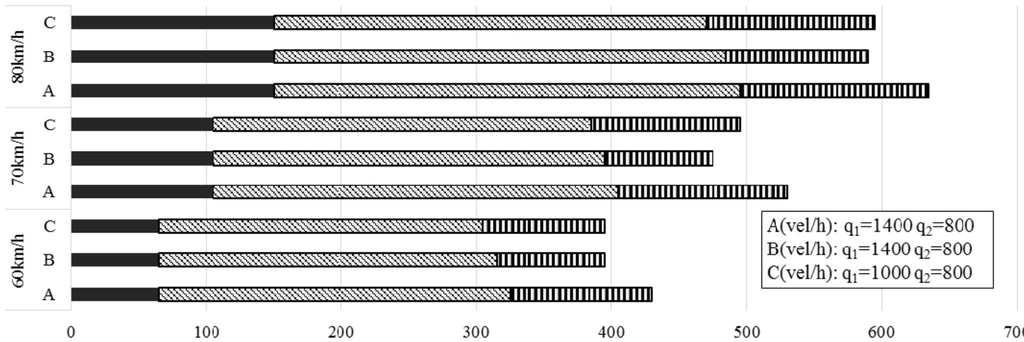
$$\begin{aligned}
\min \quad & 2\frac{1000 v_{85}}{Q_1} n_1 + \frac{1000 v_{85}}{Q_2} n_2 \\
s.t. \quad & p_{l1} + (1 - p_{l1}) p_{l2} \geq 0.95; \\
& p_{l1} = \sum_{i=1}^{n_1} C_{n_1}^{i} p_{cl1}{}^{i} (1 - p_{cl1})^{n_1 - i} = 1 - (1 - p_{cl1})^{n_1}; \qquad p_{l2} = \sum_{i=1}^{n_2} C_{n_2}^{i} p_{cl2}{}^{i} (1 - p_{cl2})^{n_2 - i} = 1 - (1 - p_{cl2})^{n_2} \\
& p_{cl1} = f(q1, K); \qquad p_{cl2} = f((q1 + q2 \cdot p_{l1} \cdot e), K)
\end{aligned}$$

Where p_{l1} and p_{l2} mean the probability of vehicles merge through L_{21} and L_{22}, $q1$ and $q2$ mean the traffic volume of lane 1 and ramp.

4 Discussion of Results

The trial results of the models above using several groups of representative data show that the minimum length of acceleration lane is more sensitive to operating speed than traffic volume. At the same time, because of the number of headways in the model is designed to be an integer, the more the traffic volume of main line, the smaller the required minimum length of acceleration lane within certain limits.

Comparing to the current specification, the code values of acceleration lane length cannot meet the vehicles' merging demand under secondary serve level especially when the operating speed is more than 80km/h.



	60km/h			70km/h			80km/h		
	A	B	C	A	B	C	A	B	C
■L1	65	65	65	105	105	105	150	150	150
L21	260	250	240	300	290	280	345	335	320
L22	105	80	90	125	80	110	140	105	125

Composition of The Minimum Acceleration Lane

■L1 L21 L22

Figure 3. The Composition of Acceleration Lane Length

5 Conclusions

(1) The drivers do not start to merge into the mainline traffic flow until the acceleration process is finished, but choose the proper gap to merge and adjust their speed at the same time when the entrance markings ends.

(2) Based on the gap acceptance theory, the minimum length calculation model of merging region is simplified as a non-linear integer programming (NLIP).

(3) The trial results of the models above using several groups of representative data show that the minimum length of acceleration lane is more sensitive to operating speed than traffic volume. And the current specifications' recommended values of acceleration lane length cannot meet the vehicles' merging demand under secondary serve level when the freeway is eight-lane and with two-lane ramp.

6 Recommendations for Future Research

The transportation flow distribution and traffic capacity of eight-lane freeway under different lane management need further investigation, especially the on-ramp lane, which is important to determine the recommended value.

Acknowledgement

This research was supported by the Science Foundation of Shanxi Provincial Communication Department (Project No.: 2013-1-21), and the Science Foundation of Guizhou Provincial communication Department (Project No.: 2014-121-025), the People's Republic of China.

References

Torbic, D. J., Hutton, J. M., Bokenkroger, C. D., & Brewer, M. A. (2012). Design Guidance for Freeway Main-Line Ramp Terminals. Transportation Research Record: Journal of the Transportation Research Board, 2309(1), 48-60.

Shuo, L. I., & Yang, Z. (2000). An application study of merging theory on designing acceleration lane for expressway. China Journal of Highway and Transport, 13(2).

Xu, Q. S., Ren, F. T., & Sun, X. D. (2007). Researches on the length of acceleration lane at freeway interchange. Journal of Beijing University of Technology, 33(3), 298-300.

ZHI, Y. F., ZHANG, J., & SHI, Z. K. (2009). Research on design of expressway acceleration lane length and merging model of vehicle. China Journal of Highway and Transport, 22(2), 93-97.

Hypermap Model for Geological Environment Recognition and Railway Location Technology

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Abstract: Based on the geological environment recognition of Hypermap Model and application technology of location design, and based on orthophoto map environment of remote sensing (RS), this thesis introducing the concept of Hypermap to the railway location system. Establishing Hypermap Model of railway location which based on geographic information, geology, and geological knowledge. Based on Extended-Catalog Structure Model to realize function which to store nonlinearly, organize, manage and browse the relationship between the information. Provide illustrations of geology, geography and geological knowledge environment for railway locating engineer, and to realize integration and application of remote sensing (RS) geological information system in three-dimensional railway location design.

Keywords: Hypermap; Railway location; Geological environment recognition.

1 Introduction

Three-dimensional geographic environment is the carrier to realize the design of railway location in virtual environment. It is an important problem in three-dimensional geographic environment modeling of railway location system that how to automatically or interactively provide railway location engineer with geographic, geological and hydrological information, and make these information more effective express, organization and application. Hypermap is a multimedia hyper-document with function of geographic data acquisition and we can get access to geographic data through geographical coordinates. The introduction of Hypermap's concept provides a more effective method for the understanding of the environment. Therefore, this paper is based on the remote sensing orthophoto map, establish the railway location's Hypermap model of geographic, geological and hydrological information in three-dimensional geographical environment. Based on Hypermap, to realize the storage, organization, management and browse of the nonlinear relationship between these information. Provided illustrations for railway location engineer with environment of geology, geography, and help railway location engineers to improve the efficiency of design in three dimensional environment.

2 The Concept of Hypermap

Laurini and Milleret-Raffort reference Hypertext and hypermedia thought, put forward the concept of Hypermap in 1990.They put map as the reference frame of a multimedia hyper-document's location, and applied to GIS. Hypermap is a combination of map and hypermedia. The connection between the map data and a variety of hypermedia data not only can through function interface or determined area on the map, but also search window. So it allows users to navigate multimedia data by themes or space. Maps and hypermedia express different data. Maps express the geoscience data but hypermedia express the non-geo-data information. Map can be used as a functional interface of hypermedia data. The way we determine the area on the map as hypermedia document information can through geographic coordinates. The retrieval way we can select a target or a regional on a map or define a window.

Hypermap theory through setting the node and hyperlinks to link different targets with way of hypertext; By the definition of nodes, to realize the obtainment of geographic information by hyperlinks and achieve management and organization of geographic information by a directory services. The concept of railway location Hypermap model which established in this paper include the Hypermap work area and Hypermap nodes. The following further is definition of these concepts.

2.1 The Hypermap work area

The Hypermap work area is a collection of the mainland layer in a certain area. As for railway location design in three-dimensional environment, it means that determine a region interactively or automatically, and all the geographical, geological and hydrological information and geological knowledge of this area.

2.2 The Hypermap nodes

As a special object, Hypermap node shows as link relations of a certain area of map or a space object. As for the three-dimensional environment of railway location design, node type is mainly the vector graphics Hypermap nodes of close geographic information relationship. Define hot zone in the image map as spatial scope of node response to of super chain. For the determine of hot zone there are generally 3 kinds of methods: set rectangular area, set the polygon area and set point, line, surface and other space objects. In which, a spatial region-wide of digital geological objects can be used as vector graphics Hypermap node directly.

3 The Hypermap Model of Railway Location in 3D Environment

3.1 The composition of model

From an object-oriented perspective, the Hypermap model of railway location in three-dimensional environment is the collection of spatial object (OS):

$$H = \{O_1^S, O_2^S, ..., O_n^S\}, i = 1,2,...,n \quad (1)$$

The spatial objects include objects of Hypermap work area: the geological object, corresponding geological knowledge, geographical, hydrological information, 3D geologic model and so on.

Every spatial object O^S includes four basic contents: the object identifier (ID^S), hypermedia (H^M), hypergraphics (H^G)and hyperlinks (H^L),expressed as:

$$O^S = \{ID^S, H^M, H^G, H^L\} \quad (2)$$

In the formula, ID^S is the unique identifier for the object; H^M on behalf of the non-geometric properties, the multimedia information such as graphics, images, 3D virtual reality; H^G representative geometric properties, such as spatial attributes and other numerical data. H^M and H^G together form the internal state of O^S; H^L is a collection of O^S method, and define the non sequential connection relation and collection of operation method between the internal object of O^S, between the object, between Hypermap and between the Hypermap inside.

3.2 Hyper-Catalog structure of model

Hypermap theory can through setting the node and the hyperlink, to link up different objects with hypertext links, and to relize the conversion of information. But like as hypertext, since the final result of hyperlink will be a complex and endless network topology. Therefore, in the case of having the information or jump too often, the structural relationship of linked is complex, and it is very inconvenient for information organization, so the efficiency is relatively low. The purpose of establishing Hyper-Catalog structure of Hypermap model is to apply the directory tree structure to the basic organization of information in Hypermap model. And with all kinds of object types as basic unit, set up a comprehensive organization structure and form of object-oriented. Putting all kinds of objects into the same concept frame, unified organization and management by Hyper-Catalog structure, and provide directory index which has function of rapid positioning.

According to the type of each object in the work area of Hypermap, organized the node by the directory tree. Every kind of geological object and its corresponding geological knowledge consists of a class, as shown in figure 1.

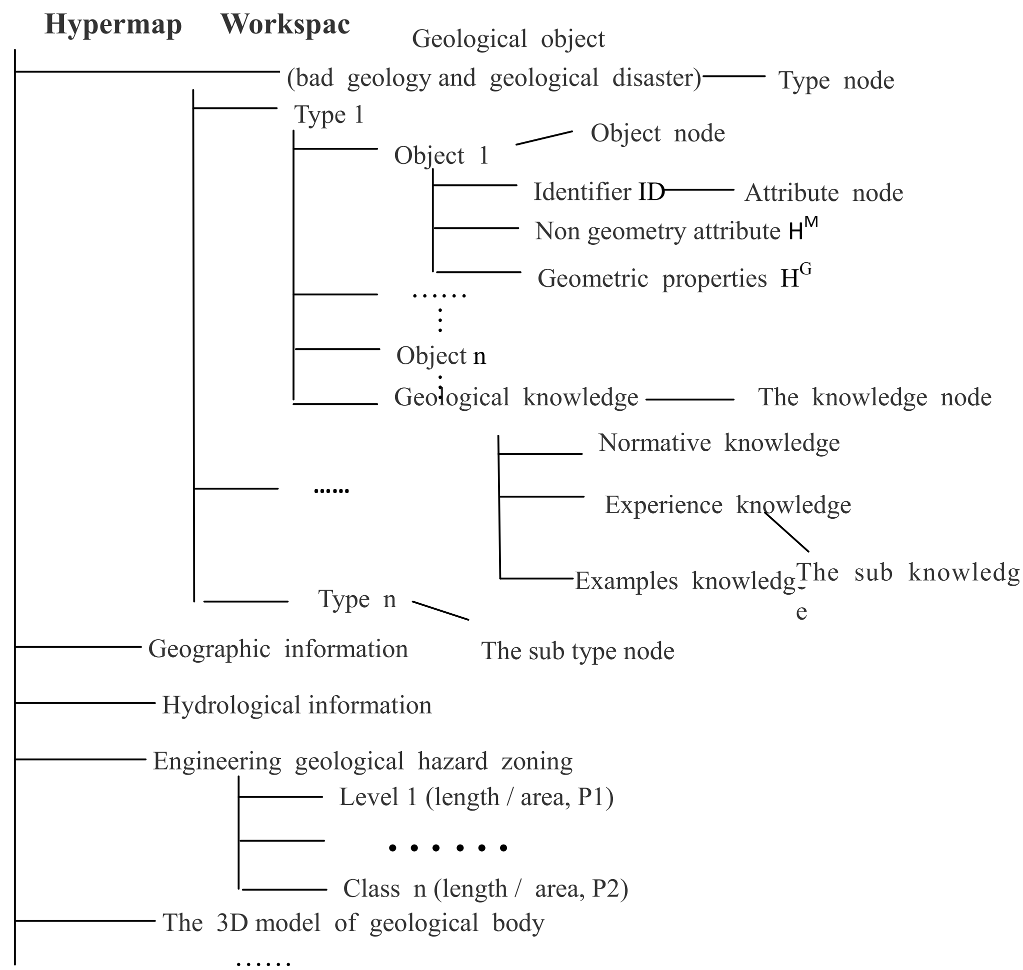


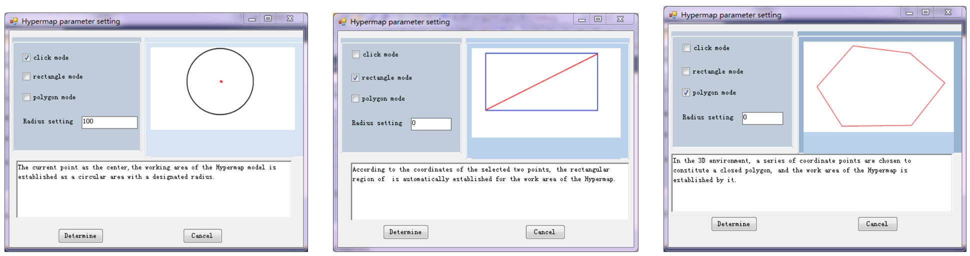
Figure 1. Hyper-Catalog structure of Hypermap model

4 Geological Environment Recognition Based on Hypermap Model

The Hypermap model of railway location in 3D environment is built in a Hypermap work area, and using Hyper-Catalog structure to organize and manage all objects (information) in the work area. Therefore, the premise of establishing Hypermap model of railway location is to establish Hypermap work region, and the premise to establish Hyper-Catalog work area is to determine the scope of regional.

4.1 Three ways of establishing Hypermap work area

Railway location engineer uses the mouse to determine interactively a closed region as the range of Hypermap work area in three-dimensional geographical environment. Then retrieval all relevant information which located in the region: the geological objects, corresponding geological knowledge and geographic hydrology and so on, and to establish Hypermap model. Classifing information, and establishing Hyper-Catalog structure, and use the Hyper-Catalog to organize and manage these objects (information). Railway location engineers can analyze and evaluate the regional geology, geography ,hydrology and other information. Determine interactively the regional range of Hypermap work area mainly in three ways: click, rectangle and polygon mode. In Fig2, (a), (b) and(c), diagram is presented.



(a) (b) (c)

Figure 2. Determine interactively the Hypermap work area – click mode, rectangle mode and polygon mode

4.2 The geological environment recognition based on Hypermap model

Recognition of geological environment based on Hypermap model also namely spatial geological objects recognition, and the problems is how to judge geological objects and other related information of railway location in the scope of working area. The way to judge by point selection mode are simple, and can be converted to the problem that judging the distance between point; The way to judge by mode of set rectangular and polygonal interactive involves to straight line, polygon and polygon spatial relation judge problem. The above two types illustrate respectively as follow.

(1) Relationship's judgment between points

Judging the distance (D) between the geological objects boundary coordinates of space and the center of a circle. If it is less than or equal to the radius(R), then can conclude the object is located in the work area. The process can be used the following pseudo code representation:

```
for(long i=1;i<=M;i++)
{for(long j=1;j<=Conpts(i);j++)
  {dij=GetDistence(Pti, j,Pcenter)       // solving for the distance between the j-th point of the
                                          // i-th geological objects border and the center
      if(dij<=R) // If less than or equal to R
      {
            SaveToArray(); // Save the geological object information
```

```
                    break;                  // to exit the current judgment of i-the geological object
                }
            }
        }
```

(2) Relation's judgment between line, polygon and polygon

Through the algorithm in this paper the problem that a straight line, polygon and polygon relation judgment can be converted to the point and polygon spatial relation judgment problem. As long as one point of the geological objects boundary in working area or on the boundary of polygon range, it can be considered that geological objects are in the work area. The process can be used the following pseudo code representation:

```
for(long i=1;i<=M;i++)
{
   for(long j=1;j<=Conpts(i);j++)
   {
      // solving if the j-the boundary point of i-the geological objects is located within the
      //workspace or on the boundary of the polygon
      BOOL m_bIn=PtInRegion (Pt_{i, j},*Pts)
      if(m_bIn==TRUE)        // If located inside or on the boundary
      {
            SaveToArray();     // Save the geological object information
            break;             // To exit the current  judgment of i-th geological object
       }
   }
}
```

5 The Application Based on Hypermap Model of Railway Location

Through the geological environment recognition technology of Hypermap model, railway location engineers will be able to identify the geological environment interactively. And the geological information will be provides to the railway location engineer with Hypermap mode. Figure 3, Figure 4 and Figure 5 shows an application example click, rectangles and polygons way, Figure 6 shows the application examples of Hypermap model.

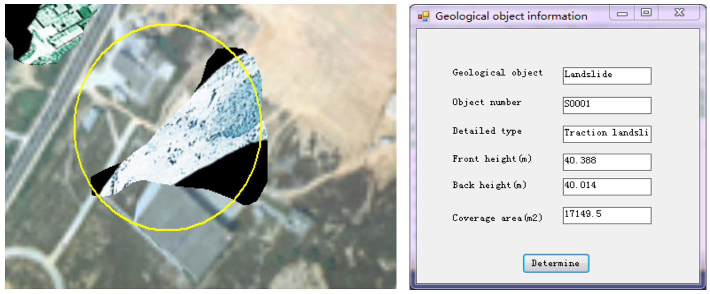


Figure 3. Hypermap model – the application of point selection mode

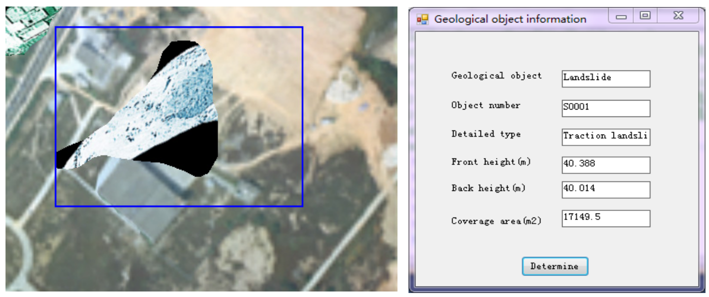


Figure 4. Hypermap model – the application of rectangles mode

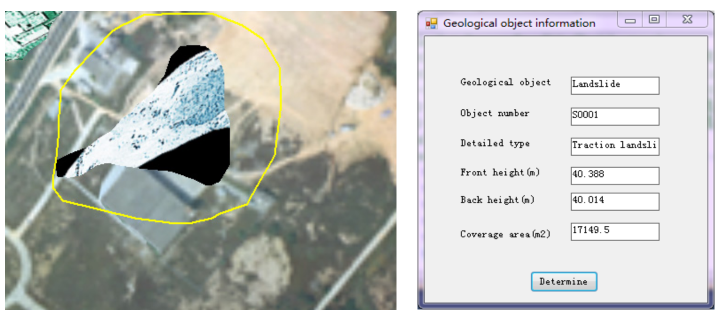


Figure 5. Hypermap model – the application of polygon mode

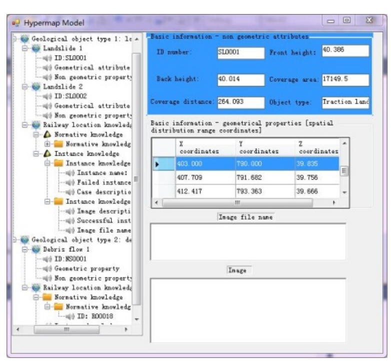


Figure 6. Application example of Hypermap model

6 Conclusions

This paper based on remote sensing images orthophoto map environment, introducing the concept of Hypermap to the railway location system. The Hypermap model of railway location is established based on geographic information, geology, and geological knowledge. To realize the relationships' non-linear storage, organization, management and browsing between the information based on Hyper-Catalog structure model. Provide engineers with illustration of geological, geographical and geological knowledge environment. To realize the integration and application of remote sensing geology information system in 3D railway location.

Acknowledgement

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References

Hall W, Davis H, Hutchings G.(1996) "Rethinking hypermedia: The microcosm approach". *Boston: Kuwer Academic Publishers*.

KorteG B(1997). "The GIS book[4th Ed][M].Santa Fe": *On Word Press*.

Kraak, M. J. Van Driel, R.(1997) "Principles of hypermaps." *Computers & Geosciences*, 23(4): 457-464.

WANG Yingjie and YUAN Kansheng(2003)."Multidimensional Dynamic Earth Science Information Visualization.". *Science Press*

YI Sirong, ZHUANG Haizhen and HAN Chunhua (2005)."Knowledge acquisition of line selection system and alignment guidance expert hypertext model." *Railway Survey* (1): 1-4

BRT Approach Capacity Calculation Method at an Intersection in an Elastic Route BRT System

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Abstract: Bus rapid transit is one of the best ways to improve urban transit. However, how to integrate the traditional bus and BRT is a problem that limits the efficiency of BRT system. Elastic route BRT system is a new BRT mode, which allows the BRT buses turn into or turn out of the bus lane at intersections. This paper puts forward a BRT approach capacity calculation method at intersection in Elastic route BRT system based on the data of Guangzhou BRT. And a case of Guangzhou BRT is studied to verify the validity developed method.
Keywords: BRT lane capacity; Elastic route BRT system; Saturation flow rate.

1 Introduction

Elastic route BRT system is an open system that allows BRT turn into or out of the BRT lane at intersections. The elastic mode ensures the connection of BRT and normal buses, and also makes the bus route more flexible. Meanwhile, there are some places that buses and cars share one lane, which makes the capacity influence factors of BRT approach become more complex. According to the current study, the researches of BRT capacity mainly concentrate on bus lane, including main factors of bus lane capacity (*Transit Capacity and Quality of Service Manual-3rd Edition*), large vehicle correction factor which influences the capacity of intersection approach (*Zhao Jing, 2008*), approach capacity model (*Code for design of municipal road* and *HCM*). The approach capacity is the maximum number of vehicles in one approach passing through the intersection in unit time. As an important part of BRT capacity, the intersection is the bottleneck. The actual BRT approach capacity at intersection is significant for completion of the intersection capacity model, bus line arrangement and reference to capacity design.

2 Analyses of Influence Factors

Four factors influence the capacity: road condition, traffic condition, management and control condition and environment condition. This paper supposes that the road condition of intersection approach basically conforms to the construction specification and the environment condition is good, so it mainly focuses on traffic condition and management and control condition. This paper places emphasis on these factors: the lost time and dwell time that influence the effective green time, and traffic composition and turning proportion that influence the saturation headway.

2.1 Lost Time of Bus Signal

(1) Front Lost Time

Figure1 shows the headway counting from the second queuing bus in each cycle.

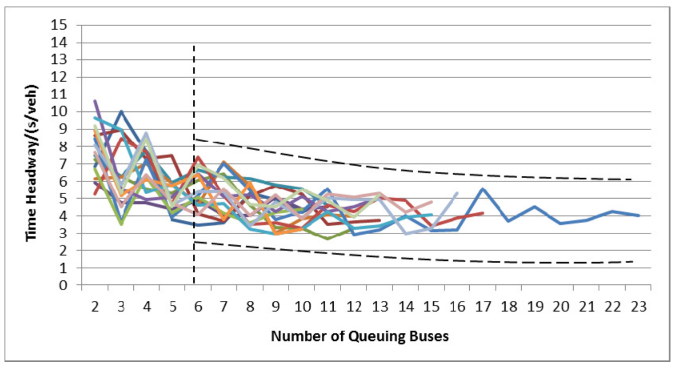


Figure1. Headway series of signal cycles

The cartogram shows that the headway of the first four buses is longer and scattered, caused by the differences in driver's response time and starting time. It becomes shorter and gradually tends to steady value starting from the fifth bus. It can be inferred that the average headway calculated from the fifth bus is more approximate to the saturation headway. Therefore, the green time subtracts the sum of first four buses headway, the time left can be regarded as the effective time of saturation flow rate.

This paper aims at building the actual capacity model, so the front lost time is divided into two parts: starting lost time of the first bus and lost time of the first four buses running at non-saturation headway. The first vehicle in a fleet composed of BRT and other social vehicles is random. It could be a BRT bus or social car, and the probability depends on the ratio of bus or car. Statistics shows that the average starting lost time of BRT is $t_{FLB} = 2.43s$ while the car's is $t_{FLC} = 1.1s$. Then, a linear equation about bus ratio and front lost time can be obtained.

$$t_{\mathrm{FL}} = 2.4\rho_{\mathrm{B}} + 1.1\rho_{\mathrm{C}} = 1.3\rho_{\mathrm{B}} + 1.1 \tag{1}$$

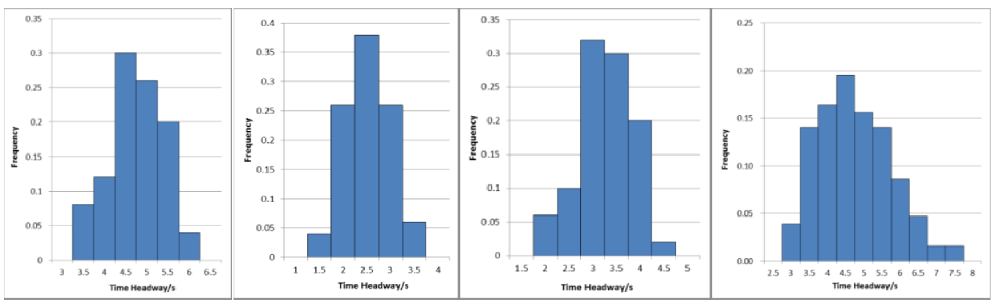
(2) Back Lost Time

The back lost time can be defined as the time that the last vehicle takes subtracts saturation headway. $t_{BL} = t_L - h_t$. Statistics tells the fact that when vehicles pass the intersection in queue, the average time is 3s from the last vehicle passing the stop line to the red light turning on. Comparison with the average headway obtained by field data shows that this 3s is less than average headway and the back lost time does not exist.

2.2 Traffic Composition

Traffic composition has great influence on saturation headway. This paper divides the queuing vehicles into two parts: the operating initial stage is the process of first four vehicles passing the stop line, and the steady stage is for the rest vehicles. The average headway of these two stages should be calculated separately.

There are four vehicle following patterns in a fleet composed of BRT and social vehicles. According to the field investigation, the headway of these four patterns is different.



(a) (b) (c) (d)

Figure2. Cartograms of four following patterns

(a) The headway of car following bus. (b) The headway of car following car.

(c) The headway of car following bus. (d) The headway of car following car.

The distribution of these four vehicle following patterns are all basically similar to normal distributionX~N(μ, σ^2). The average headway of each following pattern is obtained.

Table1. Average Headway of Four Following Patterns on Steady Stage

Vehicle following pattern	Car following bus	Car following car	Bus following bus	Bus follo- -wing bus
Average headway（s）	4.01	1.98	2.86	4.49

(1) Headway of operating initial stage

Figure3 shows the sum of first four buses' headway in BRT-only fleet in fifty signal cycles. The average of the sum is $t_{H4} = 22.91s$, so the average headway of buses on the operating initial stage is $h_t = 5.73s$.

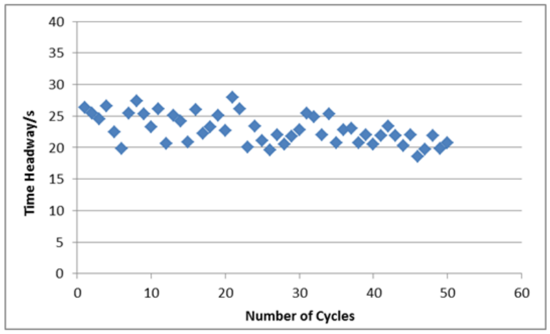


Figure3. The sum of first four buses' headway scatter diagram

According to the rules of permutation, there are 32 combinations of different probabilities for the first five vehicles. The fifth vehicle which determines the last following pattern is taken into consideration. The probability of type of vehicles arriving at the intersection can be regarded as the ratio of such type in queue, which means the probability of following vehicle's type won't change with the type of vehicles ahead. The product of sum of the first four vehicles' headway and its probability is the headway of each combination. Thus the average sum of headway of each traffic proportion can be obtained by the headway of all 32 combinations.

$$t_{H4}{}' = \sum_{i=1}^{32} P_i \times (t_{H4})_i \qquad P_i = {\rho_B}^n \times (1-\rho_B)^{5-n} \qquad (2)$$

(n is the number of bus in the first five vehicles)

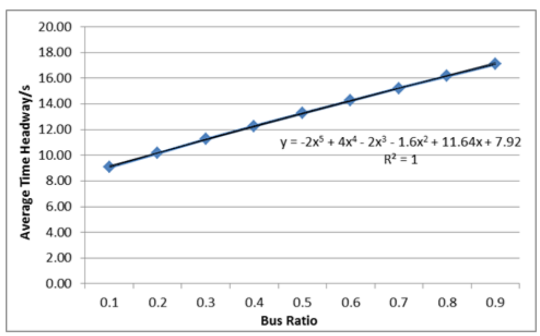


Figure4. Function of bus ratio and the sum of the first four vehicles' headway

Although the coefficient of determination is less than the quantic polynomial, linear fitting method can be used to simplify the computation.

$$t_{H4}{}' = 10\rho_B + 8.2 \qquad (3)$$

The conclusions above derive from the data of steady stage which is not suitable for operating initial stage. It is difficult to collect the first five vehicles' headway of different combinations, and the sample size is too small to support a fitting function. When there are all buses in line, which means$\rho_B = 1$, the headway of operating initial stage is 1.28 times more than that of the steady stage. This conclusion can be used here to simply deduce the headway equation on operating initial stage.

$$t_{H4} = 1.28 \times t_{H4}{}' = 12.8\rho_B + 10.5 \qquad (4)$$

(2) Headway of steady stage

Headway of the second stage – steady stage depends on the ratio of different vehicle type too. But because of the large amount of queuing vehicles and possible combinations, only the probabilistic method can be used to estimate.

The probability of bus following bus: $P_{B+B} = \rho_B^2$;
The probability of car following bus: $P_{B+C} = \rho_B \times \rho_C$;
The probability of bus following car: $P_{C+B} = \rho_C \times \rho_B$;
The probability of car following car: $P_{C+C} = \rho_C^2$.

The average headway of steady stage can be calculated by the equation below:

$$h_t = \rho_B^2 \times t_{B+B} + \rho_B \times \rho_C \times t_{B+C} + \rho_C \times \rho_B \times t_{C+B} + \rho_C^2 \times t_{C+C}$$
$$= -0.4{\rho_B}^2 + 2.91\rho_B + 1.98$$

The equation can be linear fitted for the purpose of simplification.

$$h_t = 2.51\rho_B + 2.05 \tag{5}$$

2.3 Dwell Time

The distance between the bus stop and intersection influences the effective green time. When the distance is short, queuing vehicles probably extend to bus stop and result in the dwell delay of following buses. These buses can't move into the stop until queuing vehicles dissipate out in green phase, which affects the full use of green time.

Assume D as the distance between the bus station platform and stop line of intersection approach, t_s as the lost green time(Wang Qian, 2003), t_R as the length of red phase. t_T represents the time bus stopping and starting in the stop and t_a represents the bus arriving time in one cycle. The arrival curve of buses is defined as a(t), and the leaving curve is l(t). The maximum queue length forms in the final stage of red phase, $L_{max} = a(t_R) - l(t_R)$.

Table2. Relationship of Distance and Lost Green Time

Distance	Situation No.	Time Arriving at Stop	Time Leaving Stop	Lost Time (t_s)
D>L_{max}	-	-	-	0
D>L_{max}	a	During Red Phase	During Red Phase	0
	b	During Red Phase	During Green Phase	$t_T - (t_R - t_a)$
	c	During Green Phase	During Green Phase	t_T

The probability of each situation changes with the distance. As the distance is not the main part of data collection, this paper does not emphasize the evaluation research on it but provides a thought here. Assuming the probability of each situation is 1-b%-c%, b% and c%, the average lost green time can be obtained by following equation.

$$t_s = [t_T - (t_R - t_a)] \times b\% + t_T \times c\% \tag{6}$$

2.4 Turning Proportion

When straight going and left-turn traffic share one lane, turning proportion has great influence on the value of headway since the headway of left-turn traffic is longer than that of straight going traffic. Based on the analysis of a large amount of straight going and left-turn traffic data, it can be concluded that the headway of left-turn traffic is 1.15 times longer than that of the straight going traffic. The headway of bus turning left is $h_{tl} = 4.49 * 1.15 = 5.16$, according to data above. Assume the turning proportion is ρ_l and straight going proportion is ρ_s, the average headway can be express as:

$$h_t = 5.16\rho_l + 4.49\rho_s = 0.67\rho_l + 4.49 \tag{7}$$

3 Capacity computation model

3.1 Computation of Saturation Flow Rate

Saturation flow rate is the per unit time flow that traffic continuously flows at the saturation headway under the condition without signal control. Saturation flow rate is equivalent to the steady value of Webster saturation flow rate curve.

$$\mathrm{S} = \frac{3600}{h_t} \tag{8}$$

The influence factors of headway mentioned in the last chapter include traffic composition and turning proportion. Assume the correction factor of traffic composition is f_C. It can be obtained by the way the linear function divide the average headway of straight going bus -- $h_t = 4.49$s. ρ_B represents the bus ratio in arriving traffic.

$$f_C = \frac{h_t}{h_t{'}} = \frac{4.49}{2.51\rho_B + 2.05} = \frac{1}{0.56\rho_B + 0.46} \tag{9}$$

And there is also a linear relation between saturation headway and turning proportion. The defined correction factor of turning proportion --f_{LT} can be obtained by division too. ρ_l is the proportion of left-turn traffic.

$$f_{\mathrm{LT}} = \frac{h_t}{h_t{''}} = \frac{4.49}{0.67\rho_l + 4.49} = \frac{1}{1 + 0.15\rho_l} \tag{10}$$

The corrected equation of saturation flow rate is as follows.

$$\mathrm{S} = f_C \times f_{\mathrm{LT}} \times \frac{3600}{h_t} \qquad (f_C = \frac{1}{0.56\rho_B + 0.46};\ f_{\mathrm{LT}} = \frac{1}{1 + 0.15\rho_l}) \tag{11}$$

3.2 Computation of Capacity

The capacity model is also corrected by another way – refining effective green time. So the BRT approach capacity model at intersection is corrected as the equation below.

$$\mathrm{C} = \mathrm{S} \times \frac{t_{EG}}{T} = \mathrm{S} \times \frac{t_g - t_{FL} - \Delta t_{H4} - t_S}{T} \tag{12}$$

t_g is the time of green phase. t_{FL} refers to the starting time of the first vehicle. t_s is the symbol of dwell time. Δt_{H4} represents the lost time of the first four vehicles. The actual time from the first vehicle passing the stop line to the fifth is different from the total time of these first four vehicles running at saturation headway. And the difference is the lost time.

$$\Delta t_{H4} = t_{H4} - 4 \times h_t$$
$$= 12.8\rho_B + 10.5 - 4 \times (2.51\rho_B + 2.05) = 2.76\rho_B + 2.3 \quad (13)$$

This paper counts by headway, and the last vehicle may not be included in when its passing time is shorter than the average headway. So the decimal acquired by the equation carries into integer to make up for this problem. The capacity model is shown below.

$$\mathrm{C} = \mathrm{S} \times \frac{t_{EG}}{T} = \mathrm{S} \times \frac{t_g - t_{FL} - \Delta t_{H4} - t_s}{T} = \mathrm{S} \times \frac{t_g - 4.06\rho_B - 3.4 - t_s}{T} \quad (14)$$

The complete capacity model is:

$$\mathrm{C} = \mathrm{S} \times \frac{t_{EG}}{T} = f_C \times f_{\mathrm{LT}} \times \frac{3600}{h_t} \times \frac{t_g - 4.06\rho_B - 3.4 - t_s}{T}$$
$$\left(f_C = \frac{1}{0.56\rho_B + 0.46};\ f_{\mathrm{LT}} = \frac{1}{1 + 0.15\rho_l}\right) \quad (15)$$

Assume there is an intersection, the BRT approach capacity at intersection with each bus ratio and turning proportion under the assumption above. ($t_s = 0$,T = 225s,$t_g = 60$s,$h_t = 4.49$s)

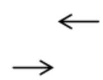
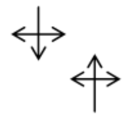
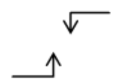
Table3. BRT Approach Capacity at Intersection with Each Proportion

B:C \ L:S	1:9	2:8	3:7	4:6	5:5	6:4	7:3	8:2	9:1
1:9	382	377	371	366	361	356	351	346	342
2:8	342	340	333	328	323	319	315	310	306
3:7	310	310	301	296	292	288	284	281	277
4:6	282	284	274	270	266	263	259	256	252
5:5	259	263	251	248	244	241	238	235	232
6:4	239	244	232	229	226	222	219	216	214
7:3	222	228	215	212	209	206	203	201	198
8:2	206	214	200	198	195	192	189	187	184
9:1	193	202	187	185	182	180	177	175	172

4 Case Study

Gangwan Road and Zhongshan Avenue intersection is located in the eastern section of Guangzhou BRT corridor. There is a straight going BRT lane and a left-turn mixed-traffic lane in one approach of this intersection. The BRT and social vehicles are under the same signal control. The time of amber light at this intersection is 3 seconds, and cycle time is 153s. The signal phase and phase sequence is shown below.

Table4. the Signal Phase and Phase Sequence

Phase	Phase 1	Phase 2	Phase 3
Phase Diagram			
Time	49s	50s	45s

Apply 3 different models including the model acquired in this paper to the capacity computation of this case, and compare the result to actual capacity data of field measurement.

(1) Measured Actual Capacity

The volume of vehicles in the mixed-traffic lane passing through the intersection in one cycle is 16 on average.

$$C_0 = \frac{3600}{T} * 16 = 376.5veh/h \cong 377veh/h$$

(2) Capacity Computed by the Model Acquired in This Paper

Substituting $t_s = 0$, $h_t = 4.3$, $T = 153$, $t_g = 45$ and $\rho_B = 0.1$ into the new model, the capacity is obtained as follows.

$$C_1 = 379.6veh/h \cong 380veh/h$$

(3) Capacity Computed by the Model in Code For Design Of Municipal Road

The *Code for design of municipal road* provides a capacity model of intersection approach lane shared by straight going and left-turn traffic. Because there is no straight going vehicle in this lane mentioned here, β_l' is equal to 1. According to the value recommendations in the standard manual, $t_0 = 2.3$ and $t_i = 2.55$. Substituting $\mathrm{T} = 153$ and $t_g = 45$ into the equation above, the design capacity of this left-turn mixed-traffic lane is shown below.

$$C_2 = \frac{3600}{T}\left(\frac{t_g - t_0}{t_i} + 1\right)\varphi * \left(1 - \frac{\beta_l'}{2}\right) = 187.89veh/h \cong 188veh/h$$

(4) Capacity Computed by the HCM Model

The *Highway Capacity Manual* provides the following equation.

$$S = S_0 \times N \times f_w \times f_{HV} \times f_g \times f_p \times f_{bb} \times f_a \times f_{RT} \times f_{LT}, (S_0 = 1800\mathrm{ve}h/h)$$

In this case, $f_w = 1 + (\mathrm{W} - 3.6)/9 = 0.99$, $\mathrm{f_{HV}} = \frac{100}{100+\%HV*(E_r-1)} = 0.91$, $N = 1$ and other coefficients are all equal to 1.

$$C_3 = 476.9\mathrm{ve}h/h \cong 477\mathrm{ve}h/h$$

After comparing the 3 models above, it is obvious that the result of model obtained in this paper is closer to the actual capacity, so this model is more appropriate to compute the BRT approach capacity at intersection.

5 Conclusions

This paper uses samples collected from Guangzhou elastic route BRT system to analyze the influence factors of entrance lane capacity, and build a BRT approach capacity model at intersection based on these factors. The model makes it possible to compute the lost time and makes the Webster saturation flow rate curve equivalent to step function.

Acknowledgements

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References

Hu Feiyu. (2010) Capacity of BRT Bus Lane and Route Wiring Optimization Study: South China University of Technology.

Li Zhiping. (2010) Capacity Study of Urban Signalized Intersection: Chang'an University.

Shui Wenbing. (2007) Study of BRT Bus Lane Capacity: Kunming University of Science and Technology.

Wang Qian, Yang Xiaoguang. (2003) Impact of Bus Stops on Delay and Capacity of Shared Approaches at Signalized Intersections: China Civil Engineering Journal; (01): 58-63+74.

Zhao Jing, Yang Xiaoguang, Bai Yu, Lao Yunteng. (2008) The Impact of BRT Entrance Lane on Signalized Intersection Capacity: Urban Transport of China; (05): 74-9.

Integrated Simulation Platform of VISSIM, VC ++, and MATLAB

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Abstract: With the development of intelligent transportation system, more and more traffic events need to be tested through modeling and simulation. In this paper, C++ as the main programming language, builds simulation platform through integrating MATALB and VISSIM. It solves the problem that it's difficult to do the secondary development of VISSIM directly and program for solving model of complex problems. The method combines the VISSIM software simulation's good effect, MATLAB's powerful calculation ability and the relevant advantages of C++ programming. On the one hand, the VISSIM and C++ editor can exchange data through VISSIM COM. On the other hand C++ can call MATLAB dynamic link library to implement the hybrid programming. The simulation platform which is used to establish by this method provides a new way for building and solving traffic management and control modes. Finally, according to the platform, this paper studies a case related to theories and applications of transport information granular computing.

Keywords: ITS; Simulation platform; VISSIM COM; VC++; MATLAB dynamic link library.

1 Introduction

In recent years, with continuous development of traffic theory of artificial intelligence, especially the big data applications, offers a new approach to study traffic management and control. Fuzzy control, neural network, genetic algorithm and ant colony algorithm and other various theories are increasingly upsurge, in the field of traffic control. But the key technical difficulties attendant is how to achieve control model, and, how to verify the model. The summary from the theory, in order to achieve and verify the control model there are three kinds of methods. The first, the model applied in practice, verified it by the field observation data, this is the most direct and most effective verification method, but it's the high cost, high risk. The second method, calculated using the mathematical theory, this method is rapid and convenient, but it simplifies the complexity of the traffic flow, reduce the credibility of the control effect. The third method is the simulation method, it's based on the programming or computer software, simulate the real scene, get the evaluation report, data analysis. But the program or software could accurately simulate the operation law of the actual traffic flow, reflect the traffic characteristics. With the advent of the mature traffic simulation software, TSIS, VISSIM, TransCad and so on, moreover, scholars continue to explore these simulation technology, the software already can effectively simulate the traffic flow. Using traffic simulation technology to verify the effect of control, has become the most effective method of peer recognition.

Chen Dewang, Cai Bogen, Wu Jianping have studied integrated construction technology of TSIS, VC, MATLAB interface traffic control simulation platform. Chen Qian, Jean Jiang Yu, Wang Wei integrated the external program VC prepared with TSIS using the interface principle of traffic dissipation, large activities conducted by simulation, to simulate of large activities traffic dissipation. Li Wenyong, Chen Xuewu integrated the TSIS and VC by using the interface principle, simulation of the traffic guidance.

The research object of this paper is the microscopic traffic simulation software, VISSIM. VISSIM has become the main traffic flow simulation software, appeared in the China traffic field since 2001. VISSIM is the most widely used in the field of traffic simulation, but VISSIM software modification based on the model parameters and VISSIM secondary development research is less. In 2010, Zhang Yu, Yu Lei studied the function of SPSA algorithm in the parameter calibration in VISSIM. In 2010, Xie Zhengquan made a study on the application of real-time data traffic simulation technology based on VISSIM. In 2012, Zhang Qinghua, Ja Limin, made a study on calibrating VISSIM microscopic traffic simulation model. In 2012, Lu Shoufeng, Wei Qin made a study of integration VISSIM, Excel VBA and MATLAB simulation platform using VISSIM secondary development technology, but it isn't fully exert the MATLAB calculation ability, at the same time, the VBA language cannot be widely used, in object-oriented programming.

In this paper, based on VISSIM COM interface technology, the master program is VC++, mixed with the MATLAB programming and interacted with the data of VISSIM, so as to establish a simulation platform, integrated VISSIM, VC++ and MATLAB, It aims to expand the VISSIM simulation function, at the same time play a MATLAB powerful numerical computation ability and the advantage of C++, make traffic control model are easier to implement.

2 Introduction of VISSIM

VISSIM is developed by PTV Corporation in Germany, a micro simulation modeling tool, based on the time interval and driving behavior, modeling for city and highway traffic. It is suitable for various modes of transportation such as personal transport, railway, walk, bike and Metro etc... It can simulate traffic conditions in all kinds of microscopic traffic conditions (lane, traffic composition, traffic signal, bus stops, etc…), VISSIM are divided into two modules: traffic simulation module and signal control module. In the traffic simulation module mainly include car following model and lane change model. Signal control module mainly extract traffic information from the detector, with 0.1 second time interval, used to identify and change the current and the next state of the signal lamp.

The use of VISSIM is divided into 3 grades according to the technical difficulty. The first is the primary use, modeling and evaluation is completed by using the basic toolbox of VISSIM. The second level is the intermediate use, complete the inductive control, using VAP module of VISSIM itself. The third level is the advanced development, realize the real-time traffic data interaction, intelligent traffic control and dynamic traffic assignment, using the COM interface provided by VISSIM and programming.

3 VISSIM and VC++ interface technology

In order to realize the external model algorithm, feature attribute, solve the user personalized control, PTV company developed the COM interface technology of VISSIM, it supports Microsoft Automation, the user can apply Rapid Application Development, scripting languages can be docked (Visual Basic or Java), programming environment can be docked(Visual C++). COM interface provides many objects list(Links， Nodes， Vehicles ,simulation…) Each object has a corresponding control method and data extraction function. For example, ‘links’ represents a collection of all the road simulation, it provides a "Get link By Number" taken out of each section of the link object, the further you can call the density （Speed, volume, simulation time , simulation lane…） of road evaluation.

COM module with the function of a library, can obtain and change almost all the impact factors of VISSIM simulation. The COM interface supports many programming languages, such as Java and Python. In this paper, the language used is C++, the main idea is to use C++ to do the external driver, create your own car type, using the external driver to achieve the related traffic management and control model.

Through the Visual C++ compiler, users can use the #import command to make the Visual C++ compiler to obtain VISSIM objects. A user may use no_namespace of this command options, if the user does not want to use a namespace to VISSIM COM server. Or the user can input VISSIM_COM Server.tlb, to achieve the same effect. Operating on the COM object, use this command to direct call Microsoft specific smart Pointers. When using other compilers, instead of using the Microsoft Visual C++, must adopta more standard way to invoke the COM component. The VISSIM_COMServer.h file and VISSIM_COMServer_i.c file contain the description of VISSIM server interface standard for C++ coding. The effects of preprocessing directives include these files or VC++ #import are similar. The language commands are #include "VISSIM_COMServer.h", #include "VISSIM_COMServer_i.c".

Now using the VISUAL STUDIO editor C++ language is the most widely, if using VISUAL STUDIO in VISSIM secondary development, it can be divided into four steps.

(1) Open a new project in Visual Studio. Choose Console Application.

(2) A COM program example to load VISSIM network and start the simulation (copy the code below into the vissim_c.cpp file)

(3) Build project: Build/Build Solution

(4) Start simulation is Debug mode from Visual Studio or by the created exe file (…\debug\ProjectName.exe).

4 VC++ and MATLAB mixed programming

MATLAB has strong ability of numerical computation and analysis, and high-level programming language of C++ is the most popular, the hybrid programming combined with both of them is very vital significance in scientific research and engineering practice. In the engineering practice, the methods C++ calling MATLAB mainly include calling MATLAB engine, C++ files with m file conversion, and DLL files generated when call m.

(1) The MATLAB engine library provides some interface functions for user, using these interface functions, the user can call MATLAB file as calculating engine in their own program. The method uses MATLAB engine to connect MATLAB and C++, adopting the client/server mode. In practical applications, the C++ as a client, MATLAB as a local server. C++ program transmit commands and data information to the MATLAB calculating engine, and receive the data information from the MATLAB calculating engine. MATLAB offers the following C++ engine functions for users: engOpen, engClose, engGetVariable, engPutVariable, engEvalString, engOutputBuffer，engOpenSingleUse, engGetVisible, engSetVisible. The user can call these interface function in the foreground program, to control of the MATLAB Engine. Using this method can almost use all function of MATLAB, but need to install MATLAB software in the machine, and the execution efficiency is low. Therefore, this method is not used in practice, it is suitable for personal use or demonstration.

(2) MATLAB Compiler is the role of the m file transform into the C++ (known as the MCC command), this source code needed to use C++ compiler to transform into a standalone application, then m files transform into independent C++ files. In principle, it is can be invoked by other C++ code. The compiler can compile M files into a series of documents, such as dynamic link library files, C++ files, executables and, by setting the MCC command. But so far, it has a lot of restrictions that the m program of MATLAB compiler is converted into C++ code.

(3) The DLL is the abbreviation of dynamic link library, and is a binary executable file. It can put a lot of general function in the DLL for multiple application calls, instead of every application in connection to add a copy of the object code in the library. Through MATLAB own Compiler, we can compile m

function file into a dynamic link library (DLL file) by MATLAB. Another method is using VC++ the wizard automatically generated m dynamic link library file through the component functionality provided by MATLAB. The following, calling encapsulated function in C++ programs can realize the use of numerical algorithm. This method makes program running out of MATLAB, reduce the uneven distribution of external storage space of file, and code sharing could be achieved, which has made great user code design. The main steps are:

a) Set MATLAB compiler, using external VC compiler.
b) Compile m file into a DLL file
c) Set up the VC the Include path and lib link library paths
d) Write C++ calling DLL

These three methods is superior to domestication, we can take different approaches to combine with different conditions. This article takes the example of the third method that is using MATLAB to produce dynamic link libraries, due to it can make data visualization by using dynamic link library and the CPU occupancy rate is lower.

5 Integrated simulation platform of VISSIM, VC ++ and MATLAB

Combined part 3 and part 4 discusses technology, advanced traffic control simulation platform is built by using VISSIM microscopic traffic flow simulation ability, efficient data communication ability of C++ editor, and ability of complex algorithm and graphic visualization in MATLAB. The main idea of the paper is using the VISSIM simulation program to get traffic index, and input it into the new traffic control model. First, make C++ as master program, through the COM interface directly call VISSIM object, and through dynamic link library directly calling MATLAB object. Second, finish the implementation of complex intelligent traffic control model in C++ editor and MATLAB. As shown in figure 2, VISSIM, C++ and MATLAB all have their own advantages, so it is necessary to integrate the advantages to build advanced traffic control simulation platform, which method is simple and versatility, and is of great significance to the study of intelligent traffic control model.

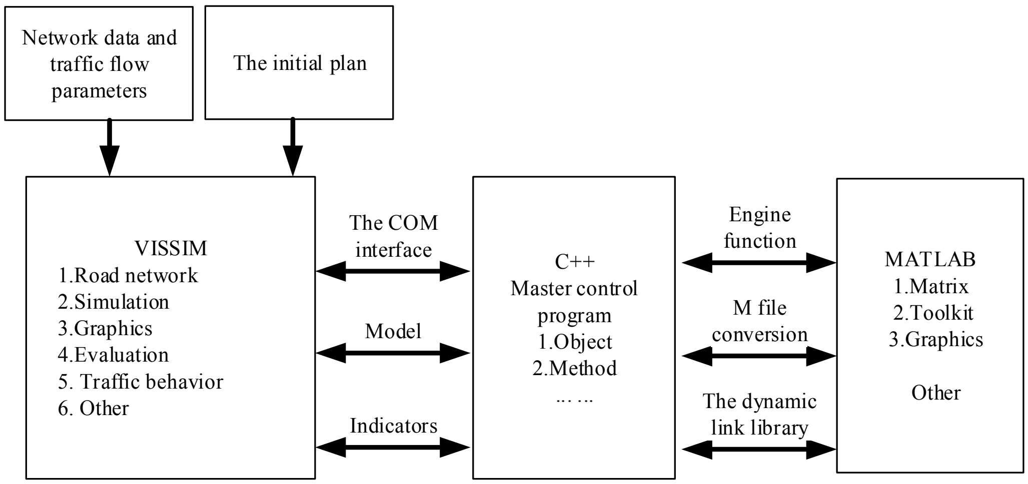

Figure 1. Integrated simulation platform of VISSIM, VC++ and MATLAB

6 Case

In this paper, an instance can be simply described as a four phase intersection in the VISSIM, which uses C++ for secondary development to realize the adaptive control, and uses MATLAB dynamic link library output one of the imports section density change trend in the form of graphics. Figure 2 shows the interface of the simulation platform, which is the interface of three kinds of software interactive operation at the same time. In the Figure 2, the lower picture is VS2010 master program interface, used to invoke the VISSIM and MATLAB, and store the data. Middle pictures of VISSIM simulation interface. The upper picture shows MATLAB graphical editor, which make a time interval of data visualization.

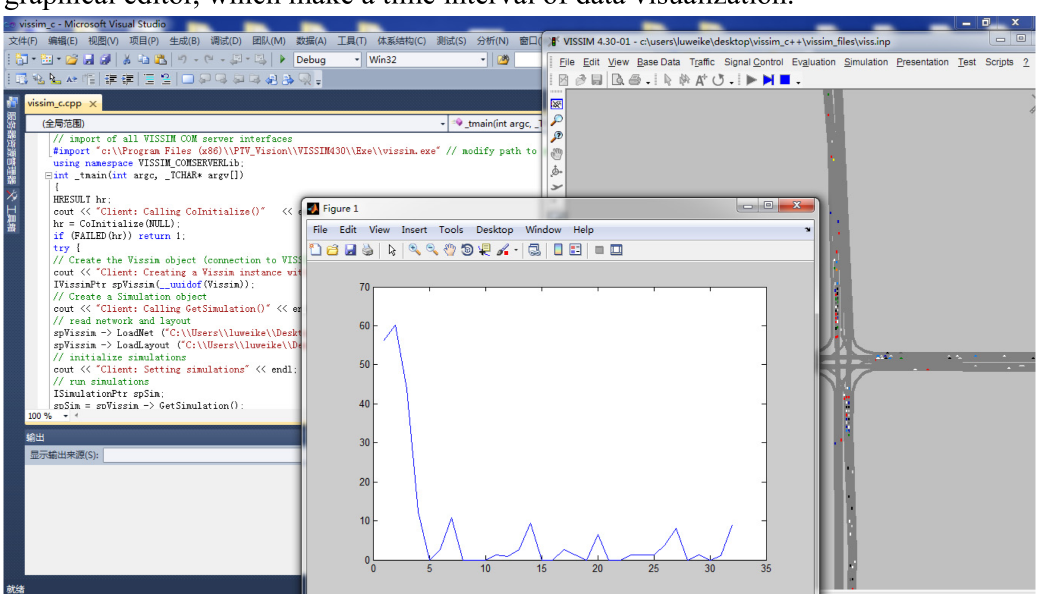

Figure 2. The interface of the simulation platform

7 Conclusions

This paper comes up with a new method that the COM interface and C++ are used to integrate VISSIM and MATLAB, which integrates the advantages of the three software to build advanced traffic control simulation platform. In the final, the paper gives detailed methods and steps to implement traffic control simulation platform, and provides examples based on the simulation platform. Compared to use single VB or VA to finish the secondary development of VISSIM, this simulation platform combines several advantages of MATLAB. But MATLAB simulation module and other mathematical functions haven't through this platform for testing and inspection in this paper, this also is the next step research main work. In order to make the simulation effect as much as possible close to the actual traffic simulation platform, it is important to make a detailed calibration parameters, such as flow, speed, acceleration, right-of-way rules, driving behavior parameters and so on, which is basis to construct almost consistent with the real operation situation of traffic flow of traffic simulation experimental environment and implement more accurate evaluation of the effect of traffic control model.

References

Fisk C. (1980).Some developments in equilibrium traffic assignment. Transportation Research Part B: Methodological. 14(3), 243-255

Guo X L, Yang H. (2005). The price of anarchy of stochastic user equilibrium in traffic networks. Proceedings of the 10th HKSTS Conference, Hong Kong: HKSTSL td.

Wong S C, Wong W T, Leung C M, et al. (2002).Group-based optimization of a time-dependent TRANSYT traffic model for area traffic control. Transportation Research Part B: Methodological.36 (4), 291-312.

Transportation Research Board. (2000). Highway capacity manual (4th edition).Washington, D. C. National Research Council.

Yin Y. (2000). Genetic-algorithm-based approach for bi-level programming modes Journal of Transportation Engineering.126 (2), 115-120.

Sun D, Benekohal R F, Waller S T.(2006). Bi-level programming formulation and heuristic solution approach for dynamic traffic signal optimization. Computer-Aided Civil and Infrastructure Engineering. 21(5), 321-333.

Intersection Signal Priority Mode of Trams on Condition of Delays

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Abstract: Aiming to solving the problem of tram delays be caused by disturbing of social vehicles, on the basis of ensuring operational efficiency of tram, an approach of intersection signal strategy of priority coordinated control contrary to unidirectional trams delay sand bidirectional tram intersection in this paper, tram load, traffic safety interval and tram delays are taken into account in this paper. Modeling by indicative function, an example is described; delays are reduced obviously as a result which can ensure trams run ordered according to diagram.
Keywords: Tram; Delay; Intersection signal priority.

1 Introduction

While operating along an incomplete separated right-of-way, it refers to trams are separated from social vehicles in road sections, but share the intersections with vehicles and pedestrians, which means tram operation is influenced by a lot of random factors (HCM, 2000). Traffic efficiency at intersections becomes the main factor which determines the stability and reliability of tram system (MA, 2010). So the study on the intersection signal priority mode of tram has great practical significance.

At present, tram control strategy at intersections can be classified into two general categories. (1) Without signal priority strategy. Trams comply with social traffic signals, and enjoy no priority right in this case. Due to the delays which incur at intersections are increased, not only affect the tram transportation efficiency (MA, 2010), but also increase the conflict points between trams and social vehicles which go against Traffic Safety (SUI, 2001). (2) Isolated signal priority strategy. This strategy requires the ability to detect trams at the signalized intersections, and provides trams priority by either extending the current phase or activating a phase early (LI, 2005). While improving trams traffic efficiency, but the delays of social vehicles are increased significantly. This strategy is not conducive to the stability of the entire traffic system (MA, 2010 and WEI, 2008).

To avoid above shortages, this paper proposed a signal priority mode of tram on the condition of delays, which be constrained by traffic flow, traffic condition and

ITS equipment condition. This mode can improve the operation efficiency of trams by the premise of traffic efficiency of social vehicles.

2 Measurement Factors of Tram Intersection Signal Priority

In this paper, tram intersection signal priority strategy is based on optimizing passenger delays, which involve the passenger counts not only in trams but also in social vehicles. In other words, the trams are given a weight that depends on the number of passengers, and whether the bus is behind schedule. The measurement factors of tram intersection signal priority determined by tram occupancy rate, social vehicle queue length, time interval of pre and post trams and tram delay.

(1) Tram occupancy rate (C)

Tram Occupancy Rate is defined as the radio of the practical passenger number and the largest passenger number of tram. It can reflect operation efficiency and service level of current tram, and can be calculated as

$$C = {c_1}/{c_2} \tag{1}$$

where c_1 is the number of passengers counts in the tram; c_2 is the largest passenger number of tram.

(2) Social vehicle queue length (L)

The intersection signal control is simplified to be dual-phase in this paper. The maximum length of social vehicles in the vertical direction of intersection can be considered as the factor of traffic flow, which can be calculated as

$$L = \max\left\{l_1, l_2\right\} \tag{2}$$

where l_1 and l_2 respectively expresse the queue lengths of social vehicle on both vertical sides direction of intersection.

(3) Time interval of pre and post trams (ΔT)

To ensure the operation safety and maintain the departing interval, time interval of pre and post trams is proposed, that is defined as the time deviation between pre and post trams by traveling through the same station. It is calculated as

$$\Delta T = \left(T_1 + t_1 + t_2\right) - T_2 \tag{3}$$

where T_1 is the arrival instant of current tram at the intersection; t_1 is the waiting time of current tram in red phase; t_2 is the travel time of current tram from current intersection to the next station by maximum speed; T_2 is the arrival instant of following tram at the same station by planned schedule.

(4) Tram delay

To ensure the practical operation is according to the planned schedule, the tram delays at every stations and intersections should be calculated, which can be expressed as the time difference between practical arrival time and planned arrival time. In other words, the departure degree of operation status from practical to plan can be responsed by this factor.

3 Tram Signal Priority Strategies

3.1 Indicative Function Model

This paper is modeled by indicative function. The indicative function of Event A can be expressed as

$$\phi_{\{A\}} = \begin{cases} 1 & \text{Event A occurs} \\ 0 & \text{Event A dosen't occurr} \end{cases} \tag{4}$$

Event A, Event B and Event C can be described as

$A \bigcup B$: Event A and Event B at least one occur;

$A \bigcap B$: Event A and Event B occur simultaneously;

$A \bigcup B \bigcup C$: Event A, Event B and Event C at least one occur;

$B \big| A$: Event B occurs unless Event A occurs.

3.2 Endowing Conditions of Tram signal priority

The endowing conditions of tram intersection signal priority, which can be described by indicative function, are including occupancy, delay and time interval of pre and post trams.

(1) Endowing condition based on tram occupancy

In order to maintain the service level of intersections, tram intersection signal priority can be endowed only when practical occupancy exceeds a certain threshold, which means the most of passengers can enjoy the priority. This endowing condition can be expressed as

$$\phi_{\{A\}} = \begin{cases} 1 & C > C_{\max} \\ 0 & C \le C_{\max} \end{cases} \tag{5}$$

where $C_{\max}$ is the threshold of tram occupancy.

(2) Endowing condition based on compensation for tram delay

If tram has been delayed at current intersection, the endowing condition of signal priority at current intersection is determined by the operation status at the following intersection. If the delay can be compensated at the *k*-th station by travelling at the speed which is lower than the maximum speed limits, then the intersection signal priority doesn't be endowed. Otherwise, because of no compensation, delays will be accumulated gradually and become uncontrollable finally. So the signal priority should be endowed in this case. This endowing condition can be expressed as

$$\phi_{\{B\}} = \begin{cases} 1 & T_1 + \Delta t + t_1 + \sum_{i=1}^{k} t_2^i > T_k \\ 0 & T_1 + \Delta t + t_1 + \sum_{i=1}^{k} t_2^i \le T_k \end{cases} \tag{6}$$

where T_k is the planned instant when current tram arrival at the *k*-th station.

(3) Endowing condition based on time interval of pre and post trams

If the time interval of pre and post trams is shorter than safety interval, which is caused by the delays of pre tram, then the signal priority must be endowed, otherwise the operation safety may be affected. This endowing condition can be expressed as

$$\phi_{\{C\}} = \begin{cases} 1 & \left|(T_1 + \Delta t + t_1 + t_2) - T_2\right| < \Delta t_1 \\ 0 & \left|(T_1 + \Delta t + t_1 + t_2) - T_2\right| \ge \Delta t_1 \end{cases} \tag{7}$$

where Δt_1 is the safety time interval of pre and post trams.

3.3 Tram Intersection Signal Control Strategies

According to the different status of arriving at intersections, three kinds of intersection signal priority strategies are proposed in this paper.

(1) Endowing strategy of priority in one direction

When endowing conditions in 3.2 at least one accrues, then tram enjoys the signal priority, otherwise implement the original traffic signal timing. The indicative function of this strategy can be described as follow.

$$\phi = \begin{cases} 1 & \phi(A) \cup \phi(B) \cup \phi(C) = 1 \\ 0 & \phi(A) \cup \phi(B) \cup \phi(C) = 0 \end{cases} \tag{8}$$

(2) Endowing strategy of priority in two direction

In order to improve the efficiency of intersections, once the first tram enjoys signal priority in one direction, then the after tram in opposite direction should be better passes the intersection as in the same green phase as possible.

1) The after tram in opposite direction passes the intersection in original priority green phase

On the condition of the first tram has enjoyed the priority in one direction, if the after tram in opposite direction doesn't satisfy the endowing conditions and can't pass the intersection in the same priority phase by accelerate, then it is operated by planned schedule; if the after tram in opposite direction satisfys the endowing conditions, then it can pass the intersection in the same priority phase by accelerate. The indicative function of this strategy can be described as

$$G^2 = \begin{cases} 0 \ (\phi^2(A) \cup \phi^2(B) \cup \phi^2(C) = 0) \cap \phi(T^2 + t^2 \notin (T_s^1, T_e^1)) = 0 \\ 1 \ (\phi^2(A) \cup \phi^2(B) \cup \phi^2(C) = 1) \cap \phi(T^2 + t^2 \in (T_s^1, T_e^1)) = 1 \end{cases} \tag{9}$$

where T_s^1 is the beginning instant of priority phase, T_e^1 is the ending instant of priority phase, T^2 is the instant of the after tram in opposite direction arriving at the station which is the neatest one to the intersection, t^2 is the time to travel from the neatest station to the intersection of the after tram by the maximum limited speed.

2) The after tram in opposite direction passes the intersection in extend priority green phase

On the condition of that the first tram has enjoyed the priority in one direction, if the after tram in opposite direction satisfys the endowing conditions but can't pass the intersection in the same priority phase by accelerate, then a time threshold (Δtf) of the arriving interval between the first and the after trams is set. When the actual interval is lower than the threshold, the green phase is extended and the both trams pass the intersection in the same priority phase. The indicative function of this strategy can be described as

$$D^2 = \begin{cases} 0 \ (\phi^2(A) \cup \phi^2(B) \cup \phi^2(C) = 0) \cap \phi(T^2 + t^2 \notin (T_s^1, T_e^1)) = 0 \\ 1 \ (\phi^2(A) \cup \phi^2(B) \cup \phi^2(C) = 1) \cap \phi(T_l^2 - T_l^1 \le \Delta tf_{\min}) = 1 \\ 0 \ (\phi^2(A) \cup \phi^2(B) \cup \phi^2(C) = 1) \cap \phi(T_l^2 - T_l^1 > \Delta tf_{\min}) = 1 \end{cases} \tag{10}$$

where T_l^1 is the time to leave the intersection of the first tram, T_l^2 is the time to leave the intersection of the after tram, $\Delta tf_{\min}$ is the minimum time interval to leave the intersection between the first and the after trams.

4 Examples

A two-phase signal intersection scene is supposed in this paper. In order to explain conveniently, the yellow phase is not considered. The signal period is supposed to be 60s, which red phase and green phase is 30s respectively. The distance from intersection to the first stations A and the after station B is 900m as the same. The normal operating speed of tram is 36 km/h. The maximum limited speed is 60 km/h. The threshold of tram occupancy is 120%.

(1) Priority strategy in one direction

This direction is defined to be the down-direction. The first tram is planned to arriving at Station A at 6:30:00 and leaving at 6:31:00. Due to the increased number of boarding and alighting passengers, the tram is delayed and leaving at 6:32:00 actually. The tram arrives at the intersection at 6:33:30 by normal operating speed.

The tram occupancy is 130% at this time, which is higher than the threshold. If signal priority is not considered, then the waiting time of this tram at the intersection is $t_1 = 30s$. The traveling time to the Station B by the maximum limited speed is $t_2 = 54s$. So the actual instant to arrive at Station B is

$$T_B^- = T_I^- + t_1 + t_2 = 6:34:54 > T_k = 6:34:30$$

where T_k is the planned instant to arrive at Station B, and $k = 1$.

According to above calculation, the tram must be delayed when it arrive at Station B without signal priority. So the purpose of signal priority is to minimize the delay. The working diagram of this strategy can be described as Fig. 1 (a).

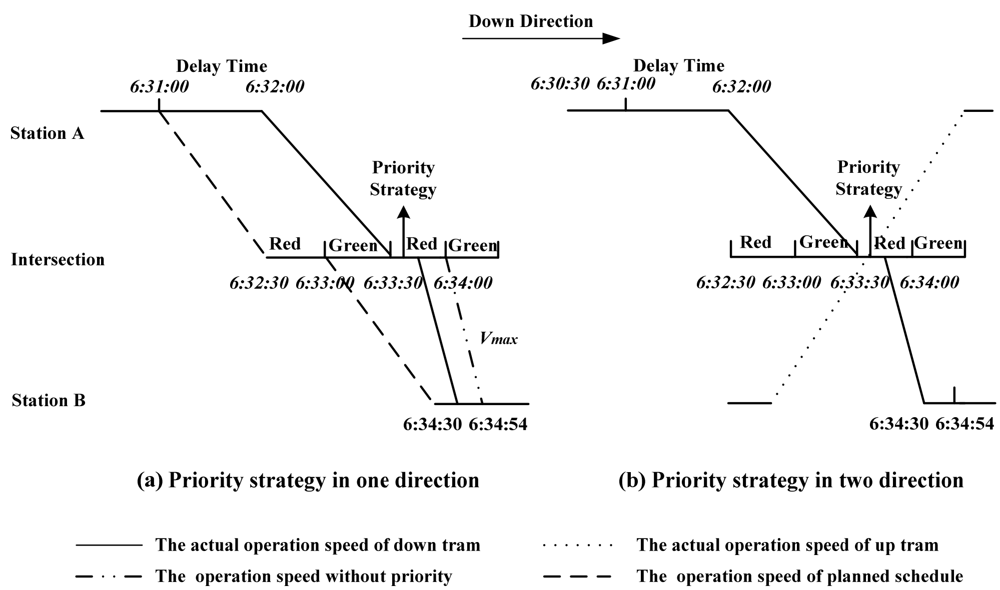

Fig.1 The operation diagram of priority strategies of tram

(2) Priority strategy in two directions

Based on the priority strategy in the down-direction, the occupancy of the up tram is assumed to be $C_A^+(1) = 80\%$, which is lower than the threshold, and the instant of the up tram to arrive at the intersection is $T_I^{'}$=6:33:33. A green priority signal phase of 5s is endowed to the down tram, which time to leave the intersection is 6:33:35. In order to ensure the up tram can pass the intersection as in the same priority phase as down tram dose, a extend strategy of green priority phase is proposed to up tram, which is additional green phase of 3s. The operation diagram of up and down tram can be described as Fig. 1 (b).

5 Conclusions

Based on the delay of tram operation, three kinds of intersection signal priority strategies are proposed in this paper. According to occupancy, delay compensation and operation interval, the indicative function model of tram operation in one direction is proposed to describe the priority control of single direction. Based on the priority control of single direction, the tram in opposite direction can pass the intersection as the same priority phase as possible by a extend priority phase.

The priority strategies proposed in this paper depend on the application of gathering, transmission and processing of tram information, which are based on the improvement of the intelligent of tram system. The organic integration of signal system of tram and urban transportation is the key point of the efficient signal management. The order of the priority measurement factors is decided based on the conditions of practical projects. The focus of the following research is the simulation design of the priority strategies.

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References

HCM (2000). “Highway Capacity Manual.” TRB.

Li Shen, Yang Xiaoguang (2005). “Harmonious Control of Modern Tramway and Road System.” *Urban Mass Transit*, (4), 43-46.

Ma Wanjing, Yang Xiaoguang (2010). “A Review of Prioritizing Signal Strategies for Bus Services.” *Urban Transport of China*, 8(6), 70-78.

Ma Wanjing，Yang Xiaoguang，Liu Yue (2010). “Development and evaluation of a coordinated bus signal priority approach.” *Transportation Research Record*, (2145), 49.

Sui Yuejia (2001). “The development of modern tram and its vehicle.” *Urban Vehicles*, (5), 35.

Wei Chao (2008). “Research on the Adaptability of Modern Tram.” *Tongji University*.

Performance of Left-Turning Motor Vehicles from a Minor Road Approach at Non-Signalized At-Grade Intersections

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Abstract: The paper has analyzed the performance characteristics of motor vehicles which turn left from minor road approach systematically, and has studied characteristics of speed variation and various impacting factors for left-turning vehicles from minor road approach, using statistical methods. Theory analysis of the performance of left-turning vehicles has been carried out and has been verified by using data collected in the field. Forecast models for acceleration of left-turning motor vehicles from minor road approach have been constructed and impacts upon traffic safety have also been discussed. Results of the paper can be used to analyze traffic performance of motor vehicles making left-turn movements from minor road approach at non-signalized at-grade intersections. They are also helpful for the analysis of traffic safety at those locations.
Keywords: Non-signalized at-grade intersection; Minor road approach; Motor vehicles; Deceleration; Acceleration.

1 Introduction

Because traffic volumes at non-signalized intersections are rather low, traffic accidents at those places are usually fewer than those at signalized intersections. However, severity of traffic accidents at non-signalized at-grade intersections is higher due to the high speeds of vehicles on intersection approaches.

Traffic accident data are used to study traffic safety and it has been used for many years. Numerous researches of traffic safety have been carried out by this kind of approach (Cirillo, 1970; Chen, 2011). Besides, traffic conflict analysis, traffic simulation and psychology survey have also been used to study traffic safety (Allen, 1978; Zhang, 2010; Zhang, 2013). Because speed variations were proved to be closely linked with traffic accidents, some researchers started to use speed variations for the study of traffic safety (Tsui, 2013).

At non-signalized intersections, drivers tend to change speeds more frequently in order to avoid potential conflicts. The aim of the paper is to explore speed variations of left-turning motor vehicles from minor road approach so as to understand their performance while turning left, which is the underlying mechanism for traffic safety of non-signalized intersections.

2 Data Collection and Methods

2.1 Data collection

A typical non-signalized at-grade intersection was chosen as the object of research. The major road has two lanes on each side. The minor road approach has two lanes; the outside lane is for right turn movement and the inside lane is for left turn movement. Traffic markings and signs at the intersection are maintained in good condition. Traffic volumes of the major road are moderate and traffic volumes of the minor road are rather low. To facilitate data collection, video recorders were used to record the movements of vehicles.

According to the characteristics of motor vehicles recorded by researchers, vehicles from the minor road approach has been classified into four types: small sized passenger car, medium sized passenger car and small sized freight car, large sized passenger car and medium sized freight car and large sized freight car. The types discussed above are represented by 1, 2, 3 and 4 respectively.

2.2 Statistical methods

Linear regression is one of the most widely studied and applied statistical techniques. The simple linear regression model with only one independent variable is given by the follows:

$$Y_i = \alpha_0 + \alpha_1 X_i + \varepsilon_i \qquad (i = 1,2,3,\cdots,n) \tag{1}$$

Where Y_i=value of dependent variable for observation i; X_i =value of independent variable for observation i; ε_i=value of disturbance term for observation i; α_1=coefficient of independent variable; and α_0=intercept (constant) term.

Nonlinear relationships can be accommodated within the linear regression framework by variable transformations. In the paper, using methods discussed above, predict models were then set up to estimate speed changes of motor vehicles making left turns from minor road approach.

3 Deceleration Performance Near Stop Line

When drivers are prepared to make left turns form minor road approach, they usually make deceleration performance in order to avoid potential conflicts with major road vehicles. Several factors were found to impact deceleration of motor vehicles near stop line during the process of left-turning movements. These factors were analyzed and discussed as follows.

3.1 Types of left-turning motor vehicles

Data analysis indicated that decelerations of most left-turning motor vehicles lie in the range of 0 and 2.5 m/s^2 and different type of vehicles had various decelerations. Among the four types of motor vehicles from minor road approach, small sized passenger cars, which are represented by 1, had the highest decelerations and the degree of dispersion of their decelerations was also the highest. Decelerations of type 2 motor vehicles (medium sized passenger car and small sized freight car) go after those of type 1 motor vehicles in both average value and degree of dispersion.

The phenomenon concerning performance of type 1 motor vehicles can be explained by the following reasons: First of all, compared with other types of motor vehicles, small sized passenger cars had better power performance and braking ability. Therefore drivers of small sized passenger cars tend to brake more harshly, resulting in higher decelerations. Besides, the driving skills of drivers of small passenger cars vary a lot, which partly explained the extremely high degree of dispersion of decelerations.

3.2 Initial speed of left-turning motor vehicles

When motor vehicles on minor road are arriving at the approach and are preparing to make left turns, their initial speed has great impact upon their subsequent deceleration performance. Based upon a psychological analysis of drivers' behavior, a higher initial speed of left-turning motor vehicles will force drivers to brake more harshly so as to obtain a low speed near stop line to ensure the safe movement of left-turning vehicles. In order to confirm the assumption discussed above, data were analyzed to study the relationship between initial speed and deceleration for left-turning motor vehicles and by using liner regression, a model was set up to predict the impact of initial speed of left-turning motor vehicles quantitatively. The model is as follows:

$$Y=-0.7555+0.0617X \tag{2}$$

Where Y=deceleration of left-turning motor vehicle near stop line on minor road approach (m/s^2); and X= initial speed of left-turning motor vehicle before braking near stop line on minor road approach (km/h).

In the model, the coefficient for independent variable is positive. This indicates that when initial speeds of left-turning motor vehicles increase, their subsequent decelerations will increase, which is in agreement with the assumption discussed above.

3.3 Average time headway of vehicles on major road

According to traffic safety law, drivers of motor vehicles from minor road approach should choose a gap in the traffic on major road, which is large enough for left-turn movements. Large time headways of vehicles on major road provide vehicles from minor road such gaps to get across the road safely. When average time headway of vehicles on major road decreases, the capacity and level of service for vehicles on minor road will be lowered and average delay will be increased. It will become more difficult for drivers to choose a gap large enough for left-turn movements. Under such circumstance, drivers from minor road approach will be more likely to brake in order to wait for a suitable gap in the traffic on major road. This means that a smaller average time headway of vehicles on major road may lead to harsher deceleration performance.

To confirm the assumption discussed above, data were analyzed to study the relationship between average time headway of vehicles on major road and deceleration of left-turning motor vehicles from minor road. By using liner regression, a model was set up to predict the impact of average time headway of vehicles on major road. The model is as follows:

$$Y=2.6174-0.39X \quad (3)$$

Where Y=deceleration of left-turning motor vehicle near stop line on minor road approach (m/s^2); and X= average time headway of vehicles on major road (km/h).

In the model, the coefficient for independent variable is negative, which indicates that when average time headways of vehicles on major road decrease, decelerations of motor vehicles making left-turns from minor road will increase, which means that drivers will brake more harshly. This is in agreement with the assumption discussed above.

4 Acceleration Performance While Merging

After crossing half of the major road, motor vehicles performing left-turns from minor road will try to merge with vehicles on the other side of the major road. This will require drivers to accelerate in order to gain speeds. Several factors were found to impact acceleration of motor vehicles during the process of merging with major road vehicles. These factors were analyzed and discussed as follows.

4.1 Types of left-turning motor vehicles

The study indicated that accelerations of left-turning vehicles are in the range of 0 and 3 m/s^2 Among the different types of motor vehicles merging with vehicles on major road, small sized passenger cars which are represented by 1, had the highest accelerations and for them the degree of dispersion of accelerations was also the highest. The phenomenon about the performance characteristics of small sized passenger cars can be explained by the following reasons: First of all, compared with other types of motor vehicles, small sized passenger cars had better power performance and braking ability. Therefore drivers of small sized passenger cars had more choice during the process of merging. Besides, most of the drivers of small passenger cars were not full-time drivers and their driving skills might not be as good as those of full-time drivers, which could cause unsteady and diverse driving behaviors, which partly explained the extremely high degree of dispersion of accelerations. The performance characteristics of small sized vehicles may bring some risks to them when they are merging with major road vehicles after crossing half of the major road.

4.2 Speeds of anterior vehicles of the merging gap

When drivers of motor vehicles from the minor road are entering the other side of the major road, they need to choose an adequate gap in the traffic stream of the other side of the major road, with which they are going to merge. During the merging process, their driving behaviors are affected and constrained by anterior vehicle of the gap greatly. If the speed of the anterior vehicle is lower, the driver of the left-turning vehicle from the minor road will be constrained and cannot choose to reach a fast running speed by quick acceleration. However, when the speed of the anterior vehicle is higher, under the influence of the front vehicle, the driver of the left-turning vehicle will tend to accelerate more quickly while merging so that the driver can follow the anterior vehicle in front of him more closely.

In order to study the assumption discussed above, data concerning accelerations of left-turning motor vehicles while merging and speeds of anterior vehicles of the gaps were analyzed. A non-linear statistical model was set up based on the data and the model is as follows:

$$Y = 0.0059X^2 - 0.2014X + 2.1484 \quad (4)$$

Where Y= acceleration of left-turning motor vehicle from the minor road while merging (m/s^2); and X= speed of anterior vehicle of the merging gap (km/h).

It was found out that when the independent variable is larger than 17 km/h, first order derivative of the dependent variable is positive and will increase with the increasing of the independent variable. Therefore, when the speed of anterior vehicle of the gap is larger than 17 km/h, acceleration of left-turning motor vehicle from the minor road will increase with the increasing of the speed of anterior vehicle, which indicates that the model is in agreement with the assumption discussed above.

4.3 Speeds of posterior vehicles of the merging gap

Similarly, when motor vehicles from minor road approach are merging with vehicles on the other side the major road, drivers' behaviors are also constrained and influenced by posterior vehicles of the gap into which they are trying to merge. If the speeds of posterior vehicles are very high, vehicles from minor road will be threatened substantially and are forced to accelerate urgently. However, if the speeds of posterior vehicles are low, drivers of vehicles from minor road will feel less pressed and therefore tend to perform acceleration more gently.

In order to confirm the assumption, data concerning accelerations of left-turning motor vehicles from the minor road and speeds of posterior vehicles of the merging gap were analyzed. A non-linear statistical model was set up based on the data and the model is as follows:

$$Y = 0.046e^{0.117x} \quad (5)$$

Where Y= acceleration of left-turning motor vehicle from the minor road approach (m/s^2); and X= speed of posterior vehicle of the merging gap (km/h).

Equation 5 shows that the dependent variable increases with the increase of the independent variable of the exponential function. Therefore, acceleration of left-turning motor vehicle from the minor road will increase with the increasing of the speed of posterior vehicle of the gap, which indicates that the model is in agreement with the assumption discussed above.

5 Conclusions

At non-signalized at-grade intersections, left-turning motor vehicles from the minor road approach have substantial impact upon the performance of traffic streams of the major road. Results of the paper can be used to analyze traffic performance of motor vehicles making left-turn movements from minor road approach at non-signalized at-grade intersections. They are also helpful for the analysis of traffic safety at those locations. In the future, similar researches should be carried out to further explore the complicated operation of motor vehicles at non-signalized at-grade highway intersections.

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References

Allen B. L., Shin B. T. and Cooper D. J. (1978). "Analysis of traffic conflicts and collision," Transportation Research Record, 667: 67–74.

Chen H., Zhou H., Zhao J. and Hsu P. (2011). "Safety Performance Evaluation of Left-Side Off-Ramps at Freeway Diverge Areas." Journal of Accident Analysis and Prevention 43:605-612.

Cirillo J. A. (1970). "The Relationship of Accidents to Length of Speed-Change Lanes and Weaving Areas on Interstate Highways." Highway Research Record, Report HRR 312.

Tsui M. A. and Garcia A. (2013). "Use of speed profile as surrogate measure: Effect of traffic calming devices on crosstown road safety performance." Accident Analysis and Prevention, 61: 23-32.

Zhang G. Q., Lu J. (2010). "Study on unsignalized access points using microscopic traffic simulation." Traffic and Transportation Studies 2010 - Proceedings of the 7th International Conference on Traffic and Transportation Studies.

Zhang Q. Y., Zhang G. Q. and Qi Y. L. (2013). "Analyzing Electric Bicycle Rider's Unsafe Crossing Behavior Based on Theory of Planned Behavior." Modern Transportation, 2(2): 15-22. 2013.

Bicyclists' Running Red Lights at Signalized Intersections

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Abstract: Cyclists' running red lights is very common in China and has been one of the major reasons for traffic accidents in urban areas. This paper has discussed psychological factors behind bicyclists' behavior of running red lights at signalized intersections such as anxiety, group psychology, deliberate action, convenience psychology, recklessness and ignorance and subconsciousness. Next, a psychological questionnaire survey has been analyzed and studied. The survey includes three subjects: reasons for running red lights, maximum waiting time and measures for prevention of running red lights. Meaningful conclusions have been drawn as to what are the main reasons that underlie cyclists' running red lights and how to prevent cyclists from running red lights effectively.
Keywords: Signalized intersections; Cyclists; Running red lights; Psychology; Questionnaire survey.

1 Introduction

Many researches were carried out both in China and abroad to study the behaviors of cyclists (Johnson, 2013; Pai, 2014; Yang, 2015; Yang, 2012; Zhang, 2013). Some meaningful conclusions were drawn to help to understand their impact upon traffic safety. However, further studies should be carried out to explore the psychological mechanism underlying cyclists' dangerous behaviors at signalized intersections.

According to the present situation in China, the research was carried out to explore reasons underlying behaviors of cyclists' running red lights by analysis of a psychological questionnaire survey. Based upon analysis of psychological factors, the survey centered around three aspects: reasons for running red lights; maximum waiting time; measures for prevention of running red lights. More than three hundred questionnaires were handed out and in all, 130 effective questionnaires were received. Among participants who had given effective questionnaires, 96 were male and 34 were female. Most of the participants were young people and 84 participants were below 30 years old, accounting for 64.6%.

2 Psychological factors for Bicyclists' Running Red Lights

2.1 Anxiety

Anxiety is such a kind of psychology with little patience in dealing with daily business. When people are anxious, they tend to lack enough patience in doing routine matters. For cyclists with anxiety psychology, they usually make haste on the road in order to get to their destination on time and they will run a red light at signalized intersections whenever it is possible.

2.2 Group psychology

Group psychology means that people who are in a group usually behave alike. The behaviors of some members of a group impacts behaviors of other members and finally everyone behaves the same way. At signalized intersections, the behaviors of red light running cyclists will have great influence upon other cyclists and will prompt other people to do the same thing as they have just done.

2.3 Deliberate action

Still, there are a few cyclists who run red lights on purpose. They have little regard for other people and do not like to obey laws. Though they know that running red lights will interfere with people or vehicles coming from other directions, they chose to do it deliberately and routinely, without respect for other traveler's lawful right. However, when policemen are present, they usually don't dare to run red lights for fear of being caught.

2.4 Convenience psychology

Convenience psychology refers to such personality, with which a person is usually a self-centered egomaniac and emphasizes efficiency, paying little attention to processes and plots. When confronted with red lights at signalized intersections, some cyclists might find it difficult to wait for a long time, especially when the traffic volumes in operation are not heavy. For convenience's sake, they will be tempted to run red lights as soon as there is a chance for them to do so.

2.5 Recklessness

The so called recklessness means that a person's mind is apart from his or her behavior so that his behavior does not correspond with his psyche completely. We usually regard this kind of psychological phenomenon as recklessness or carelessness. Those cyclists who are very concerned with their own business often get across the street while thinking about their own business without giving much attention to ambient information. At signalized intersection, without noticing the traffic signal, they might run red lights.

2.6 Ignorance and subconsciousness

Ignorance is a kind of psychological activity for people with low levels of knowledge and civilization. Lacking enough education, a few cyclists are ignorant of the modern laws and rules. They know little about traffic rules and traffic safety and chose to do whatever they want. When confronted with red lights, they usually tend to violate the laws. Once they have formed the habit of running red lights, they will do it without even being conscious of it and that is a kind of subconsciousness.

3 Psychological Questionnaire Survey

3.1 Reasons for running red lights

Eight choices were listed in the questionnaire survey concerning reasons for cyclists'running red lights. These choices are as follows: having urgent matters, waiting for the green light too long, influenced by other people's running red lights, lacking strict law enforcement, bad weather and subconsciousness. To facilitate data processing, the choices are represented by 1, 2, 3, 4, 5 and 6 respectively. People who attended the survey were asked to choose at least one item from them. Data from the questionnaire survey were carefully analyzed. The results are shown in Figure 1.

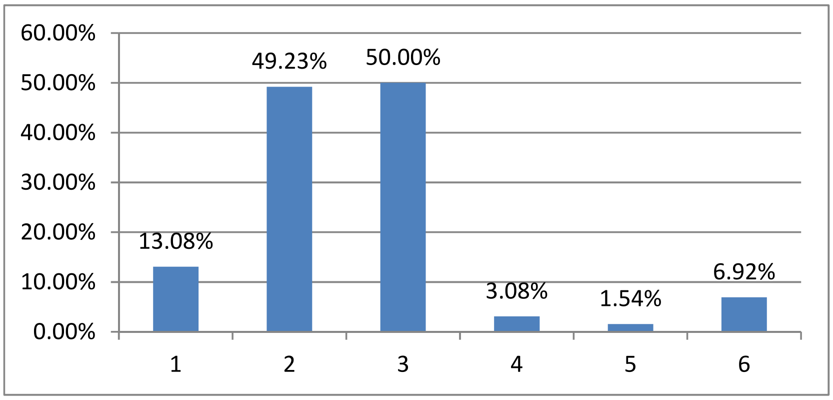

Figure 1. Reasons for running red lights

The third item, influenced by other people's running red lights, is the most frequently chosen reason for interviewees' red light running. 50 percent people have chosen it. Phycology theories indicate that people are easily influenced by others when making choices. Besides, when running red lights together, violators are more likely to be yielded by rightful motorists because the illegal crossing movements of many violators can form a traffic stream thick enough to block any other conflicting traffic no matter whether they are legal or illegal. At last, people tend to do simple tasks unconsciously and influenced by other violators. Some cyclists may run red lights out of Subconsciousness.

49.23 percent interviewees chose the second item, waiting for the green light too long. Researches have shown that patience of human beings is very limited. When confronted with long periods of waiting, most people will become anxious and are ready to behave illegally or dangerously, which can be used to explain why so many cyclists have chosen the second item as a reason for running red lights.

Item 1, having urgent matters, was chosen by 13.08 percent interviewees for reason of running red lights. In urgent situations, people tend to behave unreasonably and hastily. Therefore, during rush hours, when people are urgent to go to work on time, they have the motivation to run red lights.

6.92 percent interviewees chose Item 6, subconsciousness, for reason of running red lights while bicycling. It should be pointed out that subconsciousness alone seldom leads to cyclists' behavior of running red lights. It is combination of subconsciousness and other factors such as long waiting time and lack of strict law enforcement that leads to cyclists' running red lights. Only 3.08 percent interviewees chose Item 4, lacking strict law enforcement, for reason of running red lights. At last, 1.54 percent interviewees chose Item 5, bad weather, for reason of running red lights.

3.2 Maximum waiting time

Interviewees were asked to estimate their maximum waiting time as a cyclist at signalized intersections. There were six choices and they were as follows: less than 15 seconds, 15-30 seconds, 30-45 seconds, 45-60 seconds, 60-75 seconds and more than 75 seconds. The frequency for each of those that was chosen was calculated and their corresponding percentages were then obtained. The results are shown in Figure 2, which is a histogram for the different choices. Most people chose 30-45 seconds, 45-60 seconds or 60-75 seconds as their maximum waiting time, which accounted for 73.85 percent questionnaire survey participants.

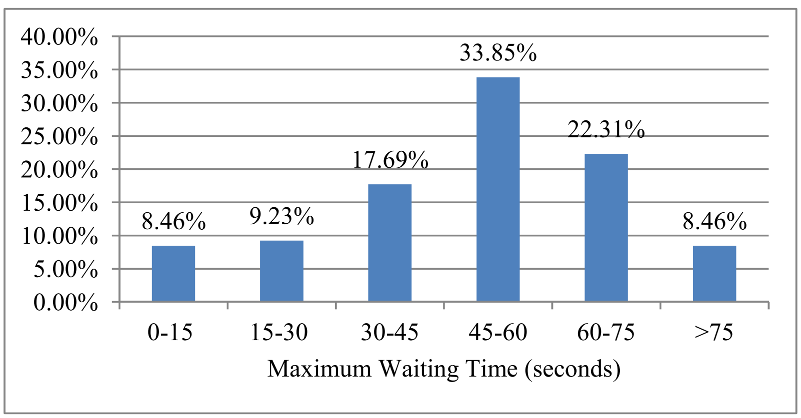

Figure 2. Relative frequency for maximum waiting time

The relative frequency for each choice has been added up to get the cumulative relative frequency, which is shown in Figure 3. It can be estimated that the proportion of interviewees whose maximum waiting time was no more than 45 seconds is approximately 35.38%, the proportion no more than 60 seconds is 69.23% and the proportion no more than 75 seconds is 91.54%.

If the pattern in Figure 3 represent the real situation, it is safe to say that at signalized intersections, the red lights for cyclists which is no more than 45 seconds is very agreeable, because most people can accept such a waiting time. And if such a time cannot be guaranteed, the red lights had to be no more than 60 seconds. On the other side, when red lights are more than 75 seconds, most cyclists cannot endure it and might possibly fail to refrain from running red lights.

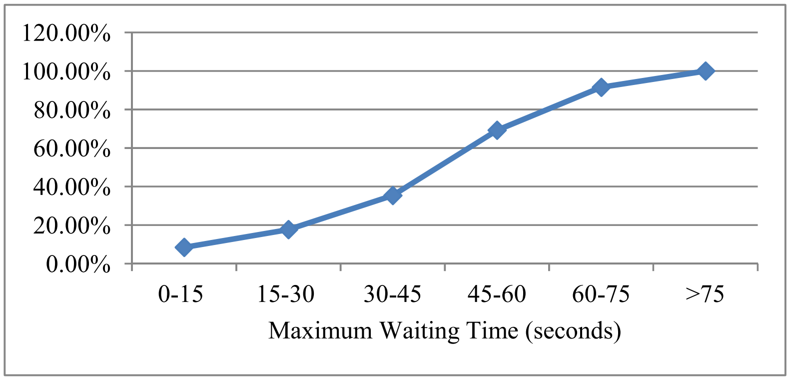

Figure 3. Cumulative relative frequency for maximum waiting time

3.3 Measures for prevention of running red lights

As for phenomenon of running red lights, the questionnaire survey has put forward three measures to prevent it and they are as follows: safety education, law enforcement and traffic engineering. The interviewees were asked to choose one from the three items as the best measure to prevent the behavior of running red lights.

Relative frequencies for selection of those measures were calculated and they are shown in Figure 4. It is obvious that most of the interviewees favor the measure of traffic engineering, which can reduce red time of traffic signals by optimizing signal timing and installing actuated signal control devices. 51.8 percent participants chose this measure. Therefore, although safety education and law enforcement are important for the prevention of red light running, improvement of service level of pedestrians and cyclists at intersections is more appealing.

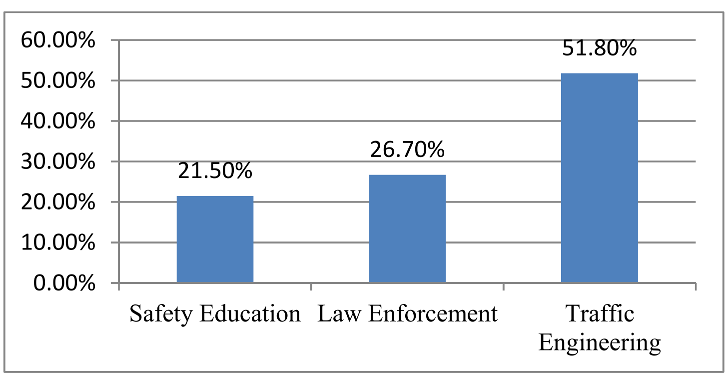

Figure 4. Relative frequency for measures to prevent red light running

4 Conclusions

The paper has discussed psychological factors underlying the behavior of cyclists' running red lights and analyzed a questionnaire survey. The results of survey shows that dangerous and unlawful behavior of cyclists' running red lights is usually brought about by the influence of other cyclists' behavior, which indicates the great impact of group psychology on people's everyday life. Besides, waiting for the green time too long is also an important factor. Cyclists' patience is rather limited when confronted with red lights and the study shows that red lights should be no more than 60 seconds. Thus, greater efforts should be made to reduce red light and improve service level of cyclists.

Although safety education and law enforcement are important for the prevention of red light running, the study indicates that traffic engineering is more preferred. Improvement of service level at signalized intersections is more acceptable, which can be realized by such traffic engineering technologies as optimizing signal timing and installing new signal control devices such as semi-actuated signal control devices and full-actuated signal control devices.

Acknowledgement

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References

Johnson M., Charlton J., Oxley J., et al. (2013). "Why do cyclists infringe at red lights? An investigation of Australian cyclists' reasons for red light infringement." Accident Analysis and Prevention, Volume 50: 840-847.

Pai C. W. and Jou R. C. (2014). "Cyclists' red-light running behaviours: An examination of risk-taking, opportunistic, and law-obeying behaviours." Accident Analysis and Prevention, Volume 62: 191-198.

Yang X. B., Huan M., Abdel-Aty M., et al. (2015). "A hazard-based duration model for analyzing crossing behavior of cyclists and electric bike riders at signalized intersections." Accident Analysis and Prevention, Volume 74: 33-41.

Yang X. B., Huan M., Si B. F., et al. (2012). "Crossing at a Red Light: Behavior of Cyclists at Urban Intersections." Discrete Dynamics in Nature and Society, Article Number: 490810.

Zhang Q. Y., Zhang G. Q. and Qi Y. L. (2013). "Analyzing Electric Bicycle Rider's Unsafe Crossing Behavior Based on Theory of Planned Behavior." Modern Transportation, 2(2): 15-22. 2013.

A Parking Space Detection Algorithm Based on Magnetic Sensors

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Abstract: Magnetic detector is a new type of vehicle detection equipment. A new roadside parking space detection algorithm is proposed based on AMR sensors in this paper. It uses state machine mechanism and overcomes the limitation of existing threshold-based algorithm. The current status is identified via processing two types of magnetic data. Combined with state-related parameters, it can achieve an accurate detection of the parking space status in different scenarios and parking modes. The experiment results show that the accuracy can reach 95%.

Keywords: Magnetic detector; Wireless sensor network; Roadside parking system; Intelligent transportation system.

1 Introduction

In recent years, with the rapid development of economy and urbanization, the amount of vehicles maintains a fast growth. However, with the limit of city land usage and expenditure, the number of parking lot does not increase correspondingly, so the parking problem is becoming a severe problem in various cities. Intelligent parking guidance system is an effective way to solve such a problem and the accurate detection is the key of the system.

Up to now, some algorithms based on magnetic sensors have been proposed for vehicle detection. Cheung proposed an algorithm using a threshold of z-axis magnetic field. In such a method, it is difficult to select the appropriate threshold to all situations. Furthermore, Knaia proposed a single intermediate state of the vehicle detection method; Jiagen Ding proposed a plurality of intermediate state machine detection, but as they rely on a reference value, the offset of the value will greatly affect their accuracy.

In order to achieve a higher detection success rate and lower computational complexity, based on the analysis of a large amount of experimental data, we propose a new method which using a state machine mechanism, and through multiple state-related parameters, it can achieve accurate real-time detection of parking spaces state in different parking modes and environment.

2 Characteristics of the Signal

The feature analysis and recognition of parking geomagnetic signal is the basis of vehicle detection algorithm in different circumstances. In our experiment, we select Honeywll's HMC1052L, a low-power two-dimensional magneto-resistive sensor, as our magnetic detector. During the experiment, each sensor is placed in the middle of parking space. Figure 1 describes the specific deployment of sensor nodes: X-axis is parallel to the direction of vehicle entering, Z-axis is perpendicular to the ground.

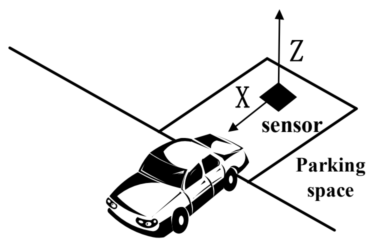

Fig 1. Placement and detection direction magnetic sensor

For considering the energy consumption problem, the magnetic sensor we use has a sleep mode and will wake up once every 100 milliseconds to collect magnetic field data. Under the aforementioned deployment and the detection direction, Figure 2 shows the magnetic signal for a vehicle entering the parking space with its head forwarding, stopping in the parking space for some time then leaving the parking space.

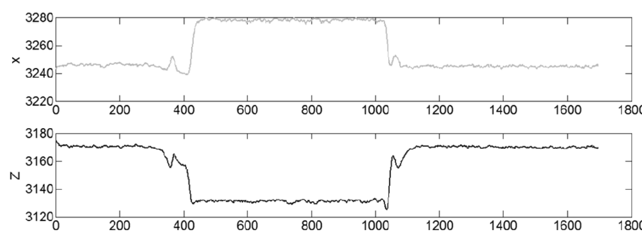

Fig 2. The ideal waveform of normal parking

Figure 2 is a normal parking process and the waveform we obtained is ideal. From the observation, we can see that when the vehicle enters or leaves the parking space, it causes a big fluctuation in both x-axis and z-axis. When the vehicle stops on the parking space, the magnetic signal returns to a stable state. Compare with the situation that no car is on the parking space, there is a distinctive offset in both axes. However, it is not always the case. Given the same situation, sometimes we may get a waveform like the Figure 3 shows. In this case, we find there is no obvious offset in the z-axis. According to several test results, we find that the stationary amplitude offset phenomenon exits at least in one axis, but on which axis it is not certain.

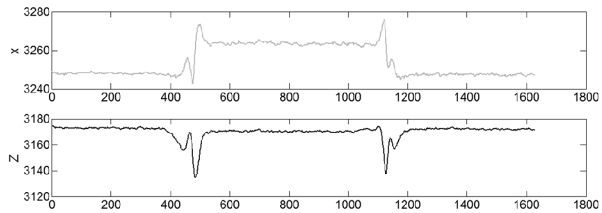

Fig 3. The imperfect waveform of normal parking

3 Vehicle Detection Algorithm

The signal data acquired from magnetic sensors is a time series data. The original data of x-axis and z-axis is denoted as $X[k]$ and $Z[k]$ respectively. As there exits electromagnetic interference, in order to ensure the accuracy of detection, it is necessary to have some filtering process to the original signal. In this paper, we use a simple weighting filtering. The process is defined as Equation (1),where $\hat{X}[k]$ and $\hat{Z}[k]$ respectively represents deal data of x-axis and z-axis.

$$\hat{X}[k] = \frac{7}{8} * X[k-1] + \frac{1}{8} * X[k]$$

$$\hat{Z}[k] = \frac{7}{8} * Z[k-1] + \frac{1}{8} * Z[k] \quad (1)$$

The processing of x-axis data and z-axis data is the same in this algorithm. So in the following description, we elaborate the whole algorithm through the process of the x-axis data. According to the previous analysis of the characteristic of the magnetic waveform, the algorithm we proposed uses state machine. It has 5 different states, presented as State(x)={init, flat, count, up, down}.

The transition between different states is decided by $E(k)$, which represents the magnetic signal's summation value in the same direction. If the sign of the current fluctuation is the same with previous one, then $E(k-1)$ accumulates current fluctuation value. Otherwise, using current fluctuation value to update $E(k-1)$. The process is defined as equation (2).

$$E(k) = \begin{cases} E(k-1) + \widehat{X}[k] - \widehat{X}[k-1] & sign(\widehat{X}[k] - \widehat{X}[k-1]) = sign(\widehat{X}[k-1] - \widehat{X}[k-2]) \\ \widehat{X}[k] - \widehat{X}[k-1] & otherwise \end{cases} \quad (2)$$

Comparing the $E(k)$ with the minimum threshold $\min\_delta$, we can get $u(k)$. The process is defined as equation (3).

$$u(k) = \begin{cases} 1 & E(k) > \text{min\_delta} \\ -1 & E(k) < -\text{min\_delta} \\ 0 & \textit{otherwise} \end{cases} \tag{3}$$

According to the value of u(k), we can get the transition relationship between different states. The transition is described in Figure 4.

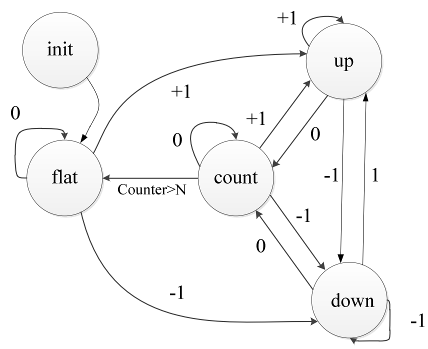

Fig 4. State transition diagram

Flat: After the system's initialization, it jumps into the flat state and stays at this state if u(k)=0.If u(k)=1, the state machine jumps into up state. If u(k)=-1, the state machine jumps into down state.

Up: The state machine stays where it is if u(k)=1.If u(k)=0, it jumps into count state. Then if u(k)=-1, it jumps into down state.

Down: The state machine stays where it is if u(k)=-1.If u(k)=0, it jumps into count state. Then if u(k)=1, it jumps into up state.

Count: The state machine jumps into down state if u(k)=-1.If u(k)=1, it jumps into up state. If u(k)=0 and the Counter value is less than N, it remains in flat state and variable Counter counts up. If u(k)=0 and Counter value is larger than N, then it jumps into flat state.

In addition to these state variables, there are still some parameters defined in the detection algorithm. These parameters include *flat_current, flat_previous, delta_flat_max, E_max.* Their updating process is defined as equation (4)-(6).

$$flat\_\text{previous} = \begin{cases} flat\_current & current\_state\_x \in \{\text{flat}\} \\ unchanged & otherwise \end{cases} \tag{4}$$

$$flat\_\text{current} = \begin{cases} \hat{X}[\text{k}] & current\_state\_x \in \{\text{flat}\} \\ unchanged & otherwise \end{cases} \tag{5}$$

$$E\_max = \begin{cases} E(k) & E(k) > E\_max \\ unchanged & otherwise \end{cases} \quad (6)$$

Based on the current state machine's status and the calculated parameter values, we can identify current parking space's status. The flow chart of the arithmetic is described in Figure 5, wherein U, FLAT_DELAT are pre-set threshold parameters and the values should be determined based on experiment results.

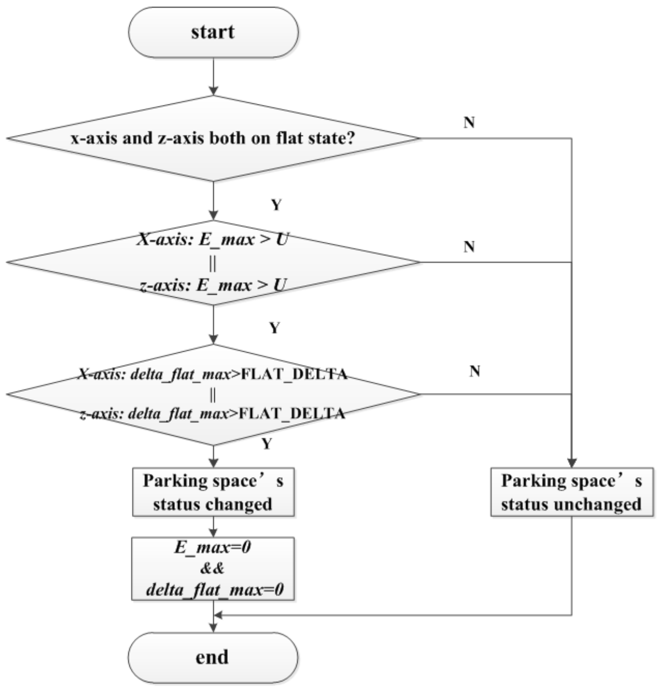

Fig 5. Flow chart of the arithmetic of parking state judgment

4 Experiment

In order to verify the accuracy and feasibility of the proposed detection algorithm, we deploy some magnetic sensors in Tongji university's roadside parking lot and conduct a number of experimental tests. The AMR chip and the actual deployment are in figure 6.

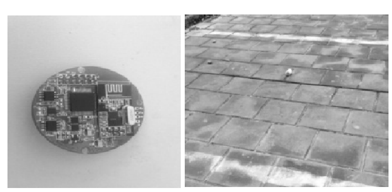

Fig 6. AMR chip and the actual testing deployment

According to the data obtained by several actual tests, we find that the algorithm can have the best performance when the parameters are set as table 1 shows.

Tab.1 Parameter Value

parameter	value	parameter	value
N	200	FLAT_DELTA	12
U	20	min_delta	6

Based on the aforementioned algorithm and the parameters setting, we conduct several testing in different parking scenarios and the results are shown in Table 2 and Table 3.

Tab 2. Results of different parking mode

Parking mode	The number of times of vehicle parking	The number of times of detected vehicle parking	Accuracy
Normal parking	120	118	0.983
Vehicle leaves on the process of parking	120	114	0.950
Vehicle enters the parking space after several times	120	115	0.958

Tab 3. Results of different adjacent condition

Condition of adjacent parking space	The number of times of vehicle parking	The number of times of detected vehicle parking	Accuracy
None	240	235	0.979
A car on the left	240	232	0.967
A car on the right	240	230	0.958
Two cars on left &right	240	228	0.950

5 Conclusion

In this paper, we have studied the magnetic sensor's application in the roadside parking lot. Based on the analysis of enormous experiment data, we have proposed a new vehicle detection algorithm, which uses state machine mechanism and overcomes the limitation of existing threshold-based algorithm. Our experiment result has proven that the algorithm is quite robust and has a high accuracy in different scenarios.

References

Cheung, S. Y., Coleri, S., Dundar, B., Ganesh, S., Tan, C., and Varaiya, P. (2005). "Traffic measurement and vehicle classification with single magnetic sensor." *Transportation research record: journal of the transportation research board*, 1917(1), 173-181.

Crowell, J. "Low Cost Solid State Attitude Sensor for Marine and General Applications." *OCEANS 2006*, 1-4.

Ding, J., Cheung, S., Tan, C., and Varaiya, P. (2004). "Vehicle detection by sensor network nodes." *California Partners for Advanced Transit and Highways (PATH)*.

Knaian, A. N. (2000). "A wireless sensor network for smart roadbeds and intelligent transportation systems,", Massachusetts Institute of Technology.

Detection and Compensation for Coded Odometer Errors Due to Train Wheel Slips and Slides

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Abstract: There might be wheel slips and slides when a train is moving. The coded odometer can be employed to measure the speed and the location of the train, which turns the linear speed of the wheel to the forward velocity of the train. Slips and slides make the two speeds different and measurement errors happen, which would be bigger and bigger over time. This paper summarizes several algorithms of identifying the wheel slips and slides such as comparing the measured accelerations with their upper bound, calculating the standard deviation of the accelerations, counting the residuals of the Kalman filtering, redundant sensors and so on. The paper also introduces a bunch of methods for compensating the errors, for example, using a fixed acceleration, interpolation and multiple sensors. Moreover, the detecting and compensating methods mentioned are simulated in Matlab with the actual experiment data and their effects of compensation are analyzed and compared at the end of this paper.
Keywords: Coded odometer; Slips and slides; Error detection; Error compensation.

1 Introduction

Wheel slips and slides always happen when a train is moving ahead. Slips are thought of as a wheel rotating fast without corresponding horizontal displacement, which are caused by the excessive pulling force over the adhesive capacity of the wheel and rail. Slides mean that the huge braking force destroys the wheel's adhesive state and makes it from rolling to sliding when the train is decelerating or braking. The slipping and sliding phenomena are shown in Figure 1.

According to the principles of the coded odometer, it approximately replaces the train velocity with the linear speed of the wheel. The two of them are almost same when the adhesive state of the wheel and rail is perfect. But when the wheel slips and slides happen, the linear speed would be greater and less than the train speed respectively. If no actions of detecting and correcting the slips and slides errors taken, the serious errors would be accumulated to an intolerable value. Consequently, it is very significant to detect and compensate for the errors of the train localization and speed measurement which is caused by wheel slips and slides.

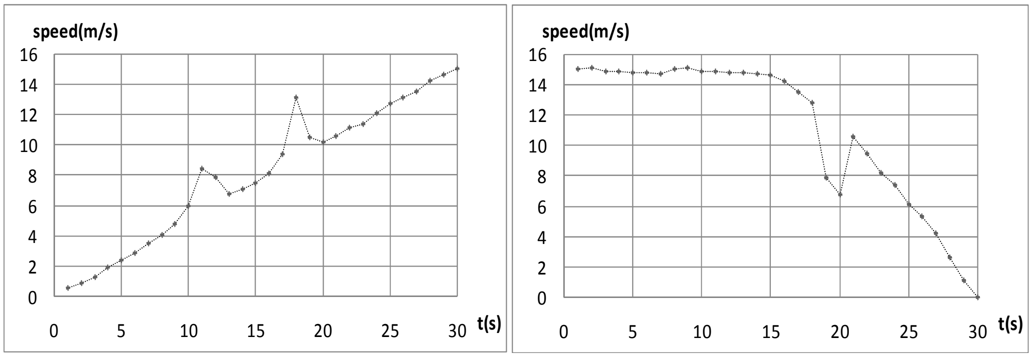

Figure 1. Wheel slips and slides phenomena

2 Detection and compensation of the wheel slips/ slides with one coded odometer

When a single coded odometer is adopted to measure the train velocity independently, the judgment of the slips/ slides should depend on the information underneath the measured data of the odometer.

2.1 Detection of the errors due to slips and slides

(1)Comparing the measured accelerations with the upper bound

The velocities measured by the coded odometer would increase or decrease sharply when the slips and slides happen to the wheel. In other words, great accelerations or decelerations would appear. One can set an upper acceleration bound a_m to sense the slips/slides, which stands for the maximum wheel acceleration or deceleration of normal rotating exclusive of slips and slides with experiences, experiments and theoretical arithmetic. The wheel is thought to have slips and slides as soon as the variation of the odometer measured speeds in unit time is greater than the upper acceleration bound a_m.

(2)Calculating the standard deviation of the measured accelerations

The accelerations also change fast when slips/slides occur to a wheel. Based on that principle, Samer S.Saab et al. designed an algorithm to decide if a train is slipping or sliding by calculating the standard deviation of the measured accelerations. k is the iteration index and T_s is the sampling time. Compute the standard deviation of the acceleration for the k th and previous $N-1$ time samples to make a decision of the slips/slides conditions of the k th sample.

$$\sigma_{\hat{a}}\left(kT_s\right) = std\left(\left[\hat{a}\left[\left(k-N\right)T_s\right], \hat{a}\left[\left(k-N+1\right)T_s\right], \cdots, \hat{a}\left[kT_s\right]\right]\right) \tag{1}$$

On the premise that the train runs perfectly at time $\left(k-1\right)T_s$ and the standard deviation of the sampling accelerations in time kT_s exceeds the tolerance, $\sigma_a\left(kT_s\right) > \varepsilon_{\hat{a}}^M$, the starting time of slips or slides can be positioned between $\left(k-1\right)T_s$ and kT_s. If the wheel slips or slides are considered on-going at time $\left(k-1\right)T_s$, and the standard deviation of the sampling accelerations in time kT_s suddenly below the judgment threshold for the end of the slips and slides, which can be presented as

$\sigma_a(kT_s) < \varepsilon_{\bar{a}}^m$, the slips and slides are thought to be finished.

(3)Counting the residuals of the Kalman filtering

Slips and slides just happen as abrupt phenomena with the train moving ahead, which is an unexpected deviate from the normal expected velocities. Technically, it is possible to judge a slip or slide by the differences between the estimated value and the observed value.

System state estimated value $\widehat{X}_{k-1}$ from the Kalman filtering for time $k-1$ should be proper when the slips and slides have not happened yet. The system state estimator $\widehat{X}_{k|k-1}$ for time k which is not considering of the observed velocity of time k can be reached by system state equations and one-step prediction equations. $\Phi_{k,k-1}$ is the one-step transfer matrix from time $k-1$ to time k.

$$\widehat{X}_{k|k-1} = \Phi_{k,k-1}\widehat{X}_{k-1} \tag{2}$$

According to the system state estimator $\widehat{X}_{k|k-1}$ at time k and the system measurement equations, the predicted measurement values $\widehat{Z}_{k|k-1}$ without considering of the actual measured velocities can be obtained. H_k mentioned here is the corresponding measurement matrix.

$$\widehat{Z}_{k|k-1} = H_k\widehat{X}_{k|k-1} \tag{3}$$

The residuals D_k of the accelerations are defined as the differences between the predicted measurement values $\widehat{Z}_{k|k-1}$ and the real measured values Z_k.

$$D_k = \widehat{Z}_{k|k-1} - Z_k \tag{4}$$

The residuals theory shows that the residuals should be the Gaussian White noises with zero mean value on condition that no slips and slides ever occur. The mean square error of the one-step prediction is $P_{k|k-1}$. The variance matrix of the measurement noises is R_k, and the variance of the residuals S_k can be calculated by:

$$S_k = H_k P_{k|k-1} H_k^T + R_k \tag{5}$$

Suppose a slips/slides detection function λ_k, which follows χ^2 distribution with freedom degree m. Stipulate a threshold value T_D, and the train is thought to run normally when the equation $\lambda_k \le T_D$ is satisfied, otherwise, slips/slides are happening.

$$\lambda_k = D_k^T S_k^{-1} D_k \tag{6}$$

2.2 Compensation of the errors due to slips and slides

After confirming the wheel slips and slides, solutions to compensate the errors caused by the odometer should be adopted immediately to avoid more errors accumulating for the moving distance calculation.

(1)Using a fixed acceleration

Set a slips/slides compensation acceleration on the basis of the train parameters and the performance of the slipping or sliding train. The slips/slides compensation acceleration would take the place of the current accelerations to get the velocities and the position of the train over the slipping or sliding period.

(2)Interpolation method

The interpolation method can be utilized to estimate the train speed during the train slips or slides after the corresponding section is identified smoothly. Although other interpolation techniques can be used as well, linear interpolation is used a lot for simplicity. Assume that the sampling time before the slips or slides is marked as $k_{start}T_s$, and we call the finished time $k_{end}T_s$. It should be noted that the train operated normally on both of the two times. In other words, the velocities measured by the odometer are the actual moving speed of the train on that two times (ignoring the calibration errors and the quantization errors). The compensation values of the train speed from time $k_{start}T_s$ to time $k_{end}T_s$ are given by (7).

$$\left[\tilde{v}\left(k_{start}T_s\right), \tilde{v}\left[\left(k_{start}+1\right)T_s\right], \cdots, \tilde{v}\left(k_{\mathrm{end}}T_s\right)\right] \equiv \mathrm{int}\,erpolate\left\{\hat{v}\left(k_{start}T_s\right), \hat{v}\left(k_{end}T_s\right)\right\} \quad (7)$$

When the linear interpolation method is employed, the corresponding model can be built as $\tilde{v}\left(kT_s\right) = a_k\left(kT_s\right) + b_k$. The parameters a_k and b_k can be determined by $\left(\left(k_{start}T_s\right), \hat{v}\left(k_{start}T_s\right)\right)$ and $\left(\left(k_{end}T_s\right), \hat{v}\left(k_{end}T_s\right)\right)$.

3 Detection and compensation of the wheel slips/ slides relying on other sensors

The methods of detecting and compensating the wheel slips and slides independently by a coded odometer mentioned in chapter 2 always need mathematical modeling or complex operations to improve the success rate of detection. In addition to that part, one can consider of using hardware redundancy to achieve the goal of slips/slides errors identification, which means using more than one coded odometer or using other sensors like an accelerometer or a Doppler radar.

3.1 Detection of the errors due to slips and slides

(1)Detection with redundant coded odometers

It is possible for two or more coded odometers installed on different train wheels to slip or slide asynchronously because of the mismatch of the installation position. So, more coded odometers can be taken into account. If the absolute value of wheel acceleration is greater than a fixed threshold, the wheel is slipping or sliding. If the difference between wheel velocities is greater than a fixed threshold, both the wheels are slipping or sliding.

(2) Detection with other train location and speed detection sensors

Other train location and speed detection sensors like accelerometers and Doppler radars would not be influenced by the slips and slides of the train according to their principles. The accelerometer can get the accelerations of the train directly which is an important evaluation indicator of slips/slides identification. The Doppler radar is derived from Doppler effects, which has nothing to do with wheel rotating. Although other sensors are not as sensitive or reliable as a coded odometer, they do identify the slips and slides efficiently. There are three methods to compare the odometer data with the other sensor's data, acceleration calculation method, velocity calculation method and sliding rate method.

The acceleration calculation method is handled this way: figure out the accelerations of the vehicle by the measured data of the two sensors respectively, and make the difference of the two accelerations. The train is slipping or sliding if the result is higher than one threshold. The velocity calculation method works in the same way but change the accelerations to velocities. The sliding rate method needs to compute the sliding rate λ of the train.

$$\lambda = \frac{v_z - v_j}{v_j} \times 100\% \tag{8}$$

v_z is the cross velocity of the wheel and v_j is the actual velocity of the train. The train is running normally if the sliding rate is between 8%~12%, but if the sliding rate is higher than 35%, the train must have a slip or slide.

3.2 Compensation of the errors due to slips and slides

(1) Compensation with several coded odometers

Install coded odometers on the different two wheels respectively. The identification results of the slips and slides will be represented by p_i. i means the i th wheel and $i = 1, 2$. p_i=0 means that wheel i is certainly not slipping or sliding, and p_i=1 just has the opposite meaning. The algorithm should judge the dynamic state of the train of being speed up or cut and express the results with variable q. The train is decelerating if $q = 0$, otherwise the train is speeding up. The compensated velocity v_k is given by (9).

$$\begin{aligned}
v_k &= \frac{v_{k1} + v_{k2}}{2} && if \quad p_1{=}0 \& p_2{=}0 \\
v_k &= v_{k1} && if \quad p_1{=}0 \& p_2{=}1 \\
v_k &= v_{k2} && if \quad p_1{=}1 \& p_2{=}0 \\
v_k &= v_{k-1} + aT_s && if \quad p_1 = 1 \& p_2 = 1 \& q = 1 \\
v_k &= v_{k-1} - dT_s && if \quad p_1 = 1 \& p_2 = 1 \& q = 0
\end{aligned} \tag{9}$$

Where a is a fixed acceleration value to compensate for the train slipping state, and d is the mean train deceleration which is given by the arithmetic mean between instantaneous wheel accelerations, filtered by a low pass filter and saturated between a higher value and a lower one.

(2)Compensation with other sensors

More and more types of speed sensors are used in modern train control systems.

The measurement accuracy of other speed sensors can be great higher than the coded odometer when slips/slides occur. Therefore, the measured data of coded odometer can be adopted when they are correct and data from other sensors would be utilized to calculate speed and distance of the train when the wheel is slipping or sliding.

Besides, to take full advantage of the data from all sensors, it can be considered to distribute weights for the sensors according to their measurement accuracy, reliability and other indexes. The least square estimation, the minimum variance estimation and other estimation theories can also be used to mix the samples together and get a better estimator. Also note that the wrong measurement values of the odometer due to wheel slips and slides should be removed. But what is astonishing is that not all information restructuring and fusion can improve the accuracy. For example, use two instruments to measure simultaneously, and one is twice as accurate as the other. The results of the least square estimate processing of the two machines are poorer than the higher precision one.

4 Comparison and analysis

This paper introduced the methods of detecting and compensating slips and slides with the own data of the coded odometer or the external data of the other sensors. Besides, we can identify the slip/slide faults by the odometer measurements and correct them with other sensors.

We made the simulation of the detection and compensation of slips and slides with the actual experimental data in matlab. The velocity and acceleration curves before compensation are shown in Figure 2.

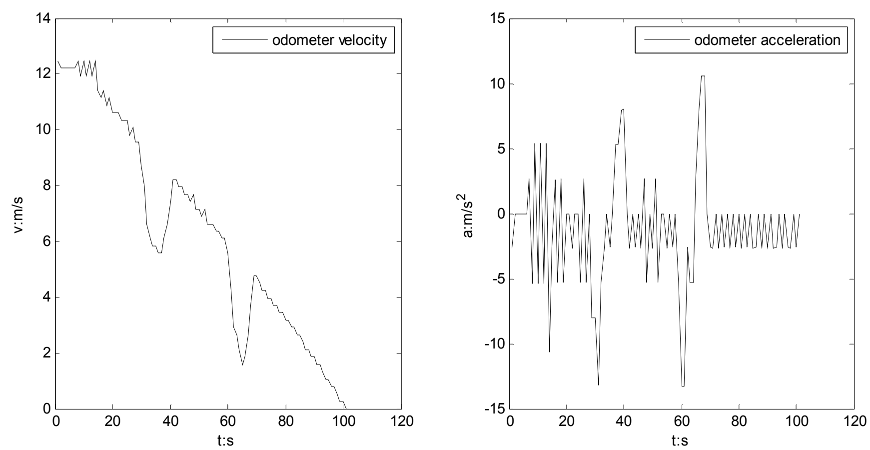

Figure 2. The velocity and acceleration curves before compensation

Figure 3 gives the results of comparing the measured accelerations with the upper bound to detect and using a fixed acceleration to compensate the slips and slides. Identification of slip/slide errors with the internal odometer data always base on the theory that the speeds and accelerations of the train would change sharply when the slips and slides occur. Although these methods do not need to increase the hardware redundancy, it is necessary to sacrifice the complexity of the algorithm to get higher precision. Comparing the measured accelerations with the fixed upper bound can be the simplest way to distinguish the rotating faults and it would not take too much operations. Besides, that method used a lot in the existing systems and it can identify most obvious slips/slides. The downside is that it is not very sensitive with the tiny changes of the velocities and accelerations and it can do nothing if there is a smooth curve in a sharp slip or slide (like the first slide of in Figure 3) . Besides, the choice of the upper boundary affects a lot about the amendment effects. After the diagnosis of wheel slips and slides, except for the absolute location correction of the transponders, other effective ways should be tried to overcome the bad influence for the measurement of train speed and distance caused by slips and slides. Using a fixed acceleration can be very simple, but using one default acceleration set beforehand to compensate in all the possible situations and no matter how serious the slips/slides are may give rise to great errors. The compensation curve is a broken line because the acceleration and deceleration situations use the different default accelerations opposite in sign.

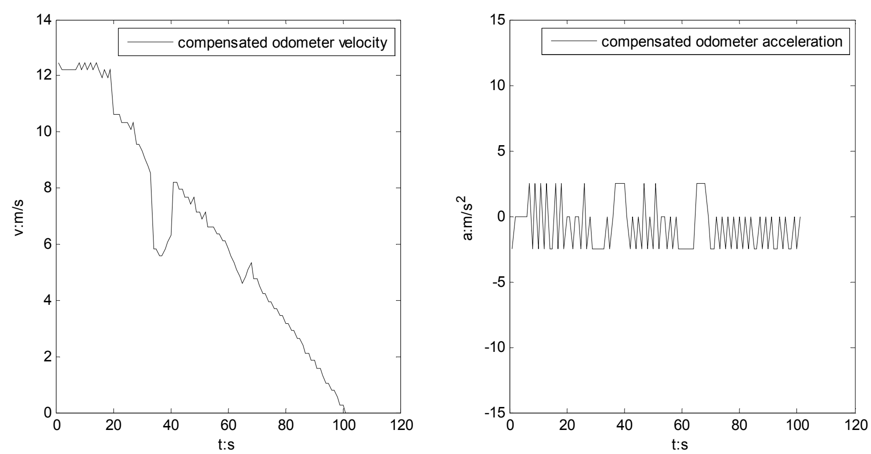

Figure 3. The velocity and acceleration curves after compensation

Figure 4 shows the results of calculating the standard deviation of the measured accelerations to detect and using the interpolation method to compensate the slips and slides. Calculating the standard deviation of the measured accelerations can work better than the acceleration compared method. Although the algorithm still cannot identify the slips and slides corresponding to angular acceleration with magnitude smaller than the maximum achievable train acceleration, the algorithm can compensate at least 86% of the errors due to wheel slips and slides successfully. And the interpolation method can be more intelligent than the fixed one. For example, we can analyze a linear interpolation situation. Although it takes a constant acceleration to calculate the speed and the displacement of the train, the acceleration is determined in real time by the correct samples before and after the abnormal wheel rotating. The improved interpolation algorithms can make the speed-time curve smoother.

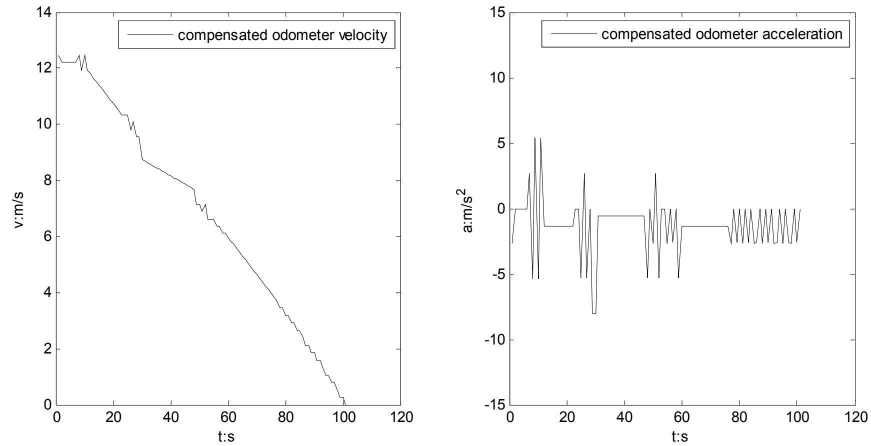

Figure 4. The velocity and acceleration curves after compensation

Figure 5 shows the detection and compensation results of using Doppler radar. Employing other sensors to realize the redundancy and complementary information is a more simple solution. But which measured result should be taken needs a proven selection criteria. Moreover, the weight allocation of the sensors or the selection of the boundary condition parameters should be taken carefully by the theoretical derivation or the experiments. Employ other sensors to compensate the wheel slip and slide errors can be the trend of the development. And it is always an emphasis of the domain.

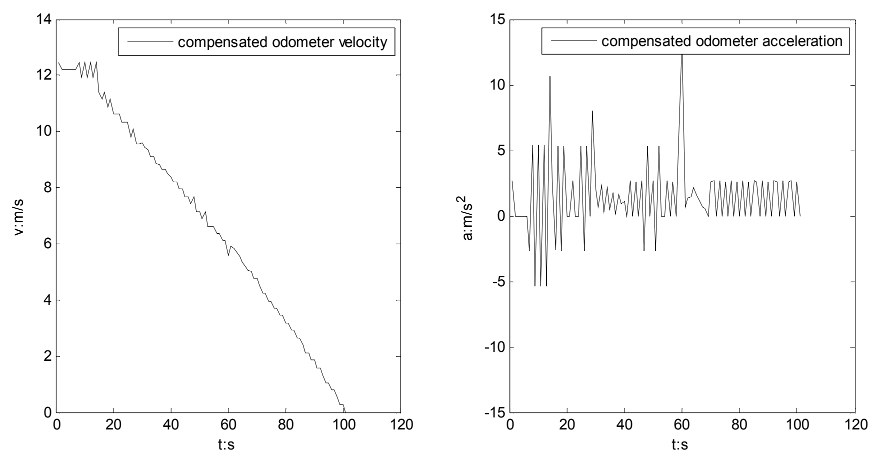

Figure 5. The velocity and acceleration curves after compensation

5 Conclusion

This paper summarizes the typical methods to detect and correct the train slips and slides. The detection of the slips and slides can be dependent on upper bound acceleration method, acceleration standard deviation method, Kalman filtering residuals method, redundant coded odometers method and the method of combined with other sensors. Methods to compensate the wheel slips and slides include fixed acceleration method, interpolation method and multi-sensors method which is more and more popular. The paper focuses on the merits and demerits of the methods. Besides, the simulation, comparison and analysis are given in the end of the paper. The comprehensive application of the methods can get more precise train localization and speed detection information.

References

Malvezzi, M., Toni, P., Allotta, B., and Colla, V. (2001). "Train speed and position evaluation using wheel velocity measurements." *2001 IEEE/ASME international conference on advanced intelligent mechatronics proceedings*, Como, Italy, 220-224.

Malvezzi, M., Allotta, B., and Rinchi, M. (2011). "Odometric estimation for automatic train protection and control systems." *Vehicle system dynamics*, 49, 723-739.

Matias, G., Rafael, S., and Jose, A.. (1997). "An antislipping fuzzy logic controller for a railway traction system." *Proceedings of the sixth IEEE international conference on fuzzy system.* Barcelona, Spain, 119-124.

Saab, S. S., Nasr, G. E., and Badr, E. A. (2002). "Compensation of axle-generator errors due to wheel slip and slide." *IEEE transactions on vehicular technology*, 51, 577-586.

Tomoki, W., Akihiro, Y., Toshio, H., Katsuyoshi, H., and Shigeru, N.. (1997). "Optimization of readhession control of Shinkansen trains with wheel-rail adhesion prediction." *Power conversion conference*, Honolulu, Hawaii, 47-50.

Wen, M., and Changlin, W. (2014). "Vehicle dynamics model and analysis of ATO key parameters." *Railway computer application*, 23(8), 8-12.

Ying, L., and Changlin, W. (2011). "Research of slip and slide detection and adjust method in onboard ATP." *Urban mass transit*, 14(3), 28-36.

Yongyuan, Q., Hongyue, Z., and Shuhua, W. (2012). *Kalman filtering and integrated navigation theory*, Xian, China.

Yu, D.. (2008). "Chapter 5.2: The working mechanism of train control system." *Wayside railway signaling and train control system,* Beijing, China.

Evaluation of the Information Transfer Ability of a High-Speed Railway Dispatching System Based on the Structural Entropy Theory

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Abstract: With the development of China's economy and transportation industries, high-speed railway continues to grow in strength in recent years, as the command center of high-speed trains operation, high-speed railway dispatching system plays an important role in ensuring the safety, high-speed and punctuality of trains. By using structural entropy evaluation theory, this paper analyzes the influence of the information flow within the system of three kinds of high-speed railway dispatching system: the whole way centralized dispatching mode, the region concentrated secondary mode and the trunk line (passage) secondary mode. This paper evaluates the ability of information transfer of the three command system modes from the perspective of time-effect, quality and order degree of information transfer, and puts forward the time-effect and quality analysis model of the information flow within the three command modes, and makes a quantitative evaluation of time-effect, quality and order degree of the system.
Keywords: Dispatching command system; High-speed rail; Structural entropy; Order degree.

1 Introduction

In the high-speed railway dispatching system, there is a longitudinal and transverse information flow of the vertical structure and the horizontal structure. In general, the information flow throughout a system is relatively stable, the time-effect and accuracy of information flows in the system are two conflicting indicators, namely, reducing the total layer of dispatching system structure will increase the speed of information flows, but due to an increasing elements of each level, it will make the bifurcation of information transmission increase, which will greatly increase the probability of error information, thus reducing the accuracy of information transmission. High-speed railway dispatching command must guarantee the traffic safety, and requires high quality of information transmission, therefore, how to configure these two conflicting indicators, the time-effect and accuracy of information transmission, to achieve the optimal system information transmission ability is an urgent problem. This paper introduces the evaluation theory of system structure entropy, through the establishment of three optional organization structure model of dispatching command modes, and then calculate and compare the order degree of the system as a comprehensive measure index of information transmission, carrying on the quantitative analysis of information communication mechanism.

2 Three kinds of high-speed railway dispatching system structure model

2.1 The whole way centralized dispatching mode

The whole way centralized dispatching mode is to set up an integrated dispatching center, and then according to the number of lines, traffic volume and other settings, build up appropriate number of dispatcher stations. And through professional dispatch, each dispatching console releases dispatching orders directly to the basic stations, and commands the fieldwork. Therefore, the system architecture can be divided into two layers: China Railway Corporation dispatching center and dispatching section. According to Rail transport [2011] No. 180 document, which considers train pairs as a main factor of dispatching section division and indicates the dispatching section-dividing principle: if there are 60 or more than 60 pairs of trains within the jurisdiction section, we set a train dispatch console at every 200-300 km; if there are less than 60 pairs of trains within the jurisdiction section, we set up a train dispatch console at every 300-400 km. In the future, China will build a "four vertical and four horizontal" high-speed railway network, China's high-speed railway mileage will reach 13000 kilometers, according to an estimation of setting up a train dispatcher station by an average of 300 kilometers, the whole high-speed network will be divided into 43 dispatching sections, as shown in figure 1.

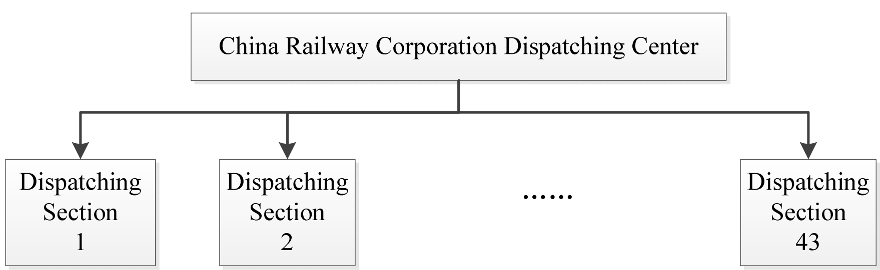

Figure 1. Structure model of the whole way centralized dispatching mode

2.2 The region concentrated secondary mode

This mode divides the entire high-speed railway dispatching system into two layers: the whole high-speed railway network dispatching command center and the regional dispatch center. Regional dispatch center is responsible for dispatching trains' daily work, releasing dispatching orders to the basic stations through each professional dispatching console. In this mode, the dispatching system structure can be divided into three layers: China Railway Corporation dispatch center, the regional dispatch center and the dispatch section. The whole high-speed network can be divided into 16 regional dispatch centers (including Harbin, Shenyang, Beijing, Jinan, Lanzhou, Taiyuan, Xi'an, Shanghai, Zhengzhou, Wuhan, Chengdu, Nanchang, Kunming, Nanning and Guangzhou dispatching center) and 43 dispatching section, as shown in Figure 2.

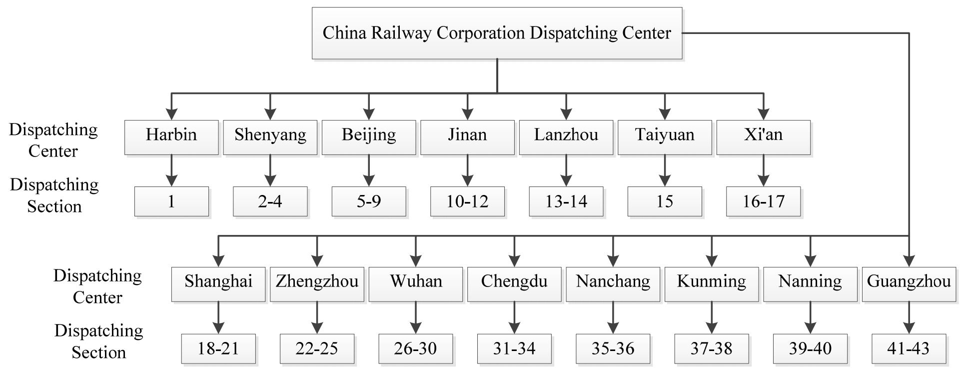

Figure 2. Structure model of the region concentrated secondary mode

2.3 The trunk line (passage) secondary mode

This mode divides also the entire high-speed railway dispatching system into two layers: the whole high-speed railway network dispatching command center and high-speed rail company dispatch center, we set up high-speed rail company dispatch center by trunk line (passage). High-speed rail company dispatch center is responsible for the daily work of train dispatching within the scope of the jurisdiction, releasing directly dispatching orders to the basic stations, and the basic stations organize the Traffic organization work at the scene in accordance with the dispatching order. In this mode, the dispatching system structure can be divided into three layers: China Railway Corporation dispatch center, trunk (channel) dispatch center and dispatch section. The whole high-speed network will be divided into 8 trunk (channel) dispatch centers and 43 dispatch sections, as shown in Figure 3.

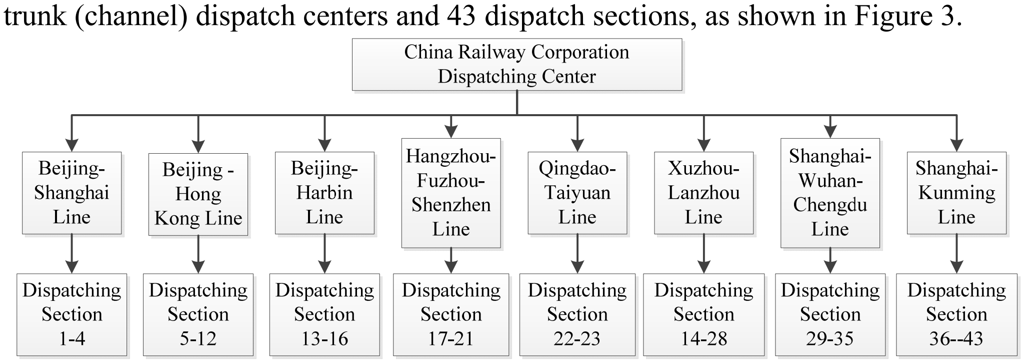

Figure 3. Structure model of the trunk line (passage) secondary mode

3. Evaluation of information transfer mechanism

3.1 The time-effect of information transfer

Time-effect entropy is defined as the measurement of the size of time-effect uncertainty when the information flows in a system. Time-effect reflects the efficiency of the mutual coordination between nodes unit in system. Assuming that there exists communication of information between k units in the m middle management agency whose span is n.

The contact length of the two elements is defined as the shortest path between two elements in the structure; the length directly connected is 1, adding one at a time at each transit.

When the organizational structure is determined, we can determine the shortest contact length L_{ij} between the subordinate elements in the system. Number of the possible routes that system evolves into a certain state is defined as the total number of micro state, the total number of microstates is larger, the system is more likely end up in this state, the total number of microstates of time-effect in a system A_t is:

$$A_t = \sum_i \sum_j L_{ij} \qquad (\mathrm{i} = 1,2 \ldots, \mathrm{m};\ \ \mathrm{j} = 1,2 \ldots, \mathrm{n})$$

Calculate the achieving probability of time-effect microscopic state of each contact:

$$P_t(i,j) = \frac{L_{ij}}{A_t}$$

Time-effect entropy between any two elements of the longitudinal hierarchy and same layer in the system:

$$H_t(i,j) = -P_t(i,j) log_2 P_t(i,j)$$

Calculate the total time-effect entropy of the system:

$$H_t = \sum_{i=1}^{m} \sum_{j=1}^{n} H_t\,(i,j)$$

Calculate the maximum time-effect entropy of the system:

$$H_{t\,max} = log_2 A_t$$

Calculate the time-effect of the system:

$$R_t = 1 - \frac{H_t}{H_{t\,max}}$$

3.2 Quality of information transfer

The quality of the system describes the accuracy of information transfer flows in the system, the quality entropy describes the uncertainty size of information quality, that is, describes the uncertainty of error opportunities in the process of information transfer.

k_i is the contact span of each node, defined as the number of nodes that directly contact with the elements in the structure diagram, total quality systems microscopic state is:

$$A_m = \sum_i k_i$$

Calculate the achieving probability of quality microscopic state of each contact:

$$P_m(i) = \frac{k_i}{A_m}$$

Calculate the quality entropy of each node of the system:

$$H_m(i) = -P_m(i) log_2 P_m(i)$$

Calculate the total quality entropy of the system:

$$H_m = \sum_i H_m(i)$$

Calculate the maximum quality entropy of the system:

$$H_{m\,max} = log_2 A_m$$

Calculate the quality of the system:

$$R_m = 1 - \frac{H_m}{H_{m\,max}}$$

3.3 The order degree of information transfer

Time-effect and quality of information transfer reflect the information transfer capability in a system, a certain level do not represent the strength of information transfer capability of the system. Therefore, in order to fully assess the information transfer capability, introduce the order degree as the comprehensive index of time-effect and quality of information transfer:

$$R = \alpha R_t + (1 - \alpha) R_m,\ \alpha \in [0,1]$$

α is the weight coefficient time-effect and quality of information transfer, $\alpha > 0.5$ means that we pay more attention to time-effect than quality of information transmission, conversely, $\alpha < 0.5$ means that we pay more attention to the quality of information transmission. The bigger R is, the higher the order degree of system is.

4 The result of order degree of three dispatching command modes

4.1 The calculation of order degree of the whole way centralized dispatching mode

According to the high-speed railway dispatching system structure model of the whole way centralized dispatching mode (Figure 1), the time-effect R_t^1 and quality

R_m^1 of this mode are calculated as shown in Table 1 and Table 2.

Table 1. The calculation of the time-effect R_t^1

Link length	$P_t(i,j)$	Sum	Micro state A_t	Time-effect R_t^1
1	1/43	43	43	$H_t^1 = 5.4263$ $H_{t\,max}^1 = 5.4263$ $R_t^1 = 0$
Sum	1.0	43	43	

Table 2. The calculation of the quality R_m^1

Link Span	$P_t(i,j)$	Sum	Micro state A_t	Quality R_m^1
1	1/86	43	43	$H_m^1 = 3.7131$
43	43/86	1	43	$H_{m\,max}^1 = 6.4263$
Sum	1.0	44	86	$R_m^1 = 0.4222$

4.2 The comparison of order degree of three modes

By the same method, we can calculate the time-effect and quality of the other two modes, and the results are shown in Table 3.

Table3. The comparison of order degree of three modes

Mode	Time-effect entropy	Quality entropy	Order degree of time-effect	Order degree of quality
The whole way centralized dispatching mode	5.4263	3.7131	0	0.4222
The region concentrated secondary mode	6.5727	3.6151	0.0833	0.3829
The trunk line (passage) secondary mode	6.4703	2.9951	0.0884	0.4720

According to the definition of order degree and the data above, the results of the order degree of three modes are shown in Figure 4.

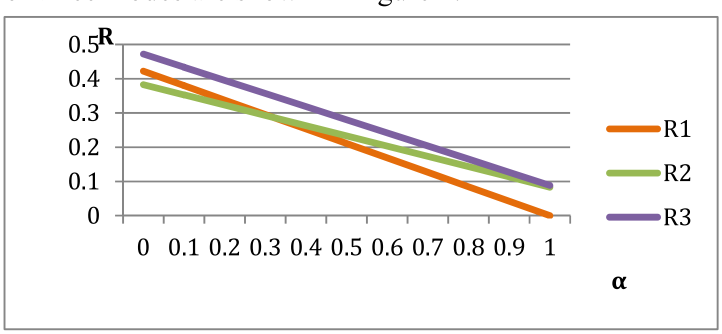

Figure 4 The order degree of three modes

No matter what value α, information transfer ability of the trunk line (channel) secondary mode are higher than the other two modes. From the perspective of the information transfer quality, the accuracy of the information transfer of the whole way centralized dispatching mode is very low, high-speed railway dispatching command must guarantee the traffic safety, and requires high quality of information transmission, therefore, this kind of mode is not recommended. In the early stages of development, China's high-speed railway that has been opened mainly adopts the region concentrated secondary mode. After our high-speed rail into the net, dispatching could be considered using trunk line (channel) centralized secondary mode in the future, although it cannot be asserted merits of these two models, but at least be able to provide a reference from the perspective of information transmission.

5 Conclusions

With the fast development high-speed railway, China's high-speed railway has gradually formed a railway net, which puts forward higher requirements on security and efficiency of dispatching command. Taking order degree of system as a comprehensive measure index of information transfer, this paper has made a quantitative evaluation of information communication mechanism, which provides a reference for the selection of information delivery mechanisms high-speed railway dispatching mode to ensure fast and accurate information transfer in the process of dispatching.

References

Lv Jian (2003). "Evaluation of Order Degree of Organization Structure by Means of Structure Entropy". *Forecasting,* 72-74

Peng Qiyuan (2006). "Dispatching Scheme for High Speed Passenger Lines in China". *Journal of Southwest Jiaotong University,* 541-548

Ruan Pingnan (2010). "Structure Evaluation Model of Network Organization Based on Entropy". *Journal of Wuhan University of Technology*， 183-200

Xu Mengqiu (2010). "Safety Research on High-Speed Railway Dispatching System". *Southwest Jiaotong University master's degree thesis*

Yan Zhilin (1997). "Evaluation of System Order Degree as Viewed from Entropy". *Systems Engineering Theory and Practice,* 45-48

Zhao chunlei (2010). "Research on high-speed railway dispatching system". *Railway Economics Research,* 15-18

Optimizing Traffic Organization in Urban Intersections: A Simulation Study

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Abstract: As important nodes on urban roads, intersections are prone to cause traffic jams and chaos. Therefore, the traffic organization of intersection is closely related to the overall performance level of the urban road net. It's necessary to improve traffic organization of existed intersections, so that the capacity of at-grade intersections can be enhanced, the traffic congestion of urban roads can be alleviated, to a certain degree. This research includes two major parts. The first part is studying the theories about timing signal control based on the running mechanism of at-grade intersection's traffic flow from the perspective of both time and space, in order to find efficient ways to optimize intersection's traffic organization. The second part is conducting a further optimization and modification on road channelization and signal control combining the above-mentioned theory with current status, eventually establishing a feasible and effective scheme. The following step is applying the micro traffic simulation software VISSIM to evaluate the present traffic of the XiYing Road-XiYan Road intersection in Xi'An based on relevant data.
Keywords: Intersection optimization; Signal control; Road channelization; VISSIM simulation.

1 Introduction

Urban transportation is the main artery for urban economy to run through. Meanwhile, the rapid development of economy does require the traffic to flow smoothly. Thus, organization of at-grade intersection is essential in traffic control. Methods for controlling the traffic of at-grade intersection contains stop control, way-giving control, signal control, etc. The first two of the methods accommodate to the intersections where the flow isn't too heavy. The rest are suitable for the intersections where the flow is heavy, which make great contribution to relieving the congestion of intersections. Compared with interchange, signal control does not overuse the land resource essentially, whereas it can effectively fulfill the departure of conflict flows. Therefore, to improve the capacity of the urban intersections in our country, the most important task of all is to improve the capacity of the intersections where signal controlled systems are applied.

2 Theoretical Consideration

2.1 Normal phase delay

As is shown in Figure 1, vertical axis represents the length of the queue, horizontal axis represents time. N_j is the length of vertical link between link *OC* and *DC* as well as the length of the queue at the entrance lane at that time. The slope of *OC* is the rate of arrival, and the slope of *DC* is the saturated flows of entrance lane. Automobile *A* needs to wait a certain time of delay t_A to pass the stop-line if there are vehicles in the front before its arrival.

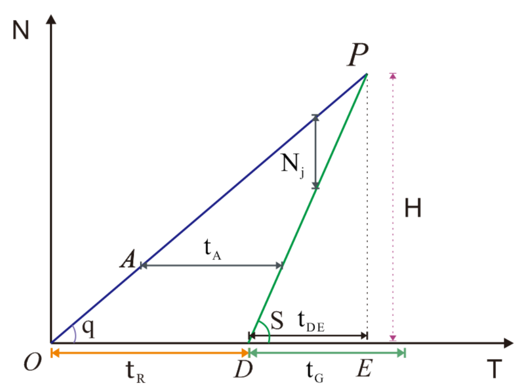

Figure 1.Chart of normal phase delay

If the arrival time is a constant, the total delay time of all vehicles within a signal cycle can be determined by the area of ΔOCD, and thus it reaches

$$\overline{d_I} = \frac{C \cdot (1-\lambda)^2}{2(1-\chi\lambda)} \tag{1}$$

with $\lambda = t_G / C$ and $\chi = q / (s \cdot \lambda)$, since $t_R = C - t_G$

where C is the cycle length of signal, t_R symbolizes time for red light, t_G symbolizes time for green light.

2.2 Random delay

Actually, the arrival rate of vehicles within different signal cycles fluctuates at random, which can result in temporary over saturated phenomenon, namely, the vehicles behind the stop-line cannot be cleared up only to increase the delay at the intersection greatly, such a phenomenon is called random delay, Webster figured out the model of random delay on the assumption that the traffic obeys Poisson Distribution, thus the average delay of vehicles is:

$$\overline{d_2} = \frac{\chi^2}{2q \cdot (1-\chi)} - 0.65\left(\frac{C}{q^2}\right)^{\frac{1}{3}} \cdot \chi^{2+5\lambda} \tag{2}$$

In the equation, the first term is the Poisson Distribution arrival that takes random fluctuation into account, the second term is the correction term figured out by means of simulation (Pu Q.,1999).

2.3 Webster delay

Combining Eq.1 and Eq.2, we can figure out the expressive equation of Webster Delay model as follows:

$$\overline{d} = \frac{C \cdot (1-\lambda)^2}{2(1-\chi\lambda)} + \frac{\chi^2}{2q \cdot (1-\chi)} - 0.65\left(\frac{C}{q^2}\right)^{\frac{1}{3}} \cdot \chi^{2+5\lambda} \tag{3}$$

2.4 Confirmation of the time span of Webster's best signal circulation

According to the theory for stable flow, the average delay time of the main traffic at an intersection can be expressed with the following equation:

$$d = \sum_{i=1}^{n}\left[\left(\frac{C \cdot (1-\lambda_i)^2}{2(1-y_i)} + \frac{\chi_i^{\ 2}}{2q_i \cdot (1-\chi_i)}\right) \cdot q_i\right] \Big/ \sum_{i=1}^{n} q_i \tag{4}$$

where *d* with index *i* is the average delay time of the main flow on the relevant lane, q_i reflects the arrival rate of the main flow on lane *i*.

As we know, "The average delay time of main flow is the least" is equivalent to "The degree of saturation of each main flow is equal". Namely:

$$\frac{y_j}{\lambda_j} = \chi_j = \chi_k = \frac{y_k}{\lambda_k} \Rightarrow \lambda_j = \frac{y_j}{Y} \cdot \frac{C-L}{C} \tag{5}$$

where *L* is the total time lost during the whole signal cycle.

Therefore it's also clear that there is certain relationship between the green ratio and signal circulation. If the circulation formula of average delay time is derivate of circulation *C*, assuming the derivative is zero, through repeated calculations, we can get the simplified formula for the best signal circulation:

$$C_0 = \frac{1.5L + 5}{1 - Y} \tag{6}$$

3 Basic Data

3.1 On-the-spot investigation

The intersection where Xiying Rd. and Xiyan Rd. cross is a typical intersection where two avenues cross. Via investigating the geometric condition, the current traffic signal control and the flow in the peak hour, we worked out the intersection plan, the current phase diagram at the intersection and the figure of the traffic, which are shown in Figures 2 and 3 and Table1.

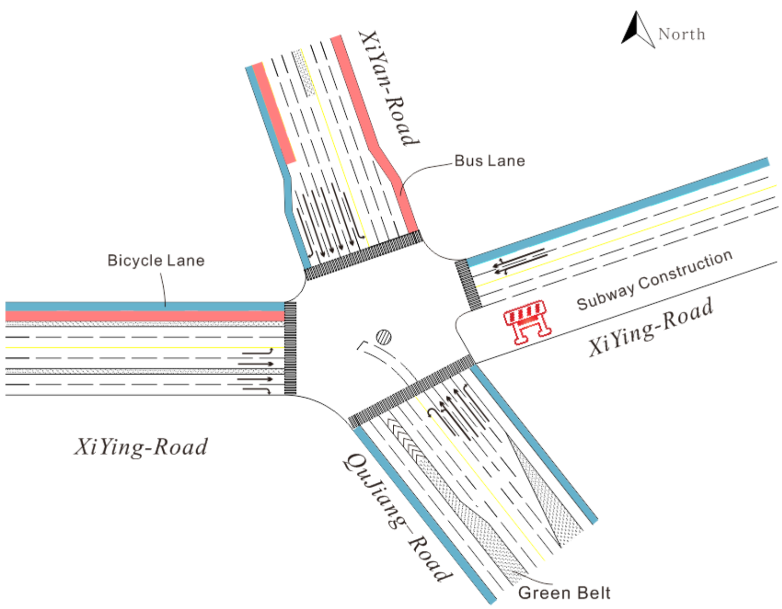

Figure 2.Current intersection plan

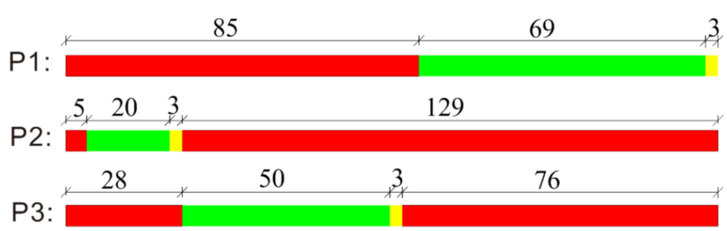

Figure 3.Current phase diagram

Table 1.Traffic distribution of peak hour

Lane / *Type*	East entrance			West entrance			South entrance			North entrance		
	L	S	R	L	S	R	L	S	R	L	S	R
Small	145	488	175	353	398	86	322	1689	218	172	1795	342
Medium	4	78	1	36	62	6	4	43	3	4	18	22
Large	0	1	0	0	1	0	0	3	0	0	0	0

L – left lane, S – straight lane, R – right lane.

3.2 Existing problems

(1) The time spent driving straight through west entrance and standing in the queue to turn right is comparatively long, causing a phenomenon of residual queue.

(2) The straight-running car at north entrance is prone to have conflicts with the pedestrian, which threatens personal safety.

(3) The set time for all-red for the 1st phase and the 2nd phase aren't so reasonable because the intersection there is larger than normal; meanwhile the all-red time can't satisfy the requirement that all the vehicles shall run across the intersection from the stop-line when the green light is coming to its end.

(4) The straight-running flows at east entrance and for the straight-running flow at west entrance as well as the left-turning flow have a more serious conflict with the flow running south or north. That's because the left-turning flow at east entrance and west entrance is heavier which is caused by no left-turning phase.

(5) This intersection isn't a firmly symmetric one, for the straight-running flow at east entrance has some serious conflict with the left-turning flow of west entrance.

(6) Since the metro construction occupied part of the lanes, it keeps an imbalance between the number of the lanes at east entrance and west entrance.

4 Rectification Measures

4.1 Rectify the plan

The rectified intersection is shown in the following figure.

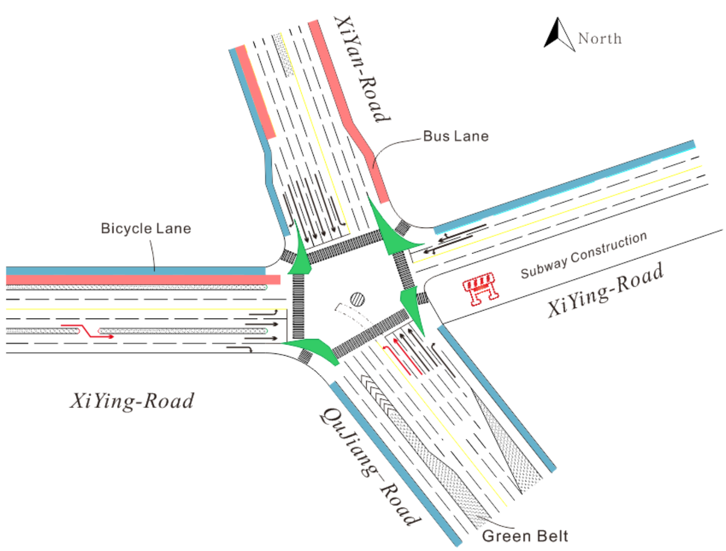

Figure 4.Rectified design for intersection plan

As is shown in Figure 4, the rectification includes the following measures:

(1) Now that the investigation reveals the fact that there is less flow along the straight lanes on the southern side, we should cut off a certain part of the green belt

to build a access which is about 50 meters away from the intersection at west entrance so that some vehicles can be led to the through lane on the southern side, as a result, the length of the queue will get shortened, which contributes to decrease the delay there.

(2) Setting traffic islands which, on one hand, is convenient for right-turning vehicles to pass; on the other shortens the distance between the stop-line and the intersection so that vehicles can pass the intersection more quickly and at the same moment pedestrians to go straightly across the street becomes safer, which can decrease the possibility for pedestrians to have conflicts with vehicles.

(3) Due to a much heavier straight-running traffic at north entrance, adjust the turning-around lane into a left-turning lane, and the straight-to left lane into a straight-running lane.

4.2 Time optimization for signals

Saturated flow is estimated by means of multiplying the common saturated flow by the correction coefficient of each affective factor, namely, the estimated saturated flow on the lanes at the entrance:

$$S_f = S_{bi} \times f(F_i) \tag{7}$$

where: S_f is the estimated saturated flow on the lanes at the entrance, pcu/h, and S_{bi} is the common saturated flow on the lanes of i style. When index i is replaced with T, L or R, it separately stands for the relevant flow of straight-running, left-turning, or right-turning. $f(F_i)$ is the correction coefficient relevant to each style of lanes at the entrance.

Correction coefficient of lane width is necessary to be determined since the width of the lane would generate some influence to the capacity:

$$f_w = \begin{cases} 1 & 3.0 \le W \le 3.5 \\ 0.4(W - 0.5) & 2.7 \le W < 3.0 \\ 0.05(W + 16.5) & W > 3.5 \end{cases} \tag{8}$$

where W is the width of the lanes at each entrance.

Influence coefficient of gradient and large vehicles' ratio should be taken into consideration due to the consumption of different space resources are different in accordance with the type of vehicles, and the road's vertical slope affects vehicle's dynamic performance (Yang X.,2013)

$$f_g = 1 - (G + HV) \tag{9}$$

where G is vertical slope, and HV is ratio of large scale vehicles.

According to Eqs.7-9, Table 2 shows the calculated parameters in signal timing.

Table 2.Signal timing parameters

Ent.	Lane	NOL	q	S_{bi}	f_W	f_g	S_f	y_i
East	T&L	1	451	1800	1	0.882	1588	0.284
	T&R	1	490	1800	1	0.882	1588	0.309
West	R	1	95	1380	1	0.905	1249	0.076
	T	2	493	2520	1	0.807	2034	0.242
	L	1	407	1800	1	0.867	1561	0.261
South	L	1	322	1550	1	0.982	1522	0.212
	T	3	1760	5400	1	0.960	5184	0.340
	R	1	223	1550	1	0.980	1519	0.147
North	L	1	178	1600	1	0.966	1546	0.115
	T	4	1822	6320	1	0.985	6226	0.293
	R	1	375	1530	1	0.912	1395	0.269

NOL – number of lane.

The calculation formula for green light interval time is:

$$I = p/v_a + t_s \tag{10}$$

If the average speed of vehicles running on the lanes v_a is 6m/s; braking time relevant to the vehicles t_s is 2s (Zheng C.J.,2005); P is the distance from the stop-line to the conflict point, here is 25m, on condition that the flow running east and west is easy to have conflicts with the flow running south and north.

According to phase order, we can get $I = 6.17$s, thus we can confirm 6s as the interval time between 3rd phase and 1st phase.

The calculation formula of total lost time L is:

$$L = \sum_{i=1}^{3} (L_c + I_i - A) \tag{11}$$

where L_c is the lost time for vehicles to start, I is the green light interval time (it contains yellow-light time and all-red time), A is the yellow light time.

Through the investigation on the spot, we can calculate the total loss time L is about 12 seconds inside one cycle.

According to Table 2, the aggregate of each phase's max flow ratio Y is 0.861, then using Eq.6, we can get the Webster best signal circulation C_0 is 165 seconds.

Through the calculation result of the above, we can work out the time of green light according to the following formula:

$$g_{ei} = G_e \times \frac{Max(y_{i1}, y_{i2}, \cdots)}{Y} \quad (12)$$

$$g_i = g_{ei} - A_i + L_i \quad (13)$$

Where g_e with the index i is the effective green time of each phase, G_e is the total effective green time, and g_i is the displaying time.

The 1st phase is for running through south and north, the 2nd phase for left-turning of south and north, the 3rd phase for all direction of east and west.

According to Eq.12 and Eq.13, through calculation we can work out the green-light time displaying in each phase are 60s, 38s, 55s in turns. Figure 5 shows the signal phase diagram according to our calculation.

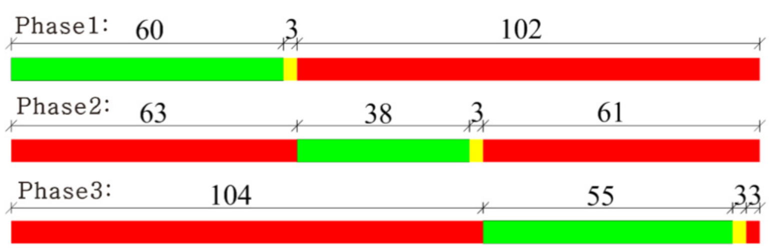

Figure5. Optimized signal phase diagram

5 Simulation and Conclusions

By modeling and calibrating the model of this at-grade intersection in VISSIM (PTV, 2007), as well as setting relative parameters while simulating, we can get a simple comparison between the current intersection and the optimized one, as shown in Table 3.

Table 3. Simulation under different situation

Time interval(sec)		200-700	700-1200	1200-1700	1700-2200	Total
Delay	Current	37.9	42.4	44.3	42	41.6
	Optimized	37	38.5	42.5	34.5	38.2
Stopd	Current	31.7	35.2	36.3	35	34.5
	Optimized	29.8	31	34.4	28.2	30.9
Stops	Current	0.61	0.72	0.83	0.64	0.7
	Optimized	0.53	0.61	0.65	0.61	0.6
#Veh	Current	568	532	530	506	2136
	Optimized	761	705	714	718	2898

Stopd – the average dwell time per vehicle (unit: second);
Stops – the average stop frequency per vehicle;
#Veh – number of vehicles passing the intersection;
Statistics start from at 200 sec, when the flow becomes stable.

As is indicated in the table, we can draw the conclusion that the optimized intersection does have minimized the total delayed cost of system, and the vehicle will stop less. And at the same time, the capacity of optimized intersection shall be improved according to the results of simulation.

The capacity and level of delay of signal controlled intersection are directly influenced by the timing scheme, therefore an optimal timing scheme is the key of improving the efficiency of the intersection. This passage has conducted a typical optimization of a current intersection using classical theory of timing signal control without taking the non-motor vehicles into account, while the signal control of non-motor vehicles under mixed traffic is rather important, which is a study aspect need of endeavor.

Acknowledgement

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References

Chen J. (2014). "Urban road's un-equilibrium traffic flow operation characteristics and space-time resource cooperative control methods." *China Communication Press,* Beijing.

Liu G. P., and Pei Y. L. (2005). "Study of calculation method of intersection delay under signal control." *China Journal of Highway and Transport,* 18(1), 104-107.

Liao M. J., Wang K. Y. et al. (2003). "The channelization design of intersection based on traffic simulation." *Journal of Beihua University (Natural Science),* 4(2), 175-177.

Pu Q. and Tan Y. C. (1999). "Signal-planning optimal model for intersection." *Journal of Shanghai Tiedao University,* 20(4), 31-34.

PTV. (2007). "VISSIM 4.30 User Manual." *Planning Transport Verkehr AG,* Germany.

Shao C.Q., Rong J. et al. (2011). "Research on the saturated flow rate and related affecting factors of signal controlled intersection." *Journal of Beijing University of Technology,* 37(10), 1505-1509.

Transportation Research Board (TRB) (2010). *Highway Capacity Manual,* Washington DC.

Yang X. and Li K.P. (2013). "Methodologies for determining the capacity of signalized intersections in the national standard in China." *Urban Transport of China,* 11(3), 8-14.

Yang K., Xu H. et al. (2006). "Safety analysis and improvement of at-grade intersections in flat area." *China Safety Science Journal,* 16(11), 38-41.

Zheng C.J., and Wang W. (2005). "Design of timing optimization under the mixed traffic flow in signal intersection." *Journal of Highway and Transportation Research and Development,* 22(4), 118-119.

Prediction of Market Segmentation Based on Attitudes towards Bus Trips and Risk Preference in an Urban Transit System by Bayesian Network

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Abstract: Transportation policy can be more efficient in attracting a considerable number of people to choose public transit as their travel mode when decision-makers tend to develop specific policies considering different groups of people. The market segmentation method based on bus commuters' attitude towards bus trip and their own risk preference is a significant approach to characterize various demands from bus commuters. Traditional segmentation approaches, however, rarely attempted to reveal the connection between commuters' socioeconomics attributes and the result of segmentation due to the fact that classic market segmentation is conducted on the basis of commuters' attitude investigation and analysis. Bayesian Network, an advanced method to make fantastic prediction, can directly predict market segmentation based on commuters' socioeconomic attributes and risk preferences. In this way, the segmentation method can still be valid on the lack of original data of attitude and risk preference. It helps market segmentation to be more practical in demand forecasting. This paper applies Bayesian Network based on K2 and TAN structure learning algorithm respectively to predict market segmentation of attitude and risk preference on the basis of socioeconomics attributes. Traditional segmentation approach is used in this work to verify the precision of predicting segmentation results. Moreover, comparison between K2 and TAN Bayesian Network is made. The results show that the total relative error of TAN network is 29.5% while that of K2 network is 32.7%. Besides, TAN Bayesian Network takes more socioeconomic attributes into consideration than that of K2 Bayesian Network, which means the structure of TAN network coincides with common sense better. It comes to the conclusion that using Bayesian Network to predict market segmentation based on attitude towards bus trip and risk preference is capable of making the segmentation method plays a more important role in traffic demand forecasting. TAN Bayesian Network, furthermore, owns much stronger effectiveness. The proposed approach is of great help to establish potent transit systems planning and management strategies.
Keywords: Bayesian network; Urban transit; Market segmentation; Attitude; Risk preference.

1 Introduction

The diversity of people is often ignored when various kinds of strategies are developed to promote public transportation. Market segmentation approach is helpful in dividing commuting market into several submarkets, where people in the same submarket share the same or similar characteristics in choosing trip mode. Hence, specialized strategies can be developed in attracting more people to choose bus as their travel mode.

In this study, the diversity of commuters in urban transit system is observed in two ways: peoples' attitude towards bus and their risk preferences. Various kinds of segmentation method have been adopted in numerous fields. (Badoe et al., 1998) As for traffic and transportation field, market segmentation according to people's attitude and risk preference has already been used in the study of traffic mode choice. (Shiftan et al., 2008) For example, attitude-based market segmentation approach has been successfully applied in the study of bicycle commuting market. (Bergstrom and Magnusson, 2003) Numerous kinds of classification approaches such as k-means Clustering method are successfully used in extracting homogeneous travelers and generating distinct market segmentation. (Li Zhibin et al., 2012)

However, it usually takes extra investigation and evaluation to measure travelers' attitude and risk preference before conducting classification while Bayesian Network is capable of predicting the result of market segmentation directly from people's socioeconomic characteristics. It is important and practical to find the inner connection between people's risk preference and their socioeconomic characteristics since the latter one is convenient to be obtained from census. With the help of Bayesian Network, market segmentation method can still be functional even when the basic information of people's attitude or risk preference towards bus trip is absent. In our work, Bayesian Network is applied in the prediction of the segmentation result of bus commuting market based on attitude and risk preference, respectively.

The remainder of this paper is organized as follows. Section 2 introduces the methodology used in this study. It contains the summary of K2-structure Bayesian Network and TAN-structure Bayesian Network. Section 3 presents the model application of this study. Comparison between those two structure learning algorithms demonstrates that TAN-structure Bayesian Network has privilege in the accuracy of prediction. Section 4 discusses the characteristics of submarkets and policy implications. The paper ends with final conclusion in Section 5.

2 Bayesian Network

This section introduces the specific methods of this study including both K2 and TAN structure Bayesian Networks.

Bayesian Network (BN) is a widely-adopted model consisted with directed acyclic graph (DAG) structure and a set of parameters. It studies probability distribution among conditional independent variables $X=\{x_1,\ldots,x_n\}$ in the following way:

$$P(x_1,\ldots,x_n)=\prod_{i=1}^{n} P(x_i \mid \prod(x_i)) \qquad (1)$$

In this paper, we focus on the structure learning part of establishing a BN. The structure of a BN reflects the underlying relations among nodes. Robinson (1977) demonstrated that the number r(n) of possible structures for a BN with n nodes is:

$$r(n)=\sum_{i=1}^{n}(-1)^{i+1}\frac{n!}{i!(n-i)!}2^{i(n-1)}r(n-i) \quad (2)$$

Function (2) reveals that the number of potential structures for a BN is massive when variables of the case are diverse. The intention of Bayesian structure learning is to find B_S which inosculates database (D) best. In other words, it means to find the BN with the biggest posterior probability ($P(B_s|D)$).

$$P((B_s|D)=\frac{P(B_s,D)}{P(D)} \quad (3)$$

In function (3), P(D) is a constant which makes the intention of Bayesian structure learning to find out the B_s with the biggest $P(B_s, D)$.

$$\max_{B_s}[P(B_s,D)] = P(B_s)\prod_1^n \max_{\pi_i}[\prod_{j=1}^{q_i}\frac{(r_i-1)!}{(N_{ij}+r_i-1)!}\prod_{k=1}^{r_i}N_{ijk}!] \quad (4)$$

As for function (4), n is the number of nodes. r_i represents the possible value assignments of variable x_i. π_i represents a set of parents that each variable x_i in B_s has. q_i represents the unique instantiations of π_i. N_{ijk} represents the number of samples in D in which variable x_i has the k value and π_i is instantiated as w_{ij}. Let $N_{ij} = \sum_{k=1}^{r_i} N_{ijk}$.

K2 and TAN structure learning algorithm are respectively applied in this paper to predict the market segmentation of bus commuters. The flow chart of K2 and TAN algorithm to construct Bayesian Network is presented as follows.

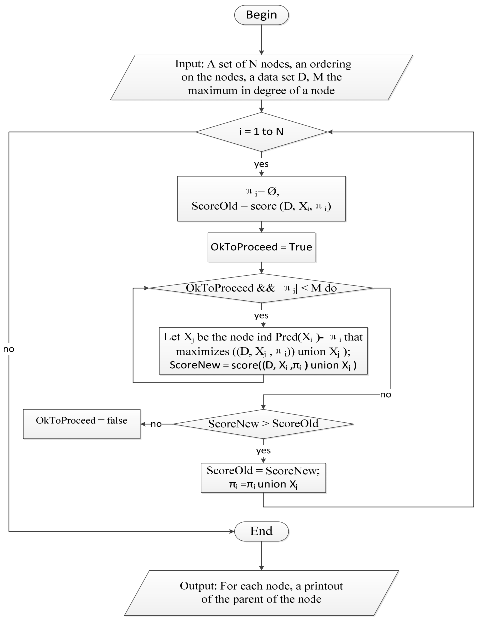

Fig 1. Flow chart of K2 algorithm

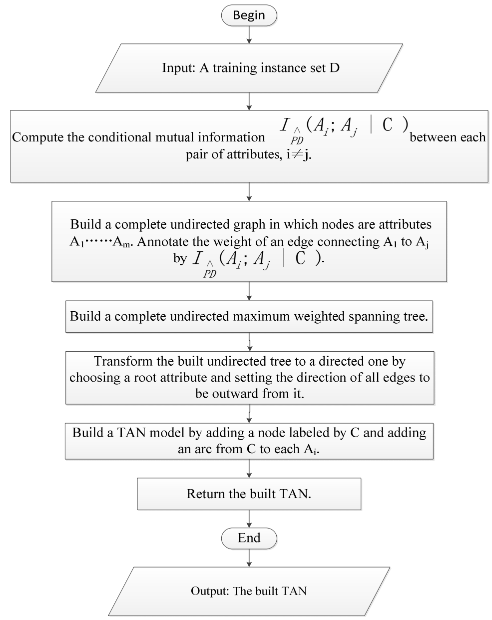

Fig 2. Flow chart of TAN algorithm

3 Results

3.1 Data resources

The survey was conducted in seven bus routes in 2014 in Nanjing, China. Respondents are people who take bus as one of the trip methods. The investigation contains three parts which are respectively socioeconomic characteristics, attitudinal factors and risk preference of respondents concerned with bus trip. Our work is conducted on the basis of 657 valid questionnaires after eliminating invalid information. The effective rate of the survey is 84.5%.

Both K2 and TAN algorithms are implemented with the help of toolbox of Matlab using the socioeconomic characteristic data. Specifically, the socioeconomic variables are gender, age, education, annual income, number of children at home, number of cars in possession and average travel time. 70% of the samples are used to establish a BN, while 30% of the samples are used for the verification of the BN.

3.2 Market segmentation based on attitude

To evaluate the performance of BN, we adopted the market segmentation result of K-means clustering which is conducted on the basis of the attitudinal data from this research. Four attitudinal factors (time, price, comfort, and transfer times) are selected to conduct K-means clustering on account of Structural Equation Model Examples. Bayesian Network is established through learning the result of K-means clustering.

With the help of BNT toolbox, structure learning is conducted by K2 structure learning algorithm in Matlab. K2-structure Bayesian Network is built through learning the discrete data generated from K-means clustering. The structure is generated and presented in Fig 3.

According to K2 Bayesian Network, gender makes no difference in attitudinal market segmentation of bus commuters in this study. The segmentation has two obvious parent nodes: education and time. In addition, characteristics themselves are interplayed at the same time.

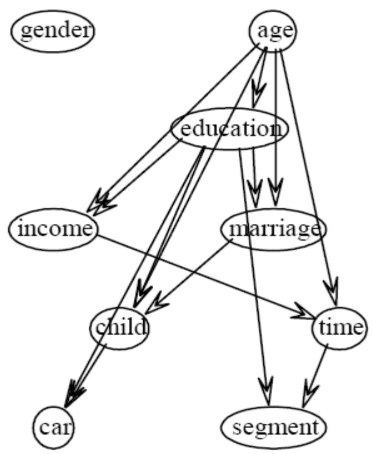

Fig 3. Structure of K2 Bayesian Network based on attitude

Statistics of each submarket are presented in Table 1. Comparison between prediction result of K2-sturcture Bayesian Network and classic segmentation result of K-means clustering are made in Table 1 as well.

Table 1. Comparison of statistics between K2 and original data in attitude

Submarket	Prediction of K2	Original data	Relative error (%)
1	71.55	79	9.4
2	69.58	71	2.0
3	32.92	31	6.2
4	19.57	17	15.1

According to Table 1, the total relative error of K2 structure Bayesian Network is 32.7%.

Similarly, TAN structure learning algorithm in Matlab with the help of BNT toolbox as well. TAN-structure Bayesian Network is built through learning the discrete data generated from K-means clustering. The structure of TAN is presented in Fig 4.

According to TAN Bayesian Network, the segmentation has eight parent nodes: income, education, time and so on. In addition, characteristics themselves are interplayed in a more complicated way than that of K2-structure Bayesian Network.

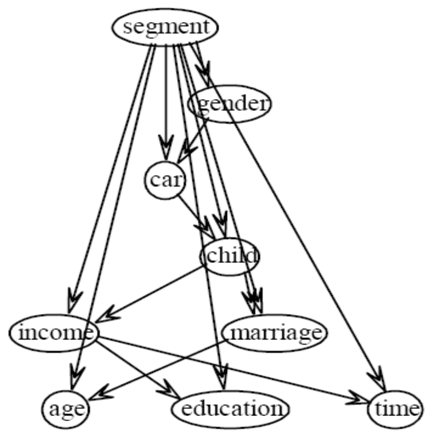

Fig 4. Structure of TAN Bayesian Network based on attitude

Statistics of each submarket are presented in Table 2. Comparison between prediction result of TAN-structure Bayesian Network and classic segmentation result of K-means clustering are made in Table 2.

Table 2. Comparison of statistics between TAN and original data in attitude

Submarket	Prediction of TAN	Original data	Relative error (%)
1	72.44	79	8.3
2	66.53	71	6.3
3	29.63	31	4.4
4	18.79	17	10.5

The total relative error of TAN structure Bayesian Network is 29.5%. It is found that both K2 and TAN Bayesian Networks show approximant with K-means clustering in predicting submarket 1, 2 and 3. Both of them present a relatively high error in predicting submarket 4. However, considering the size of our sample is limited and the number of S4 is small comparing to others, the relative error is considered to be acceptable and the prediction results are advisable.

3.3 Market segmentation based on risk preference

In this paper, bus commuters are divided into four submarkets based on risk preference. The classification is made according to our risk investigation and it has been verified through scenarios. The features of every submarket are presented in Table 3.

Table 3. Characteristic of submarket based on risk preference

	Preference towards certainty	Preference towards avoidance
M1	High	High
M2	Low	High
M3	High	Low
M4	Low	Low

The structure of K2 and TAN Bayesian Networks are respectively presented in Fig 5 and Fig 6.

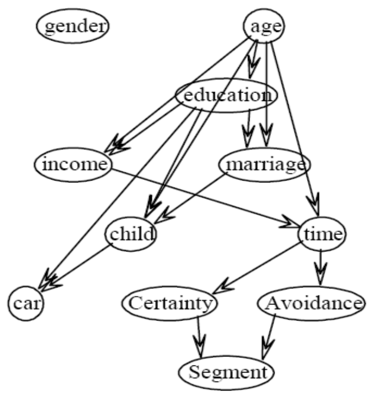

Fig 5. Structure of K2 Bayesian Network based on risk preference

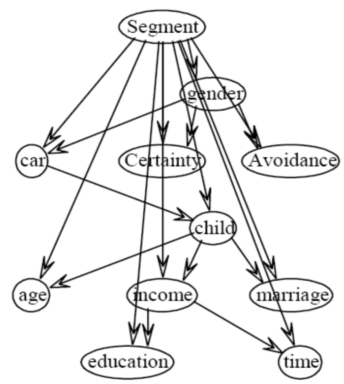

Fig 6. Structure of TAN Bayesian Network based on risk preference

Detailed results of comparison between the prediction precision of K2 and TAN structure Bayesian Network and original segmentation are presented in Table 4 and Table 5.

Table 4. Comparison of statistics between K2 and original data in risk preference

Submarket	Prediction of K2	Original data	Relative error (%)
1	63	51	23.5
2	52	64	18.8
3	34	38	10.5
4	50	45	11.1

Table 5. Comparison of statistics between TAN and original data in risk preference

Submarket	Prediction of TAN	Original data	Relative error (%)
1	66	51	29.4
2	59	64	7.8
3	34	38	10.5
4	40	45	11.1

The result indicates that the total relative error of TAN structure Bayesian Network is 58.8% while that of K2 structure is 63.9%.

Table 6. Comparison between the predictions

Segmentation	Total relative error of K2	Total relative error of TAN
Based on attitude	32.7%	29.5%
Based on risk preference	63.9%	58.8%

Comparison between four predictions is made in Table 6 to present a legible result. In conclusion, TAN Bayesian Network is superior to K2 Bayesian Network in its structure and accuracy when predicting. It reveals the connection between bus commuters' characteristics and their risk preference in a better way in this study.

4 Conclusions

This study increases the feasibility of market segmentation with the support of BN. With the help of BN, market segmentation can be preceded without inquiring bus commuters' attitude or risk preference. Bus commuters are clustered into several submarkets with the data from census. Then, more focused strategies or policies can be made to attract more people to choose bus as their trip mode. Bus commuters' needs are taken into consideration in a more practical way.

As the comparison reveals, the relative error of BN reveals its defect in accuracy. Future studies can focus on improving the accuracy of BN. Furthermore, different kinds of parameter learning methods may result to different result while this study only considers the diversity of structure of BN. The authors recommend that future studies could focus on various kinds of BN based on other algorithms.

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Reference

Badoe, D.A., Miller, E.J., (1998). “An automated segmentation procedure for studying variations in mode choice behavior.” Journal of Advanced Transportation 32, 190–215.

Bergstrom, A., Magnusson, R., (2003). “Potential of transferring car trips to bicycle during winter.” Transportation Research, Part A 37, 649–666.

Bouchaala, Afif Masmoudi, Faiez Gargouri, Ahmed Rebai., (2010). “Improving algorithms for structure learning in Bayesian Networks using a new implicit score.”, Expert Systems with Applications, Volume 37, Issue 7, July 2010, Pages 5470-5475, ISSN 0957-4174.

Cooper GF, Herskovits EA., (1992) “A Bayesian method for the induction of probabilistic networks from data.” Mach Learn 1992;9:309-347.

Friedman, N. Geiger, M. Goldszmidt., (1997), “Bayesian network classifiers.” Machine Learning 29 (1997) 131–163.

Ji Jun-Zhong, Zhang Hong-Xun, Hu Ren-Bing, Liu Chun-Nian., (2009). “A Bayesian Network Learning Algorithm Based on Independence Test and Ant Colony Optimization.”, Acta Automatica Sinica, Volume 35, Issue 3, March 2009, Pages 281-288, ISSN 1874-1029.

Kelner, Boaz Lerner., (2012). “Learning Bayesian network classifiers by risk minimization.”, International Journal of Approximate Reasoning, Volume 53, Issue 2, February 2012, Pages 248-272, ISSN 0888-613X.

Li Zhibin, Wang Wei, Yang Chen, Ragland David R., (2013). “Bicycle commuting market analysis using attitudinal market segmentation approach.”, Transportation Research Part A: Policy and Practice, Volume 47, January 2013, Pages 56-68, ISSN 0965-8564.

Neapolitan, R. E., (2003). “Learning Bayesian Networks.” New York, NY, USA: Prentice Hall.

Robinson, R. W., (1977). “Counting unlabeled acyclic digraphs.” Combinatorial Mathematics, 622, 28–43.

Shiftan, Y., Outwater, M.L., Zhou, Y.S., (2008). “Transit market research using structural equation modeling and attitudinal market segmentation.” Transport Policy 15, 186–195.

Sierra, Pedro Larrañaga (1998). “Predicting survival in malignant skin melanoma using Bayesian networks automatically induced by genetic algorithms. An empirical comparison between different approaches.”, Artificial Intelligence in Medicine, Volume 14, Issues 1–2, September–October 1998, Pages 215-230, ISSN 0933-3657.

Outwater, M.L., Castleberry, S., Shiftan, Y., Ben-Akiva, M., Zhou, Y.S., Kuppam, A., (2003). “Attitudinal market segmentation approach to mode choice and ridership forecasting–structural equation modeling.” *Transportation Research Record* 1854, 32–42.

Transfer Study of Public Transport Modes

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Abstract: Priority to the development of public transport is the only way to solve the increasingly serious urban traffic problems, it also become the consensus of the governments at all levels in our country. Bus, subway as one of the most important part of urban public traffic, reasonable transfer to join to play their respective advantages, to achieve convenient passenger travel is of great significance. This article summarized domestic and foreign research status on transit with other public transportation transfer, on the basis of analysis of the bus and subway and other public transportation transfer to research the basic train of thought, finally bring forward the transfer process and the recognition principle of public traffic transfer.
Keywords: Public transport; Transfer process; Recognition principle.

1 Summary

With the acceleration of urbanization, urban economic level and increasing levels of urban vehicles, there has been a series of traffic problems, including urban traffic congestion, accidents and environmental pollution. Faced with such a complex environment and residents' growing travel demand, priority to the development of public transport has become the only way to solve the growing problem of urban traffic problems, which has become the consensus of all levels of government. Bus, subway as the most important part of urban public transportation, it is important to optimize the transfer and play their strengths to achieve convenient passenger travel. In addition, the emergence of public bicycles, bus rapid transit, urban light rail and other public transportation, but also has made important contributions to ease the pressure on urban public transport to meet passenger demand. Based on this, the priority development of public transport, the construction of city bus system, which build a rapid rail transit as the backbone, conventional ground bus as the main, feeder buses to supplement, has become a major urban passenger transport development strategy of our country. The research work on transfer convergence of urban public transport systems, for the convenience of passengers traveling to achieve urban transport efficient, timely, orderly, integrated transport is essential to form.

2 **Literature review**

The transfer of urban public transport is the demand of urban public transport development in recent years, which has become one of the hot issues of public transportation development research. Currently, researches on the transfer of urban public transport system mainly from the following aspects:

(1)The planning and operation of the urban public transport transfer system.

(2)Transfer between bus, BRT, rail, bike and other public transport.

(3)Recognition and application of urban public transport interchange behavior.

In the planning of urban public transport hubs, studies start very early abroad. Lee.Schonfeld (1992),IanS. J.Dickins(1998), Chen,I.J.Steven and Feng-Ming Tsai (2003) have been studied on the existing urban transport system transfer function and type of facilities, transfer stations scale, configuration, location and other issues, and made recommendations for improvement in order to optimize the bus lines, improve transfer efficiency, passengers are encouraged to use public transport.At home, Xie Yujie (2006) discusses the layout on conventional rail and bus lines, the integration and coordination of vote transfers and other issues raised in the integration thinking of transport modes. Xu Kun (2009) mentioned that take the travel time as a major factor in the transfer selection, and made a function on travel time, transfer distance and the transfer ways, determined the value of the three variables.

Bus Rapid Transit is an advanced public transportation developed in recent years, as a supplement to conventional buses, it plays an important role for ease traffic pressure. Studies abroad on BRT mainly in the rapid transit hub and route planning(Steven I.chiental(2003),Pedro Szasz (2007));BRT and rail traffic or slow traffic coordination to facilitate the transfer; real-time scheduling(Lee & Chonfeld(1991),Md.Shoaib Chowdhur(2001), Manuel J.Martinez(2003),).In domestic, studies on BRT mostly based on the actual situation of our country, in broad areas. Rapid transit public transportation network planning and infrastructure utilization (Wang Yang et al. (2009)); coordination and operations of bus and BRT (Huang Wenjuan,Jiang Ping (2008)); the transfer optimization of BRT and bus(Sun Mingzheng et al. (2009)); grid frequency optimization(Bai Zijian et al. (2007)); BRT planning, operations and service evaluation(Wu Jiaqing (2006),Chen Zhangyuan et al.(2008)).

The transfer between a bike and public transport has become one of the main contents of the current city transport studies, the current study focused primarily on how to improve the cycling environment, improving public transport and convergence transfer service levels, improve satisfaction of resident traffic travel, proposed construction of an integrated urban bike and public transport interchange system, and discuss specific issues transfer implementation. (Martens (2007), Ryosuke Ando et al. (2007), Marc Dijk et al. (2011), Cao Ping & Chen Jun (2008), Liu Fang (2012) et al.).

In the recognition and application of urban bus transfer behavior, scholars also made some achievements. Widespread use of public transportation IC card has brought great convenience to the research. Chu and Chapleau (2008) infer full passenger journeys for a bus network, then analyze multiple days of AFC data to estimate general activity types for cardholder's recurrent journeys. Farzin (2008) automates the majority of the destination-inference process on a portion of a large bus network and constructs a zonally aggregated OD matrix. Munizaga et al (2011) automate the inference of origins and destinations for a large multi-modal network and, using a simple interchange-inference algorithm, construct a full-journey origin-destination matrix for AFC cardholders.Gao Yong, Deng Xiaoyong(2008) proposed road bus transfer recognition method based on the IC card data, travel time is about twice time difference when typing on the bus, compared with the threshold and then identify whether the transfer behavior and analyzed factors affecting the method. Zhang Zi, Zou Liang, Zhu Lingxiang (2011) take the bus IC card as the starting point, the time difference of twice card typing data and the bus GPS time points were analyzed, and then identify the passenger car is the transfer behavior or travel behavior. Li Haibo, Chen Xuewu (2013) to start the process from bus travel, bus transfer process will be for some time abstract node. Combined with the characteristics of existing bus system data, through the effective integration of bus IC card and AVL data, calculate the time passengers get off before the transfer time and walk to the transfer site. Judgment based on the "pick away" travel assumptions made by the comparison of the transfer time off, take time on the bus line and transfer vehicle arrival time to conduct transfers.

3 Transfer process and the recognition principle

Transfer (Interchange), refers to the replacement of vehicles traveling on the way. It can refer to switch to a different means of transport properties; can also refer to the replacement of the same nature in different lines of transport. In the urban public transport system, to interchange is the act of transferring between modes or between different services of the same mode. For example of a transfer between bus services, when a passenger alights from Route 119 and then waits for and boards Route 56 in order to continue his or her journey to the ultimate destination, it is considered to be an interchange. However, transfers between trains without exiting the system, the passenger enters through a ticket gate until they exit through a ticket gate, which is hard to recognize the interchange. Besides, if the passenger who is transferring between modes or between different services of the same mode takes time to buy a magazine at the corner, is this still considered an interchange? What if they meet a friend for lunch? Or, they take 15 minutes to pick up their child from school? The point is that there is a spectrum of activities that people may engage in between journey stages and often that activity is actually the purpose of the journey, such as meeting a friend for lunch, rather than some non-travel activity incidental to the interchange, such as buying a magazine. In the case of incidental activities, the passenger would consider the two journey stages to be part of the same complete journey so they should be linked together, however in the case of an activity that was the main purpose of travel we do not want to link the journey stages together into a complete journey even if the activity duration is very short.

However, intelligent traffic data itself has no way to determine whether the activities of the different stages should be linked together. These data can only provide up to passenger travel time and location information for us. Therefore, we can make the necessary assumptions, passengers will not stay too long at the transfer position, and will select the most convenient transportation as much as possible to start the next journey stage. Therefore, transfer time and transfer distance is an important constraint. However, the value of the two constraints may have a great difference in different cities, different traffic conditions, and even in different regions. Therefore, it is determined after an analysis according to the corresponding conditions and data. Temporarily not discussed here.

According to the analysis of the foregoing, reference Seaborn (2009) study, the whole process is determined as follows figure 1:

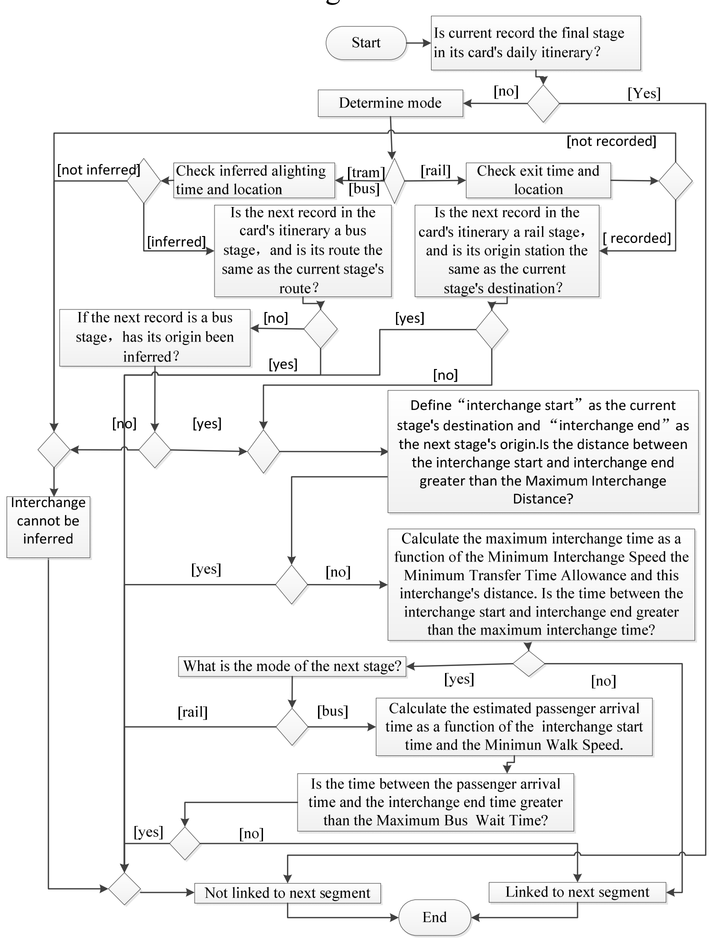

Figure 1. Activity diagram of the interchange-inference process

As showed in Figure 1, we take every single record of IC card as a journey, the diagram presents a method for inferring whether each of a card's journey stages was linked to the next through an interchange (or transfer). Doing so, we should first infer the origin and destination of every single journey stage, and then through the test to finish the transfer recognition. If any one test fails, the transaction record is considered "not linked" to the following transaction: all further tests are skipped for that record and testing resumes with the next transaction record. If a test fails because of missing data, the interchange status is considered to be "non-inferable."

Acknowledgement

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References

Bai Zijian, He Guoguang, Zhao Suzhi, Wang Min (2007). Optimization algorithm design and implementation of BRT vehicles Taboo scheduling, Computer Engineering and Applications,43(23):229-232.

Cao Ping, Chen Jun (2008). Cycling - Metro station siting and demand forecast .Technology & Economy in Areas of Communications, 10(3)：87-89.

Chen,I.J.Steven and Feng-Ming Tsai. (2003) Optimization of Multiple-Route Feeder Bus Service- An Application of Gis. Washington.D.C.

Chen Zhangyuan, Shi Jing, Yuanjian (2008). Beijing BRT user satisfaction surveys and comparative analysis. Journal of WUHAN University of Technology (Transportation Science & Engineering), 32(5).

Chowdhury, Chien (2001). DYNAMIC VEHICLE DISPATCHING ATINTERMODAL TRANSFER STATION. Transportation Research Record, No.01-3108.

Chu, Ka Kee Alfred and Robert Chapleau. (2008). "Enriching archived smart card transaction data for transit demand modeling." Transportation Research Record: Journal of the Transportation Research Board, 2063:63-72.

Dickins, S. J. Ian. (1998). Joint optimization of a rail transit line and its feeder bus system. Journal of Advanced Transportation, 32(3):251-284

Farzin, Janine M. (2008).Constructing an automated bus O-D matrix using smart card and GPS data on sao Paulo, Brazil. Transportation Research Record: Journal of the Transportation Research Board 2072:30-37.

Gao Yong, Deng Xiaoyong. (2007) Identification method based on bus transfer IC card data． 3rd China Annual Conference on ITS Proceedings．

Gao Y，DENG X Y.(2007) Recognition method of transit transfer based on intelligent card record data. Proceedings of the 3rd China Annual Conference on ITS

Huang Wenjuan, Jiang Ping. (2008) Coordination Assessment of Cities bus and Bus Rapid Transit System. Communications Standardization, 2008, (4).

Karel Martens. (2007) Promoting bike-and-ride: The Dutch experience. Transportation research part A, 326-338.

Lee,K.K.T. and Sehonfeld,P.M. (1991) Optimal slack times for timed transfers at a transit terminal. Journal of Advanced Transportation 25(22).281 – 308.

LEE. K. K. T, Schonfeld. (1992). Optimal headway and slack times multiple route timed-transfer terminals. College Park; University of Maryland.

Li Hai-b0, Chen Xuewu. (2013). A Method to identify public transfers based on IC and AVL Data. Journal of Transportation Systems Engineering and Information Technology.

Liu Fang. (2012) Public bike and Urban Rail Transit Study. Modern Urban Transit, 4,71-73.

Manuel J. Martinez. (2003) Value of Facilities and Attributes of New Heavy Rail and Bus Rapid Transit Projects in a Developing City. The Case of Lima, Peru. Transportation Research Record, No.2003-00058.

Marc Dijk, Carlos Montalvo. (2011) Policy frames of Park-and-Ride in Europe. Journal of Transport Geography, 1106-1119.

Munizaga, Marcela, Carolina Palma, and Daniel Fischer (2011). Estimation of a disaggregated multimodal public transport OD matrix form passive smart card data from Santiago, Chile. 90th Annual meeting of the Transportation Research Board, Washington, DC.

Pedro Szasz. (2007). Bus Rapid Transit system capacity study,. Http://www.brtehina.org/ReportC/BRT

Ryosuke Ando，Motohiro Yamazaki. (2006). An analysis on feasibility of park & cycle ride system in a Japanese local city [J]. Procedia Social and Behavioral Sciences，2012, 37-46.

Stevenl.Chien, ZhaoqiongQin, RongfangLiu. (2003). OPTIMAL BUS STOP LOCATIONS FOR IMPROVINGTRANSIT ACCESSIBILITY. Transportation ResearchReeord, No.2003- 000972

Sun Mingzheng, Liu Xuejie, Ma Haihong. (2009) Analysis of the effect of Beijing BRT Line 2. Urban Transport of Chian, 7(3).

Tan Yu et al. (2000) Rail and Bus interface systems analysis. Urban mass transit research, (02).46．

Wang Yang, Chen Xiaohong, Yang Chao et al. (2009). The study of Road BRT operations scheduling objectives. Urban mass transit research, 12(3).

Wu Jiaqing. (2006). Construction of Bus Rapid Transit Evaluation System. Urban Public Transport, 2006, (7).

Xie Yujie. (2006). Passenger Integrated Urban Rail Transit and Ground Conventional Public. Urban Rapid Rail Transit.2006.19(01).32-34.

Xu Kun. (2009). Competition and coordination of rail transit and bus. Science & Technology Review.2009(04).226.

Yan Kefei et al. (2000). Urban Comprehensive Passenger Transport System Transfer Research. Journal of Changsha Communications University.2000.16(06).69.

Zhang Z,ZOU L,ZHU L X. (2011). Method to collect public transportation transfer data based on IC card. Journal of Transportation Information and Safety, 29(164).

Optimal Path Choice Based on Multi-Modal Public Transport—A Case Study of the Chengdu Qinghua Road Area

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Abstract: In recent years, Chengdu has opened the subway and BRT. Among them, Chengdu Qinghua Road area has constituted a multi-modal public transport network which involves regular bus, rapid rail and BRT. Therefore, paper chooses Chengdu Qinghua Road area as the research object chooses generalized minimum cost as optimum principle, builds a multi-mode transit network model and a multi-mode transit optimal path choice model in Chengdu Qinghua Road Area. Quantitative analysis of the value of the generalized impedance, through the psychological characteristics of Chengdu residents' bus travel survey. Utilization breadth-first search obtained options which have the minimum generalized impedance as the recommended travel schemes and selecting the optimal scheme among the recommended schemes by passenger travel conditions .Otherwise, the case analysis of the optimal path from Huiyuan Building to the Sichuan Province Orthopedics Hospital, and the result that different passenger travel conditions affect the optimal path proves the optimal path search algorithm in this thesis has certain reference.
Keywords: Multi-mode bus; Route search; Generalized cost.

1 Introduction

Public transport network plays an important role in urban transport systems; therefore, study on the optimal route of multi-modal Public transport network has positive significance.

In the analysis of the multi-modal transit optimal path, there are several path search algorithms: The first algorithm combines graph theory, including the classic Dijkstra algorithm and Floyd algorithm; second algorithm combining traditional intelligence theories, including depth-first algorithm, breadth-first algorithm; third algorithm combines intelligent simulation technology, such as the ant colony algorithm.

China's rail transportation, BRT and other modes of public transport's development have a late start compared to abroad. Related research domestic, most optimal path selection is on regular bus about. For the combination of multiple modes of public transport travel path of the research is still relatively lacking.

2 Modeling foundation

Scope of this study is the demonstration of a block area of Chengdu, specifically selected by the Second Ring Road, West Fuqin Road, West Dashi Road, Xiaonan Street and other roads, enclosed area as the scope of the demonstration area, shown in Figure 1. Selected part of the road network, regular bus lines, BRT and subway lines to build the road network and multi-modal public transport network as a case study in this paper.

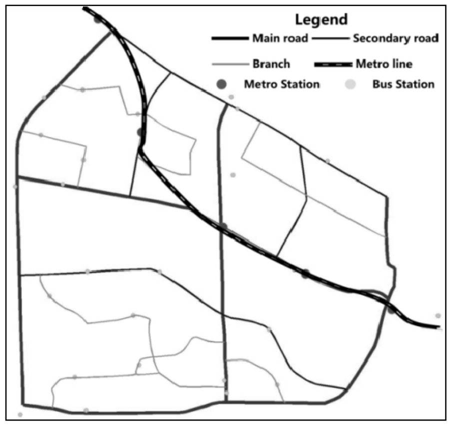

Figure 1. The area of demonstration zone

Summary the Public transport in the region constituted. BRT: K2 Rapid Transit Line Metro: Chengdu Metro Line 2; Bus: Bus No.59, Bus No.43, Bus No.1031, Bus No.82, Bus No.53. Above are summarized in Table 1.

Table 1 .Summarizes the bus information

Transit Type	Transit Line Name	Passing road
Metro	Line 2	——
BRT	K2	Second Ring Road
Bus	No.59	West Fuqin Road, Jinqin Road, East Qingjiang Road, Ring Road
	No.43	West Fuqin Road, Ring Road, Jinhe Road
	No.1031	Second Ring Road, North Caotang Road, East Qingjiang Road, Ring Road, Qinghua Road
	No.82	Second Ring Road, Qinghua Road, Ring Road
	No.53	Xiaonan Street, East Dashi Road

According to the results of Chengdu Public transport survey, take a data processing of the importance of walking time, waiting time, travel time and ticket cost for residents in Chengdu. The conclusions as a generalized cost weighting of each factor, So get the weights: ω_1=0.2， ω_2 =0.19， ω_3=0.48， ω_4 =0.13.

3 Methodologies

In this paper, take a trip which chose building Huiyuan as the starting point and Orthopedic Hospital in Sichuan Province as the final point for a case study. Consider the case of public transport, combining Public transport driving route, re-edit the road network. The transfer point as a node, use public transport travel route connecting the nodes, the public transport network simplified to Figure 3.

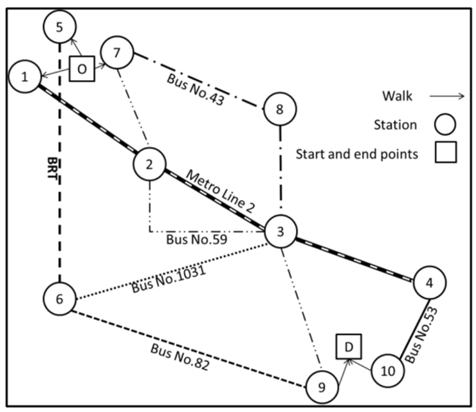

Figure 2. The public transport network diagram

According to the diagram, list the public transport options between the Building Huiyuan and Orthopedic Hospital in Sichuan Province. All transportation travel schemes are summarized in Table 2.

Table 2. Scenario summary

Numbe r	Scheme	Number	Scheme
1	7-BUS59-9	7	1-Rail2-2*-BUS59-9
2	7-BUS43-3*-BUS59-9	8	5-K2-6*-BUS82-9
3	7-BUS59-2*-Rail2-3*-BUS59-9	9	5-K2-6*-BUS1031-3*-BUS59-9
4	7-BUS59-2*-Rail2-4*-BUS53-10	10	1-Rail2-2*-BUS59-9
5	7-BUS59-3*-Rail2-4*-BUS53-10	11	1-Rail2-3*-BUS59-9
6	7-BUS43-3*-Rail2-4*-BUS53-10	12	1-Rail2-4*-BUS53-10

* Indicates a transfer Station

Multi-modal public transport network models are available for established schemes described above. Since the scheme up to as many as 12, there only a brief description of the front three scheme. As shown in Figure 3.

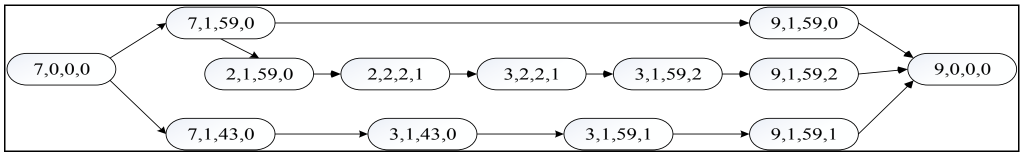

Figure 3. Schematic diagram of front three schemes

The first number indicates the node, and the second number indicates the bus type (0 indicates this point is the start 1 indicates regular bus, 2 indicates subway, 3 indicates BRT), the third number indicates the type of bus number, and the fourth number indicates the number of transfers.

fter all alternative travel program search is completed, take a second layer of search, and calculate generalized impedance of the programs. Select a minimum of five generalized impedance path of travel program as recommended scheme. In Scenario 1 and 4, for example, is described alternatives generalized impedance calculation process.

Scheme 1 includes a walking time for starting point and a walking time for ending point. Where the walking time for starting point $T_{w(O\text{-}7)}$=6.5min, the walking time for ending point $T_{w(9\text{-}D)}$ =2.5min. The total walking time

$$T_w = T_{w(O\text{-}7)} + T_{w(9\text{-}D)} = 9\text{min} \quad (3\text{-}1)$$

Waiting time of Bus No.59 is the total waiting time (f indicate bus service frequency, ∂ indicate the deviation between theory and practice).

$$T_{wa} = \frac{1}{2f} + \partial = 3+1 = 4\text{min} \quad (3\text{-}2)$$

Travel time is the time spending in taking the Bus No.59 from site 7 to site 9.

$$T_{bus(7\text{-}9)} = 3.5+13+4.5 = 21\text{min} \quad (3\text{-}3)$$

Take the bus costs 2 Yuan for ticket, so a generalized impedance scheme 1 is

$$C^1_{O-D} = \omega_1 \cdot T_{wa} + \omega_2 \cdot T_w + \omega_3 \cdot T_{bus} + \omega_4 \cdot Fare \cdot T_F = 13.19 \quad (3\text{-}4)$$

Scheme 4 includes a walking time for starting point, a walking time for transfer point and a walking time for ending point. Where the walking time for starting point $T_{w(O\text{-}7)}$=6.5min, the walking time for transfer point $T_{w(BUS59\text{-}Rail2)}$=1.5min, $T_{w(Rail2\text{-}BUS53)}$ =4.5min, the walking time for ending point $T_{w(10\text{-}D)}$=4.5min. The total walking time

$$T_w = T_{w(O\text{-}7)} + T_{w(BUS59\text{-}Rail2)} + T_{w(Rail2\text{-}BUS53)} + T_{w(10\text{-}D)} = 17\text{min} \quad (3\text{-}5)$$

Total waiting time includes Waiting time of Bus No.59, $T_{wa(BUS59)}$ =4min, Waiting time of Bus No.53, $T_{wa(BUS53)}$ =4min, and Waiting time of metro line 2, $T_{wa(Rail2)}$ =2.5min.

$$T_{wa} = T_{wa(BUS59)} + T_{wa(BUS53)} + T_{wa(Rail2)} = 10.5\text{min} \quad (3\text{-}6)$$

Travel time is the time spending in taking the Bus No.59 from site 7 to site 2, taking the metro line 2 from site 2 to site 4 and taking the Bus No.53 from site 4 to site 10.

$$T_{bus(rail)} = T_{bus(7\text{-}2)} + T_{rail(2\text{-}4)} + T_{bus(4\text{-}10)} = 14.5\text{mi} \quad (3\text{-}7)$$

The tickets cost 6 Yuan, so a generalized impedance scheme 4 is

$$C_{O-D}^{4} = \omega_1 \cdot T_{wa} + \omega_2 \cdot T_w + \omega_3 \cdot T_{bus(rail)} + \omega_4 \cdot Fare \cdot T_F = 15.9 \quad (3\text{-}8)$$

Compare scheme 1 and 4.The generalized impedance of scheme 1 is smaller so the scheme 1 for a better comparing to scheme 4. Intuitively, scheme 1 for a direct, do not spend time walking on transfer and cost less in waiting time and ticket costs. But it is undeniable that longer travel time in Scheme 1, there may be alternatives to a travel scheme generalized impedance is smaller that have shorter travel time and need to transfer. In order to compare the various bus travel scheme generalized impedance better, according to the method above, calculation generalized impedance for each schemes. As shown in Table 3.

Table 3. Generalized impedance of each scheme

Sche-me	Walking time for starting point	Walking time for transfer point	Walking time for ending point	Waiting time for transit	Waitin-g time for transfer	Trav-el time	Tick-ets cost	Gener-alized imped-ance
1	6.5	0	2.5	4	0	21	2	13.79
2	6.5	3	2.5	4	4	10.5	4	11.33
3	6.5	6	2.5	4	6.5	10	6	13.36
4	6.5	6	4.5	4	6.5	14.5	6	15.90
5	6.5	8.5	4.5	4	6.5	25.5	6	21.66
6	6.5	7	4.5	4	6.5	15	6	16.33
7	5	2	2.5	2.5	4	19	4	14.63
8	6.5	3.5	2.5	0.5	4	15.5	4	13.12
9	6.5	2	2.5	0.5	6.5	17.5	6	15.50
10	5	2	2.5	2.5	4	19	4	14.63
11	5	4.5	2.5	2.5	4	8	4	9.83
12	5	4.5	4.5	2.5	4	12.5	4	12.37

Shown in the above table, most of the schemes have a value of distributed between 10 and 15. The largest value of generalized impedance is 21.66, from scheme 5. The least value of generalized impedance is 9.83, from scheme 11. The generalized impedance values are arranged in ascending order of each scheme, Followed by the first five: scheme 11, scheme 2, scheme 12, scheme 8 and scheme 3. Analysis for single factor, minimum walking time is 5min, from scheme 7, scheme10, scheme11 and scheme 12. Minimum number of transfers is 0, from scheme 1, and it has lowest fare, 2 Yuan. The shortest travel time is 8min, from scheme 8.

If the principles of passengers choose bus travel path are not the optimal generalized least, recommended travel scheme may change. When travelers choose minimal transfer times or the least cost or fare, recommended travel scheme is scheme 1. And when travelers choose the shortest travel time, recommended travel scheme is scheme 11.

4 Discussions of Results

In this paper, the actual data have collection to modeling and analysis wishes of passengers choose to travel path in multi-modal public transport network. And through the actual trip simulated recommended travel plan. As can be seen from the subjective, recommended solutions have high acceptability. Description methods and theories used in this modeling analysis is feasible

In the modeling process in this paper, the proportion of generalized impedance of each factor determines by a field survey. The single survey in some areas does not have complete universality. So when the generalized impedance counts with a certain bias between the actual situations that this conclusion may not apply to every resident in Chengdu. This parts of the content needs to be demonstrated b further research.

5 Conclusions

This paper dissertation on the established multi-modal public transport network in Chengdu to investigate, to complete the network attribute parameter calibration, combined with the optimal path search algorithm, Calculate the five travel route plan from the Orthopaedic Hospital of Sichuan Huiyuan Building that haveminimum generalized impedance values. In these five schemes, travel for passengers of different process requirements will affect the choice of the optimal path. Public transport proved optimal path search algorithm used paper has certain significance.

The idea of the algorithm is: First in a multi-modal transit network to search out the options that transfer less than or equal to 2 times from the station between the end starting point and ending point. Then the generalized impedance values calculated for each option. Generalized minimum impedance value of several multi-mode transit trip paths as the recommended travel plan, and finally find the travel path in line with the requirements of the passengers in the recommended plan as the optimal solution.

Acknowledgement

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References

Mark Hickman (2002). Robust Passenger Itinerary Planning Using Transit AVL Data . Intelligent Transportation Systems. Proceedings. The IEEE 5th International Conference on. IEEE, 2002: 840-845.

Tong C O, Wong S. C.(1998). A stochastic transit assignment model using a dynamic schedule-based network. Transportation Research Part B: Methodological, 33(2): 107-121.

Short-Time Traffic Flow Forecasting Based on the K-Nearest Neighbor Model

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Abstract: In order to accurately forecast the short-term traffic flow, a K-nearest neighbor model was set up, study the influence of key factors in model on predicted result. Using combination of different state vectors and distance metrics to form four kinds of K-nearest neighbor model, combined with Beijing real road traffic data apply four kinds of models to carry out example verification, pick up relative error and equalization coefficient evaluate forecasting result. The results show that: with time-space parameters of a higher prediction accuracy, which has minimum prediction error, average 7.8%. take index weights into distance metric can be more precise in neighbor selection, which has minimum prediction error, average 7.34%. Visibly, compared to traditional K-nearest neighbor short-term traffic flow forecasting model which only consider the time dimension, K-nearest neighbor model with time-space parameters and index weights more accurately reflect the state of the traffic flow change condition, can be used as effective road traffic flow forecasting means.
Keywords: Flow forecast; K-nearest neighbor model; Time-space parameters; Exponent weight.

1 Introduction

K-nearest neighbor algorithm is a common one in nonparametric regression relatively, need no prior knowledge, just enough historical data[3], the new observational data can be easily added to the model, and the algorithm has good data digging and transplanting performance [4]. there are many researchers has applied it in short- term traffic flow forecasting for now[5]. But all these studies mostly focused on the relationship between the target road traffic real-time conditions and historical conditions, ignoring the spatial dimension, also ignoring several key factors in different settings' affection on the predicted outcome at the same time.

In this paper, proposed the improved k-nearest neighbor model with time-space parameters and exponent weight. Firstly, four kinds of k-nearest neighbor model is formed by setting the state vector and the distance metrics. Then carry simulation experiments based on the same historical database and test data. Finally compare the forecasting result. Verify the impact on forecasting results caused by the time-space parameters and the exponent weight, proved the improved K-nearest neighbor algorithm can more accurately reflect the changes of traffic flow. The method can be used as an effective means of forecasting.

2 Data source

This paper mainly consider the impact on model accuracy caused by spatial dimension, therefor only select traffic as a state factor. This paper selects the Haidian District Willow road as target road. The total length of road sections is 0.58km, 10-lane two-way, north access Zaojun temple road, south access sorghum-bridge road, the spatial location of each section as figure2-1 below.

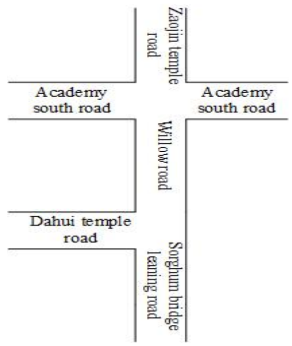

Figure 2-1. The position of research road

Select the morning rush hour (6:30 - 9:30) as research period, collected willow road and adjacent sections (Zaojun temple road and sorghum-bridge road) morning peak flow to build a historical database. In this paper, the traffic data come from the Beijing Traffic Operation Monitoring and control Centre (TOCC). Because that there usually have a small amount of data gaps and abnormal data in original data, need to do the necessary screening, excluding outliers. Select September 8, 2014 to September 21, 2014 morning peak continuous traffic data as samples. Set 5min for the prediction time interval. After dealing with data, we got a continuous traffic flow sample size for 504. Sample data shows periodicity of this road morning peak flow, as shown in Figure 2-2. Abscissa 1~8 respectively represents 8 to 15 September at 6:30 every day.

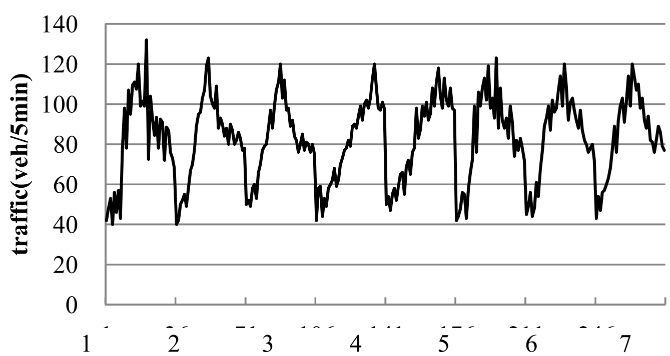

Figure 2-2. traffic volumes

3 Model Construction

3.1 The definition of state vector

Take time dimension and spatial dimension into the state vector will theoretically get higher forecasting accuracy. Because it searches neighbors witch have higher quality. Tow kinds of prediction mechanism as figure3-1.

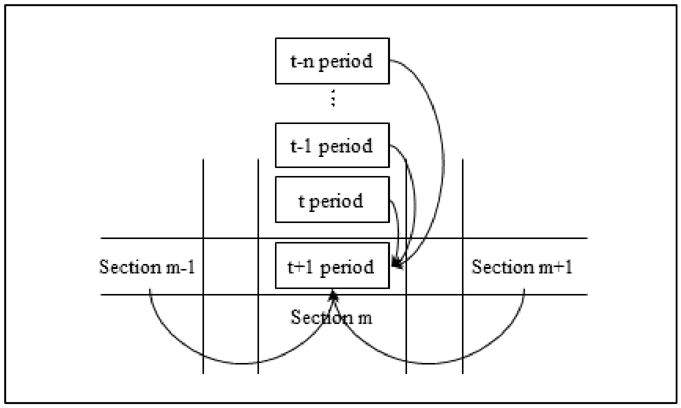

Figure 3-1. prediction mechanism based on time-space parameter

To compare the experimental results, the state vector is divided into the following article groups:

$$X(1)=[v_m(t),v_m(t-1),v_m(t-2),v_m(t-3),v_m^{'}(t),v_m^{'}(t-1)v_m^{'}(t-2),v_m^{'}(t-3)] \quad (1)$$

Wherein, $v(t)$ and v(t-1) respectively represent the current time and the previous time traffic; $v\ '(t)$ and $v'(t\text{-}1)$ represent current time and the previous time traffic in the historical database. Here take four adjacent time intervals to current time, and the four corresponding traffic in the historical database. Herein the interval is 5 minutes.

$$X(1)=[v_m(t),v_m(t-1),v_m(t-2),v_m(t-3),v_{m-1}(t),v_{m+1}(t),v_m^{'}(t),v_m^{'}(t-1)v_m^{'}(t-2),v_m^{'}(t-3), v_{m-1}^{'}(t),v_{m+1}^{'}(t)] \quad (2)$$

Wherein, $v_{m-1}(t)$ and $v_{m+1}(t)$ respectively represent sections m-1 (upstream section) and the sections m+1 (downstream section) traffic; $v'_{m-1}(t)$ and $v'_{m+1}(t)$, respectively represent section m-1 (upstream section) and the sections m+1 (downstream section) traffic in the historical database.

3.2 Distance metrics

Due to road traffic system variability is strong, the same road section traffic conditions in different historical periods vary greatly, importance to predict the future traffic condition is also different. Therefore, this paper add weights to components of the time dimension state vector to get higher accuracy, using two methods: the correlation coefficient weighted method and the index weighted method.

The correlation coefficient weighted method mechanism shown as Figure 3-2, the t+1 period is the target period.

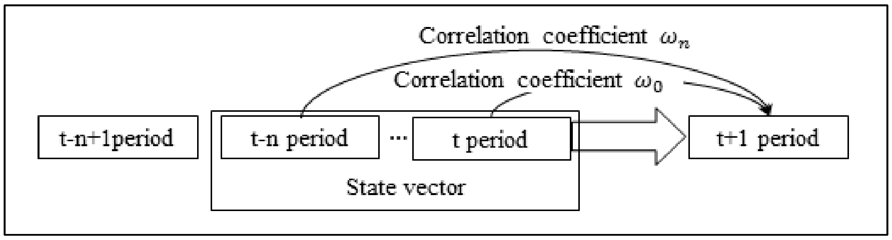

Figure 3-2. The correlation coefficient weighted method

Index weighted method mechanism shown as figure3-3, thought that the closer the distance to the target period t + 1, the greater the impact on the target time by the historical period data.

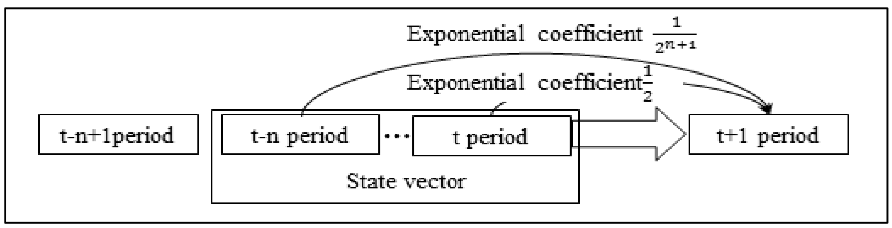

Figure 3-3. The exponential coefficient weighted method

3.3 Selection of the value of k

K value chosen related to historical data largely, there is no determined metrics to guide the selection of k. both too large k and too small k affect the prediction accuracy. In this paper, make k value vary between 2~20 in the experiment, and finally discuss the value of k count on result.

3.4 Prediction Algorithm

$$v_m(t+1) = \sum_{k=1}^{k} \frac{d_k^{-1}}{\sum_{k=1}^{k} d_k^{-1}} v_k^{'}(t+1) \tag{3}$$

Wherein, d_k represent the distance of the current data and the k-nearest neighbor; $v_m(t+1)$represent the traffic of section m; $v_k'(t+1)$ represent the t+1 period the traffic correspond the k-nearest neighbor searched in the historical database.

3.5 Model Set

Consider the combination of two state vectors and three distance metrics, formed 4 kinds of K-nearest neighbor short-term traffic flow forecasting models, for convenience of description, numbered models, as table3-1 shown below, using pre-treated historical database to predict. Evaluate the forecasting result by relative error, properly considered equalization coefficients.

Table 3-1. Models Set Description

Method Number	State Vector	Distance Metric
F1	X(1)	Equal Weight
F2	X(2)	Equal Weight
F3	X(2)	Correlation coefficient weighted method
F4	X(2)	Index weighted method

4 Discussion of Results

Experiments use historical database mentioned above, and the k values 2~20, respectively use four methods forecast morning rush hour traffic flow every 5min of September 22, 2014. Record relative error of forecasting traffic under different k. And summarizes the results of the entire peak periods forecast result.

4.1 Discussion On The Value Of K

As shown as table 4-1, forecasting results of 4 kinds of model all have good effect, the equalization coefficients are greater than 0.9. Seeing from Figure 4-1, 4 kinds of methods error decreases as K increases from 2 to 8, and after it the effect of decreases is less obvious. Particularly among the three methods got the smallest average relative error when K is 13.

Table 4-1. average equalization coefficient under different K

	F1	F2	F3	F4
equalization coefficient	0.961905	0.962095	0.962295	0.962242

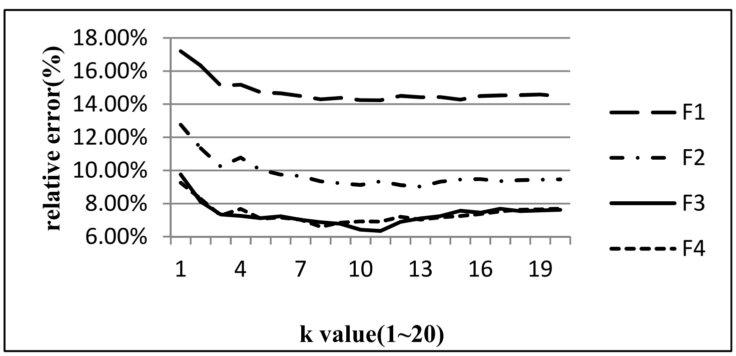

Figure 4-1. relative error graph under different k

4.2 Comparison Of Different Models

Effect of four models forecasting have differences. Comparing F1 and F2 can test effect on results with different state vector. As figure 4-2 shown, the forecasting effect of the first model is worst, relative error is 14.75%, which shows the forecasting effect of the k-nearest neighbor model only consider the time dimension was significantly worse than the model take the time and spatial dimensions into consideration.

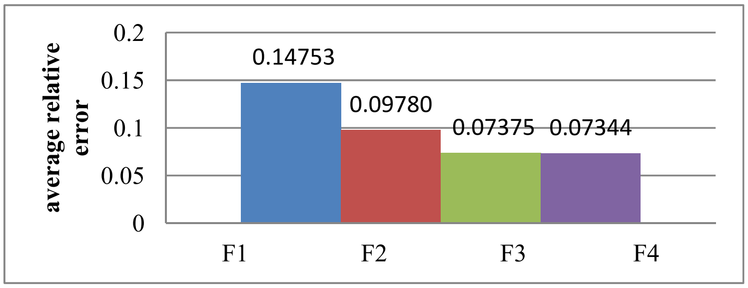

Figure 4-2. relative error

Contrast F2, F3 and F4 can test the proved effect on model with different distance measure metrics. By comparison with the weighted distance metric is significantly better than the distance metric without weights, and different weighed measure effect on improving model have little difference. Compared to the correlation coefficient weighted method, the average relative error of index weighted coefficient is lowest, is 7.34%, indicating that use a weighted distance measure in the model is a reasonable way, can significantly improve the prediction accuracy of k-nearest neighbor model

.

5 Conclusions

This paper pick up the Haidian district Willow sections in Beijing as research object, constructed improved K-nearest neighbor short-tome traffic flow forecasting model based on time-space parameters and weighed distance metrics, use morning rush hour traffic data to verify different parameters' effect on predicted result accuracy. By comparing before and after the improvement of the prediction accuracy of the model, found take time dimension and spatial dimension into account at the same time is obviously better than the model only consider time dimension, and use a weighted distance metric in the model is better than the model without weighted distance metrics. After comparison, found the improved K-nearest neighbor model, the prediction accuracy can reach above 90%, more suited to real-time road traffic flow in real-time forecasting.

Acknowledgement

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References

DAVIS G A, NIHAN N L. Nonparametric regression and short-term freeway traffic forecasting, Journal of Transportation Engineering, 1991， 117(2): 178-188.

SMITH B L，WILLIAMS B M, OSWALD R K. (2002)Comparison of parametric and nonparametric models for traffic flow forecasting, Transportation Research Part C: Emerging Technologies, 10(4): 303-321.
ZHANG Tao, C'HEN Xian, XIE Meiping, et al.(2012) K-NN based nonparametric regression method for short-term traffic flow forecasting, Systems Engineering-Theory and Practice, 30(2): 376-384. (in Chinese)
ZHANG Xiaoli, HE Guoguang, LU Huapu. (2009)Short-term traffic flow forecasting based on K-nearest neighbors non-parametric regression, Journal of Systems Engineering, 24(2): 178-183. (in Chinese)
ZHOU Xiao-peng, PENG Qi, SUN Li-jun.(2006) Short-term traffic flow forecasting based on nearest neighbor algorithm, Journal of Tongji University: Natural Science, 34(10): 1494-1498(in Chinese).

Impact Analysis of a Downstream Stretching Segment on Traffic Capacity at a Signalized Intersection

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Abstract: To improve the traffic capacity in signalized intersections, stretching-segment are applied both in upstream and in downstream in some criteria and guidance. However, the methods to calculating the traffic capacity of signalized intersections usually consider the impact of stretching-segment in upstream. Based on investigations on some intersections in Chengdu, this study analyzes the impacts on traffic capacity caused by downstream stretching-segment, and shows that the length of downstream stretching-segment and the signal of the intersections are the two key factors for its capacity. Then this study investigate the trends and the extent of the impact using a VISSIM simulation model.
Keywords: Downstream stretching-segment; Signalized intersections; Traffic capacity; Simulation and analysis.

1 Introduction

It has been widely applied in many cities about downstream stretching-segment (it is also called short lanes or lane drop in downstream) in intersections. However, there isn't a reasonable criterion about downstream stretching-segment. It also does not have any quantitative procedure with respect to lane drop effects in assessing the capacity of signalized intersections.

The objective of this study was to assess the effects of downstream stretching-segment in signalized intersections and analyze the trends of the impact caused by two key factors--the length of downstream stretching-segment and the signal cycle. The methods of this study were field investigation and VISSIM simulation. In the field research, this study adopted a method of comparative analysis. The intersection with downstream stretching-segment was selected as the experimental group, and intersections without downstream stretching-segment were selected as the control groups. This study measured the saturation headway of three kinds of intersections and then made a contrast. The impacts on capacity would reflected through the difference of saturation headway. Since there were some uncontrollable factors in field study, VISSIM simulation was applied to make further research. In the simulation research, the length of downstream stretching-segment and signal cycle were selected as two key factors to study the impacts on capacity in signalized intersections.

The research scope was restricted to three-lane-to-two-lane drops for the through movements, such as figure1.

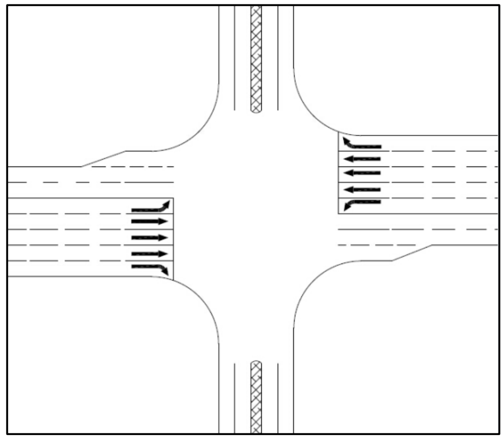


Figure 1. three-lane-to-two-lane drops for the through movement

The structure of the paper is the following. Firstly, in section 2, literature review focuses on some criteria and research, which were related to downstream stretching-segment. Then section 3 is some request for the investigation sites. Section 4 shows the analysis result of the field investigation. The section 5 is the research on VISSIM simulation. The last section is the conclusion of the paper and proposes directions for further research.

2 Literature Review

The study on stretching-segment is usually associated to short lanes in signalized intersection. They assessed the impact of short lanes through the lane utilization.

The Highway Capacity Manual (National Research Council, Washington, D.C., 2000) involved lane utilization in some special lanes when estimating capacity and LOS for signalized intersections. However, current guidance on the selection of lane utilization in the HCM is inadequate and could lead to poor estimation of capacity, delay, and LOS when a lane drops shortly after the signal (Jae-Joon Lee, 2005).

The Canadian Capacity Guide (CCG) for signalized intersections estimates lane flow based on equal flow ratio (that is, the ratio of demand flow to saturation flow). However, the CCG does not put the case of downstream lane drops into account (Teply, 1995).

The Swedish Capacity Guide (Stenberg, 1995) addresses the effects of short lanes on intersection capacity. However, it just considered the upstream short lane effect on capacity without taking the downstream short lane impact into account.

The aaSIDRA model in the Australian Capacity Guide (Akcelik,1984) takes into account the downstream lane-drop effect and regards the length of short lane as a main factor influencing the capacity of signalized intersections. However, this method was not widely used.

The criteria in these countries do not have a reasonable description about the downstream stretching-segment.

Some researchers has made contributions to the impacts of lane drops in downstream on capacity. Tarawneh (Tarawneh, 2001) put forward a view that the utilization of short lane will vary with the degree of crowd of traffic. Lee (Jae-Joon Lee, 2005) researched variety of lane drops in downstream and studied fourteen possible factors influencing the capacity when there is a downstream stretching-segment.

There are also some criterion and research about downstream stretching-segment in China. Table 1and 2 show the criteria.

Table 1. Criteria about downstream stretching-segment in China

	Setting conditions	composition	length	width	Influence by bus stop	Number of lanes
Urban Road Intersections Planning Norms （GB50647-2011）	√	√	√	—	√	—
Urban Road Intersections Design Procedures （CJJ152-2010）	√	√	√	√	√	√
Urban planning Norms Provision in Road Intersections（GB2010）	√	—	—	—	—	√
Urban Road Engineering Design Specifications （CJJ37-2010）	√	—	—	√	—	—

Table 2. Criteria about downstream stretching-segment in some cities

	Setting conditions	composition	length	width	Influence by bus stop	Number of lanes
Shanghai Urban Planning and Design of Intersection Rules	√	√	√	√	√	√
Wuhan Urban Traffic Intersection Planning ,design and management	√	√	√	√	—	√
Intersections of Urban	√	√	√	√	—	√

Road Planning and Design Specifications in Zhejiang						
Tianjin Urban Planning and Management Technical Requirements	—	√	√	√	—	—

However, these criteria were not well consistent, they were also lack of the impact on capacity caused by downstream stretching-segment in signalized intersections. There is few researches of downstream stretching-segment in China. Zhang Hai and Zhao Jing (Zhang Hai, 2007) put forward that three factors made key contributions to the capacity of signalized intersections with short lane in downstream. They were the length of short lane, effective green time, and obstruction wave velocity.

However, criteria and researches on downstream stretching-segment are not complete, especially in China. In addition, some research results were based on data from other countries, which might exhibit different driving behavior.

3 Experimental Sites and Control Sites

There are several requirements for experimental sites, they should be as follow:

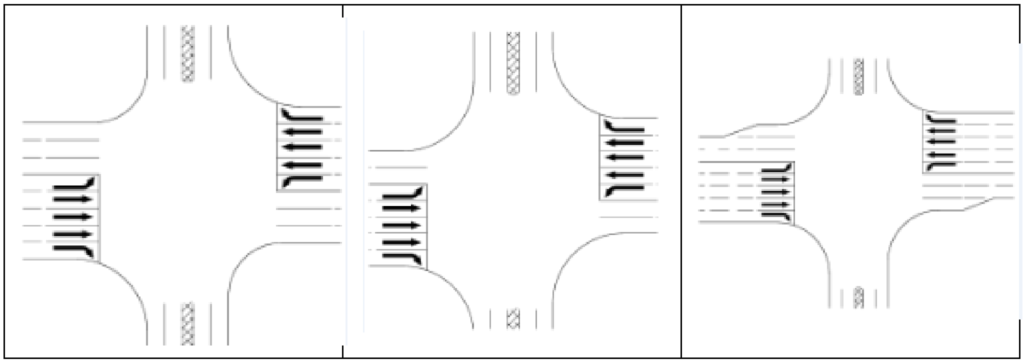
- less heavy vehicles and signalized intersection;
- three through lanes in upstream and three-lanes-to-two-lanes in downstream;
- more than 8 vehicles before the green time in a signal cycle in morning peak or evening peak;

The control sites is similar to the experimental sites, but lane of downstream should be three lanes or two lanes without stretching-segment.

Finally, we selected Yizhou-Jiaozi Intersection (three through lanes to two lanes in downstream) for experimental sites and Hongxing-Shudu intersection (only two lanes in downstream but three through lanes in upstream) and Dongannan-Shudu intersection (there is no stretching-segment) for control sites. They were shown as table 3.

Table 3. experimental sites and control sites

Control sites		Experimental sites
Dongannan-Shudu Intersection	Hongxing-Shudu Intersection	Yizhou-Jiaozi Intersection



4 Data Collection and Reduction

Since capacity of intersections can be reflected by the saturation flow rate, we recorded the selected intersections in the morning peak, and get the saturation headway. The saturation flow rate can be calculated with following equations:

$$S = \frac{3600}{\overline{h}_t} \tag{1}$$

where S=saturation flow rate;

$\overline{h}_t$ =saturation headway.

The results were shown in table 4.

Table 4 Saturation Flow Rate

		Saturation headway （s）	Saturation flow rate （pcu/h）	Total saturation flow rate(pcu/h)
Dongannan-Shudu intersection	inner lane	2.66	1353	1416
	middle lane	2.29	1572	
	outside lane	2.76	1304	
Hongxing-Shudu intersection	inner lane	2.37	1519	1358
	middle lane	2.83	1272	
	outside lane	2.89	1246	
Yizhou-Jiaozi intersection	inner lane	2.74	1314	1425
	middle lane	2.43	1481	
	outside lane	2.43	1481	

From table 4, it can not clearly reflect the impact caused by downstream stretching-segment on saturation flow rate. This is because saturation flow rate is not just influenced by downstream stretching-segment, other factors can also have an effect on saturation flow rate.

To weaken effects caused by other factors, the survey date is subjected to degree of fitting processing. Every saturation headway divided the average saturation headway in every intersection in this study. Then making a comparison between three curves. Results are shown in figure 2.

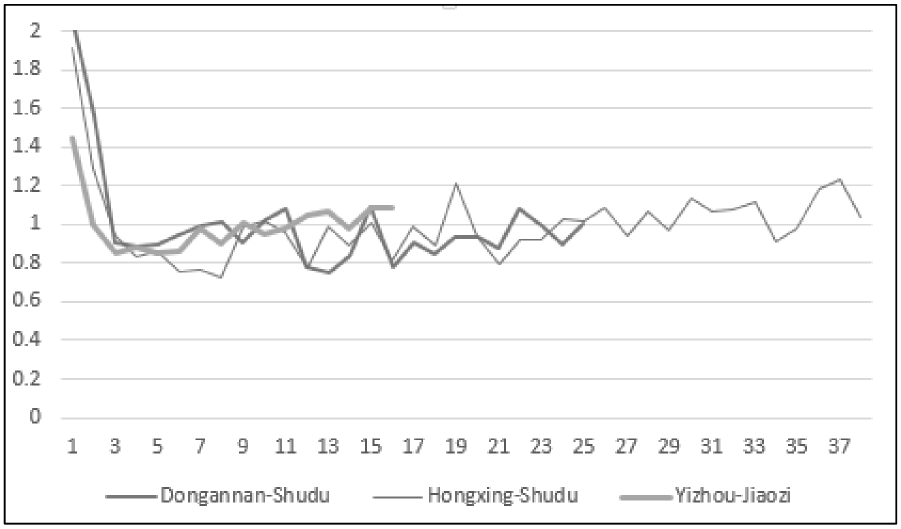


Figure 2. three curves about saturation headway after degree of fitting

We can see from figure 2: the longest curve(Hongxing-Shudu intersection) start to descended behind 1 rapidly, then raise up to 1 , and finally reached 1.2; the second longest curve(Dongannan-Shudu intersection) start to descended behind 1 rapidly, and then fluctuated around 1; the shortest curve(Yizhou-Jiaozi intersection) start to descended behind 1 rapidly, then raise up to 1.1 slowly.

We can see that the peak of the longest curve is higher than the shortest one, this showed that the saturation headway in the Hongxing-Shudu intersection is larger than the one in Yizhou-Jiaozi intersection. This is because the downstream stretching-segment could offer more space for vehicle to merge.

Besides, the speed of the longest curve is larger than the shortest one, this reflected that the storage function of downstream stretching-segment. For intersection with downstream stretching-segment, the merging points would be transferred to the downstream section, while intersection without downstream stretching-segment, vehicles would merge in the intersection, which would be easier to reach saturation.

These results can reflect that downstream stretching-segment can improve capacity of intersection compared with intersection without stretching-segment.

5 VISSIM Simulation Analysis

It is difficult to control the variable in the field research. So it is necessary to make simulation study. Based on the experimental sites, simulation model was built to analyze the impacts on signalized intersection caused by different length of downstream stretching-segment and different signal cycles.

This study assessed the capacity when the length of downstream short lane is 20m, 30m, 40m, 50m, and 60m, while taper is 20m and the signal cycle is 120s. The results were shown in table 5.

Table 5. capacity of intersection

short lane(m)	20	30	40	50	60
Inner lane(pcu/ *h*)	1593	1608	1533	1605	1598
Middle lane(pcu/ *h*)	1014	1032	1050	987	1004
Outside lane(pcu/ *h*)	945	966	918	987	1002
Total(pcu/ *h*)	7562	7654	7732	7796	7825

From table 4, we can see that capacity of the intersection will increase with the length of short lane increasing.

This study also assessed the capacity when the signal cycle is 60s, 90s, and 120s.The green time ratio would be fixed and the length of downstream stretching-segment （short lane 30m and taper 20m）would also be unchanged. The result was shown in table 6.

Table 6. Capacity of intersection

Signal cycles(s)	60	90	120
Inner lane(pcu/ *h*)	1650	1593	1548
Middle lane(pcu/ *h*)	1317	1194	1128
Outside lane(pcu/ *h*)	1134	1191	1056
Total (pcu/ *h*)	8652	8418	7881

Conclusion can be taken from table 6 that capacity would decrease with the increase of signal cycle.

6 Conclusion

Based on the field study, we can make a conclusion: downstream stretching-segment could improve the capacity of signalized intersections compared with intersection without stretching-segment.

With simulation results, we can make conclusions as follows:

(1)For intersection with downstream stretching-segment, signal cycle will take an effect on its capacity. With a certain range, capacity would descend with the increase of signal cycle.

(2)For intersection with downstream stretching-segment, the capacity will increase with the length of stretching-segment increases, but the increased speed will be lower and lower. The capacity would not change when the length of stretching-segment is longer than a certain distance.

(3) For intersection with downstream stretching-segment, the outside lane will be more sensitive.

7 Recommendations for Future Research

This survey is not very accurate because of the limited simple size. The future research will be based on larger simple sizes and make some deeper theoretical study.

References

Akcelik, R. SIDRA-2 Does It Lane By Lane. *Proceedings of 12th ARRB Conference,* Vol. 12, Part 4, Victoria, Australia, August 1984, pp.137–149.

Highway Capacity Manual. TRB, National Research Council, Washington, D.C., 2000.

Lee, J.-J., Hummer, J. E., and Rouphail, N. M. (2005). "False capacity for lane drops." Final Rep. for Project HWY-2003-07, *North Carolina Dept. of Transportation and North Carolina State University., Raleigh, NC.*

Stenberg, L. and T. Bergh. *CAPCAL-2* Model Description of Intersection with Signal Control. *Swedish National Road Administration*, Sweden, 1995.

Tarawneh, S.M. and T.M. Tarawneh, Effect of Utilization of Auxiliary Through Lanes of Downstream Right-Turn Activity, *Transportation Research Board 80th Annual Meeting CD-ROM*, Washington, D.C., 2001.

Teply, S., D. I. Allingham, D. B. Richardson, and B.W. Stephenson. Canadian Capacity Guide for Signalized Intersections. *Second Edition, ITE District 7*, Canada, June 1995.

Zhang Hai, Zhao Jing. Impact of Short Lane on Signalized Intersection Capacity, *Municipal Engineering in China*, D.C, 2007.

Correlation between Road Networks' Structural Characteristics and the Distribution of Traffic Volume Based on ArcGIS

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Abstract: The structure of road network in a city will not only affect the spatial morphology of a city, but also have influence on the operating performance of all kinds of ground transportation and people's travel behavior. Therefore it's necessary to identify the methods and indicators to describe network structure, and analyses its impacts on the distribution of vehicle volume. The authors first used ArcGIS on road network's topological analysis, then used dual approach to abstract the stroke graph into connectivity graph, which as a result figured out the indicators of road network structure. Multiple regression and simple regression were used to analyze how road network structure impact the distribution of vehicle volume. In the end the contrasted results of the two methods lead two most representative indicators of road network structure and the distribution of vehicle volume, which are Betweenness and vehicle kilometers traveled. So the conclusion is that Betweenness and vehicle kilometers traveled shows simple linear relationship, which means the more important of a stroke in road network is, the more vehicle kilometers there will be on the stroke.
Keywords: Road network; Topology; Distribution of traffic volume; Regression analysis.

1 Introduction

In the traditional study of traffic volume distribution, traffic demand, land use and the distribution of traffic facilities' capacity are often considered, while the role of road network structure is often ignored. But as we all know, road network is the infrastructure of the city, its structure and layout can reflect the distribution characteristics of geographic features, so it has great effect on the distribution of traffic demand. At present, many researches on the structure of road network have been made on the international, and the relationship between road network structure and traffic volume distribution is preliminary discussed. Based on the study, this paper made a research on the influence of road network structure to traffic volume distribution.

The structure of tis paper is described as following. Firstly, section 2 shows the literature review which focuses on the influence of road network structure to traffic volume distribution. Then, Section 3 is a description of road network topology and its indicators. Section 4 introduces the indicators of traffic volume distribution and section 5 shows the relationship between road network structure and traffic volume distribution. The last two sections are the conclusion of this paper and proposes direction for further research.

2 Literature Review

Montis and other researchers studied the structure of the network representing the interurban commuting traffic (Montis, 2007), they also characterized quantitatively the traffic backbone and gave evidence for a very high heterogeneity of the commuter flows around large cities.

Lammer analyzed the 20 largest German cities and found that traffic strongly concentrates on only a small fraction of the roads (Lammer, 2006). The distribution of vehicular flows over the roads obeys a power law, indicating a clear hierarchical order of the roads.

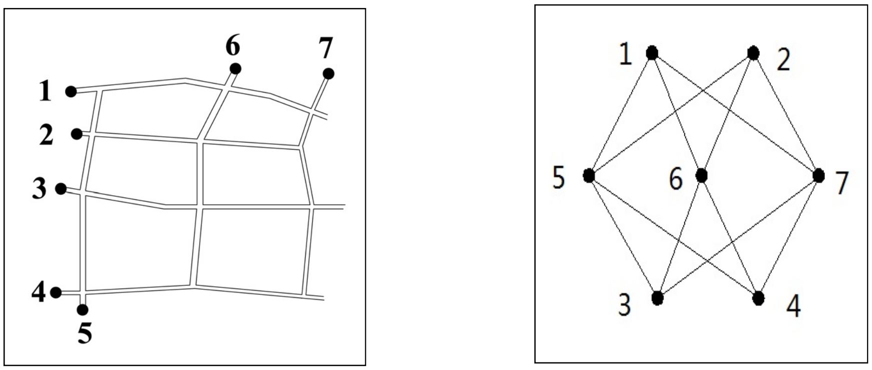
Jiang and Liu made research on Hong Kong's road network and found that vehicle flow is correlated to a morphological property of streets and suggest the topological analyses as a new analytical means for geographic knowledge discovery (Jiang Bin, 2007).

Flavio Bono and others studied the path-dependencies in closed trails and computed their global and spatial correlations with measured traffic flows (Flavio Bono, 2010). They found that the heterogeneous distribution of traffic intensity is mirrored by the distribution of agglomerate path-dependency and that high traffic roads are packed along corridors at short-to-medium trail lengths from the ensemble of nodes.

3 Road Network Topology

3.1 Brief description of road network topology

Road network topology is significant for expressing the network structure, from which way people can understand the complexity of road network more simply and intuitively. There are two main approaches to build network topology, namely the primal approach and dual approach (Jiang Bin, 2004). In the primal approach, intersections are abstracted to nodes and the roads are abstracted to connections; in the dual approach, roads are abstracted to nodes and intersections are abstracted to connections. In order to obtain scale-free networks, stroke (A series of roads that have continuity in direction) is used as the node in the dual graph (Ye Pengyao, 2008). Compared with the primal approach, the dual approach retains not only spatial relationships between strokes but also structural characteristics of transport networks, therefore it is particularly suitable for analyzing the transport routes network (Sergio Porta, 2006). So in this paper the authors will use the dual approach. Figure 1 is a dual graph which is based on dual approach.



a）Stroke network b) Network based on dual approach

Figure 1. Dual graph

3.2 Indicators of road network topology

Network centrality is often used as indicator in the analysis of characteristics of network topology (Park K, 2004). There are three main centrality indicators, namely degree, closeness and betweenness. The three indicators can be used to evaluate the importance of nodes in the network.

(1) Degree

Degree is defined as the normalization of the number of nodes which are directly connected to a particular node. Its expression is as follows:

$$C_D(x) = \frac{k_i}{N-1} \tag{1}$$

Where N is the number of nodes in the network, k_i is the number of nodes which are directly connected to a particular node. The degree can also be named as "local degree", because it only considers the number of nodes which directly connect to a particular node while ignoring the number of nodes which indirectly connect to the particular node.

(2) Closeness

The Closeness of a node is the reciprocal of the sum of the shortest topological distances from the node to all other nodes in the network. Its expression is as follows:

$$C_C(x) = \frac{N-1}{\sum_{y=1}^{N} d_{xy}} \tag{2}$$

Where d_{xy} is the shortest topological distance between node x and node y. It is not suitable for closeness to describe the structural importance of a node, because either the arterial road or the branch road, as long as the shorter the distance between road and central region is, the bigger of the road's closeness will be, but this does not mean that the road plays a more important role in the road network (M.E.J. Newman

2003).

(3) Betweenness

Betweenness is defined as the probability of shortest paths between any pairs of nodes in the network which go through a particular node:

$$C_B(x) = \frac{2g(x)}{(N-1)(N-2)} \tag{3}$$

It's easy to see from the description that betweenness is a global indicator. A stroke with a lower degree may also play an important role as "intermediary", which means it is important in communicating the entire road network.

4 Road Network Structure's Effect on The Distribution of Traffic Volume

4.1 Indicators of the distribution of traffic volume

On different roads, traffic volume shows different characteristics, therefore several indicators are needed to describe the distribution of traffic volume clearly. In this paper, road's average traffic volume (RAV) and stroke's vehicle kilometers traveled (VKT) were chosen to describe the distribution characteristics of traffic volume.

(1) Road's average volume, RAV

The road's average volume is defined as the average volume of each road in a stroke. As the number of lanes in each road may be different, which can lead to a different traffic distribution, so it is necessary to analyze the average volume.

(2) Stroke's vehicle kilometers traveled, VKT

Vehicle kilometers traveled is defined by the U.S. government as a measurement of kilometers traveled by vehicles in a specified region for a specified time period. The stroke's VKT is the sum of each road's vehicle kilometers traveled. It is easy to see that, the RAV only considers the characteristics of traffic entity, but ignoring the differences that caused by the natural properties of each road. The VKT precisely makes up for the shortcoming, it indicates the using of the stroke when the vehicles are traveling on it.

4.2 Impact analysis

In the previous section, we introduced three indicators of network topology, and qualitatively described each indicator's role in describing the importance of a stroke in the network. But it is not clear that the road network structure's impact on the distribution of traffic volume is a result of the combined action of these three indicators, or just only one certain indicator. So, multiple liner regression and simple liner regression are used to make quantitatively research on how road network structure impact the distribution of vehicle volume.

5 Case Study

The experimental data is three cities' (Deyang, Ziyang and Mianyang) road center line graphs and vehicle traffic volume. Figure 2 shows Deyang’s road network. ArcGIS, Stroke Analysis (Ye Pengyao, 2008) and Ucinet were used to calculate the indicators of road network structure, and then the indicators of road network structure and the distribution of traffic volume were matched together. Deyang’s matching result is shown in table 1.

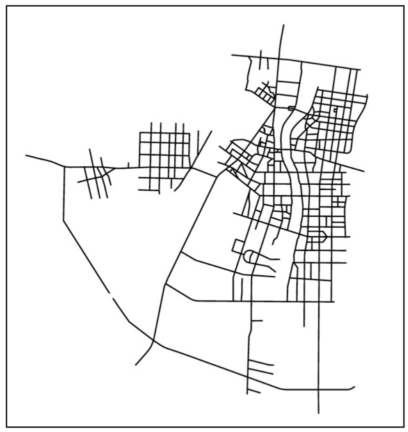


Figure 2. Deyang’s road center line

Table 1. The match result of the two kinds of indicators

Stroke ID	Degree	Closeness	Betweenness	RAV（pcu/h）	VKT（pcu·km/h）
1	0.06383	0.286585	0.050803	1057	5864.3
2	0.177305	0.287755	0.095604	1073	7452.6
3	0.219858	0.313333	0.274021	2248	25754.6

5.1 Multiple linear regression analysis

Multiple linear regression analysis was carried out on the indicators of network structure and traffic distribution. The purpose of the analysis is to quantitatively describe the influence of the structure to the distribution.

In the regression analysis, the road network structure indicators are the independent variables and the traffic distribution indicators are treated as dependent variables. Set the significance level of 0.05. The regression results of the VKT and RAV for the three cities are as follows:

Table 2. The results of multiple liner regression analysis of the VKT

Name of road network	Indicator of structure	significance	Independent variables of the function
Deyang	Degree	0.442	Betweenness
	Closeness	0.121	

	Betweenness	0.002	
Ziyang	Degree	0.158	none
	Closeness	0.956	
	Betweenness	0.712	
Mianyang	Degree	0.01	Degree Betweenness
	Closeness	0.217	
	Betweenness	0.005	

Table 3. The results of multiple liner regression analysis of the RAV

Name of road network	Indicator of structure	significance	Independent variables of the function
Deyang	Degree	0.086	Betweenness
	Closeness	0.175	
	Betweenness	0.002	
Ziyang	Degree	0.076	none
	Closeness	0.879	
	Betweenness	0.142	
Mianyang	Degree	0.198	none
	Closeness	0.542	
	Betweenness	0.177	

From the results of the regression analysis we can see that the type of indicators which have influence on VKT are different, that is to say, the type of indicators will change by different cities. While in the result of RAV, the values of significance (P-value) are all above 0.05 expect the value of Deyang's betweenness, which indicates that the structure indicators almost have no effect on RAV, so we abandon it in the next study. The multiple regression analysis cannot help to determine the type and number of the formula of the three cities, so simple regression analysis will be used in the next study.

5.2 Simple liner regression analysis

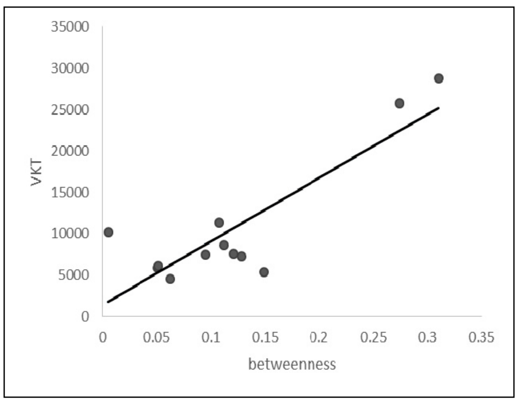
From table 2 we can see that the significance of VKT and betweenness tends to be the best, and from the definition of betweenness we can see it is a global indicator, a stroke with a lower degree may also play an important role as "intermediary", which means it is important in communicating the entire road network. Therefore, in the simple liner regression analysis, only betweenness and VKT are taken into account.

Set the significance level of 0.05, the model summary of simple liner regression analysis is showed in table 4.

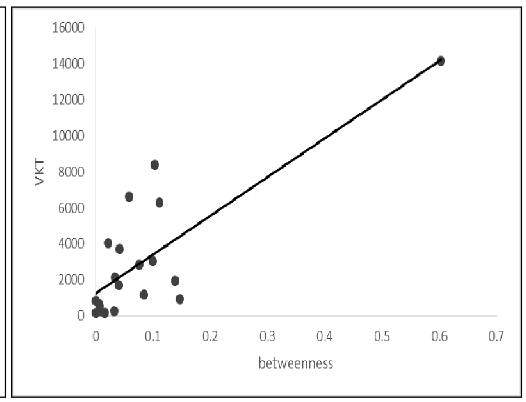
Table 4. Model summary

Name of road network	Indicators	R	R Square
Deyang	VKT betweenness	0.858	0.737
Ziyang		0.799	0.638
Mianyang		0.897	0.804

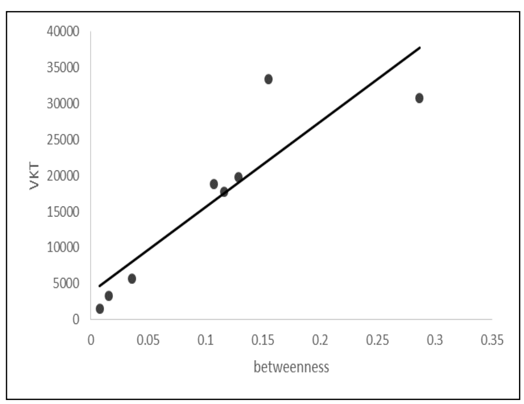
Table 4 shows that the fitting degree of VKT and betweenness are all favorable in the three cities. Figure 3 shows the three cities' scatter diagram of VKT and betweenness. Table 4 and figure 3 indicate that VKT and betweenness is proportional, that is to say the lager betweenness of a stroke is, the more VKT there will be on it.



a) Deyang



b) Ziyang



c) Mianyang

Figure 3. Three cities' scatter diagram of VKT and betweenness

6 Conclusion

Based on the study of road network topology, this paper introduced that the structure of road network will influence the distribution of the traffic, and the idea is verified by three cases. The result of multiple linear regression analysis indicates that the betweenness is the very structure indicator which has greatest influence on traffic distribution; of the two traffic distribution indicators, VKT is the very indicator which is more significant effected by the network structure. The result of simple liner regression shows that the impact of network structure on the distribution of traffic is linear.

7 Recommendations for Future Research

As we all know, the distribution of traffic volume is also affected by the traffic demand, therefore, in the follow-up studies, combined effects of traffic demand and network structure on traffic distribution will be analyzed.

Acknowledgement

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References

Flavio Bono, Eugenio Gutierrez, Karmen Poljansek. (2010). “Road traffic: A case study of flow and path-dependency in weighted directed networks.” *Physica A*. 2010.

Jiang Bin, Liu Chengke. (2007) “Street-based Topological Representations and Analyses for Predicting Traffic Flow in GIS.” *International Journal of Geographical Information Science.* 23(9):1119–1137

Jiang B, Claramun C. (2004). “Topological analysis of urban street networks.” *Environment and Planning B*.2004,31: 151-162

Lammer S, Gehlsen B, Helbing D. (2006). “Scaling laws in the spatial structure of urban road networks”. *Physica A.* 363(1): 89-95

M.E.J. Newman. (2003). “The structure and function of complex networks.” *SIAM Rev*.2003, 45(3): 167–256.

Montis A D, Barthelemy M, Chessa A, et al. (2007) “The structure of inter-urban traffic: a weighted network analysis.” *Environment and Planning B: Planning and Design*. 34(5): 905 –924

Park K, Lai Y, Ye N. (2004). “Characterization of weighted complex networks.” *Physical Review E*. 2004, 70: 026109.

Sergio Porta, Paolo Crucitti, Vito Latora. (2006). “The network analysis of urban streets: A dual approach.” *Physica A* .2006, 369(2006):853–866

Wu Jianjun. (2010). “The complexity of urban transport system.” *Science Press.* 2010:36-38

Ye Pengyao. (2008). “Research on structure characteristics of urban road and street network.” *Tongji University.* 2008:99-100

Speed Guiding-Based Multi-Objective Coordinated Control Strategy for Tram Operation at an Intersection

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Abstract: The multi-objective coordinated control strategy of tram in the intersection based on speed guidance in this article is the evaluation basis of the control strategy which is built on the basis of existing tram priority control in the intersection with the index of additional passengers' total delay time in the intersection; the tram and social vehicle can be coordination controlled by speed guidance or giving the tram passing priority in the intersection in order to minimize additional passengers' total delay time in the intersection.
Keywords: Speed guidance; Tram; Intersection; Multi-objective coordinated control.

1 Introduction

Trams (Bie Yiming, 2011) belong to the ground bus rapid transit, mostly a semi independent row form is used in space, and social vehicle drives together on the road, in the presence of plane intersection, which all will cause the tram in conflict with social vehicles at the intersection. So, in order to maintain the high efficiency of tram, using the maximum capacity of transporation. So far, most research focus on the aspect of priority control of signal at intersection in China. Mainly includes: passive priority control strategy, the absolute priority control strategy, conditional priority control strategy and real-time priority control strategy; the main methods are: the red light, green light delay and early fault phase insertion etc. But the primary goal of these strategies is to give the tram priority at intersections, not mainly considering the delay impact to other social vehicles (or the way of phase compensation to reduce the impact on other social vehicles). However, the the fundamental purpose of intersection signal control is to reduce the delay time of whole passenger at intersection, improving the traffic efficiency, so this paper is based on this for judgement, combined with the traditional research and coordinated control of the existing bus priority control, proposing a kind of tram road intersection coordination control strategy based on speed guided. Firstly, judging whether is it possible to go through the intersetion by accelerated guide in the green phase before the end, if not, setting how to minimize the intersection of additional total passenger delay time as the goal to guide the distribution of trams and social vehicles right of way and speed, so as to achieve the best efficiency of intersection traffic.

2 Determination of the Control Strategy Basis

Coordinated control strategy proposed in this paper contains the following assumptions:

The left turn phase and the yellow light phase in signal phase is not considered.

(2) Left social traffic flow is far less than the straight social flow.

(3) The tram line layout is central type.

(4) The interaction of tram platform and intersection is not considered.

2.1 Intersection planar structure

As shown in Figure 1, (Cao Chenghai,2006)central type is applied at the trolley lines, the platform is located in the middle of the road. Each import all has left, straight, right lane. Social vehicle detector is laid out at each entrance, which of the distance and intersection are L1; each the tram line of imports also emplace a tram detector, the distance from intersection is L2(the specific value L1, L2 should be determined according to the actual speed and intersection status). The width of the intersection is L4, tram length is L3, for the convenience of the subsequent calculation, making L3= L_t ,L4= L_i ,L1=L_{cd} ,L2=L_{td} .

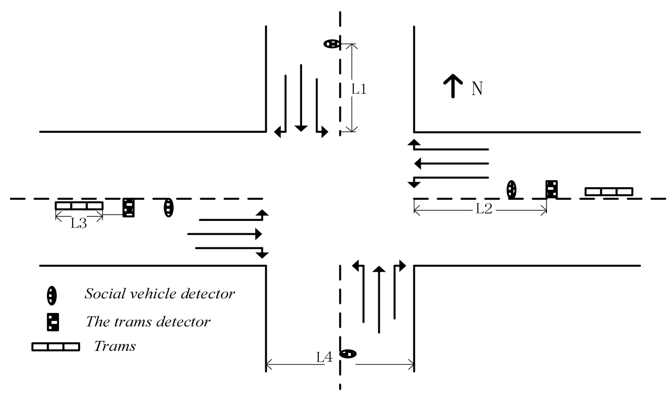

Figure 1. Planar intersection structure

2.2 Control strategy basis

In figure 1, social vehicle detector(Li Sheng,2005)collects information are: straight, left turn traffic flow, traffic flow of intersection queue number; the collected information of tram detector are: the tram reaches a detector when the time, speed, number of passengers. First of all, when detecting the tram arrived, the system will predict the tram arrived at the intersection of the moment, if it is not able to pass the intersection in the light phase, it is determined whether it should be accelerating guided through the intersection, If applicable, then calculate guiding target speed value; if not, then analysis in process shown below:

Assumption of the trams take priority control strategy (the red light, green light delay early break), social vehicles on the conflict phase using speed guide, it will produce additional delay of social vehicles on the vertical direction (Figure 1: South - North going straight and turning left vehicle), but at the same time，it will reduce the delay of tram and same phase of the straight vehicle in the cross (Fig. 1 : Middle East - West to straight vehicle). So in this case the intersection of additional total passenger delay time is as follows:

$$D_{total}^{1} = D_{NS} + D_{NL} + D_{SS} + D_{SL} - D_{WS} - D_{ES} \qquad (1)$$

In the formula: D_{total}^{1}: In case of tram priority control, intersection of additional total passenger delay time. D_{NS}: The north entrance of straight vehicle additional total passenger delay time. D_{NL}: The north entrance of left turning vehicle additional total passenger delay time . D_{SS}: South entrance of straight vehicle additional total passenger delay time. D_{SL}: The South Port Road turning left additional passenger vehicle total delay time. D_{WS}: Total corresponding reduction passenger delay time of westward entrance straight vehicle. D_{ES}: Total corresponding reduction passenger delay time of east entrance straight vehicle.

Assuming that it applies deceleration guidance to tram, instead of priority control strategy, means the intersection signal phase without any changes, then the intersection of the additional total passenger delay time is shown as follows:

$$D_{total}^{2} = D_{T} \qquad (2)$$

In the formula: D_{total}^{2}: Total delay time of additional passenger at intersection with tram deceleration guide. D_{T}: Total delay time of additional passenger at tram

So, to sum up:

When $D_{total}^{1} < D_{total}^{2}$, priority control strategy should be taken for the tram, guiding the social vehicle speed. When $D_{total}^{1} > D_{total}^{2}$, the intersection keeps the original signal phase invariant, decelerate guide should be taken to the tram.

3 Analysis of Tram Arrival Patterns

In this article, (Li Kai,2013)each red light and green light phase is divided into three stages, which are early stage, intermediate stage and later stage. The lengths of early stage and later stage are assumed to be a quarter of the corresponding phase, while the length of intermediate stage is half of the phase (Proportion of the specific time shall be determined according to actual situation intersections), which is shown in figure 2.

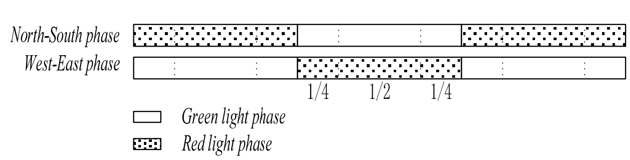

Figure 2. Phase structure

3.1 Arrival patterns

Assumes(Ma Wanjing,2009)that the average speed of tram is V_i when passing the intersection in the actual operation, time used to pass the intersection is Δt, moment to enter the intersection is T_{is}, moment to leave the intersection is T_{ie}, so:

$$\Delta t = \frac{L_t + L_i}{V_i} = T_{ie} - T_{is} \tag{3}$$

In this article, according to the arrive time detected by the trams detector, the predicted situations of the tram reaching the intersection can be divided into 9 model, which is shown in figure 3.

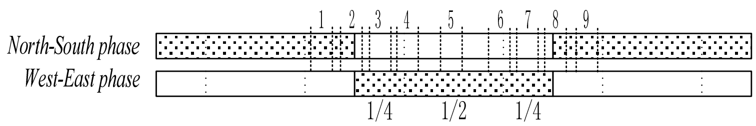

Figure 3. The tram arrival patterns

In pattern 1 and pattern 9, the moment to reach and leave the intersection of the tram are in green light phase thus they won't be considered in the following passage. In pattern 4, 5 and 6, the moment to reach or leave the intersection of the tram are in the intermediate stage of the red light phase, there will be a great influence on original phase's time series and passing efficiency if the tram is priority controlled in this condition, so speed guidance can be taken to the tram in order to decrease the stopping time.

3.2 Calculation of additional passengers' total delay time in the intersection

Pattern 2: The tram is predicted to enter the intersection in green light phase and leave the intersection in red light phase, which is shown in figure 4.

Pattern 3: The tram is predicted to enter the intersection in red light phase and leave the intersection in red light phase, which is shown in figure 5.

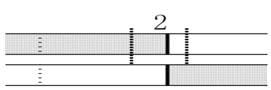

Figure 4 .Phase diagram of pattern 2

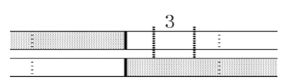

Figure 5. Phase diagram of pattern 3

If we take priority control strategy to the tram (delaying the green light), and guide social vehicles' speed, the following can obtain by formula (1):

$$\begin{aligned} D_{total}^{1} &= (Q_{NSW} + Q_{NLW} + Q_{SSW} + Q_{SLW}) \bullet \Delta t' \bullet \lambda + \\ &\frac{1}{3600}(q_{NS} + q_{NL} + q_{SS} + q_{SL} - q_{WS} - q_{ES}) \bullet \int_0^{\Delta t'} (\Delta t' - t)\, dt \bullet \lambda \\ &= (Q_{NSW} + Q_{NLW} + Q_{SSW} + Q_{SLW}) \bullet \Delta t' \bullet \lambda + \\ &\frac{1}{7200}(q_{NS} + q_{NL} + q_{SS} + q_{SL} - q_{WS} - q_{ES}) \bullet \Delta t'^2 \bullet \lambda \end{aligned} \tag{4}$$

In the formula: Q_{NSW} is the number of vehicle waiting to go straight in the north entrance; Q_{NLW} is the number of vehicle waiting to turn left in the north entrance;

Q_{SSW} is the number of vehicle waiting to go straight in the south entrance; Q_{SLW} is the number of vehicle waiting to turn left in the south entrance; q_{NS} is the traffic flow to go straight in the north entrance, pcu/h; q_{NL} is the traffic flow to turn left in the north entrance, pcu/h; q_{SS} is the traffic flow to go straight in the south entrance, pcu/h; q_{SL} is the traffic flow to turn left in the south entrance, pcu/h; q_{WS} is the traffic flow to go straight in the west entrance, pcu/h; q_{ES} is the traffic flow to go straight in the east entrance, pcu/h; $\Delta t'$ is green light delay time, s, $\Delta t' = T_{ie} - T_{rs}$, T_{rs} is the moment when the red light hits; λ is the average passenger number in each vehicle.

If we don't change the original signal phase in the intersection, just guide the tram to slow down, then:

$$D_{total}^{2} = (t_r + T_{rs} - T_{is}) \bullet N \tag{5}$$

In the formula: t_r is the duration of red light phase; N is the passenger number on the tram.

Pattern 7: The tram is predicted to enter the intersection in red light phase and leave the intersection in red light phase, which is shown in figure 6.

Pattern 3: The tram is predicted to enter the intersection in red light phase and leave the intersection in green light phase, which is shown in figure 7.

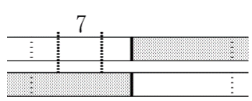

Figure 6. Phase diagram of pattern 7

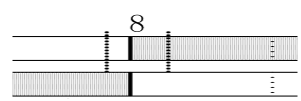

Figure 7. Phase diagram of pattern 8

If we take priority control strategy to the tram (turning off the red light early), and guide social vehicles' speed, the following can obtain by formula (1):

$$\begin{aligned} D_{total}^{1} &= \frac{1}{3600}(q_{NS} + q_{NL} + q_{SS} + q_{SL} - q_{WS} - q_{ES}) \bullet \int_0^{\Delta t'} (\Delta t' - t)\, dt \bullet \lambda - \\ &\quad (Q_{ESW} + Q_{WSW}) \bullet \Delta t' \bullet \lambda \\ &= \frac{1}{7200}(q_{NS} + q_{NL} + q_{SS} + q_{SL} - q_{WS} - q_{ES}) \bullet \Delta t'^{2} \bullet \lambda - \\ &\quad (Q_{ESW} + Q_{WSW}) \bullet \Delta t' \bullet \lambda \end{aligned} \tag{6}$$

In the formula: Q_{ESW} is the number of vehicle waiting to go straight in the east entrance; Q_{WSW} is the number of vehicle waiting to go straight in the west entrance; $\Delta t'$ is the lead time to turn off the red light, s, $\Delta t' = T_{re} - T_{is}$, T_{re} is the moment when the red light turn off.

If we don't change the original signal phase in the intersection, just guide the tram to slow down, then:

$$D_{total}^{2} = (T_{re} - T_{is}) \bullet N \tag{7}$$

4 The Determination of Guided Speed

Because social traffic flow(Wang Yizhe,2014) is composed of many single vehicles, while speed of the social vehicle is guided, this paper doesn't take the method of giving targeted speed value, but in the form of the countdown to display end time of the red light phase and green light phase. But for the tram, this paper takes the method of giving targeted speed value to guide its speed. The determination of targeted speed value of the accelerated speed guidance and decelerated speed guidance will be discussed respectively in following contents.

Accelerated guidance(Zeng Ying,2009): When tram passes the intersection at end moment of the green light phase time, the targeted speed value of the accelerated guidance is minimum. It can be determinate by following formulae:

$$T_{rs} - T_{td} = \frac{v_1 - v_0}{a_a} + \frac{v_1 - v_i}{a_d} + \Delta t^{"} + \Delta t \tag{8}$$

$$L_{td} = \frac{v_1^2 - v_0^2}{2a_a} + \frac{v_1^2 - v_i^2}{2a_d} + v_1 \Delta t^{"} \tag{9}$$

In the formula: T_{td} is the moment when tram reach the detector, v_1 is the targeted speed value of guidance, v_0 is the speed when tram reach the detector, a_a is the average acceleration of the tram, a_d is the average deceleration of the tram, $\Delta t^{"}$ is the traveling time of the tram at v_1 speed .

Note: Because the tram is affected by vehicle characteristics and safety in the process of driving, there is a threshold of the travelling speed. If the calculative guided speed is faster than top limit of the travelling speed($v_1 > v_{max}$), the accelerated guidance can't be taken.

Decelerated guidance: When tram enter into the intersection at end moment of the red light phase time, the targeted speed value of the decelerated guidance is maximum. It can be determinate by following formulae:

$$T_{re} - T_{td} = \frac{v_0 - v_1}{a_d} + \frac{v_i - v_1}{a_a} + \Delta t^{"} \tag{10}$$

$$L_{td} = \frac{v_0^2 - v_1^2}{2a_d} + \frac{v_i^2 - v_1^2}{2a_a} + v_1 \Delta t^{"} \tag{11}$$

5 The processes of the coordinated control

By above knowable, the logic process of this paper proposed coordinated control strategy is shown in figure 8:

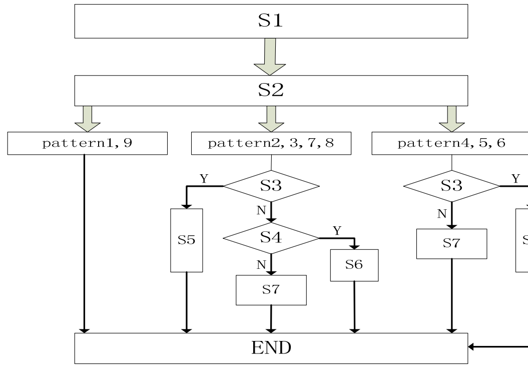

Figure 8. The processes of the coordinated control

In the figure:S1: Collect data by detector.S2: Predict the arrival time and arrival patterns of the tram.S3: Can take the accelerated guidance for the tram? S4: $D_{total}^{1} < D_{total}^{2}$? S5: Give the targeted speed value of the accelerated guidance.S6: Take the priority control strategies (delaying the green light or turning off the red light early).S7: Take the decelerated guidance and give the value of the targeted speed.

6 Conclusions and Outlook

Technically, the proposed control strategy can be a good way to solve the problem of low efficiency due to the frequent changes in the original phase of the intersection. In the subsequent study, this control strategy will be verified through the simulation and actual situation. At the same time, the condition with the existence of yellow light phase and left-turn phase will be analyzed deeply.

Acknowledgements

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References

Bie Yiming.(2011).”Multiple-Phase Bus Signal Priority Strategy for Arterial Coordination Intersection.” *Journal of South China University of Technology (Natural Science Edition)*. College of Traffic, Jilin University, Changchun 130022,Jilin, China. 2011,10:111-118.

Cao Chenghai. (2006).”Study on Bus Priority Signalized Coordination at Intersections in City.” *Agricultural Equipment & Vehicle Engineering*. Harbin Institute of Technology, Harbin 150090, China. 2006,10:22-28.

Li Sheng.(2005).”Harmonious Control of Modern Tramway and Road System.” *Urban Mass Transit*. School of transportation engineering, Tongji university, Shanghai.2005,04:57-60.

Li Kai.(2013).”Study on the Control Projects for Modern Tramcars at Signal

Intersections." *Urban Rapid Rail Transit*. Beijing Urban Engineering Design and Research Institute Co.,Ltd.,Beijing 100037. 2013,02:104-107.

Ma Wanjing.(2009)."A coordinated intersection-group bus signal priority control approach." *China Civil Engineering Journal*. Key Laboratory of Road and Traffic Engineering of the Ministry of Education, Tongji University, Shanghai 201804, China.shanghai. 2009,02:105-111.

Wang Yizhe(2014)."The speed guidance and signal priority control of the modern streetcar Based on the VII." *The 9th China intelligent transportation annual meeting*. School of transportation engineering, Tongji university. Shanghai. 2014:11.

Zeng Ying.(2009)."Study on Synergy Problem of Dynamic Lane-use Assignment and Signal Control at Intersections." *Journal of Tongji University(Natural Science).* Key Laboratory of Road and Traffic Engineering of the Ministry of Education,Tongji University,Shanghai 201804,China. 2009,07:903-908.

A Method of Intersection Traffic Volume Statistics Using Aerial Video

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Abstract: This paper proposes a new method of detecting traffic volume of intersections from aerial video processing by software, and made a simple example. First, we use aeromodelling to get traffic flow video of target area. Then, we process the video with software we developed independently, to access data we need. The software developed on the platform of MFC and OPECV based on the C++ program. We used the mixed Gauss background difference method to identify vehicles in a single frame, and the L-K algorithm and corner detection algorithm to track vehicles in the continuous video. By this way, we extract trajectories of vehicles, and then get the speed and acceleration according to the relationship between time and displacement. On this basis, we propose a method of intersection traffic volume statistics. Proved by the experiment, the data gathered from the aerial video by our software is very accurate, and the error of intersection traffic volume is within 2%. It meets the requirements of the traffic survey well. The foreground of the software is considerable.

Keywords: Model aircraft; Traffic volume; Software.

1 Introduction

With the rapid development of China's technology and economy, traffic problems are seriously increasing. Meanwhile, the industry of transportation is gradually moving towards intelligent. The traffic volume statistics of intersections plays an essential position in the whole industry. However, due to various reasons, the intersection traffic volume still using manual statistics most of the time. Obviously, it is far from intelligent.

Among various data, the investigation on the traffic volume of intersections is being the most basic and important thing. It helps us to understand almost all aspects of an intersection in the actual working situation, such as traffic capacity, the traffic flow distribution and so on. Based on the data, we also can make an evaluation of the road intersection’s service level to provide a basis for the traffic problems diagnosis. At the same time, we also can access the information of characteristics of the road network traffic load, and determine the level of road network load. The index above is important basis for relevant departments to make decisions such as traffic jam improvement, traffic flow status prediction, and road network planning.

Therefore, the importance of intersections traffic volume survey is going without saying. However, in this information and automation age, detecting of intersections traffic volume is still not realized automation. In most cases, the method of intersections traffic volume gathering is artificial counting, which is not only squandering manpower, but very inconvenient. In order to solve this problem, based on the model view video, we developed a kind of software which can complete the intersection traffic volume statistics automatically.

2 System Introductions

We developed the hardware system and software system at the same time. The hardware system is mainly to build a model aircraft traffic observation system, by integrating the aeromodelling equipment and flight control technology, enabling it to have the air traffic observation ability. On the other hand, we developed software for the extraction of traffic targets coordinate and track, which based on the MFC and OpenCV platform, and using it for the extraction of road coordinates, speed, and acceleration of the vehicle from videos.

2 .1 Hardware system（aeromodelling system for observation）

We set up the video acquisition platform with four axis fixed wing model as foundation, which can collect the traffic streaming video, providing aerial view video material of for our software. Our aeromodelling system for observation is divided into two parts of airborne system and the ground station system.

Airborne system includes camera for aircraft, aeromodelling flight control module, receiver, data transmission module and image transmission module; the groud station includes computer, monitor, remote control, data transmission module and image transmission module.

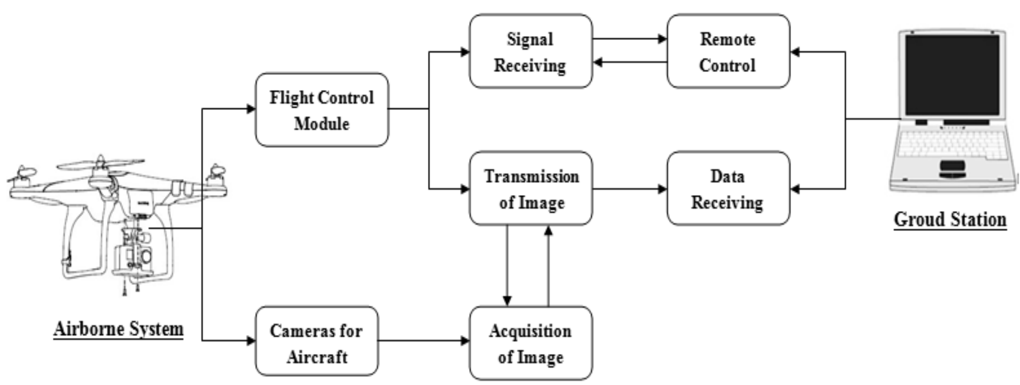

Figure 1. Schematic diagram of the hardware system

2 .2 Software system

The following is a brief introduction to part of our software's function.

2 .2 .1 The stabilization of video

For the quality of aerial videos is easily affected by wind and the user's operation, there will be different degrees of jitter in the videos. However the video's stability is a prerequisite for efficient and accurate of the software. A corner detection approach is used in the software to stabilize the jittering video. The "corner" as a feature point on the image, is the extreme point of the gray level gradient, which is easily being identified and tracked in the continuous frames in a video. The software will detect and track the static "corner" fixed on earth (usually the buildings on the roadsides). Then, the software will redefine the coordinate of the image referring to these static "corner", in order to get a more stable and easier to processing video.

2 .2 .2 Identification and tracking of traffic flow

The identification module of the software uses the mixed Gauss background difference method to segment the foreground (the traffic flow) from the background (road or highway). After eroding and dilating processing, we will get the foreground image that only contains vehicles filtering the environment noise. When the software running, there will cost a few seconds to found and accumulate the background before the identification procedure work, and the longer the software runs, the more accurate it will be.

The vehicle tracking procedure uses the L-K (Lucas & Kanade) algorithm. By identifying the corner of one contour in the foreground image (the gray level change rate between vehicles and roads is very high, and usually the boundary will be identified as the corner) and tracking it in the continuous frames, the algorithm will get the moving vehicles' coordinate information and trajectories.

2. 3 A new method of counting the intersection traffic volume

After obtaining the coordinate and trajectory information of the vehicles, we propose a statistical method of intersection traffic volume.

Aerial video is the simplification of three-dimensional scene to two-dimensional plane. It is perfectly preserved traffic volume information, with the useless terrain factors been removed.

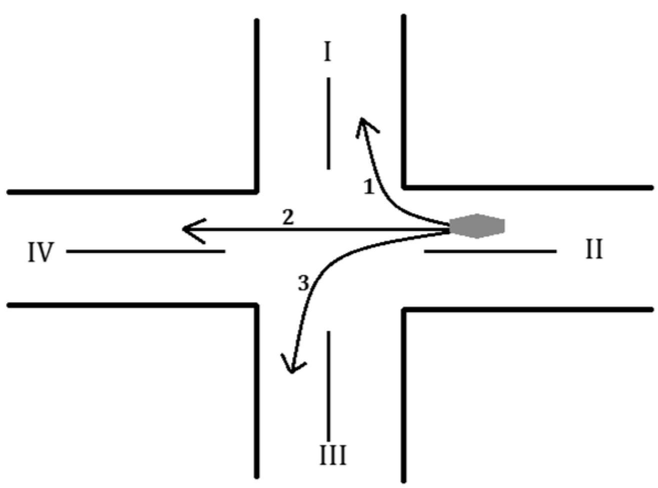

Figure 2. Schematic diagram of the hardware system

Figure 2 is the most common intersection, we numbered the four branches, respectively, I, II, III, IV.

When the vehicle enters one rectangle, the software will do the corner detection and track the trajectory information. After that, by ranking the sequence of vehicle entering the rectangle, we will get the vehicle's steering information.

When it comes to count the traffic volume, we propose a new method: using the corner detection algorithm to record the steering information, while using the area of the contours as a weight to record the quantity of traffic.

Figure 3. Result of the mixed Gauss background difference

Normally, the target can be segmented from background completely (the right of Figure 3),but under some special light, due to the reflection of the vehicle windscreen, or the color similarity between the road and cars, the case can happen that one target is segmented into two pieces (the left of Figure 3). However, using the weight to count the quantity, by comparing the standard vehicle, we will get the correct quantity of traffic volume.

3 An Example

We test the software at the intersection of Suyuan Avenue and Jiyin Avenue in Jiangning District, Nanjing city.

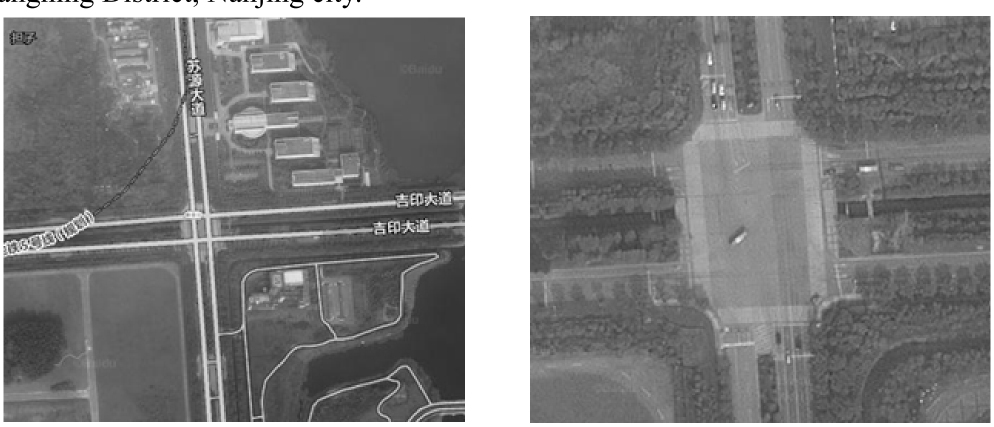

Figure 4. Schematic diagram of the hardware system

Among them, the East-West is Jiyin Avenue, to the North-South is Suyuan Avenue. The intersection is located on the Southeast University campus nine lung Lake outside the Northwest corner， Jiangning District of Nanjing City.

The two avenues are designed according to the highway design standards, more and more to assume the function of city road. They both have a design speed of 80km/h, and a forbid speed of 70km/h, and both are two-way four lane road with a broad central divider.

Due to the road shape, the intersection area is very large, so it has a wide field of vision.

There are four lanes before the intersection, is the non motor vehicle lanes, through lane, straight lane, and the left turn lane respectively. The intersection is outside of bustling area, large traffic flow only apartments during peak hours..

Since the peak period traffic in the evening is large, we chose the under time to conduct our investigation for a more representative data.

October 12, 2014, 17:00 p.m.

We are starting from 17:15 and 17:45, had twice traffic volume investigate, every time lasts 10 minutes.

Artificial statistical results of traffic volume as follows:

Intersection	Directions	Vehicle（17：15—17:25）			
of Ji Yin Avenue & Suyuan Avenue		Left	Straight	Right	SUM
	South	18	131	11	160
	North	37	50	33	120
	East	11	45	41	97
	West	36	74	8	118
Intersection	Directions	Vehicle（17：45—17:55）			
of Jiyin Avenue & Suyuan Avenue		Left	Straight	Right	SUM
	South	8	71	13	92
	North	29	43	21	93
	East	11	47	24	82
	West	37	55	14	106

Software statistical results of traffic volume as follows:

Intersection	Directions	Vehicle（17：15—17:25）			
of Jiyin Avenue & Suyuan Avenue		Left	Left	Left	Left
	South	17	129	11	157
	North	37	50	33	120
	East	11	45	39	95
	West	35	72	8	115
Intersection	Directions	Vehicle（17：15—17:25）			

of		Left	Left	Left	Left
Jiyin	South	8	69	13	90
Avenue &	North	28	43	21	92
Suyuan	East	10	47	23	80
Avenue	West	36	54	14	104

4 Data Analysis

We can assume the artificial statistics result is accurate.

The data error analysis is as follows:

	17：15—17:25	17：45—17:55
South	98.13%	97.82%
North	100%	98.92
East	97.93%	97.56%
West	97.45%	98.11%
SUM	98.38%	98.12%

By analysis, error of this software may be related to the following reasons:

I. Because the algorithm is based on the gray discriminator, a grey vehicle and similar color is not easy to be identified in the video, and leads to the occurrence of omission;

II. Time of shooting video and artificial statistical has not completely unified, they may not start and end at the same time, which resulting in the variable is not single;

III. When a non-motorized vehicle driving in motorcycle lane, if the target is large also may be identified as vehicles, causing the error formation.

5 Conclusions

From the above experimental data, the statistical results of traffic volume from software processing compared with it from artificial method, has an accuracy rate reached to 98.25%, meanwhile an error rate of 1.75%. According to our present research status, this method is convenient operation, and the intersection traffic volume survey data from software are quite accurate. So we initially considered it can replace the artificial observation.

6 Recommendations for Future Research

The traffic investigation is the basis of traffic work, but also the most crucial step. In the era of intelligent traffic, we should open up some new thoughts. The purpose of this paper is to propose a simple, convenient and accurate method of traffic volume investigation. This method combines the knowledge of traffic and computer technology, and reflects the idea of intelligent traffic very well. Its an liberation of human and material resources with a high accuracy.

Moreover, it also has broad prospects,

I. Improving the software, makes it achieved a function of the road intersections service level comprehensive after a combination with other indicators;
II. Realizing the detecting of roundabouts traffic volume which is complicated than intersections based on the present achievements;
III. Completing the development of traffic delay function based on the data has been obtained in the software. (trajectory, coordinate, velocity, acceleration)

Acknowledgement

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References

Albright, & David. (1991). History of estimating and evaluating annual traffic volume statistics. *Transportation Research Record*.

Harding, B. (1989). Model aircraft as survey platforms. The Photogrammetric Recor d, 13, 74, 237–240.

He, Z., Zhaosheng, Y., & Yiwu, L. (2002). Study on forecast of traffic volume at nondetec tor intersections. *Journal of Highway and Transportation Reseach andk Development*.

Lei, W., & Han, X. (2008). The study on forecasting for traffic volume in its. *China Science and Technology Information*.

Mei, J. (2007). Application of its in solving city road traffic jams.*Communications Standardization*.

Ming, Y., Yuhui, L., Bo, L., & Fan, Z. (2014). Vehicles extraction in highway surveillance video. *Microcomputer & Its Applications*.

Wen-ping, J., Bao-long, G., & Gui-guang, D. (2004). Detecting traffic volume statisti cs based on virtual coil with optical flow method. Computer Simulation, 21, 1 , 109-117.

Wang, H., Huo, L., & Zhang, J. (2011). Target tracking algorithm based on dynamic template and kalman filter. *Communication Software and Networks (ICCSN), 2011 IEEE 3rd International Conference on*, 330 - 333.

Wu, J. R., & Yuan, P. (2011). Statistics analysis and optimization design for intersection traffic volume on urban road. *Advances in Civil Engineering and Architecture*.

Wen-ping, J., Bao-long, G., & Gui-guang, D. (2004). Detecting traffic volume statistics based on virtual coil with optical flow method.*Computer Simulation, 21, 1*, 109-117.

Generalized Speed-Density Models for Urban Freeways under Rainy Weather

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Abstract: Based on Shanghai elevated road traffic flow, six kinds of speed-density models are calibrated by least square method for clear and rainy weather and the respective best models to estimate free-flow speed and capacity are determined. Next, the function between free-flow speed and rainfall intensity is also fitted and it is integrated into generalized speed-density models. It is found that both weather and number of lanes influence free-flow speed and capacity, and generalized speed-density models also vary with different combination of weather and number of lanes.
Keywords: Free-flow speed; Capacity; Least square method; Rainfall; Number of lanes.

1 Introduction

Lately transport system hazards due to adverse weather, e.g. traffic safety and traffic congestion, are on the rise and they will cause huge loss if not treated well. However traffic flow characteristics under adverse weather is not well studied, and because it is dependent largely on local driving behavior, so it requires more related researches carried worldwide.

The speed-density models under rainy weather, as an extension of existing traffic flow relationship studies, are gradually investigated at home and abroad. Previous studies generally take advantage of actual traffic flow and metrological data to develop different speed-density models with various categorized rainfall intensity, e.g. light rain, heavy rain etc. For example, Ibrahim and Hall (1994) observed that only the slope in linear speed-flow-occupancy model became smaller, which meant traffic flow key parameters like free-flow speed, capacity and speed-at-capacity changed under adverse weather. Unrau and Andrey (2006) analyzed variation of expressway traffic flow under light rainy weather and dry weather, and found under uncongested regime the speed-volume model is in the form of quadratic function whereas under congested regime it is in the form of exponential function. For highway or expressway traffic flow under adverse weather, Van Aerde model is most frequently used (Rakha et.al.,2008; Zhang C. et.al ,2013) as well as two-regime modified Greenshields model (Hou et.al,2013). Xiao L.(2013) maintained Underwood model is the best model to fit Beijing urban freeway traffic flow data under heavy rain. Soheil Sajjadi et.al (2014) compared Northwestern,Van Aerde, Modified Greenshields, and HCM three-regime model for expressways under rainy and snowy weather conditions, and they found that the dual-regime Modified Greenshields model estimate free-flow speed best; however, none of them can make reasonable capacity estimation. Therefore, one empirical thresholds approach is recommended in their study.

Free-flow speed is an important parameter in every speed-density model and is found to be affected by various factors such as road geometry feature, traffic composition, speed limit and weather condition (TRB,2000). In terms of weather factors, so far the relationship between free-flow speed and precipitation is described by exponential function (Lam, W.H.K., et al., 2013), power function (Jia Yuhan et al,2015) and piecewise linear function (Shi Lijuan,2012). Besides precipitation variable, the other meteorological variables like lightness, temperature, visibility, wind speed, snow layer depth are also considered in some free-flow speed regression models (Shi Lijuan,2012 and Camacho, F.J. et al.,2010).

As is seen from above, at broad highway or expressway speed-density-volume relationships were analyzed and different models were calibrated. Nevertheless, such model calibration for urban freeway is scarcely seen at home. Moreover, previous traffic flow analysis and modeling are based on lane traffic data instead of segment traffic flow, which may cover the impact of number of lanes on segment free-flow speed and capacity. Therefore this study aims to explore the impact of weather condition and number of lanes on segment traffic flow characteristics and to develop generalized speed-density models by integrating those observed impacts.

2 Data Collection

According to weather historical records, two days,ie.2012/10/18 and 2012/08/08, are chosen to represent clear weather and rainy weather respectively. It rained in nearly every hour on 2012/08/08 due to the typhoon and hourly precipitation is shown in figure 1.

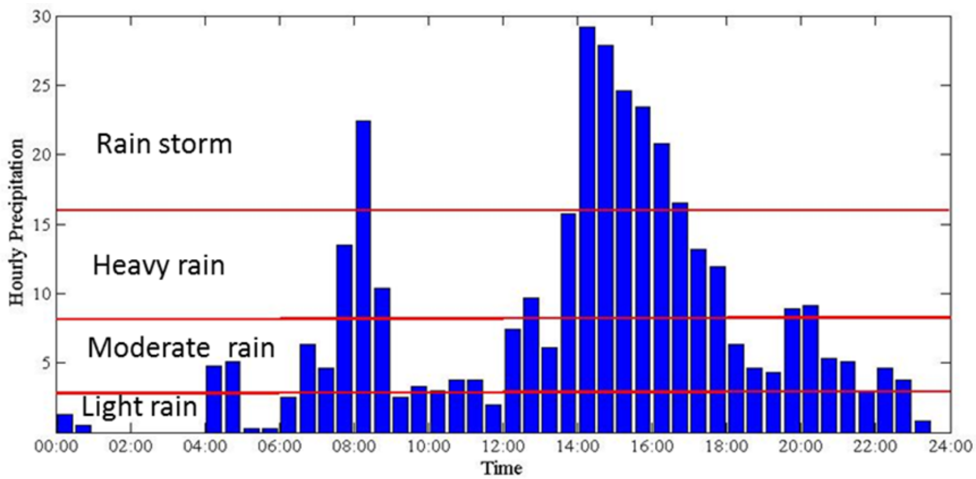

Figure 1. Rainfall classification of August 8th, 2012

The above figure indicates 24-hour accumulated precipitation reaches 175.5mm. So it belongs to heavy or stormy rain category according to China meteorological standard. Meanwhile, traffic flow data at 184 segments of Shanghai freeway are collected every 5 minutes on both days. Congested segments from A1 to A6 are used for model calibration and uncongested segments from B1 to B3 for free-flow speed model establishment. These selected segments are given in table 1. Segment name is coded using names of off/on ramps at both ends of that segment. For example, 'NBYD-DO->NBYD-DI' means eastbound road segment starting from the end Yandong off-ramp to the end Yandong on-ramp of South-North elevated road.

Table 1. Basic information about used segments

Segment Id	Segment name in database	Number of lanes	Length (m)	Freeway name
A1	NBYD-DO->NBYD-DI	2	1038	South-North elevated road
A2	NBYD-XO->NBYD-XI	2	1429	
A3	NBXJH-DO->NBXJH-DI	3	1937	
A4	NBLB-DI2->NBXJH-DO	3	1661	
A5	NBXJH-DI->NBHHZ-DO	4	1935	
A6	NBHHZ-DO->NBYD-DO	4	1288	
B1	NHZSB-NO->NHDBS-NI	2	1323	Inner Ring elevated road
B2	ZHJG-WO->ZHJG-WI	3	2117	Middle Ring elevated road
B3	ZHJG-NI->ZHZJZ-NO	4	3571	

3 Method

The six commonly used one-regime speed-density models are adopted and compared, with their respective function forms and parameters in table 2. Among all variables and parameters, v is operating speed variable; k is density variable; v_f is free-flow speed parameter; v_m is optimal speed parameter; k_j is jam density parameter; k_m is optimal density; and n is positive integer.

Table 2. Six one-regime speed-density models

Model name	Shortened Name	Model function form	Parameters
Greenshields	Gs	$v = v_f(1 - \frac{k}{k_j})$	v_f, k_j
Greenberg	Gb	$v = v_m ln\,(\frac{k_j}{k})$	v_m, k_j
Underwood	Uw	$v = v_f\ e^{(-\frac{k}{k_m})}$	v_f, k_m
Northwestern	Nw	$v = v_f\ e^{-\frac{1}{2}(\frac{k}{k_m})^2}$	v_f, k_m
Drew	Dw	$v = v_f[1 - (\frac{k}{k_j})^{n+\frac{1}{2}}]$	v_f, k_j, n
Pipes-Munjal	Pm	$v = v_f[1 - (\frac{k}{k_j})^n]$	v_f, k_j, n

Model calibration is one curving fitting problem in essence. So least square method is adopted, which can make the optimal function parameter estimation by solving one mathematical optimization problem with the help of Matlab (Xue Dingyu, et al,2004). Meanwhile, further preprocessing work is needed to obtain input data for traffic flow model. So traffic flow rate q, average spatial speed u_s, and density k are respectively converted in the following equations:

$$q = 12 \times q_{5min} \quad (1)$$
$$u_s = 1.026u_t - 1.890 \quad (2)$$
$$k = q/u_s \quad (3)$$

In addition, actual free-flow speed and capacity are also required in advance for evaluating model's estimation effectiveness. According to previous studies, free-flow speed is obtained by taking the minimum between 85th percentile of operating space speed and speed limit value (Li C., 2010);

$$v_f^{obs} = min\{v_{85}, v_{limit}\} \quad (4)$$

where v_f^{obs} is observed free-flow speed（km/h）, v_{85} *and* v_{limit} are 85th percentile of observed operating space speed and speed limit.

Capacity is obtained by taking the mean of 99th percentile of traffic flow rate (Chung E, Ohtani O, Warita H, et al，2006) and the average of the top fifth percentile of the observed flow rates (Soheil Sajjadi et al,2014; Smith B L, Byrne K G, Copperman R B, et al，2004) .

$$cap^{obs} = \frac{1}{2}(q_{99} + \frac{1}{n}\sum_{i=1}^{n} q^i) \quad (5)$$

Where cap^{obs} is observed capacity (pcu/h), q_{99} is 99^{th} percentile observed flow rate,q^i is ith of the top 5% highest flow rates and n is sample size of top 5% highest flow rates.

4 Results Analysis

4.1 Reduction in Traffic Flow Key Parameters

Using equation (4) and (5), free-flow speed and capacity of every segment are calculated both under clear weather and heavy rain weather, which are shown in Table 3.

Table 3. The influence of weather and number of lanes on key parameters

Segment id	Free-flow speed (km/h)			Capacity (vehs/h)		
	Clear weather	Heavy rain	Reduction percent	Clear weather	Heavy rain	Reduction percent
A1	69.3	69.0	0.4%	3877	3250	16.2%
A2	68.0	68.0	0.0%	3881	3263	15.9%
A3	80.0	76.0	5.0%	5150	4389	14.8%
A4	76.0	69.0	9.2%	6164	3546	42.5%
A5	69.0	67.0	2.9%	7666	4996	34.8%
A6	69.0	68.0	1.4%	6617	5767	12.8%

It can be seen from above table that under heavy rain weather, reduction of free-flow speed are respectively 0~0.4%, 5~9.2%, and 1.4~2.9% for 2-lane, 3-lane and 4-lane freeway segment. Moreover, reduction of capacity are respectively 15.9~16.2%, 14.8~42.5% and 12.8~34.8% for 2-lane, 3-lane and 4-lane freeway segment.

4.2 Model Calibration and Selection

This section presents detail results of 6 kinds of speed-density models for segments A1, A3 and A5 both under rainy and clear weather. The Drew model has two versions, Dw1 or Dw2 for parameter n being 1 or 2. So does Pipes_Munjal model, i.e., Pm2 for n being 2 and Pm3 for n being 3 respectively. Every model is labeled by linking model shorten name, segment ID and weather flag. For example, 'Gs_a1r' means Greenshields model for segment A1 under rainy weather; and 'Gs_a1c' is also Greenshields model for segment A1, but under clear weather.

In terms of 2-lane segment A1, calibration results are given in Table 4. v_f^{est} $and\ cap^{est}$ are estimated free-flow speed and estimated capacity. The other badly-calibrated models like Drew models are not given because they have negative adjusted R2 values.

Table 4. Calibration results of speed-density models for segment A1 under two weather conditions.

model	Adj_R2	v_f^{est} (km/h)	cap^{est} (veh/h)	v_f^{obs} (km/h)	cap^{obs} (veh/h)	Estimation error of v_f	Estimation error of Cap
Gs_a1r	0.95	71	3115	69	3250	2.6%	-4.2%
Gb_a1r	0.68	110	2700			59.3%	-16.9%
Uw_a1r	0.92	75	4402			8.4%	35.4%
Nw_a1r	0.97	67	2972			-3.0%	-8.6%
Gs_a1c	0.93	85	3496	69.3	3877	22.0%	-9.8%
Gb_a1c	0.69	152	3723			119.2%	-4.0%
Uw_a1c	0.87	90	5297			29.9%	36.6%
Nw_a1c	0.95	76	3476			9.1%	-10.3%
Pm3-a1c	0.81	64	4162			-7.1%	7.4%

Similarly the calibration process is carried for 3-lane and 4-lane segments, but their results are omitted due to space limit. Finally the best models to estimate free-flow speed and capacity are summarized in table 5. They are found to vary with different combinations of weather and number of lanes. So Greenshields model and Northwestern model are recommended in practice for rainy weather and clear weather condition respectively, with their estimation errors below 11%.

Table 5. Best models for key parameter estimation under different combination of weather and road condition

Weather condition	Number of lanes	model	Adj_R2	Estimation error of v_f	Estimation error of cap
Rainy	2	Gs_a1r	0.95	2.6%	-4.2%
Clear	2	Pm3-a1c	0.81	-7.1%	7.4%
Rainy	3	Uw_a3r	0.75	4.7%	6.7%
Clear	3	Nw_a3c	0.97	3.3%	0.3%
Rainy	4	Gs_a5r	0.86	-10.8%	1.8%
Clear	4	Nw_a5c	0.96	3.9%	-5.7%

Also based on calibration results, the models that have biggest R2 value are those best models for speed prediction under different weather and road conditions. It is found that for 2-lane and 3-lane segment, Northwestern model are better than the others under both weather conditions. In contrast, for 4-lane segment Underwood model performs best under rainy weather and Greenshields model under clear weather. Due to space limit, only Northwestern models at segment A3 are compared with actual observation shown in Figure 2.

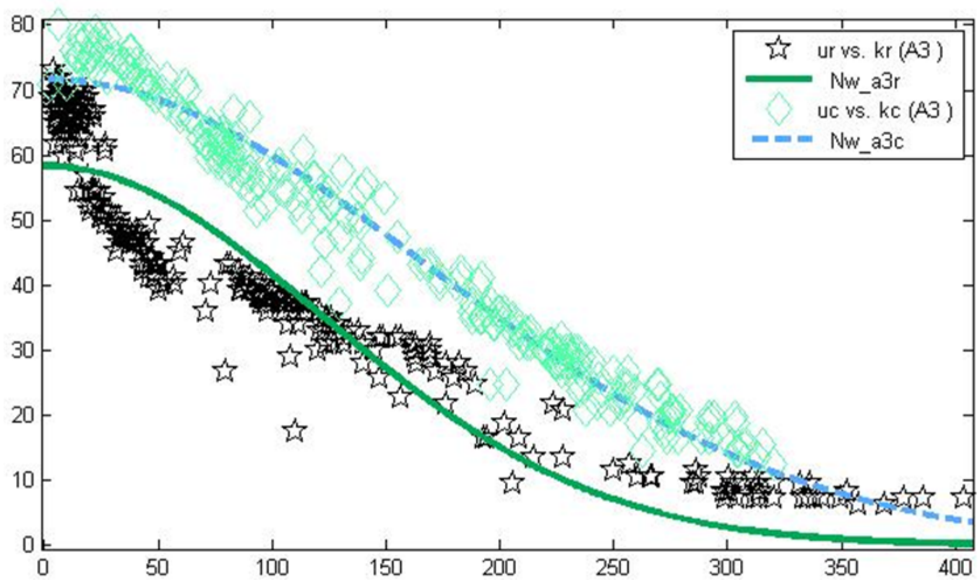

Figure 2. Fitness of Northwestern model at segment A3 under both weather

4.3 Generalized Speed-Density models for multi-lane segments

Firstly, it further to check if both weather and number of lanes have significant impact on free-flow speed using traffic flow data of uncongested segments B1, B2 and

B3. These three segments are spatially isolated and not dependent. Hourly free-flow speed and precipitation are collected from 5:00am to 19:00pm on both days. Each hourly average speed of each combination of weather and number of lanes is regarded as an experiment, and Two-Way-ANOVA test is made. From below table, the P-values for these two factors are less than 0.05, which confirms that free-flow speed is function of weather condition and number of lanes at least.

Table 6. Results of Two-Way-ANOVA test

Source of variation	SS	df	MS	F	P-value	F crit
Weather condition (4 categories)	22.068	3	7.356	9.189	0.0116	4.7571
Number of Lanes (3 categories)	37.3	2	18.65	23.297	0.0015	5.1433
Error	4.8031	6	0.8005			
Total	64.171	11				

Secondly, in order to fit the function between free-flow speed and rainfall intensity, their scatterplot is drawn in figure 3. For each segment, as rainfall intensity increase from 0 to 8mm/h, free-flow speed decreases linearly, and after that free-flow speed surprisingly increases and fluctuated. This abnormity should be cautioned because of small sample size of heavy rain and above category.

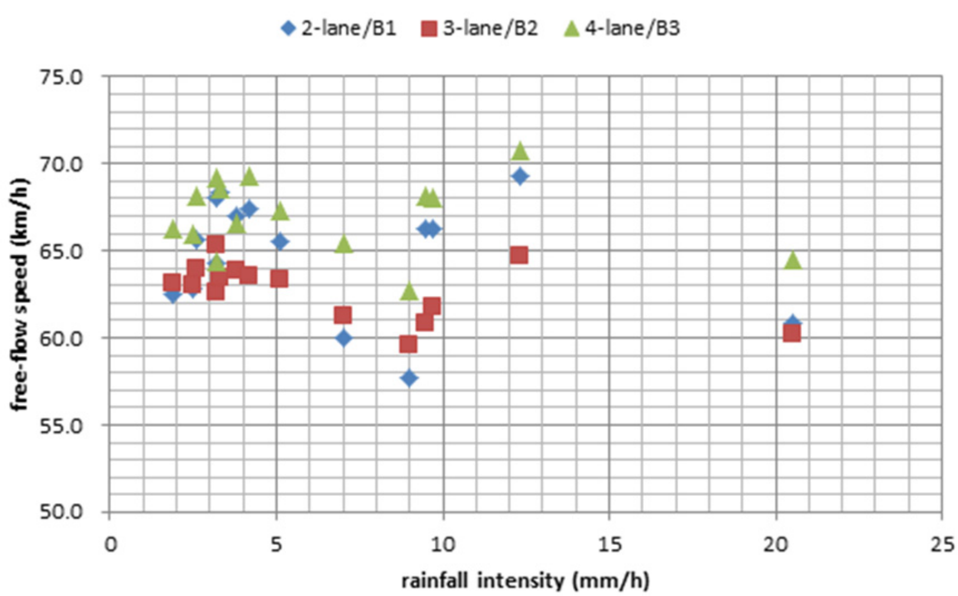

Figure 3. Scatterplot of free-flow speed and rainfall intensity by number of lanes

Therefore, the linear relationship between free-flow speed (v_f) and rainfall intensity (i) belonging to moderate rain can be fitted for segments with different number of lanes. For example, the linear model for 3-lane segment is as follows:

$$v_f = -0.3759i + 64.733, R^2 = 0.2833 \quad (6)$$

Though R-square value in equation 6 is small due to small sample size, the linear relationship can be confirmed in other study (Shi Lijuan,2012).. Last, by substituting the above function for category-related free-flow speed parameter, generalized speed-density model can be yielded and this kind of model is more suitable for on-line dynamic traffic management and control. For example, for 3-lane segment B2, according to results in section 4.2 and equation (6), its generalized Northwestern speed-density model under rainy weather can be rewritten into equation (7):

$$v = (-0.3759i + 64.733) * e^{-\frac{1}{2}\left(\frac{k}{320}\right)^2}, i \in [2.6, 8] \quad (7)$$

Where v is speed (km/h), k is density (veh/ km.3lane) and i is rainfall intensity (mm/h).

5 Conclusions

Here we may draw the following conclusions: (1) reduction in free-flow speed and capacity are affected by both weather and number of lanes; (2) the best models to estimate free-flow speed and capacity also varies with different combination of weather and number of lanes; (3) Both weather and number of lanes influence hourly free-flow speed significantly, and there exists linear relationship between free-flow speed and rainfall intensity being to moderate rain. Those conclusions shed light on selection of speed-density model under different weather and segment conditions, and also are helpful for online traffic management and control.

References

Camacho, F.J., A. García and E. Belda. (2010)."Analysis of Impact of Adverse Weather on Freeway Free-Flow Speed in Spain". *Transportation Research Record* (1): 150-159.

Chung E, Ohtani O, Warita H, et al. (2006)."Does weather affect highway capacity" Paper presented at 5th international symposium on highway capacity and quality of service, Yakoma, Japan.

Hou, T., Mahmassani H.S., Alfelor R. M., Kim J., Saberi M., (2013). "Caliberation of

Traffic Flow Models under Adverse Weather and Application in Mesoscopic".Paper presented at 91st Annual Transportation research Board Meeting, Washington D.C.

Ibrahim, A.T., and F.L. Hall. (1994). "Effect of Adverse Weather Conditions on Speed-Flow-Occupancy Relationships". *Transportation Research Record*, 1457, Washington, D.C., 184-191.

Jia Yuhan, Wu Jianping, Du Yiman et al. (2015). "impacts of rainfall weather on urban traffic in Beijing: analysis and modeling" Paper presented at 94rd annual meeting of the Transportation Research Board, Washington DC.

Lam,W.H.K., Tam L.M., Cao Xinqing, et al., (2013). "Modeling the Effects of Rainfall Intensity on Traffic Speed, Flow, and Density Relationships for Urban Roads". *Journal of Transportation Engineering*, (7): p. 758-770.

Li Chenxi. (2010). "The analysis of the road network status based on the road traffic delay [Master thesis]". Beijing: College of Transportation of Beijing Jiaotong University.

Rakha H., Farzaneh M. (2008). "Inclement Weather Impacts on Freeway Traffic Stream Behavior," *Transportation Research Record*, 2071, 8-18.

Sajjadi S, Schroeder B, Rouphail N. (2014). "Traffic Stream Model Evaluation under Inclement Weather Conditions using a Fused Database". Paper presented at Transportation Research Board 93rd Annual Meeting.

Shi Lijuan. (2012). "The effects of Adverse Weathers on Urban Freeway Traffic Flow". Shanghai, China:School of Transportation Engineering of Tongji University.

Smith B L, Byrne K G, Copperman R B, et al. (2004)."An investigation into the impact of rainfall on freeway traffic flow" Paper presented at 83rd annual meeting of the Transportation Research Board, Washington DC.

Transportation Research Board (2000).*Highway Capacity Manual,* Special Report 209.

Unrau D, Andrey J. (2006). "Driver response to rainfall on urban expressways". *Transportation Research Record*, 1980(1): 24-30.

Xiao Lin.(2013). "Propagation Mechanisms and Trends Assessment of Traffic Congestion Under Special Conditions[Master thesis]". Shanghai, China:School of Transportation Engineering of Tongji University.

Xue Dingyu, Chen Yangquan.(2004). *Advanced Applied Mathematical Problem Solutions with MATLAB*. Beijing: Tsinghua University Press.

Zhang Cunbao, Wan Ping, Mei Zhaohui, et al. (2013). "Traffic Flow Characteristics and Models of Freeway Under Rain Weather". *Journal of Wuhan University of Technology*,03:63-67.

Short-Term Travel Time Prediction for a Car Dynamic Navigation System

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Abstract: This paper works on the short-term travel time prediction, aiming at predicting dynamically(or fixed-frequency) by considering dynamic road traffic index volatility and average speed, and then providing the real-time travel time prediction for users in advance. This paper improves the prediction algorithm, referenced to current traffic parameters prediction methods basing on Kalman filter, and solves the time lag and the automatic update of historical average data needed. Then this paper uses 4 evaluation indexes to make known the degree of deviation and goodness of fit between predictive value and actual value, and to verify that improved algorithm could make predictive travel time more accordant with the practical situation.

Keywords: Short-term travel time prediction; Dynamic navigation; Kalman filter.

1 Introduction

Existing travel time prediction is based on static information like road level and vehicle speed limit, offering fixed travel reference information without taking out the impact the fluctuation of traffic index have on travel time, especially during travel peak hour or traffic incident period, which is easy to provide error messages and result the delay too long. Analyzing various methods comprehensively, we selected Kalman filter method because of its simple model, easy to implement and high precision, and the Kalmen filter can use real-time section travel time to correct the state variable in prediction, also adapt to fluctuation of traffic state.

2 Methods

In this paper, the prediction model takes into account the traffic index and the actual average speed of traffic. The travel time prediction value is calculated by the actual vehicle speed and road length, and able to reflect the traffic operating efficiency of roads and network during peak hour or traffic incidents periods, which means it considers the vehicle speed of the same level roads or the same speed limitation roads is different during the actual traffic operation. The model takes real-time vehicle speed as the basis of prediction data updating.

Compared to the previous Kalman filter prediction model, this model uses the current travel time divided by its historical average travel time, which can eliminate the time lag of Kalman filter method prediction. In this paper, the calculation of historical average travel time (scilicet $\overline{q^t}(d) = \frac{\sum_{i=1}^{count} q^t(d)}{count}$) is progressively updating over time, which is no human involvement. In addition, the traffic situation is obvious different between holidays and non-holidays. Even if in non-holidays, the traffic situation on different days in a same week also have their own characteristics, called week feature, which means the traffic situation on the corresponding day in different weeks (all are non-holiday) are analogous.This paper uses the improved Kalman filter model to predict short-term travel time considering the impact of above factors, and draws the following travel time prediction model:

$$o(t+1) = p_0(t)q(t) + p_1(t)q(t-1) + p_2(t)q(t-2) + w(t) \quad (1)$$

Among them:

$p_0(t)$, $p_1(t)$, $p_2(t)$ is state coefficient; $w(t)$ is observation noise, assumed to be a zero mean white noise, and set a given value here. $o(t+1)$ and $q(t)$ are defined as follows:

$$o(t+1) = \frac{q^{t+1}(d)}{\overline{q^{t+1}}(d)} \quad (2)$$

$$q(t) = \frac{q^t(d)}{\overline{q^t}(d)} \quad (3)$$

Among them: d is {1, holiday; 2, Saturday and Sunday; 3, Monday to Friday} one kind of these three, the priority of type 1 to 3 is followed by decreasing;

$q^t(d)$: current date of target section is d type day, the travel time weight of the section in t period;

$\overline{q^t}(d) = \frac{\sum_{i=1}^{count} q^t(d)}{count}$, the historical average travel time of the target section in t period on historical d type days, this statistics is constantly updating with the advance of the date, $count$ is the number of d type days until one day before the prediction day.

3 Model Solution

In order to solve the model, given

$$\mathbf{A}(t) = [q(t), q(t-1), q(t-2)] \quad (4)$$

$$\mathbf{X}(t) = [p_0(t), p_1(t), p_2(t)]^T \quad (5)$$

$$y(t) = o(t+1) \quad (6)$$

Whereby the following equations:

$$\mathbf{X}(t) = \mathbf{B}(t)\mathbf{X}(t-1) + u(t-1) \tag{7}$$

$$y(t) = \mathbf{A}(t)\mathbf{X}(t) + w(t) \tag{8}$$

Among them: $y(t)$ is observed variables; $\mathbf{X}(t)$ is state vector; $\mathbf{A}(t)$ is observation matrix; $\mathbf{B}(t)$ is state transition matrix, set as the unit matrix; $u(t-1)$ is model noise, assumed to be zero-mean white noise, and its covariance matrix is $\mathbf{Q}$. $\mathbf{Q}$ is assumed to be a given value, scilicet the error of the model from a state to next is constant, because under normal circumstances, in a short time, the outside influence of the system will not change much. However, the calculation of $\mathbf{Q}$ should base on objective fact and statistics on large amounts of data actually, and this paper does not discuss this issue.

According to Kalman filtering theory, we found equations as follow:

Kalman filter time update equations:

$$\hat{\mathbf{X}}(t+1|t) = \mathbf{B}(t+1)\mathbf{X}(t) \tag{9}$$

$$\hat{\mathbf{P}}(t+1|t) = \mathbf{B}(t)\mathbf{P}(t)\mathbf{B}^T(t) + \mathbf{Q} \tag{10}$$

Kalman filter state update equations:

$$\mathbf{K}(t+1) = \hat{\mathbf{P}}(t+1|t)\mathbf{A}^T(t+1).(\mathbf{A}(t+1).\hat{\mathbf{P}}(t+1|t).\mathbf{A}^T(t+1))^{-1} \tag{11}$$

$$\mathbf{X}(t+1) = \hat{\mathbf{X}}(t+1|t) + \mathbf{K}(t+1).(y(t) - \mathbf{A}(t+1).\hat{\mathbf{X}}(t+1|t)) \tag{12}$$

$$\mathbf{P}(t+1) = (\mathbf{I} - \mathbf{K}(t+1).\mathbf{A}(t+1)).\hat{\mathbf{P}}(t+1|t) \tag{13}$$

In equations, $\hat{\mathbf{X}}(t+1|t)$ is the result of the next state prediction; $\mathbf{X}(t+1)$ is the best result of the next state; $\mathbf{K}(t+1)$ is Kalman gain matrix; $\mathbf{P}(t+1)$ is filtering error variance matrix; $\hat{\mathbf{P}}(t+1|t)$ is prediction error covariance matrix.

It can be seen from the definition of the above formula that this model only can begin prediction from the third time period, because the value of the first two periods are the initial parameters. This paper assume the model start at $t=1$, then the third time period is $t=3$. This model take 5 minutes as the time interval, so one day 24 hours has 288 periods. Given the initial value of the Kalman filter has a certain extent to the prediction accuracy, this paper use the methods (Lu, 1997) to calculate the initial value of $\hat{\mathbf{X}}(3)$, $\mathbf{P}(3)$, $\mathbf{Q}$. Operate the travel time weight as follow after the initial value is determined:

Firstly, calculate the time update equations, scilicet calculate the equation (9) (10).

After determining $\hat{\mathbf{X}}(t+1|t)$, we found:

$$y(t) = \mathbf{A}(t)\hat{\mathbf{X}}(t+1|t) \quad (14)$$

Further, we found road travel time predictive value is:

$$\hat{q}^{t+1}(d) = \mathbf{A}(t)\hat{\mathbf{X}}(t+1|t) \times \overline{q^{t+1}}(d) \quad (15)$$

When observed value of time $t+1$ (scilicet $y(t)$ has come), calculate Kalman filter state update equation, (11) (12) (13), to get the travel time predictive value of the next time period. If need to predict the travel time of whole network, we can base on forward calculation and operate the same method to the other road separately. Figure 1 is the shor-time travel time prediction algorithm flow chart.

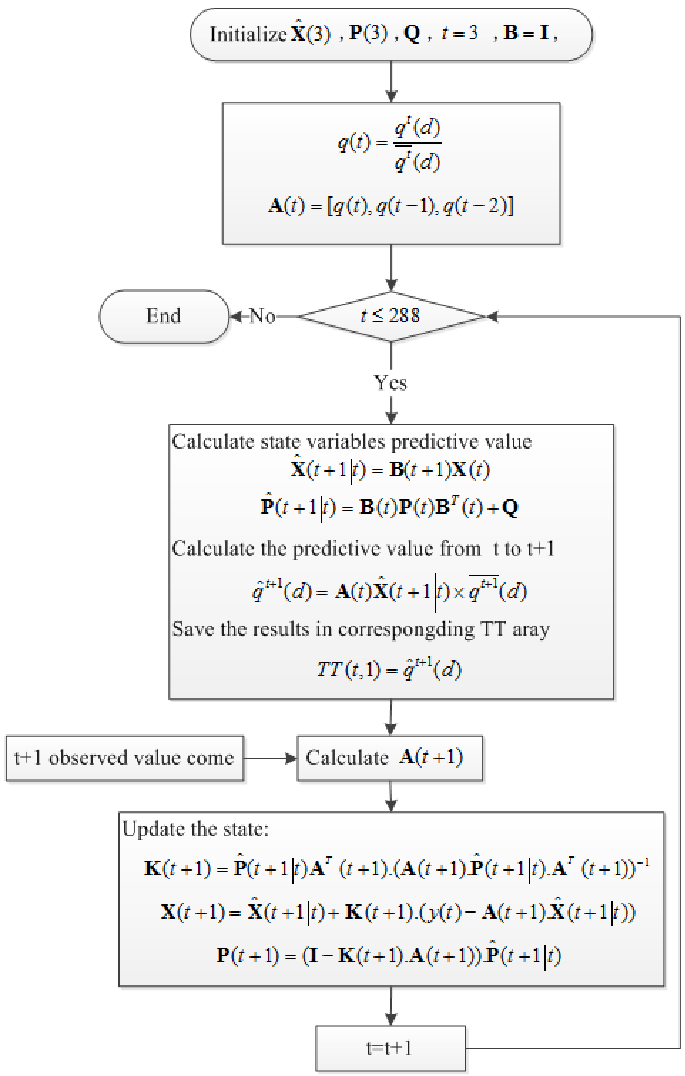

Figure 1. the shor-time travel time prediction algorithm flow chart

4 Data Analysis

To test the performance of the Kalman filter short-term travel time prediction model for car dynamic navigation system in this paper, we select the error indicators (Shen, 2011). Let $q_{pij}^{t}(d)$ be the real value and $\hat{q}_{pij}^{t}(d)$ be the prediction value, then:

Relative error percentage: $E_{PR} = \frac{\left|\hat{q}_{pij}^{t} - q_{pij}^{t}(d)\right|}{q_{pij}^{t}(d)} \times 100\%$

The average relative error percentage: $E_{PMR} = \frac{1}{288}\sum_{t=1}^{288}\frac{\left|\hat{q}_{pij}^{t}(d) - q_{pij}^{t}(d)\right|}{q_{pij}^{t}(d)} \times 100\%$

Rms relative error: $E_{RR} = \sqrt{\frac{1}{288}\sum_{t=1}^{288}\left(\frac{\hat{q}_{pij}^{t}(d) - q_{pij}^{t}(d)}{q_{pij}^{t}(d)}\right)^{2}}$

Equalization coefficients: $C_{E} = 1 - \frac{\sqrt{\sum_{t=1}^{288}\left(\hat{q}_{pij}^{t}(d) - q_{pij}^{t}(d)\right)^{2}}}{\sqrt{\sum_{t=1}^{288}\left(\hat{q}_{pij}^{t}(d)\right)^{2}} + \sqrt{\sum_{t=1}^{288}\left(q_{pij}^{t}(d)\right)^{2}}}$

This paper predicted the 10 days data separately to test the universality of the model and calculated the corresponding means of several error and equalization coefficients. This paper selected one-day data randomly from the test data of 10 days, found the following results:

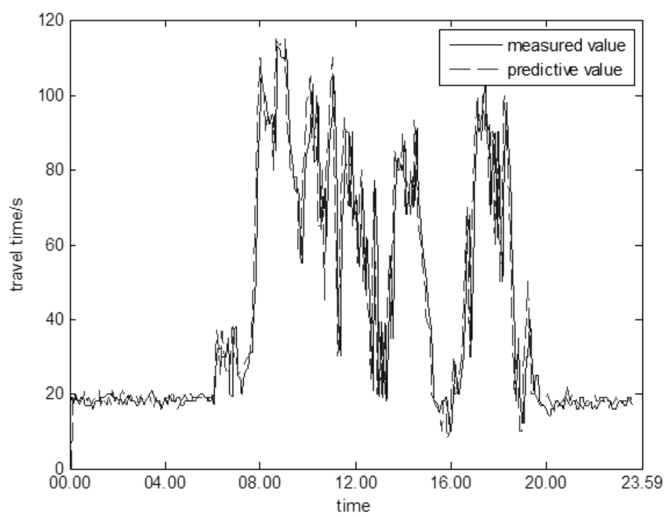

Figure 2. The predicted value and the actual value comparison

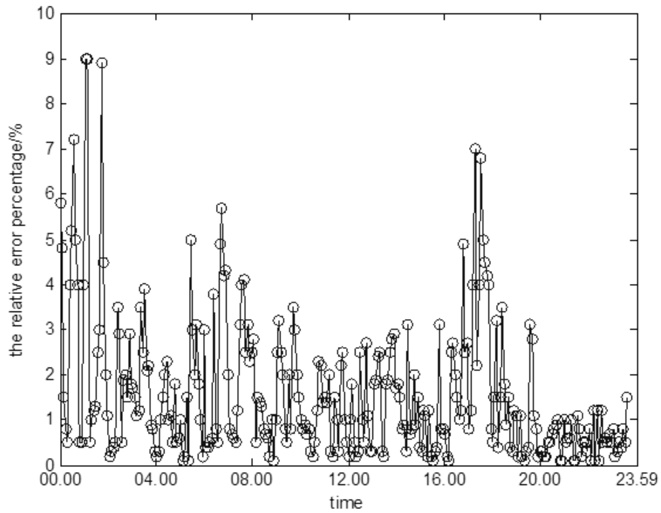

Figure 3. Relative error percentage of the prediction

5 Discussion of Results

According to the data analysis above, we found:

1. In the morning and evening peak hours, the prediction error is lager because of the greater volatility of travel time, and the error is relatively small other periods.

2. The E_{PMR} of the Kalman filter model is 5.54% in worst case, and 5.07% in average. The prediction accuracy is 1-5.07%=94.93%, and goodness of fit is 94.85% in worst case, which means it has high accuracy and good fitting results. According to Figure 1, the model has no time lag. Each average prediction index of 10 days is ideal, and not much different with the best and worst value, which means the stability and robustness is good and the model is universally applicable.

6 Conclusions

This paper selected Kalman filter method to predict, and the short-term travel time prediction model for car dynamic navigation system involves simple parameters, save the computing time and solve the time lag. The model can achieve the automatic update of the historical data, and have high accuracy and stability.

Acknowledgement

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References

Lu, Ruhua, Xu Chuanyu, Zhang Ling and Mao Weixing (1997). “Kalman filter initial value calculation method and application.” *Quarterly Journal of Applied Meteorology,* 8(1):34-42.

Shen, Guojiang, WANG Xiaohu and KONG Xiangjie (2011). "Short-term traffic flow intelligent combination prediction model and application." *Systems Engineering-Theory & Practice,* 2011, 31(3): 561-568.

John, Erikvan Z(2004). "A simple and effective method of predicting travel times on freeways." *IEEE Transportation on Intelligent Transportation Systems*, 2004, 5(3): 200-207.

Hinsbergen, C.P., van Lint, J.W.C. (2008). "Bayesian combination of travel time prediction models." Transportation Research Record, 2008, 20(64):73-80.

Kwon, Coifman, B., Bickel, P.J. (2000). "Day-to-day travel time trends and travel time prediction from loop detector data." *Transportation Research Record*, 2000, 1717/2000:120-129.

Lam, S.H. Toan, T.D. (2008). "Short-term travel time predictions using support vector regression." *The 87th TRB Annual Meeting*, Washington, DC, 2008.

Wang, Markos, P. (2005). "Real-time freeway traffic state estimation based on extended Kalman filter: a general approach." *Transportation Research Part B*, 2005,39(2):141-167.

Travel Time Characteristics of Vehicles on Urban Arterial Roads Analysis Based on License Plate Data

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Abstract: As we are living in era of motorization, cities are expanding rapidly, the urban population has risen dramatically, more and more motor vehicles runs on the roads. The problem of urban transportation exacerbates. Intelligent transportation technology（ITS）is regarded as one of the best methods to solve the problem of urban traffic. A large number of traffic monitoring equipments have widely used as the development of intelligent transportation systems. With a large number of traffic monitoring system has been built, we can collect abundant operational data from the ITS systems. Mining and making good use of these data It becomes more and more important of mining and making good use of the data. License Plate Recognition (LPR) system is an important component of the intelligent transportation system. In the past, the License Plate Recognition system has been used in analysis of traffic peccancy and the tolling system. The data mining of the License Plate Recognition system is rarely been applied. The dissertation researches the theories and methods of how to analysis the time characteristics of urban vehicles based on License Plate Recognition data. With the help of real-time data which is got from license plate recognition technology of urban arterial road, we get the motor vehicle travel characteristics of vehicles by mining license plate data. In this paper, we did empirical research by using license plate data in Shenzhen. Time clustering method has been used to separate the vehicle travel behavior. By analyzing the trip frequency of the vehicles during the working day, we can extract the rigid vehicles and get travel time characteristics of vehicles on urban arterial road.
Keywords: License plate recognition; Data mining; Travel features; Vehicles.

1 Introduction

As we enter the era of motorization, intelligent transportation technology has been regarded as one of the best way to solve the problem of urban traffic. As a large number of traffic monitoring system has been built, we can collect abundance operational data from the ITS systems. Mining and making good use of these data becomes more and more important. License Plate Recognition (LPR) system is an important component of the intelligent transportation system. The data mining of the License Plate Recognition system is rarely been applied. The dissertation researches the theories and methods of how to analysis the time characteristics of urban vehicles based on License Plate Recognition data. With the help of real-time data which is got from license plate recognition technology of urban arterial road, we get the motor vehicle travel characteristics of vehicles by mining license plate data.

2 License Plate Data Overview

2.1 Features of License Plate Data

License plate number is the only tag of vehicle identity. License Plate Recognition system has become an important part of intelligent transportation management system. By using pattern recognition method for camera equipment to analyze the captured vehicle image, we get effective recognition of license plates number. Then the system can transmit data to the central processing system. The analysis of License plate recognition data is different from other data. Monitoring equipments are laid on important sections in urban arterial roads. Due to limitations of the distribution of the monitoring equipments in the city, we can only get the data from the arterial roads.

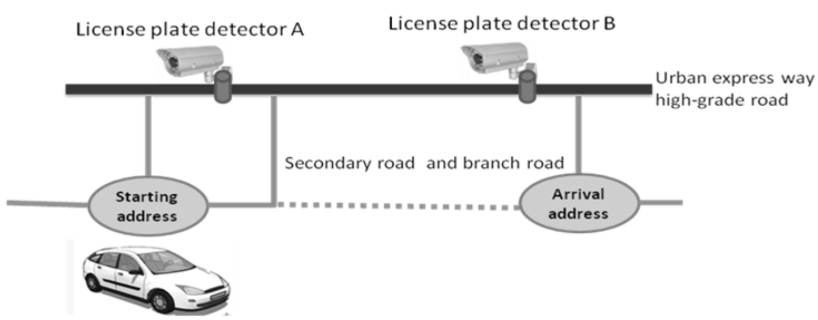

Figure 1.The position license plate detection equipment

2.2 Overview of original raw data

(1) Original data collection

We selected data from April 1 to April 30 in Shenzhen as the study time frame. The data time span is one month, which includes 22 Weekdays. Time monitoring of all road license from 00:00:00 AM to 23:59:59.PM

(2) Scale of the data

The total size of analyzed data is determined by road traffic flow and the number of monitoring equipment emplaced locations. The number of data records per day is from 2.7 to 3.6 million.

(3) The field format of original data

The original data contains multiple fields, The fields include: license plate number (PLATENO), the monitoring point number (JCDID), road lane number (LANEID), the vehicle through time (PASSTIME), license type (TYPE), square-wave length (FBCD).

Table 1. License plate recognition data format

Field	Examples	Explanation
PLATENO	YUE BN813A	License plate number
JCDID	10200402	Monitoring device number（Unique ID）
LANEID	1	road lane number
PASSTIME	2009-04-06 08：15：20	the vehicle through time
TYPE	0	Types of vehicles
FBCD	360	square-wave length

3 The vehicle travel frequency analysis

We analyzed the collected data from April 6 to April 10，and we get the frequency distribution of vehicles. 816,825 vehicles with a number of 16,842,872 records are detected in the 5 weekdays. For convenience of description, we introduce a concept called WTF（Weekday Travel Frequency）,which is the number of vehicles traveling days in weekdays from Monday to Friday. We have also introduced the concept of vehicle travel intensity in weekdays.

Vehicle weekday travel intensity = Number of vehicles*Weekday Travel Frequency.

The number of days of vehicle is recorded in the week days is 1-5, Therefore, the working frequency of vehicle trips (WTF) is 1-5. By statistical analysis of all the vehicles WTF from April 6 to April 10, we get the distribution of all vehicles in working days. The following table shows all vehicles travel distribution in Weekdays.

Table 2. Weekdays trip of all vehicle distribution

Weekday Travel Frequency (WTF)	Number of vehicles	Proportion of the number of vehicles	Vehicle weekday travel intensity	Proportion of Vehicle weekday travel intensity
1	1024824	56.41%	1024824	27.26%
2	242154	13.33%	484308	12.88%
3	162068	8.92%	486204	12.93%
4	174710	9.62%	698840	18.59%
5	213069	11.73%	1065345	28.34%
Total	1816825			

As shown in the table, 56.41% vehicles WTF are 1, which accounted for 27.26% of the total trip intensity; 9.62% vehicles WTF are 4, which accounted for

18.59% of the total trip intensity; 11.73% vehicles WTF are 5,which accounted for 28.34% of the total trip intensity.

Therefore, though the number of vehicles whose WTF are low is large, but the trip intensity is in the relatively low proportion. So it is necessary to carry out statistics of the vehicle trip frequency every workday, in order to analysis the traffic proportion of different types of vehicles WTF within a day. The results are shown in the columnar section as follows.

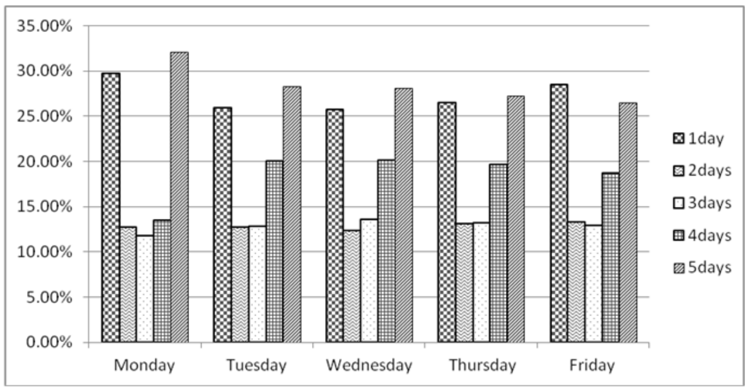

Figure 2.The proportion of vehicles with different WTF.

It is evident from figure that, the proportion of two kinds of vehicles（WTF=1 and WTF>=4） is larger. The left vehicles（WTF=2 and WTF=3）is in low proportion. This shows that the urban road network traffic flow is mainly composed of two types of vehicles in working days. One type of vehicles travel almost every day in workdays, which accounts for nearly 50% of the total traffic; Another type of vehicles are almost rarely seen in workdays, which accounts for 30% ~ 40% of the total traffic. First part of the vehicles represent "rigid" travel, analysis of travel characteristics and time-space distribution of this part of the vehicles is the key to solve the problem of urban traffic.

From the previous analysis, a large proportion of traffic flow on city road is normal travel vehicles, namely the vehicles on behalf of the is a kind of regularity travel behavior. Regularly vehicles travel in time, generally associated with commuter travel. The rigid travel which is composed of commuter travel, is the important cause leading to the urban road traffic congestion. But rigid travel is also a guarantee for normal operation of the urban social economic activities, The urban traffic system must first meet the needs of rigid travel, and also can solve the problem of urban traffic congestion.

4 vehicle travel time cluster analysis

4.1 License plate data clustering analysis method

Time consumption of single trip in cities might be within a certain range under normal circumstances. Therefore, the vehicle data will show strong time clustering features. The data whose time interval between each other is relatively small is considered to be one group. Thus, the time interval of two data are smaller recognized as a trip. In this way, we can put the data chronologically divided into several groups, each group represents a trip. For example, we get the vehicle license plate named "Guangdong BTG408" "9:36" to "21:36" 12 times at April 6 the detection recording time distribution. As shown below, we can see that the detection time has obvious clustering properties. It is apparent from the figure, the day time data clustering can be divided into five groups, that is, by separating the car license plate data we get 5 trips.

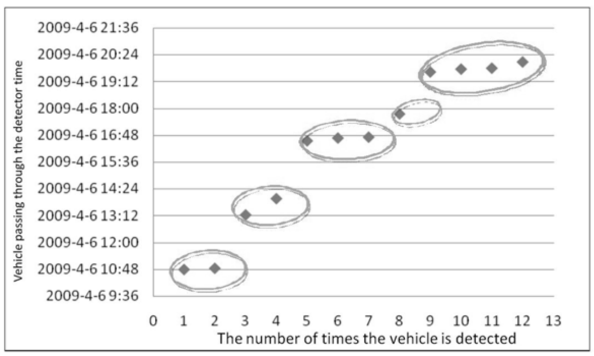

Figure 3.Time clustering analysis of vehicle license plate data

Before clustering analysis is necessary to determine the minimum threshold detection recording interval (T_{min}). If the time interval is less than the threshold T_{min}, we put the data into one group. The choice of time interval threshold value is very important, too large or too small will result in a determine error. If T_{min} value is too large, we may put different travel data recorded as a group. If Tmin value is too small, we may divide one group of travel data into two groups .Calculation procedure of time clustering method to extract vehicle travel behavior is as follows:

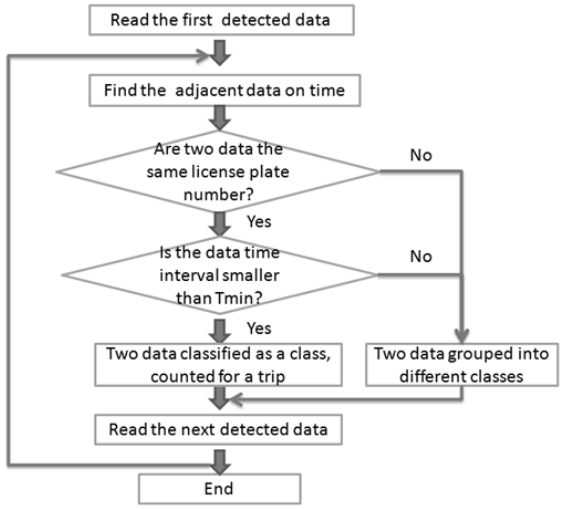

Figure 4. Analysis of motor vehicle travel time clustering process

4.2 Empirical Analysis of Shenzhen

We selected the license plate data on April 7 (weekdays) and April 12 (weekend), then analyzed the time distribution of the vehicles. We can see that:

(1) The rigid trip vehicles in the morning peak periods slightly higher than the proportion of the overall level; Shows rigidity travel is more concentrated in the morning rush hour. The morning rush hour is later than our everyday perception, it may be because the data collection points are located on high level roads.

(3) It is worth noting that the number of vehicles detected is small, peak-hour factor is only 8% to 9%. Travel characteristics described in this way may not fully reflect inhabitants.travel survey characteristics This phenomenon is partly due to travel license plate detection error data; on the other hand may also not part of the rigid commuter travel-related travel.

(4) The rigid travel feature is significant different in weekdays and weekend. There are two travel time peaks in the morning and evening on weekdays, the traffic distributed more evenly 8:00 to 18:00 on weekends

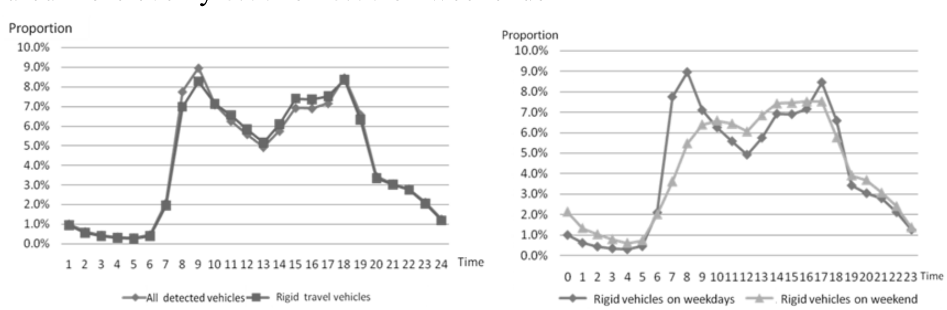

Figure 5.Time characteristics of rigid travel vehicles

5 Conclusions

Based on the Shenzhen vehicle license plate data analysis, we found the urban traffic flow is composed of two types of vehicles on weekdays-- rigid trip vehicles and occasional trip vehicles. And we proposed time clustering method to separate the travel behavior of each trip. And data in Shenzhen has been verified, you can run out of the rigid rules of the vehicle traveling on the arterial roads. We use Shenzhen data verify this method, so we can get the operation characteristics of the rigid vehicles on the arterial roads.

References

Chen Jun. Research on Travel Demand Analysis of Urban Public Transportation Based on Smart Card Data Information. Tongji University, 2009

Dion F, Rakha H. Estimating dynamic roadway travel times using automatic vehicle identification data for low sampling rates. Transportation Research Part B: Methodological. 2006, 40(9): 745-766.

Lelitha D. Vanajakshi, Williams B M. Improved Flow-Based Travel Time Estimation Method Improved Flow-Based Travel Time Estimation Method. JOURNAL OF TRANSPORTATION ENGINEERING. 2009, 135(1): 26-36.

Li R. Examining travel time variability using AVI data. Melbourne: Monash University, 2004.

Speed Guidance Model of Urban Expressways Based on a Meso-Traffic Simulation Model under Severe Weather

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Abstract: The paper establishes the speed guidance model of urban expressway based on meso-simulation traffic flow model, which can provide the role of speed control and short-term traffic prediction according to the real-time severe weather. And the model regards gross vehicle travel time as the objective function and the weather condition as influence factors to optimize the design of model and be implemented by C++. Then, it simulates and analyses the results based on the east line of the southern section of Shanghai North-South Elevated road. Simulation result shows that both speed variance and speed mean square error decrease remarkably. The speed guidance control reduces the overall difference of speed of the traffic flow that can improve traffic safety and the model is effective.
Keywords: Meso-simulation model; Severe weather; Speed guidance model; Zone algorithm; Urban expressway.

1. Introduction

With the increase of the vehicle, the operating efficiency of urban expressway is decreasing and it causes the growing problems of traffic jam and safety, especially, under adverse weather conditions (MA Jian, 2011). In order to better ensure the unobstructed traffic and traffic safety, the speed guidance is the most widely used method in recent years (Wang W., 2008). The primary factors affecting traffic safety are mainly wind, rain, fog, snow, and high and low temperature (Berhanu, G., 2000). Statistical data shows, with the gradual increase of adverse climatic conditions, the share of traffic accidents occur under adverse weather conditions is increasing. Traffic accidents on roads in China, 50% occurred under poor weather conditions. And 71% of major accidents and 65% of the direct economic losses occurred under adverse climatic conditions (Ministry of Transport, 2006). Traffic safety enhancement and traffic accident prevention have become essential under adverse weather conditions.

Speed guidance is a rational way and effective means to solve this problem. The paper establishes the speed guidance model of urban expressway based on meso-simulation traffic flow model, which can provide the role of speed control and short-term traffic prediction according to the real-time severe weather. Furthermore, it simulates and analyses the results based on the east line of the southern section of Shanghai North-South Elevated road. Simulation results demonstrate the validity and practicality of the model.

2. Meso-traffic simulation model of considering the compression and viscous properties

Figure 1 describes a kind of traffic state in the car-following scenario. $x_n(t)$ is the position of vehicle n at t. $x_{n+1}(t)$ is the position of vehicle $n+1$ at t. $s(t)$ is the time spacing between the front of the vehicle at t. T_r is the relaxation time. d_1 is the driving distance of vehicle $n+1$ within T_r. d_2 is the braking distance of vehicle $n+1$. d_3 is the braking distance of vehicle n. L is the safe distance of stopping.

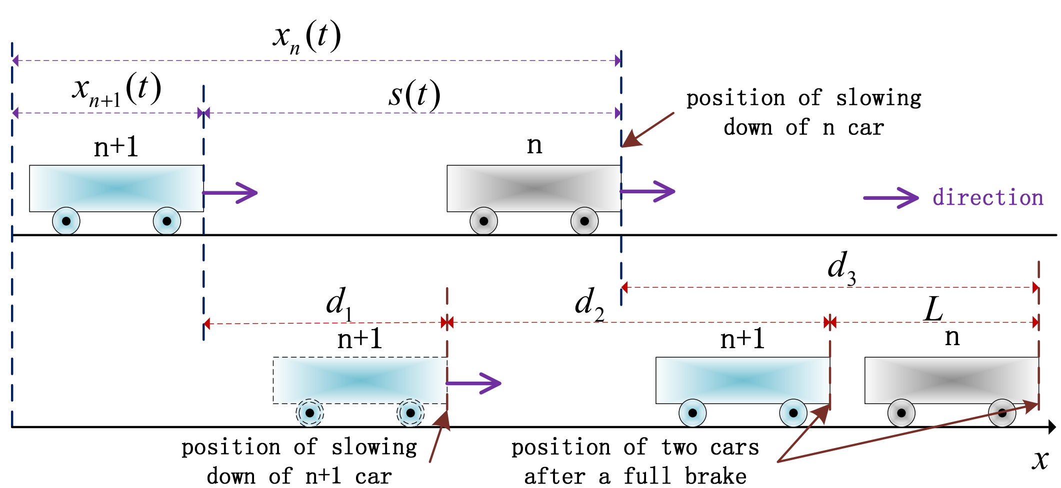

Figure 1. Comparisons of average speed

The paper builds the macro-traffic simulation model considered the properties of traffic compression and viscous based on the car-following model. The macro-model is represented as shown below.

$$\frac{du(x,t)}{dt}=\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}=\frac{u_e(k)-u(x,t)}{T_r}+\frac{\Delta x}{\tau}\frac{\partial u}{\partial x}-W \tag{1}$$

$$\frac{\Delta x}{\tau}=-ku_e'(k)\equiv a(k)>0 \tag{2}$$

$$W=(\delta_{w1}+\delta_{w2}) \tag{3}$$

$$\delta_{w1}=\mu\cdot k\cdot\Delta u\cdot u\cdot S_z/S_j \tag{4}$$

$$\delta_{w2}=\alpha\cdot k\cdot\Delta u\cdot u\cdot S_z/S_j \tag{5}$$

$$\Delta u=u_i-u_{i+1}\begin{cases}\Delta u & \Delta u>0\\ 0 & \Delta u=0\text{或}\Delta u=\varepsilon\\ 0 & u<0\end{cases} \tag{6}$$

$$\frac{\partial k}{\partial t}+\frac{\partial q}{\partial x}=g(x,t) \tag{7}$$

Wherein k is traffic density, q is traffic flow, u is velocity, x and t represent space and time respectively. $g(x,t)$ represents traffic flow when vehicles in and out of the roads researched, known as source sink term, if there is no vehicle in and out of the road, set to zero. $\frac{\Delta x}{\tau}$ is the speed of sound. W is the transport characteristics item. δ_{w1} is the transport viscosity characteristics item. δ_{w2} is the transport compression characteristics item. τ is the required time of the disturbance propagating backward Δx distance. α is the compression coefficient. μ is the viscosity coefficient, the unit is $m/(veh\cdot s)$. S_z is the braking distance, the unit is m. S_j is the viewing distance, the unit is m.

The meso-traffic simulation model derives from the macro-traffic simulation model based on the analysis of traffic compression and viscous properties(MA Jian,2013). Based on the above macro-model, the paper establishes the meso-traffic simulation model. Figure 2 is the schematic diagram of general grid partition for the simulation scenario.

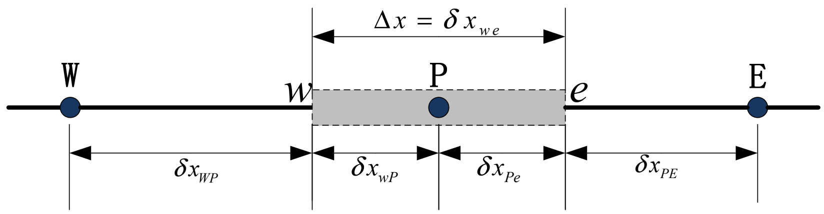

Figure 2. Schematic Diagram of General Grid Partition for The Simulation Scenario

For a one-dimensional control volume, in the time interval from t to $(t+\Delta t)$, the integral volume control equation:

$$\int_{t}^{t+\Delta t}\int_{\Delta v}\frac{\partial k}{\partial t}dvdt+\int_{t}^{t+\Delta t}\int_{\Delta v}\frac{\partial q}{\partial x}dvdt=\int_{t}^{t+\Delta t}\int_{\Delta v}g(x,t)dvdt \tag{8}$$

$$\int_{t}^{t+\Delta t}\int_{\Delta v}\frac{\partial u}{\partial t}dvdt+\int_{t}^{t+\Delta t}\int_{\Delta v}u\frac{\partial u}{\partial x}dvdt=\int_{t}^{t+\Delta t}\int_{\Delta v}F(k,u)\frac{\partial u}{\partial x}dvdt+\int_{t}^{t+\Delta t}\int_{\Delta v}\frac{u_e-u}{T_r}dvdt+\int_{t}^{t+\Delta t}\int_{\Delta v}G(k,u)dvdt \tag{9}$$

The followings can be gotten according to the Gauss–Ostrogradsky theorem.

$$\int_{\Delta v}\left(\int_{t}^{t+\Delta t}\frac{\partial k}{\partial t}dt\right)dv+\int_{t}^{t+\Delta t}[(Aq)_e-(Aq)_w]dt=\int_{t}^{t+\Delta t}\bar{g}(x,t)\Delta vdt \tag{10}$$

$$\begin{aligned}&\int_{\Delta v}\left(\int_{t}^{t+\Delta t}\frac{\partial u}{\partial t}dt\right)dv+\int_{t}^{t+\Delta t}a[(Au)_e-(Au)_w]dt=\int_{t}^{t+\Delta t}F(k,u)[(Au)_e-(Au)_w]dt\\&+\int_{t}^{t+\Delta t}\int_{\Delta v}\frac{u_e-u}{T_r}dvdt+\int_{t}^{t+\Delta t}\int_{\Delta v}G(k,u)dvdt\end{aligned} \tag{11}$$

Wherein A is control volume surface area, in one dimension, A=1; Δv is control volume, $\Delta v = A \cdot \Delta x$,where Δx is control the length of volume Δx_{we} ; $\overline{g}(x,t)$ is the average intensity of the source term.

3. Optimal design of control parameters under severe weather

According to the figure 1, the paper optimizes the design of control parameters of the traffic simulation model under severe weather(Samba, D.,2010, Watkins, K. E.,2010).. The following is parameters expressions.

$$d_1 + d_2 \le x_n(t) + d_3 \tag{12}$$

$$d_1 = v_{n+1} \cdot t \tag{13}$$

$$d_2 = v_{n+1}^2 \big/ [254(f - i)] \tag{14}$$

$$d_3 = (t_1 + t_2)v_n \big/ 3.6 \tag{15}$$

Wherein v_n is the velocity of vehicle n. v_{n+1} is the velocity of vehicle $n+1$. t is the braking reaction time of the driver of the vehicle $n+1$. f is the road adhesion coefficient. i is the gradient of the road. t_2 is the braking time of the rear vehicle $n+1$.

4. Speed Guidance Control Model

According to meso-simulation model of short-term traffic flow prediction of Urban Expressway and dynamic control of speed guidance, total vehicle travel time is as the objective function Z, thus:

$$Z = T\sum_{k=1}^{M_1}[\sum_{i=1}^{M_2}\rho_i(k)L_i\lambda_i] \tag{16}$$

Where, i is section number(1, ……, M_2); k is data collection interval number(1, ……, M_1); M_2 is maximum link number of sections; M_1 is maximum data collection time interval number; T is data collection cycle; L_i is the length of section i; λ_i is lane number of cellular road i; $\rho_i(k)$ is the density of the road section i at time k.

5. Case study

5.1 Simulation Scenarios

This paper chooses the east line of the southern section of Shanghai North-South Elevated road as the research object. This section is 8.45 km in length, with a total of 10 entrance ramps and 11 exit ramps. Actual testing data adopt the September 22, 2009 detector data, with the sampling frequency of 60 seconds.

The main parameters of the model are set as follows:

Ramp parameters:

$Q_0 = 2100veh/h$, $k_{\max} = 140veh/km/lane$, $k_{critical,u} = 40veh/km/lane$;

Mainline parameters: $\Delta t = 60s$, $k_{u,1} = 33.5veh/km/lane$, $u_{free} = 80km/h$, $u_{critical,i} = 45km/h$;

Viscous and compression parameters: $\alpha = 0.5$, $\mu = 0.5$, $S_z = 100m$, $S_j = 1000m$;

Weather influencing parameters $t = 0.3s$, $f = 0.45$, $i = 0.005$, $t_2 = 2s$;

Initial value of the total flow of the section ramp entrance: $Q_{in} = 585veh$;

Probability of section ramp export flow:

$$P_{out,i} = \{0,0,0.2,0,0.15,0,\{0.3,0.35\},0,0.2,0,0,\{0.5,0.4\},0.2,0,\{0.2,0.7,0.1\}\},$$

$$\rho_0(i) = \begin{cases} 0.025 & 1 \le i \le 5 \\ 0.02 & 6 \le i \le 10 \\ 0.018 & 11 \le i \le 15 \end{cases} ; \text{ Unit: } veh/m;$$

T is 300 simulation steps, the section length is 8.45km. Evaluation indexes include Variance and Mean Square Error.

5.2 Analysis of Simulation Results

Figure 3 is average speed comparison diagram under the conditions of no control and speed guidance on urban expressway. As we can see from this figure, in most of the sections, the average speed of the traffic flow in the situation of speed guidance are higher than the situation without control. At the same time, speed changes in the situation of speed guidance are smoother than that in the situation without control.

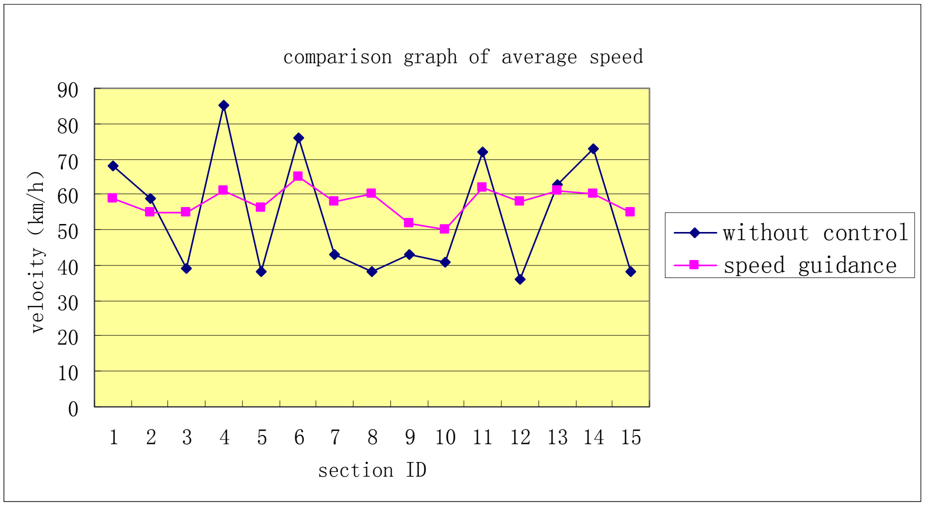

Figure 3. Comparison diagram of average speed

Table 1 is the comparison of speed variance and mean square error of all sections under different control conditions. As we can see in the table 1, after the implementation of speed guidance control, speed variance dropped from 297.12 (km/h) 2 to 15.89 (km/h) 2, the speed mean square error dropped from 17.24 (km/h) to 3.99 (km/h). It suggests that, compared with no control, speed guidance control has reduced the total speed difference of traffic flow and improved the traffic safety in the research sections.

Table 1. Comparison of speed variance and mean square error of all sections under different control conditions.

Items	Value
Speed variance of all sections without control $(km/h)^2$	297.12
Speed variance of all sections with guidance $(km/h)^2$	15.89
Mean square error of all sections without control (km/h)	17.24
Mean square error of all sections with guidance (km/h)	3.99

6. Conclusions

The paper presents a speed guidance control in urban expressway under adverse weather conditions. A meso-simulation traffic flow model of considering the compression and viscous properties is established on that basis. The simulation research and comparing analysis of the east line of the southern section of Shanghai North-South Elevated road shows that compared with no control situation, speed guidance control has reduced the overall speed difference of traffic flow and improved the traffic safety.

7. Acknowledgment

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References

Berhanu,G.(2000). “Effects of road and traffic factors on road safety in Ethiopia”. *Norwegian University of Science and Technology*, Trondheim, Norway.

MA Jian, SUN Jian, LI Keping and ZHANG Liyan(2011), “A study on multi-resolution scheme of macroscopic-microscopic traffic simulation model”, *2011 Intelligent Transportation Systems (ITSC)* , 1421-1426.

Ma Jian, Zhang Li Yan, Li Keping, Sun Jian, Zhu Chongkun(2013). “A new concept of traffic flow in the kinematic model LWR model.” *Wuhan University of Technology (Transportation Science & Engineering)*, 4:707-712.

Ministry of Transport(2006), http://www.transdata.cn. “The road traffic accident statistics under adverse weather conditions in 2006.” *The Science Data Website of Republic of China Ministry of Transport*.

Samba, D. and Park, B.(2010), “Probabilistic Modeling of Inclement Weather Impacts on Traffic Volume” , *89th Transportation Research Board Annual Meeting* , Washington, D.C., 2010 .

Wang W., Chen S.Y. and Hu X.J.(2008). “Novel Integrated Method of Bus Speed Guidance and Dispatching based on ‘One Route One Line and Run Straight Mode’”. *Journal of Southeast University*. 38(6): 1110-1115.

Watkins, K. E. and Hallenbeck, M., (2010), “Impact of Weather on Freeway Travel Times in the Rain City”, *TRB 2010 Annual Meeting*, Washington D.C..

Research on the Method and Application for a Vehicle's Online Diagnosis Based on a Testability Model

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Abstract: The study of online diagnosis based on testability models has been greatly concerned, due to the advantages of generality, real-time performance, intuitive modeling and high efficiency. The paper presents a technique of the vehicle's online diagnosis based on testability models. Firstly, a basic algorithm is proposed, and a universal machine is designed for real-time performance. To fulfill the demands of online application, a reasoning prototype is developed with the embedded platform of VxWorks. The experimental results prove the performance and effectiveness of the universal real-time reasoning machine. Such a technique of online diagnosis can be applied to other equipments of traffic and transportation.
Keywords: Testability; Online diagnosis; Reasoning machine; VxWorks.

1 Introduction

This paper analyzes the issue of online diagnosis, which is of great significance for a vehicle's long-term operation. Currently, the strategies of fault diagnosis can be categorized as the sequential and the concurrent (Yan, 2012).

The sequential diagnostic method is to perform the process of fault isolation in a certain order. In essence, that is to execute a test, determine the system's status, and guide people to the next test of the most meaningful. The method mainly focused on how to generate or optimize the diagnostic rules in the last decade, and solved a lot of theoretical and practical problems (Pattipati, 1990; Tu. 2003; Yang, 2008; Zhang, 2013). The sequential diagnostic method is most suitable for a deep diagnosis in an offline way, taking the case of maintenance operations. Under that circumstance, a clear diagnosis timeliness requirement is usually not necessary. Thus, real-time embedded sensors and testing informations should be considered.

Concurrent diagnosis refers to a one-off reasoning of the health status from all the acquired testing data. Usually, an alarm is triggered with the help of real-time monitoring of operating parameters when an exception occurs. The possible drawn exception sites can be located to provide reference informations for reconfiguration of the system. A real-time diagnosis method can quickly detect the presence of failure, reducing "can-not reproduce" problems (Deb, 2000). That is significant for online applications demanding for high safety, for example, a complex vehicle, which involves multi-energy domains, multi-system couplings, special environments, and possible catastrophic consequences after a failure (Kurtoglu, 2008).

Usually, the online diagnostic systems can be constructed in different ways, such as model-based, data-driven or rule-guided, to achieve real-time performances. With the increasing complexity of modern vehicles, the diagnostic technique which is based on testability model has become widely accepted. The method will make full use of design information of testability, optimize and re-allocate measuring points. That will greatly improve the fault coverage at the vehicle design stage, and also the effectiveness of fault diagnosis. What’s more, the model is relatively standard and unified, which will help to improve the versatility of fault diagnostic systems.

Currently, one of the most widely marketed real-time reasoning toolkit is QSI TEAMS-RT, which provides an excellent diagnostic machine based on testability modeling way of multi-signal flow graph (Mathur, 1998). TEAMS-RT is part of the famous TEAMS tools, which has a long-term history of development (Deb, 1997). However, it’s not open-source and restricts to its specific model file format, which indeed greatly limits the possible domestic applications with different embedded platforms, especially for special fields of vehicle. Thus, there exists urgent demands for developing high-performance reasoning machine with independent intellectual copyrights. This paper is intended to investigate a universal method and application of real-time diagnostic embedded system based on testability models, including the design of reasoning algorithm, the development of embedded diagnostic machine under VxWorks platform. Finally, the software/hardware architecture and operation performance is analyzed, outlining its possible prospects.

2 Algorithm

The diagnostic process is to analyze any defective states of the vehicle, based on the test results obtained and pre-implanted testability models from the interface files. An online diagnostic system is used to monitor the normal process, and ensure the critical safety of operation. Thus, there exists a great demand for real-time reasoning algorithm with high performance, especially for a large-scale system. The diagnostic results are also expected with accuracy.

As we all know, sets operations in Mathematics have a great efficiency by way of Boolean calculation basics. Accordingly, the development of a real-time reasoning machine can be achieved by way of set operations to improve the execution speed by computers. The basic algorithm is as follows:

Algorithm Input: (1) Normal and abnormal testing data, processed as 0/1
(2) Testability model interface file (correlation matrix)

Algorithm output: Normal, faulty, suspicious and unknown sets,

(Note: each module will be classified into one set.)

Algorithmic process:

Step one: all modules are marketed suspicious objects;

Step two: process the normal tests (binary 0);

Find out all the associated modules in the correlation matrix from the testability model, and mark them as normal, and update the different sets.

Step three: similarly, process the abnormal tests (binary 1);

Removed the normal modules from the abnormal sets, which is associated with the abnormal tests in the correlation matrix. If the remaining number of modules is only 1, mark it into the faulty set. Otherwise, keep it unchanged.

3 Real-time Diagnostic System under VxWorks

The VxWorks operating system is owned by Wind River System (WRS) of USA. The company designed VxWorks in 1983. It can be greatly customized according to the vehicle, and has a strong real-time performance on the target. The advantages include the sustainable development, efficient kernel and user-friendly environment. Currently, it is widely used in the fields with real-time requirements, i.e. aviation, aerospace, communications and other sophisticated circumstances (Liu. 2009).

A prototype is developed to demonstrate the online diagnostic application, and verify the real-time performance. The reasoning machine is developed with VxWorks, the popular embedded platform. The system configuration is shown in Figure 1.

The target VxWorks platform parameters are: 500MHz, PPC7410CPU, 512MB RAM. Experimental results show that the diagnostic results from the reasoning machine are consistent with the expected by simulation. The prototype machine has a high precision, giving that the reasoning time is proportional to the system size (the correlation matrix of the number of elements). For example, an analysis with a 1000 × 1000 system (i.e. 1000 failure modes and 1000 tests) is presented in Table 1. The parameter of matrix density describes the proportion of 1-element in the correlation matrix, and a larger density usually means a higher cost of mathematic calculations.

As is shown, the performance of the prototype is quite excellent. Diagnostic results are always proved correct by simulation, under the conditions of a single fault and multiple faults. The reasoning speed is very fast, and the time costs are obviously scoped in the scale of "hundred" milliseconds. The performance is no less than that of QSI TEAMS-RT (Mathur. 1998). Even for the worst case that most of the testing data are abnormal (for example, matrix density of 30%, 10 faults implanted), the reasoning speed is still quite fast. It's believed to be suitable for online diagnosis of the large-scale systems.

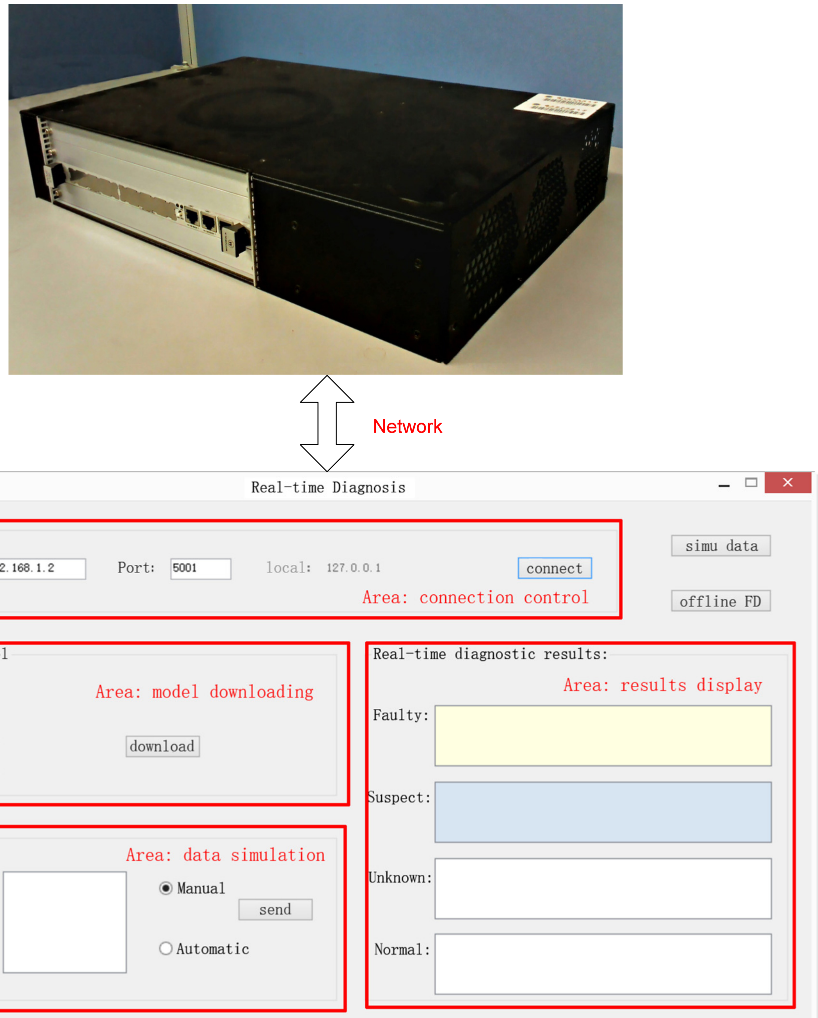

Figure 1.VxWorks target server and PC client

Table 1. Prototype performance of 1000 × 1000 system

Matrix density	Number of faults	Number of passed tests	Faulty modules (reasoning)	Suspect modules (reasoning)	Fault identify rate	Time cost (ms)
1%	1	991	1	0	100%	85
	2	979	2	0	100%	87
	5	955	5	0	100%	89
	10	914	10	0	100%	92
10%	1	898	1	0	100%	88
	2	807	2	0	100%	98

	5	606	5	0	100%	124
	10	369	10	0	100%	164
20%	1	803	1	0	100%	97
	2	635	2	0	100%	115
	5	326	5	0	100%	167
	10	104	10	0	100%	229
30%	1	705	1	0	100%	104
	2	514	2	0	100%	131
	5	183	5	0	100%	204
	10	42	10	0	100%	262

4 Conclusions

Real-time diagnosis is significant to ensure safe operation of the vehicle. This paper presents an online fault diagnosis method based on testability model, and also a systemic description of the prototype. Basic steps of the reasoning algorithm are discussed. The general architecture of the reasoning diagnostic system is summarized. A VxWorks target machine is developed and analyzed in detail by way of simulation. The performance, effectiveness and efficiency are finally proved by the experimental results. Such a diagnostic system is applicable to different traffic and transportation equipments, for example, power devices, satellites, aircrafts, vehicles, and so on. A further research on robust real-time algorithms and more applications of such an online diagnosis technique will be expected.

Acknowledgement

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References

Pattipati, K. R., and Alexandridis, M. G. (1990). “Application of heuristic search and information theory to sequential fault diagnosis.” *IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans,* 20(4), 872-886.

Deb, S., Pattipati, K. R., and Shrestha, R. (1997) "QSI's Integrated Diagnostics Toolset." *IEEE Autotestcon, Anaheim,* CA, USA: IEEE.

Mathur, A., Deb, S., and Pattipati, K. R. (1998) "Modeling and real-Time Diagnostics in TEAMS-RT." *American Control Conference,* Philadelphia, Pennsylvania, USA.

Deb, S., Ghoshal, S., and Malepati, V. N. (2000) "Tele-diagnosis: remote monitoring of large-scale systems." *IEEE Aerospace Conference,* Big Sky, MT, USA: IEEE.

Tu, F., and Pattipati, K. R. (2003). "Rollout strategies for sequential fault diagnosis." *IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans,* 33(1), 86-99.

Yang, P. (2008). "Optimization design of diagnostic strategies based on correlation model." (In Chinese) *National Defense University of Science and Technology*, Changsha.

Kurtoglu, T., Johnson, S. B., and Barszcz, E. (2008) "Integrating system health management into the early design of aerospace systems using Functional Fault Analysis". *International Conference on Prognostics and Health Management,* Denver, Colorado, USA.

Liu, L. Q., Xing, X. M., and Liu, C. (2009) "Embedded software technology." *Harbin Institute of Technology Press,* Harbin.

Yan, P. C., Lian, G. Y.n and Liu, X. Q. (2012). "Sequential multi-fault diagnosis based on fuzzy group." (In Chinese) *Computer Measurement & Control,* 20 (1), 34-37.

Zhang, S., Hu, Z., and Wen, X. (2013) "Test sequencing problem arising at the design stage for reducing life cycle cost." *Chinese Journal of Aeronautics.* 26(4), 1000-1007.

A New Computational Method of the Friction Power Loss of Spiral Bevel Gears of a Helicopter Reducer

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Abstract: The objective of this paper is to develop a new computational method of friction power loss of the spiral bevel gears transmission system of the helicopter tail reducer. At first, the velocity and force of the meshing point were analyzed during meshing process. Then a computational model of friction power loss for spiral bevel gear was established based on the principle of meshing and tribology theory, considering the effects of actual contact ratio and time-variant factors. This model considered the effects of actual contact ratio and time-variant factors including mesh point relative sliding velocity of mesh point, normal load, friction coefficient, etc.
Keywords: Computational method; Friction power loss; Spiral bevel gears.

1 Introduction

The spiral bevel gears transmission system is the key part of the helicopter tail reducer. In its operation process, the heat generated by the gear and bearing friction deforms the parts of the transmission due to its temperature rise, which will decrease the transmission performance. Especially in the case of insufficient lubrication and cooling, the great amount of frictional heat easily cause the serious failure phenomena such as teeth bonding, bearing raceway burns, cage fall even gear stuck and bearing axle etc. Thus, the computational methods of friction power loss and temperature field distribution of spiral bevel gears transmission system are very important for thermal characteristics analysis and lubrication design.

The computational method of gear friction power loss are the testing method, the look-up table method and the direct computational method (Diab, 2006). The test method is long and costly, and the look-up table method is estimated from the mechanical manual but not universal. In the direct computational method, the gear friction power loss model is established, and the result is more reasonable. In recent years, many authors have been used the direct computational method to analyze different cases of the gear friction power loss (Handschuh, 1996). Su H (Su, 2000) analyzed the speed and force of the meshing point and has obtained the friction power loss based on gear meshing and contact analysis theory. However, the meshing point velocity and loadings are very difficult to determine due to the complex nature geometry of the spiral bevel gear tooth surface and the method is complicated to compute. Yu D J (Yu, 2005) used Anderson-Loewenthal equation (Anderson, 1981) of spur gear power loss model to simplify the model, and calculated the spiral bevel gear friction power loss. But its method did not consider the relative sliding velocity, normal load, friction coefficient of meshing points, which varied with the meshing position. Besides, only 1/4 length of the meshing line of the frictional meshing points was taken as the average gear friction power loss and the computational results were not accuracy.

In view of the above problems, the objective of this paper was to develop a new computational method of the temperature field of the spiral bevel gears transmission system of the helicopter tail reducer in the normal lubrication. In the first part of this paper, the velocity and force of meshing point are analyzed based on meshing theory. Then, a computational model of friction power loss will be established based on gear meshing and tribology theory. This model considered the effects of actual contact ratio and time-variant factors including mesh point relative sliding velocity of mesh point, normal load, friction coefficient, etc.

2 Velocity and force analysis of meshing point

2.1 Equivalent theory of spiral bevel gear

The relative sliding velocity of mesh point, normal load and friction coefficient are three important factors during meshing of the spiral bevel gears. In this part, the velocity and force of meshing point are firstly analyzed based on equivalent spur gear meshing theory. Effects of instantaneous sliding friction is then deeply investigated under different lubrication conditions.

The space meshing theory of the spiral bevel gear is complicated, so the friction power loss is difficult to be directly calculated. If the spiral bevel gear was equivalent to the equivalent spur gear on the promise of the constant velocity and normal load of the equivalent gear midpoint, the problem could be simplified(Zeng, 1989), as shown in Fig.1. In that case, the spiral bevel gear is firstly transferred to the equivalent spur gear, and the structural parameters are shown in Tab.1.

2.2 Meshing velocity analysis

The velocity and force of the meshing point were then analyzed based on meshing theory. Fig.2 shows the velocity analysis of the spur gear meshing point, in which P is pitch point, C is transient meshing point, r_1 and r_2 are pitch radius of driving and driven gear, r_{a1} and r_{a2} are outside radius, N_1N_2 is meshing line in theory, r is the distance from axle center O_1 to meshing point C, α is the pressure angle of pitch circle, α_c is the pressure angle of meshing point C, T is input torque, ω_1 and ω_2 is the angular velocity of driving and driven gear, B_1 is the initial meshing point , B_2 is the end meshing point, and B_1B_2 is the actual meshing line(Yang, 1999).

Table 1. Structural parameters of spiral bevel gear and its equivalent spurgear

Gear type	pitch cone angle		number of teeth		pitch cone distance midpoint	spiral angle	pitch radius	
	driving gear	driven gear	driving gear	driven gear			driving gear	driven gear
Spiral bevel gear	δ_1	δ_2	z_1	z_2	R	β	——	——
Equivalent spur gear	——	——	$\frac{z_1}{\cos\delta_1 \cos^3\beta}$	$\frac{z_2}{\cos\delta_2 \cos^3\beta}$	——	——	$\frac{R\tan\delta_1}{\cos^2\beta}$	$\frac{R\tan\delta_2}{\cos^2\beta}$

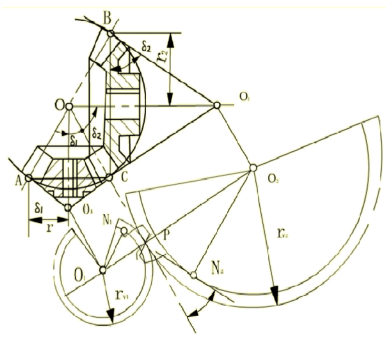

Figure.1 Equivalent spur gear theory

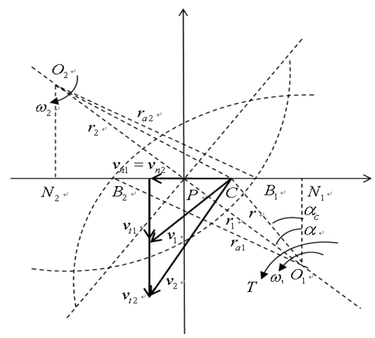

Figure. 2 Velocity analysis on meshing point

The velocity of meshing point C following the driving gear is separated to normal and tangential velocity, and the tangential velocity $\vec{v}_{t1}$ can be expressed as:

$$\vec{v}_{t1} = \vec{v}_1 \sin\alpha_c = r\omega_1 \sin\alpha_c = |N_1C|\omega_1 \tag{1}$$

Similarly, the tangential velocity of driven gear $\vec{v}_{t2}$ can be expressed as:

$$\vec{v}_{t2} = |N_2C|\omega_2 \tag{2}$$

In that case, the relative sliding velocity is deduced as follows:

$$v_s = |\vec{v}_{t1} - \vec{v}_{t2}| \tag{3}$$

And the entrainment velocity is expressed as:

$$v_t = \frac{|\vec{v}_{t1} + \vec{v}_{t2}|}{2} \tag{4}$$

2.3 Force analysis of meshing point

The spiral bevel gear is a certain approximate to its equivalent gear in movement, but the meshing force of the two cannot be equivalent. To assure the accuracy of the friction power loss in computational model, the normal force of the tooth breadth midpoint of spiral bevel gear must be equal to the equivalent spur gear. The force equations on the reference circle of the tooth breadth midpoint of spiral bevel gear are shown in reference (Zeng, 1989).

The normal force of gears is determined on basis of the force principle of the equivalent spur gear meshing point and force computational equations in Table.2, and the normal force F_n is defined as:

$$F_n = \frac{F_t}{\cos\alpha_c} \tag{5}$$

where $F_t = \frac{T}{r}$, $r = \frac{r_1 \cos\alpha}{\cos\alpha_c}$.The reference pitch p_b and overlap ratio ε_α of spur gear are defined as[10]:

$$p_b = \frac{2\pi r_1 \cos\alpha}{z_1} \tag{6}$$

$$\varepsilon_\alpha = \frac{|B_1B_2|}{p_b} \tag{7}$$

If the overlap ratio was equal to 1($\varepsilon_\alpha = 1$), only a pair of gears is meshing at the same time. In practice, the overlap ratio is always above 1, and a plurality of teeth were meshing simultaneously. If $1 < \varepsilon_a < 2$, the single and double teeth is alternative meshing. The normal force variation of a single teeth is shown in Fig.4. In the single meshing area B_4B_3, only a pair of gears bears the normal force. But, the two pairs of gears must bear the normal force in the double meshing area B_1B_3 or B_4B_2. The relationship between the meshing length and meshing ratio is expressed as:

$$B_1B_3 = B_4B_2 = B_1B_2 - P_b = (\varepsilon_\alpha - 1)P_b \tag{8}$$

Generally, the normal force was assigned in two teeth in average. In this case, the normal force should be assigned in the two simultaneous meshing teeth, and the normal force F_n can be expressed as:

$$F_n = \begin{cases} \dfrac{T}{r_1 \cos\alpha} & \text{single} \\ \dfrac{T}{2r_1 \cos\alpha} & \text{double} \end{cases} \tag{9}$$

3 Computational model of friction power loss

3.1Transient sliding friction coefficient

The gear sliding friction coefficient is related with many factors, such as the structural parameters of gears, meshing position, normal load, rotational speed, the tooth surface roughness, lubrication condition, oil viscosity and temperature effects et.al. The thickness ratio of lubrication oil-film λ[14] is defined as:

$$\lambda = \frac{h_{\min}}{\sigma} \tag{10}$$

$$\sigma = \sqrt{\sigma_1^2 + \sigma_2^2} \tag{11}$$

where $h_{\min}$ is the minimum oil-film thickness between teeth surfaces, σ is the average roughness of the tooth surface, and σ_1 and σ_2 are the roughness of the contact two teeth surfaces.

Many scholars have studied different methods to determine the sliding friction coefficient based on the elasto-hydro-dynamic lubrication(EHL) theory (Tallian, 1973). In Martin K's papers (Martin, 1978), the sliding lubrication conditions can be divided into three types: the fully EHL state($\lambda > 2$), the mixed EHL state($0.2 < \lambda < 2$), and the boundary lubrication state($\lambda < 0.2$). Therefore, different computational model of the sliding friction coefficient should be established due to different lubrication conditions. In that case, Wen S J (Wen, 1992) developed an equation to calculate EHL thickness,

$$h_{\min} = 6.67\mu^{0.53}(\eta v_t)^{0.75} E^{-0.06} R^{0.41} F_L^{-0.16} \tag{12}$$

where μ is the pressure-viscosity coefficient of lubrication oil(m^2/N), η is the dynamic viscosity coefficient of lubrication oil($Pa \cdot s$), $E = 2\big/\left(1-\nu_1^2/E_1 + 1-\nu_2^2/E_2\right)$ is the equivalent Young's modulus(Pa), E_1 and E_2 are the Young's modulus of driving and driven gears, ν_1 and ν_2 are the Possion ratio of driving and driven gears, $R_{eq} = R_1R_2/(R_1+R_2)$ is the equivalent curvature radius(m), $R_1 = |N_1C|$ and $R_2 = |N_2C|$ are the curvature radius of driving and driven gear meshing point(m), $F_L = F_n/L$ is the unit force of contact length(N/m), and L is contact length(m). The sliding friction coefficient of the fully EHL state was then calculated by Winter and Michaelis:

$$f_m = 0.0607(\frac{F_L}{v_s R})^{0.2} \eta^{-0.05} \left(\frac{\sigma}{d_1}\right)^{0.25} \tag{13}$$

3.2 Model of friction power loss

The friction between the meshing tooth are sliding friction, rolling friction and internal friction caused by metal plastic deformation during meshing process. And the rolling friction and internal friction are in small proportion, often negligible. Generally, only sliding friction is considered to compute the power loss (Su, 2000).

When the degree of contact ratio is $1<\varepsilon_\alpha<2$, the transient friction power loss of the single gear meshing zone B_4B_3 is,

$$q_c = f_1F_{n1}v_{s1} \tag{14}$$

And, the transient friction power loss of the double gear meshing zone B_1B_4 and B_3B_2 are,

$$q_c = q_{c1}+q_{c2} = f_1F_{n1}v_{s1}+f_2F_{n2}v_{s2} \tag{15}$$

where f_i is the friction coefficient of the i^{th} gear tooth meshing point, F_{ni} is the normal load of the i^{th} gear tooth meshing point, v_{si} is the relative sliding velocity of the i^{th} gear tooth meshing point, and $i=1,2$ represent the front and rear pairs of simultaneously meshing teeth respectively.

In a meshing cycle, the total friction heat are,

$$Q=\int_{t_{B1}}^{t_{B2}} q_c dt = \int_{t_{B1}}^{t_{B3}} \left(f_1F_{n1}v_{s1}+f_2F_{n2}v_{s2}\right)dt + \int_{t_{B3}}^{t_{B4}} f_1F_{n1}v_{s1}dt + \int_{t_{B4}}^{t_{B2}} \left(f_1F_{n1}v_{s1}+f_2F_{n2}v_{s2}\right)dt \tag{16}$$

where $t_{Bj}=\dfrac{\alpha_{Bj}-\alpha_{B1}}{\omega_1}$ is the time from the beginning meshing point B_1 to B_j, and $j=1,2,3,4$.

Thus, the computational model of the average friction power loss of the teeth is,

$$q_m=\frac{Q}{t_{B2}} \tag{17}$$

4 Conclusions

(1) In this paper, a friction power loss calculation model of spiral bevel gear was established. In this model, the spiral bevel gear is equivalent to the equivalent spur gear, and the gear meshing point during the relative sliding velocity, normal load, friction coefficient time-varying factors et.al are considered. In that case, the analysis model could be easier, and the calculation results could be more reliable.

(2) The friction power loss calculation model of spiral bevel gear, established in this paper, could be taken as the reference to thermal analysis of spiral bevel gear drive system and heat calculation in the lubricating design.

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References

Diab Y, Ville F, Velex P(2006). Prediction of power losses due to tooth friction in gears. *Tribology Transactions,* 49(2): 260-270.

Handschuh R F, Kicher T P(1996). A method for thermal analysis of spiral bevel gears. *Journal of Mechanical Design*, 118(4): 580-585.

Su H, Zhang Y H, Chen G D, et al(2000). On spiral bevel gear's thermal tribology behavior. *Mechanical Science and Technology,* 19: 130-132. (in Chinese)

Yu D J(2005). Study on gear box bench test and analysis for type X helicopter. *Shanghai: Shanghai Jiaotong University*. (in Chinese)

Anderson. N. E, Loewenthal. S. H(1981). Effect of geometry and operating condition on spur gear system power loss. *Mechanical Design*, 103(4): 151-159.

Zeng T(1989). Design and process of spiral bevel gears. *Harbin: Harbin Institute of Technology Press*, 47-52. (in Chinese)

Yang K Z, Cheng G Y(1999). Fundamentals of the machine design. *Beijing: High Education Press*, 45-60. (in Chinese)

Martin K(1978). A review of friction prediction in gear teeth. Wear, 49(2): 201-238.

Wen C Z, Yang P R(1992). Elasto-hydro-dynamic lubrication. *Beijing: Tsinghua University Press*, 122-129. (in Chinese)

Tallian. T. E(1973). Pressure and traction rippling in elasto-hydro-dynamic contact of rough surfaces. American Society of Mechanical Engineers, n 73-Lub-18.

City Transit Ridership Forecasting Based on Weather Conditions—Case Study of the Chicago Transit Authority (CTA)

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Abstract: Chicago Transit Authority (CTA) total ridership data is analysis considering weather data of the weekday. The results that lower temperature influences the transit ridership a lot and the influence reduces when the mean temperature goes higher are discovered. Different weather factors are analyzed to see how they affect the total ridership. In addition, a logistical regression model is generated based on the January 2014's weekday data.
Keywords: Transit forecasting; CTA; Weather condition.

1 Introduction

During the past 30 to 40 years, the transit share of total travel has been declining. More and more people live at suburban area but work at downtown, which provides great challenges for public transportation system. Therefore, how to maintain transit ridership and what operation strategies to use are problems facing by many transportation agencies today. One of the key issues to solve these problems is to figure out what factors affect the transit ridership.

One of the most famous strategies to forecast the ridership is Logit model based on census data. However, census reports are published very five years by the government and it is based on questionnaire. Transit ridership could change significantly through the five years' period based on the employment situation, transit development, government policies, climate changes and some other factors.

A lot of researchers studied travel demand forecasting in past several decades but with little of them take the weather as a factor which influences the transit ridership. In order to better understand the characteristics of transit ridership, a further analysis of transit ridership and a model that can reflect changes in transit ridership corresponding to changes in factors affecting ridership is needed.

The Chicago Transit Authority (CTA) operates the second largest public transportation system in the United States, and covers the City of Chicago and 35 surrounding suburbs. Approximately 1.7 million rides are taken on the CTA on an average weekday. (http://www.transitchicago.com/about/overview.aspx)

The objective of this paper is to examine potential variables that may have effects on CTA transit ridership and to develop a mathematical model to forecast ridership as a function of weather factors without census data. The rest of the paper is organized as follows. Section 2 offers a literature review on ridership forecasting. Section 3 analyzes existing ridership and weather data. Model analysis is described in section 4. Finally, section 5 presents the final conclusions as well as directions for future work.

2 Literature Review

Methodologies of transit ridership forecasting began to blossom in the 1970s and 19080s. Some scholars developed techniques to forecast system-level or route-level transit ridership in 1980s, either through a modified four-step travel model (Ulberg 1982; Levinson 1984; Horowitz 1985; Levinson 1985), or regression models using combination of population, employment, automobile ownership, etc.

(Menhard, 1983) summarized route-level ridership prediction techniques and characterized four of them, which are ‘Professional judgment; Noncommittal or stated-preference surveys; Cross-sectional models, ranging in sophistication from similar routes and rules of thumb to regression analyses; Time-series models, including elasticity-based approaches and trend analysis’. Those techniques were ranked subjectively based on some factors, but summarized that ‘insufficient information was available to address accuracy and transferability’ (Boyle, 2006). (Stopher, 1992) proposed a model to forecast ridership changes - based on route extensions, headway changes, service span changes, route shortenings, new routes, short-lines on existing routes, or a combination of actions – at route and time-of-day levels. (Peng, 1997) developed a ridership model that incorporated transit demand, supply, and inter-route factors on a route level by time-of-day and direction. The study realized that it is likely to cause a ridership decrease on competing or parallel routes lately, when ridership on a given route increased by service improvement.

(Lane, 2006) proposed a ridership-forecasting tool on a sketch-level for light and commuter rail. This model was improved by (Parsons, 1996) through taking into account service-related variables like travel speed, midday headways, and fare, as well as by introducing reverse commutes trips. (Marshall, 2006) presented a sketch level transit planning model that sensitive to land usage, matches suburban transit ridership better, and cost less than the traditional four-step model.

3 Data Analysis

The CTA ridership data is from CTA website and the dataset shows system-wide boardings for both bus and rail services provided by CTA, dating back to 2001. There are three kinds of day types, weekday, Saturday, and Sunday/holiday. The weather data comes from “weather underground” website contains high, average and low data for temperature (F), dew point (F), Humidity (%), sea level press (In), wind (mph) and events (fog, rain, snow etc.).

Figure 1 shows total ridership in January 2013. It is easy to see that there are huge gaps between weekdays and weekends. In this paper, weekday data is used to analysis how the weather influences the transit ridership. Because total commute trips in weekday will not change a lot in different weather conditions. By analysis weekday data, we could not only know how transit ridership changes in different weather condition but also how the transit share considers the weather.

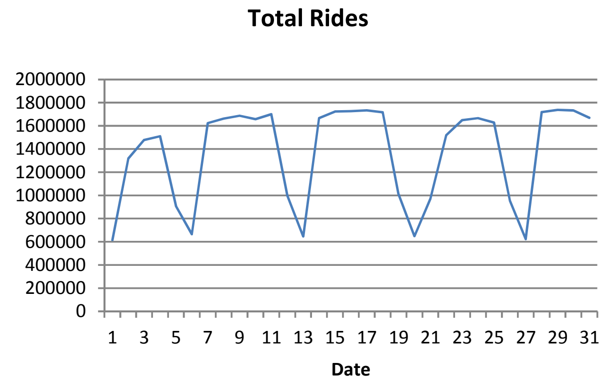

Figure 1. CTA Total Ridership in January 2013

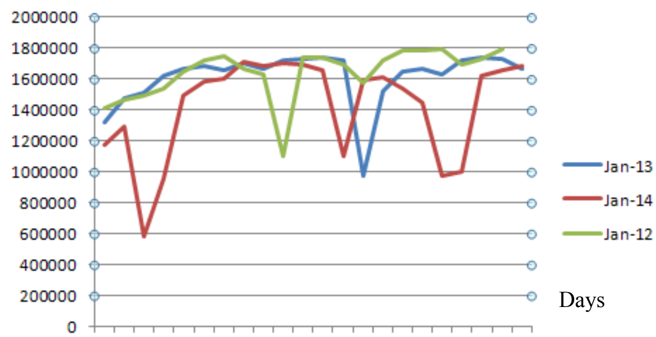

Figure 2. CTA Total Weekday Ridership in January 2012, 2013 and 2014

Figure 2 shows CTA Total Ridership in January 2012, 2013 and 2014. It is clear that ridership in January 2014 is much lower than in 2012 and 2013. From the weather data, we could know that the temperature in Chicago area is much lower in January 2014 than in January 2013. Figure 3 shows the relationship between mean temperature of a day and the total CTA transit ridership in January 2014. It is quite straightforward that when the average temperature of a weekday is quite low, the ridership of the transit is also very low.

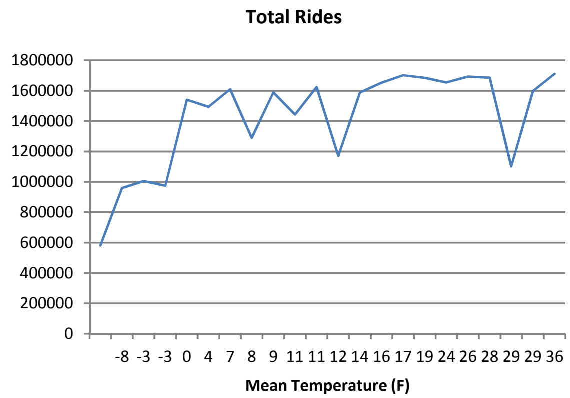

Figure 3. Relationship between Mean Temperature and Total Weekday Ridership in January 2014

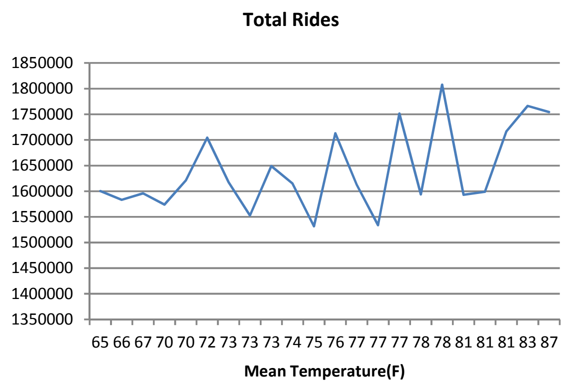

Figure 4. Relationship between Mean Temperature and Total Weekday Ridership in August 2013

Figure 4 displays how ridership changes due to the mean temperature changes of the weekday in August 2013. The ridership does not change as much as in January 2014. Even though the total ridership fluctuates, the trend goes up as temperature going up.

To sum up, it is clear that the CTA ridership on weekday is influenced by the mean temperature of the day. Next section will discuss the mathematical relationship between transit weekday ridership and weather condition (temperature, humidity, wind and events like fog, rain, snow etc.).

4 Model Analysis

First we tried logistic regression contains all weather factors to see which factors influence the weekday ridership significantly. The regression result shows in figure 6 based on the weather and weekday CTA total ridership data in January 2014.

As we forecasted before, mean temperature of the day is a very important factor of the transit ridership. Besides, mean wind speed and mean humidity also affect the ridership more or less. When we considered only mean temperature and mean wind speed to do the logistic regression, the result shows that mean wind speed is not significantly influence the total ridership. The regression model of transit ridership will only consider the mean temperature of the day which is easy to get the data and affects the ridership significantly. The regression output is displayed in figure 7 and the model is the following: Total CTA Ridership = 1172764 + 16870 * (Mean Temperature of the day/F).

```
Call:
glm(formula = total_rides ~ Mean.TemperatureF + Event + Mean.Hum
    Mean.VisibilityMiles + Mean.Wind.SpeedMPH + CloudCover, data

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-256877   -99405    27358   104796   268635

Coefficients:
                     Estimate Std. Error t value Pr(>|t|)
(Intercept)           3316856    1101987   3.010 0.010046 *
Mean.TemperatureF       25264       5071   4.982 0.000251 ***
Event                   12001     117419   0.102 0.920154
Mean.Humidity          -24353      11872  -2.051 0.060960 .
Mean.VisibilityMiles   -35008      40862  -0.857 0.407111
Mean.Wind.SpeedMPH     -29104      12477  -2.333 0.036389 *
CloudCover              19529      34670   0.563 0.582831
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 6. Logistic Regression Results Consider Multiple Weather Factors

```
Call:
glm(formula = total_rides ~ Mean.TemperatureF, data = b)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-559839  -163664    42949   202877   302319

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)        1172764      82689  14.183 1.47e-11 ***
Mean.TemperatureF    16870       4206   4.011 0.000747 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 7. Logistical Regression Result Consider Mean Temperature Only (Jan 2014)

Here the problem comes, the regressions above based on the data in January 2014, the month Chicago has the lowest average temperature in the past twenty years. However, in January 2013, the mean temperature is from 13F to 45F, which are much higher than in January 2014. The regression results for January 2013 and August 2013 show that mean temperature is not as significant as in 2014. The logistic regression outcome shows in figure 8.

```
Call:
glm(formula = total_rides ~ Mean.TemperatureF, data = d)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-118776   -58839     7171    36837   148550

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)        1137916     212651   5.351 3.08e-05 ***
Mean.TemperatureF     6682       2821   2.369    0.028 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 8. Logistical Regression Result Consider Mean Temperature Only (Aug 2013)

5 Conclusion

By comparing the CTA ridership data and Chicago weather data, we find that the mean temperature of a weekday influences the transit ridership significantly especially the temperature is low. When the temperature is not low like in January 2013 and August 2013, the mean temperature also influence the transit ridership a lot but not as significantly as in January 2014. The trend is when the temperature is higher the transit ridership is also higher. It might because that many people do not want to take transit to school or work in an extreme weather condition especially when they have alternative choices.

A logistic regression model is also given based on the January 2014 data which is Total CTA Ridership = 1172764 + 16870 * (Mean Temperature of the day/F). We can forecast the CTA total ridership in extreme cold weather based on this model and change the operation strategy to serve residents better.

There are still a lot of things need to do in the future. First, the importance of factor temperature varies when the temperature level is different. A parameter should add to interpret this variance. Second, we did not verify the model with other data and sensitivity analysis to check the model performance. Furthermore, this model only considered the weather data. Usually the transit ridership also affected by the land use, transit routes, transit accessibility, household characters and so on. And the weather data could be included in the error term of the model to influent the total ridership. Hence, model comparison should be done in the future to compare different model performances and analysis the error term as well to see how weather conditions influent the error term and total transit ridership.

Reference

Ulberg, C., "Short-Term Ridership Projection Model," Transportation Research Record 854, Transportation Research Board, National Research Council, Washington, D.C., 1982

Levinson, H.S. and O. Brown-West, "Estimating Bus Ridership," Transportation

Research Record 994, Transportation Research Board, National Research Council, Washington, D.C., 1984

Horowitz, A.J., Transit Ridership Forecasting Model: Reference Manual, Urban Mass Transportation Administration, U.S. Department of Transportation, Washington, D.C., 1985.

Levinson, H.S., "Forecasting Future Transit Route Ridership," Transportation Research Record 1036, Transportation Research Board, National Research Council, Washington, D.C., 1985

Menhard, H.R. and G.F. Ruprecht, "Review of Route-Level Ridership Prediction Techniques," Transportation Research Record 936, Transportation Research Board, National Research Council, Washington, D.C., 1983

Stopher, P.S., "Development of a Route-Level Patronage Forecasting Method," Transportation, Vol. 19, No. 3, 1992

Peng, Z.-R., et al., "A Simultaneous Route-Level Transit Patronage Model: Demand, Supply, and Inter-Route Relationship," Transportation, Vol. 24, No. 2, May 1997

T-BEST (Transit Boardings Estimation and Simulation Tool), Florida Department of Transportation, Tallahassee [Online]. Available: www.tbest.org [accessed Feb. 15, 2006].

Chu, X., et al., "A Framework of Modeling and Forecasting Stop-Level Transit Patronage," Presented at the 52nd Annual North American Meeting of the Regional Science Association International, Las Vegas, Nev., Nov. 10–12, 2005.

Pendyala, R.M., I. Ubaka, and N. Sivaneswaran, "Geographic Information System-Based Regional Transit Feasibility Analysis and Simulation Tool, Transportation Research Record 1799, Transportation Research Board, National Research Council, Washington, D.C., 2002

Lane, C., M. DiCarlantonio, and L. Usvyat, "Sketch Models to Forecast Commuter and Light Rail Ridership: Update to TCRP Report 16," Presented at the 85th Annual Meeting of the Transportation Research Board, Washington, D.C., Jan. 22–26, 2006.

Parsons, Brinckerhoff, Quade & Douglas, Inc., et al., "Commuter and Light Rail Transit Corridors: The Land Use Connection," TCRP Report 16: Transit and Urban Form, Vol. I, Part II, Transportation Research Board, National Research Council, Washington, D.C., Mar. 1996.

Marshall, N. and B. Grady, "Sketch Transit Modeling Based on 2000 Census Data," Presented at the 85th Annual Meeting of the Transportation Research Board, Washington, D.C., Jan. 22–26, 2006.

Box G. E. P. and Tiao G. C. "Intervention analysis with application to economic and environmental problems", J. Am. Statistical Assoc. 70. 70-79, 1975

Kyte M., Stoner J. and Cryer J. "A Time-Series Analysis of Public Transit Ridership in Portland, Oregon, 1971-1982”, Transportation Research Part A: General, Vol.22(5), 1988

Daniel Boyle, and Associates, 2006. Fixed-Route Transit Ridership Forecasting Service Planning Methods, Transportation Research Board，Washington, D.C., 2006

CTA Ridership Data: https://data.cityofchicago.org/Transportation/CTA-Ridership-Daily-Boarding-Totals/6iiy-9s97

Weather Data from Jan. 2012 to Jan. 2014: http://www.wunderground.com/history/airport/KMDW/2012/1/1/CustomHistory.html?dayend=1&monthend=1&yearend=2014&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=

Introduction of Chicago Transit Authority: http://www.transitchicago.com/about/overview.aspx

Development of a Traffic Demand Prediction Model for a Transport Corridor Based on Multivariate Regression Analysis

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Abstract: In general, traffic demand regression analysis is conducted independently on a certain path of transport corridor with little consideration about the effects from other adjacent paths which have the same directions. Separate multivariate linear regression analysis and that of multiple dependent variables are conducted respectively based on research data of two paths of traffic corridor between Shenyang and Shanhaiguan. Analysis results indicate that associative regression prediction has higher accuracy than separate regression prediction. Research results of this paper provide a more accurate theoretical calculation method for transport corridor traffic demand prediction in practical engineering projects.
Keywords: Transport corridor; Traffic demand prediction; Multivariate regression.

1 Introduction

Predictions separately in each direction or OD-based four-step prediction method are usually adopted to forecast traffic demand in regional transport corridors. Prediction values of the former method are prediction values of perspective traffic of corridors under planning research which are aggregated from quantitative predictions of basic traffic, diverted traffic and induced traffic of the corridors in future years. However, interaction effects among several paths of a corridor are not taken into consideration in predictions separately in each direction. Four-step prediction method is a prediction method which developed during studying urban transportation planning and is widely utilized in urban transportation planning, but it is not suitable for corridor traffic demand prediction because of the significant difference between urban traffic and regional transport corridor traffic. To be specific, directional distribution of traffic flow in urban traffic is complicated with high divergence where traffic flow in corridor has simple directional distribution. Besides, numerous paths from O to D are available for travelers to select in urban traffic systems where the paths in corridor are commonly fixed with little choice for traveler.

In previous studies, with adequate consideration about influence factors on traffic demand, Li (2006) determined correlations between traffic demand and influences on it such as social events and economic development, forecast gross traffic demand according to the correlation coefficient, and obtained traffic volumes of feasible paths using attracting weight and logit assignment method. Zhu (2007) studied common methods of passenger traffic demand prediction and introduced thought, methods and models of corridor passenger traffic demand prediction based on the special characteristics of corridor passenger traffic. He also developed game theory model and fuzzy synthetic evaluation model through corridor competition analysis. Li et al. (2013) built a prediction model on diverted traffic and induced traffic of freeways under reconstruction and expansion. Based on the actual situation, PHAN et al.（2009）combined advantages with the existing freeway y traffic forecasting, respectively according to the original channel within the traffic demand of natural growth, induced by the new high-speed traffic and other traffic in the path of the transfer of these 3 aspects of forecasting, and made different sensitivity analysis on current toll level on expressway. Multivariate linear regression prediction of multiple dependent variables will be adopted to forecast traffic demand of transport corridors in this paper.

2 Model development

2.1 Models

In this paper, Transport corridor is comprised of several paths sharing the same origin and destination, serving large traffic flow and passing through almost the same locations according to the definition giving by Zhu (2007).

Influence factors on traffic demand need to be determined before forecasting traffic demand of transport corridors. Consulting general influence factors on traffic demand (Wang, 2007) and considering requirements of this study and characteristics of transport corridors, the following factors are selected to do regression analysis:

- Road grade

Multiple paths with the same origin, destination, and direction are the study targets which have particular correlation when forecasting traffic demand. Road grade has such significant influences on traffic demand that it needs to be considered.

- Area

Different areas between the origin and destination passed by a path don't always raise the same traffic demand. Thus, effects on traffic demand caused by areas should not be neglected.

- Population

People is one of basic elements of transportation. It is inevitable that the variation of resident population could affect aggregate traffic demand.

- GDP

Transportation is a category of derived demand, a large proportion of which belongs to productive and working transportation demand. Higher regional economic development level could generate larger demand of these categories. Besides, regional economic development influences income and consumption level of inhabitants which cause variation of living transportation demand. Thus, regional economic development level has great impacts on traffic demand. Generally, GDP is adopted to estimate the economic development level.

- Lanes

Lanes have direct effect on traffic demand. Specifically, more lanes could provide larger service traffic volume and less lanes may result in less traffic demand.

- Distance from location of data detector on the road to downtown

In addition to resident population and regional GDP, distance from downtown (areas with high population density and economic level) to location of data collectors on roads has an impact on path selection propensity of travelers.

- Others

Large number of unknown factors affecting traffic demand of corridors makes it unable to list them in detail. One variable is used here to represent all other unknown influence factors.

In traffic demand prediction, regression prediction method is to establish regression equations through discovering statistical regularities among prediction objects and their influence factors. As a relatively scientific prediction method, it could analyze major influence factors of prediction objects concretely and do statistical tests on rationality of models and reliability of prediction. The precondition of applying regression models is that traffic volumes have high sensitivity to explanatory variables. With inappropriate explanatory variables, fake regressive phenomenon would arises easily and multicollinearity could exist in multivariate linear regression. This study is based on sufficient data from two paths of traffic corridor between Shenyang and Shanhaiguan and conducts separate and associative multivariate linear regression analysis.

2.2 Model development

A hypothesis is made that the multivariate linear regression equation, which traffic volume of Path 1 and its road grade, number of lanes, regional resident population, regional GDP, and distance from downtown satisfy, is Eq.(1). The equation that Path 2 satisfies could be expressed as Eq.(2). Eq.(3) denotes the associative multivariate linear regression equation that Path 1 and Path 2 satisfy.

$$y_1 = b_{10} + b_{11}x_{11} + b_{12}x_{12} + b_{13}x_{13} + b_{14}x_{14} + b_{15}x_{15} + \varepsilon_1 \quad (1)$$

where: y_1 = traffic volume of Path 1;

$x_{11} \sim x_{15}$ = respectively represents road grade, number of lanes, regional resident population, regional GDP, and distance from downtown of Path 1;

$b_{10} \sim b_{15}$ = undetermined coefficients;

ε_1 = random error, $\varepsilon_1 \sim N(0,\sigma^2)$.

$$y_2 = b_{20} + b_{21}x_{21} + b_{22}x_{22} + b_{23}x_{23} + b_{24}x_{24} + b_{25}x_{25} + \varepsilon_2 \quad (2)$$

where: y_2 = traffic volume of Path 2;

$x_{21} \sim x_{25}$ = respectively represents road grade, number of lanes, regional resident population, regional GDP, and distance from downtown of Path 1;

$b_{20} \sim b_{25}$ = undetermined coefficients;

ε_2 = random error, $\varepsilon_2 \sim N(0, \sigma^2)$, ε_2 and ε_2 are independent of each other.

$$\begin{cases} y_1 = b_{10} + b_{11}x_{11} + b_{12}x_{12} + b_{13}x_{13} + b_{14}x_{14} + b_{15}x_{15} + \varepsilon_1 + \theta \\ y_2 = b_{20} + b_{21}x_{21} + b_{22}x_{22} + b_{23}x_{23} + b_{24}x_{24} + b_{25}x_{25} + \varepsilon_2 + \theta \end{cases} \quad (3)$$

where: θ = the variable that represents all other unknown variables which affect correlations between y_1 and y_2. Its value varies with variation of areas. $\theta \sim N(0, \sigma_\theta^2)$. Concrete meanings of other variables are the same with above but ε_1 and ε_2 are not independent of each other.

Obviously, $y_1 \sim N(\beta_1 x_1, \sigma_1^2)$, $y_2 \sim N(\beta_2 x_2, \sigma_2^2)$, where $\beta_1 = (b_{10}, b_{11}, b_{12}, b_{13}, b_{14}, b_{15})$, $x_1 = (1, x_{11}, x_{12}, x_{13}, x_{14}, x_{15})$, $\beta_2 = (b_{20}, b_{21}, b_{22}, b_{23}, b_{24}, b_{25})$, $x_2 = (1, x_{21}, x_{22}, x_{23}, x_{24}, x_{25})$. The value of θ varies upon different areas and the corresponding estimated values of y_1 and y_2 varies as well. y_1 and y_2 obey associative bivariate normal distribution, which is given as $(Y_1, Y_2) \sim N(\mu_1, \mu_2, \sigma_1^2, \sigma_2^2, \rho)$.

3 Model calculation

On the basis of field data of over the years, separate and associative multivariate linear regression analysis are conducted respectively between traffic volumes of two paths and their road grades, numbers of lanes, regional resident population, regional GDP, and distances from downtown, with 5% significance level. Regression calculation results are illustrated in Table 1and Table 2.

As shown in Table 1, the correlation coefficient of associative multivariate linear regression equation is 0.8628, which means that multivariate linear regression equations of two paths have high correlation with 5% significance level. Judging from parameters prediction results, x_{22} is ruled out due to the absence of prediction value of b_{22}, which indicates that there is no significant linear relation between traffic volume of Path 2 and its number of lanes since Path 2 has the same number of lanes in all field research areas. Positive value of a coefficient indicates a positive correlation between traffic demand and these parameters where negative value indicated a negative correlation. To be specific, the traffic volume of Path 1 rises with the increase of its road grade, number of lanes, and regional *GDP* as well as the decrease of regional resident population and distance from downtown. Besides, the traffic volume of Path 2 rises with the increase of its road grade and regional *GDP* as well as the decrease of regional resident population and the distance from downtown. Note that traffic demand reduces with the growth of regional resident population of areas where a path passes through. Fig.1 illustrates the scatter diagram of traffic demand and resident population. A conclusion could be drawn that traffic demand and resident population have no significant linear relation but a general negative correlation. It is the major reason for this distortion that there is no large population in the area where

Table 1. Estimation results of associative multivariate linear regression equation parameters

Coefficients	*Mean*	*Variance*	2.50%	Median	97.50%
b_{10}	1819	978	-88.55	1810	3685
b_{20}	-1657	965.7	-3631	-1627	187.3
b_{11}	1757	970.3	-150.9	1727	3741
b_{21}	6.195	1003	-1930	-2.237	1986
b_{12}	10230	465.1	9273	10240	11080
b_{13}	-107.4	22.85	-139.3	-113.6	-56.55
b_{23}	-41.92	20.59	-74.45	-46.26	0.2759
b_{14}	6.202	0.9095	4.314	6.245	7.817
b_{24}	6.129	0.8559	4.548	6.093	7.929
b_{15}	-27.69	23.48	-71.77	-27.96	18.71
b_{25}	-51.26	15.21	-82.03	-51.29	-21.14
correlation	0.8628	0.1099	0.5644	0.8967	0.9822
σ^2	5.64E+07	4.23E+06	4.87E+07	5.62E+07	6.51E+07
σ_θ^2	7.63E+08	1.24E+09	7.51E+07	4.88E+08	3.06E+09

Table 2. Estimation results of separate multivariate linear regression equation parameters

Coefficients	*Mean*	*Variance*	2.50%	Median	97.50%
b_{10}	1544	994.6	-389.2	1559	3460
b_{20}	1135	941.5	-672.5	1142	2970
b_{11}	1594	989.7	-326.8	1587	3526
b_{21}	12.87	994.7	-1934	-13.28	1977
b_{12}	9354	388.7	8576	9352	10120
b_{13}	-0.2246	8.094	-16.21	0.1211	14.8
b_{23}	18.95	5.603	7.953	18.83	30
b_{14}	-3.201	0.9354	-4.965	-3.24	-1.368
b_{24}	1.655	0.8918	-0.1064	1.659	3.355
b_{15}	-48.37	27.96	-104.2	-48.24	4.998
b_{25}	-4.892	17.79	-41.11	-4.88	29.53

The segment with the highest traffic demand of the path. This distortion manifests as high traffic demand in areas with little population and low traffic demand in areas with large population. Apart from this, regional resident population continues to increase with decreasing growth rate. Traffic demand of paths are influenced by multiple factors, contributing to wider fluctuation. Thus, it is believable that regression models have relatively high reliability with introduction of θ and other influence factors.

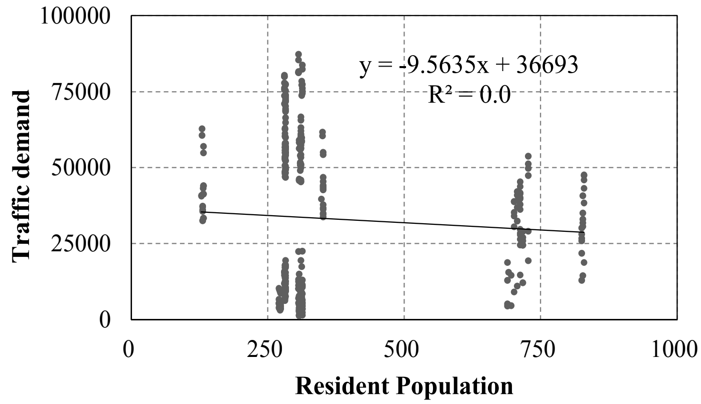

Figure 1. The scatter diagram of traffic demand-resident population

4 Regression prediction and comparative analysis

Traffic demand predictions are conducted using the associative multivariate linear regression equation obtained from Table 1. The comparative analysis results of predicted values and measured values are shown in Fig.2; Traffic demand predictions are conducted using separate multivariate linear regression equations obtained from Table 2. The comparative analysis results of predicted values and measured values are shown in Fig.3. According to Fig. 2 and Fig.3, the square of the correlation coefficient of the prediction results of the associative regression equation and measured values R^2=0.9095, which is approximately 1(when prediction values exactly match to measured values). It suggests that the prediction results of the associative multivariate linear regression equation are in good agreement with the measured value. Whereas, the square of the correlation coefficient of the prediction results of separate regression equations and measured values R^2=0.8368, which shows relatively poor prediction performance. The accuracy of associative prediction can be computed as *e*=1-|predicted value- measured value|/measured value =1-0.305955349=0.694044651 and the accuracy of separate prediction can be computed as *e* =1-0.362926922=0.637073078. Thus, applying associative prediction could improve prediction accuracy by 5.7%.

5 Conclusion and prospect

This paper firstly analyzes influence factors of regional transport corridor traffic demand and establishes the separate multivariate regression model and associative multivariate regression model based on those factors. Then calibration of regression models are conducted with field data of two paths of traffic corridor between Shenyang and Shanhaiguan. Calibrated models are applied finally to forecast traffic demand. Results of comparative analysis indicates that associative regression prediction has higher prediction accuracy than separate regression prediction. Only part of influence factors are selected in the analysis and numerous unknown factors have impacts on accuracy of regression prediction and correlation among multiple paths. To obtain higher accuracy, more influence factors will be analyzed and taken into consideration of model development in sequential studies. In practical engineering application, there are always multiple paths in a corridor in multiple traffic modes and what effects the correlations among various traffic modes have on demand prediction will be proposed in another paper.

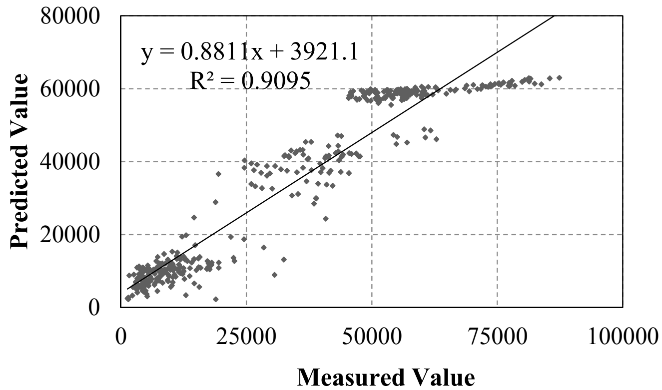

Figure 2. Prediction results of associative regression

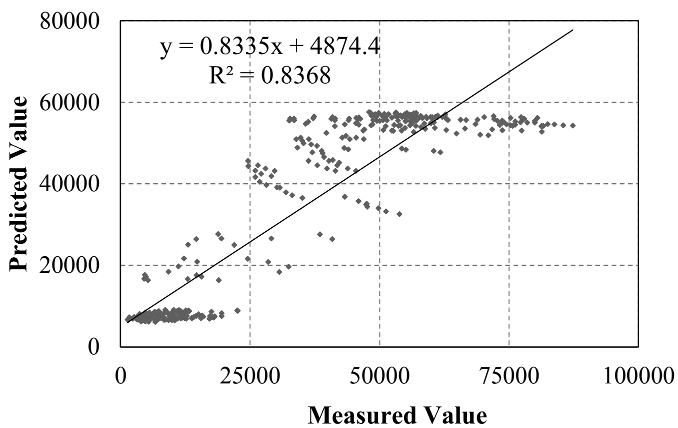

Figure 3. Prediction results of separate regression

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References

Huang Y.T., Zhu N., Liao Y.R., Zhang L.Q., (2013). “Superiority Discrimination of Principal Component Prediction in the Multivariate Linear Model with Multiple Dependent Variables,” *Journal of Guilin University of Electronic Technology*, Vol.33, No.5, pp 412-415.

Li J. (2006). “Application of Correlation Coefficient Method for Corridor Traffic Demand Forecast,” *China Journal of Highway and Transport,* Vol.19, No.5, pp 98-101, Sept.
Li X., Hu H.C., Chen Z.Y. (2013). “Traffic Demand Prediction of the Reconstruction and Extension of Expressway,” *China Venture Capital*, pp 230 & 252.
Phan H.N., Luo X., Lei L. (2009). “Traffic Demand Forecasting for Kunming-Haiphong Transport Corridor (Hanoi – Laocai Expressway),” *International Conference on Transportation Engineering 2009 (ICTE 2009)*, pp 3207-3212.
Wang W., Chen X.W., (2007). “Transportation Planning,” Beijing: China Communications Press, pp 38-75.
Yue Z. (1993). “Associative Influence Analysis in Multivariate Linear Regression,” *Journal of Shanxi Teacher’s University (Natural Science Edition)*, Vol.7, No.2, pp 6-9.
Zhu X.H. (2007). “Corridor Passenger Transportation Demand Analysis,” Chengdu: Southwest Jiaotong University.

Transport Priority and Economic Growth in China's Ethnic Area: A Case Study of Guizhou Province

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Abstract: It is an important item to assess the effects of west transportation improvement on economic growth in China's Ethnic Area. Our findings show that local economy growth doesn't benefit from transportation improvement in Guizhou ethnic area. That is to say, the effects of transportation improvement are fully spilled. Although the transportation costs of households and firms are reduced by transportation improvement, the flow of production factors (population mobility & movement of goods) are one-way from ethnic area to developed region. On this condition, transportation improvement has negative spatial spillover effects to the economic development in ethnic area.

Keywords: Transportation improvement; Economic growth; Spatial spillover effects.

1 Introduction

The ethnic area in Guizhou Province is a typical Karsts region in southwestern China. which are not littoral or riparian or border areas. The dirt road and mountain road have been the bottleneck of local development.

As transport priority in western development strategy has been implementing, the transportation infrastructure construction in Guizhou ethnic area has acquired a real breakthrough. Fixed asset investment across the region totaled 4006.95 trillion Yuan during ten years (2001 to 2011). The total mileage of highway reached up to 80145km and all the countries and villages have been connected by the oil way or high way. In particular, the total mileage of expressway are from 0km on 1988 to 1978km on 2014. For example, 234 townships in Qiannan autonomous prefecture have been connected by oil, accounting for 97.1 percent of total 241 townships. and 796 villages have been connected by oil, 1542 villages have been connected by highway, accounting for 33.6 and 98.94 percent of total 2363 villages respectively (Tao Mouli, 2014). The huge transport investment and the strong economic growth did not existed in history, the accessibility and the convenience level have been improved significantly in all ethnic areas.

At the same time, the economy in Guizhou ethnic area grew rapidly. GNP are rising from 314.49 trillion Yuan on 2000 to 1560.5 trillion Yuan on 2011. For example, PGDP in Qiannan autonomous prefecture break through the $1000 mark firstly on 2010, and GDP increased to 312.57 trillion Yuan with average annual growth rate of 12.7% during the period of "the 11th five year plan", which is 2%

higher than the rate in the period of "the 10^{th} five year plan" and exceeded the average growth level of the corresponding period in Guizhou province.

However, to what extent did the economical growth benefit from the transportation improvement in Guizhou ethic area? it is no doubt that this question is the crucial issue for people.

It is well known that the development economical theory which used to be popular, such as "big-push" theory (Rodan, 1943), "economic take-off" theory (Rostow., 1960) regard transportation improvement as the precondition of economical growth in less developed region. World Bank Report also pointed out that transportation improvement was pioneer capital for economic development in developing country (World Bank, 1994). Furthermore, Aschauer (1989) once computed the output elasticity of transportation improvement for economical growth using neoclassical economical model, and the result was 0.39.

However, Tatom (1991) and Holtz-Eakin (1994) had queried if the result is reasonable. They thought that diversity in different cross-section data were not involved in neoclassical economical growth model, so it was inappropriate when computing output elasticity based solely on time series data. Banister and Berechman (2001), their research shown that transport infrastructure investment acted as a complement to other more important underlying conditions, including economic externalities, investment factors, and political factors, which must also be met if further economic development is to take place.

In a word, the relationship between transportation improvement and economical growth is neither unidirectional causality nor simple linearity. Thus how about the relationship in Guizhou ethnic area? It is no doubt that this question has unique meaning in theory and reality especially on the day when Go-west Campaign has last more than one decade.

The organization of the paper is as follows. Section 2 gives 6 key variables to measure transportation improvement and economical growth, and presents its statistical descriptions. Section 3 are data analysis, including co-integration analysis and Granger Causality Test. Section 4 draw main conclusions.

2 Variable , Data and Description

In this paper we set 6 variables: Passenger-Kilometers (PK,10,000) and Freight Ton-kilometers (FTK) are used to measure transportation improvement. Primary industry GDP (GDP1), Secondary industry GDP (GDP2), Tertiary industry (GDP3) and Total GDP (GDP), those variables are used to measure economical growth. All data comes from Guizhou Statistical Yearbook (1992-2011) and Transport Yearbook (1992-2011). So why we choose these variables and the period from 1992 to 2011? the reasons are just as the data of variables is continuous and 2000 is the time when western development strategy was issued. To describe above 6 variables, time series plot were given as Figure1, Figure 2, Figure 3.

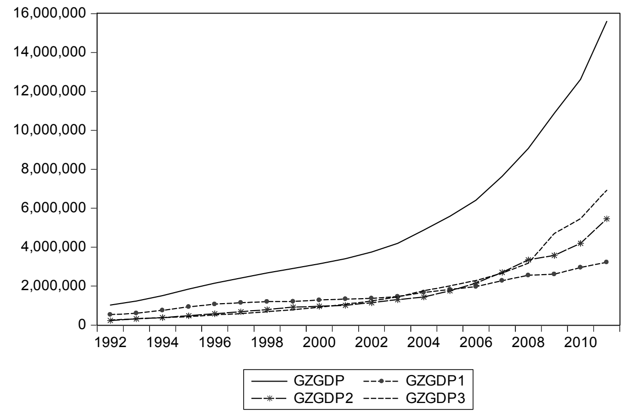

Figure 1. Time Series Plot of GDP

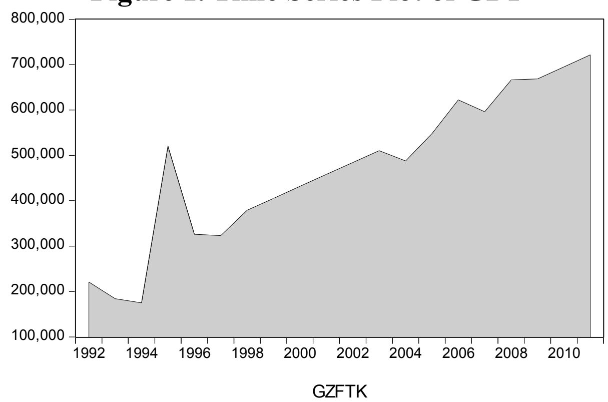

Figure 2. Time Series Plot of FTK

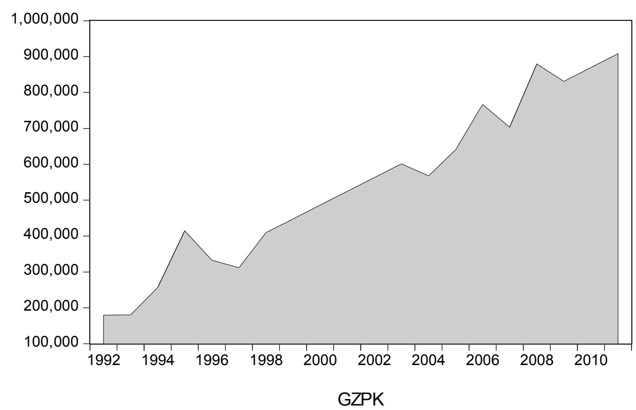

Figure 3. Time Series Plot of PK

From figure1, figure2 and figure3, we can speculate that all the time series are not stationary.

3 Data Analysis

3.1 Unit root test

As time series are not stationary, So unit root test should be used firstly. To make time series more stationary, we take logarithm of variables and record them as LogFTK, LogPK, LogGDP1, LogGDP2,LogGDP3, LogGDP. we apply ADF to test whether a time series is stationary by Eviews 7.0 (similarly hereinafter). the estimated results of ADF test as follows:

Table 1. ADF Test of LogFTK& LogPK

Null Hypothesis: D(LOGFTK) has a unit root				Null Hypothesis: D(LOGPK) has a unit root			
Exogenous: Constant				Exogenous: Constant			
Lag Length: 1 (Automatic - based on SIC, maxlag=4)				Lag Length:1 (Automatic - based on SIC, maxlag=4)			
		t-Statistic	Prob.*			t-Statistic	Prob.*
ADF test statistic		-5.987927	0.0002	ADF test statistic		-4.973256	0.0012
Test critical values:	1% level	-3.886751		Test critical values:	1% level	-3.886751	
	5% level	-3.052169			5% level	-3.052169	
	10% level	-2.666593			10% level	-2.666593	

*MacKinnon (1996) one-sided p-values.

Table 2. ADF Test of LogGDP1& LogGDP2

Null Hypothesis: D(LOGGDP1) has a unit root				Null Hypothesis: D(LOGGDP2) has a unit root			
Exogenous: Constant				Exogenous: Constant			
Lag Length: 4 (Automatic - based on SIC, maxlag=4)				Lag Length: 0 (Automatic - based on SIC, maxlag=4)			
		t-Statistic	Prob.*			t-Statistic	Prob.*
ADF test statistic		-3.776448	0.0151	ADF test statistic		-3.126374	0.0425
Test critical values:	1% level	-4.004425		Test critical values:	1% level	-3.857386	
	5% level	-3.098896			5% level	-3.040391	
	10% level	-2.690439			10% level	-2.660551	

*MacKinnon (1996) one-sided p-values.

Table 3. ADF Test of LogGDP3& LogGDP

Null Hypothesis: D(LOGGDP3) has a unit root				Null Hypothesis: D(LOGGDP，2) has a unit root			
Exogenous: Constant				Exogenous: Constant			
Lag Length: 0(Automatic - based on SIC, maxlag=4)				Lag Length: 0 (Automatic - based on SIC, maxlag=4)			
		t-Statistic	Prob.*			t-Statistic	Prob.*
ADF test statistic		-3.979571	0.0078	ADF test statistic		-3.059262	0.0493
Test critical values:	1% level	-3.857386		Test critical values:	1% level	-3.886751	
	5% level	-3.040391			5% level	-3.052169	
	10% level	-2.660551			10% level	-2.666593	

*MacKinnon (1996) one-sided p-values.

The results indicate that the time series variables are non-stationary in their levels but stationary in the first differences except for GDP, which is stationary in second differences. That is to say, FTK&GDP1/GDP2/GDP3 or PK &GDP1/GDP2/GDP3 are integrated of order one [I(1)] and confirms the possibility of long run equilibrium relationship between them.

3.2 Co-integration analysis

One aim of this paper is to find whether there are relationships of co- integration between transportation improvement and economical development in Guizhou ethnic area. how to verify co-integration between FTK and GDP1/GDP2/GDP3 or between PK and GDP1/GDP2/GDP3?

Generally, Johansen test and E-G test are two popular methods: The former applies to two variables, and the later applies to multiple variables. This paper test the co-integration between two variables, so chose E-G test:

Do regressions analysis:LogGDP1/logGDP2/logGDP3 as dependent variable, LogPK (or LogFTK) as independent variable, then get time series of residual as following:e1、e2、e3、 e4 、e5、 e6:

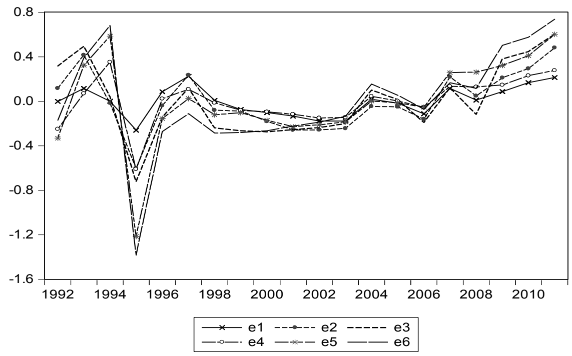

Figure4 Time Series Plot of e1/e2/e3/ e4/e5/ e6

The second step is to test residual to find if they have unit root (Table4-6):

Table 4. Unit root Test of e1/e2

Null Hypothesis : $e_1$has a unit root				Null Hypothesis: $e_2$has a unit root			
Exogenous: None				Exogenous: None			
Lag Length: 0 (Automatic - based on SIC, maxlag=1)				Lag Length: 0 (Automatic - based on SIC, maxlag=1)			
		t-Statistic	Prob.*			t-Statistic	Prob.*
ADF test statistic		-2.533560	0.1237	ADF test statistic		-2.294100	0.1835
Test critical values:	1% level	-3.831511		Test critical values:	1% level	-3.831511	
	5% level	-3.029970			5% level	-3.029970	
	10% level	-2.655194			10% level	-2.655194	

*MacKinnon (1996) one-sided p-values.

Table 5. Unit root Test of e3/ e4

Null Hypothesis: $e_3$has a unit root				Null Hypothesis: $e_4$has a unit root			
Exogenous: None				Exogenous: None			
Lag Length: 0 (Automatic - based on SIC, maxlag=1)				Lag Length: 0 (Automatic - based on SIC, maxlag=1)			
		t-Statistic	Prob.*			t-Statistic	Prob.*
ADF test statistic		-2.130237	0.2359	ADF test statistic		-4.283164	0.0039
Test critical	1% level	-3.831511		Test critical	1% level	-3.831511	

values:	5% level	-3.029970		values:	5% level	-3.029970	
	10% level	-2.655194			10% level	-2.655194	

*MacKinnon (1996) one-sided p-values.

Table 6. Unit root Test of e5/ e6

Null Hypothesis: $e_5$has a unit root				Null Hypothesis: $e_6$has a unit root			
Exogenous: None				Exogenous: None			
Lag Length: 0 (Automatic - based on SIC, maxlag=1)				Lag Length: 0 (Automatic - based on SIC, maxlag=1)			
		t-Statistic	Prob.*			t-Statistic	Prob.*
ADF test statistic		-0.953440	0.7447	ADF test statistic		-3.104423	0.0433
Test critical values:	1% level	-3.886751		Test critical values:	1% level	-3.831511	
	5% level	-3.052169			5% level	-3.029970	
	10% level	-2.666593			10% level	-2.655194	

*MacKinnon (1996) one-sided p-values.

Table4-6 show that the co-integration relationship only exist between FTK and GDP1 (p=0.0039) or between FTK and GDP3 (p=0.0433).

Lastly, establish error correcting model (ECM). the dependent variable is the first difference of GDP1 or GDP3, the independent variables are the first difference of FTK and error correction item e4 $_{（t-1）}$ or e6 $_{（t-1）}$ .then we get the ECM as follows:

$$D\log gdp1 = \text{-3.82E-17} + 1.07\, D\log ftk + e_{4(t-1)} + v_t$$

（p=0.9557）（p=0.0000）（p=0.0000）

$$D\log gdp3 = \text{8.48E-15} + 2.01\, D\log ftk + e_{6(t-1)} + \varepsilon_t$$

（p=0.0018）（p=0.0000）（p=0.0000）

3.3 Granger casualty test

The other aim of this paper is to investigate the direction of causation in the Granger sense between transportation improvement and economical development in Guizhou ethnic area. Table7 show the result of Granger Causality test: no Granger cause between FTK and GDP1/GDP3.

Table7. Granger Causality Test between GDP1/GDP3and FTK

Sample: 1992 2011			
Lags: 2			
Null Hypothesis:	Obs	F-Statistic	Prob.
GDP1 does not Granger Cause FTK	18	3.73564	0.0523
FTK does not Granger Cause GDP1		0.00755	0.9925
GDP3 does not Granger Cause FTK	18	1.53045	0.2530
FTK does not Granger Cause GDP3		0.10864	0.8979

4 Conclusions

All above studies clearly show a paradoxical relationship between economical growth and transportation improvement. Although the co-integration relationship exist between FTK and GDP1 or GDP3. there are no Granger cause between them. In another word, the transportation improvement has no direct effect on local economic growth. the effects of transportation improvement in Guizhou ethnic area are fully spilled. The conclusion suggests that it is a prime topic to turn the negative spatial spillover effects to positive.

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References

Tao Mouli (edit). *Guizhou Statistic Yearbook(1991-2014)*. China Statistic press, 1991/2014.

PP. N. Rosenstein-Rodan. (1943). "Problems of Industrialization of Eastern and South-Eastern Europe", *The Economic Journal*, Vol. 53, No. 210/211. pp. 202-211.

W.W. Rostow. (1960). *The Stages of Economic Growth: A Non-Communist Manifest*o. Cambridge: Cambridge University Press.

World Bank. (1994). *Report of world development*. Beijing: China Financial and Economic Publishing House.

Aschauer D A. (1989). "Is public expenditure productive?" .*Journal of Monetary Economics*, 23(2): 177-200.

Tatom J A. (1991). "Should government spending on capital goods be raised". *Federal Reserve Bank of St. Louis Review*, 73(2): 3-15.

Holtz-Eakin D. (1994). "Public-sector capital and the productivity puzzle". *The Review of Economics and Statistics*, 76(1): 12-21.

D. Banister and Y. Berechman. (2001). "Transport Investment and the Promotion of Economic Growth, " *Journal of Transport Geography*, 9(3): 209-218.

Spatial Spillover Effects of Highway Transport Infrastructure on Economic Growth in Northwest China

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Abstract: The possibility of spatial spillover effects of transport infrastructure on economic growth was examined in Northwest China, which is analyzed based on spatial spillover theory and Cobb - Douglas production function, using panel data from 1990~2012. The results show that: (1) The output coefficient of local road infrastructure on economy in the Northwest is 0.1325, which means that local highway infrastructure plays a significant role in promoting local economic growth. (2) The output coefficient of ecdemic highway infrastructure on local economy is 0.1512, comes to the conclusion that there is a significant positive spillover effect of ecdemic highwayinfrastructure on local economic growth.

Keywords: Highway investment; Economic development; Spatial spillover effects; Northwest China.

1 Introduction

Transport infrastructure investment is a very important means of economic regulation by the government, and important transport infrastructure can cause significant changes in the pattern of economic space, so that the relationship between transport infrastructure and economic growth is still a research focus to economists. The national economy of Northwest China has been developed rapidly since the implementation of the Western Development Strategy, but it is still lagging behind compared with the eastern part of China. With the proposition of Silk Road Economic Belt Strategy, economic and social development of the Northwest region has been concerned widely，however，there is a huge gap between the economic development level of the Northwest and its economic circles at both ends due to the inconvenience of its transport and the poor natural environment. As its complex international environment, highway in Northwest China plays an important role in national economic growth.

Spatial Spillover Effects describes the mechanism of polarization of economic growth in different regions from the aspects of cumulative circulation of supply and demand, which is proposed by New Economic Geography in these years. GDP in all surrounding areas are added together to measure the size of the potential demand of a region's products and services, and is taken as the market potential to examine factors affecting wages in this regions (Gregory, 1994). Holtz-Eakin and Schwartz (1995) firstly started to study the spatial spillover effects of transport infrastructure on economic growth, they built spatial weights matrix and added infrastructure variables in adjacent areas to traditional production function, however, they didn't confirm the existence of the spatial spillover effects. Mas，Maudos (1996) tried to look for spillover effects of infrastructure on regional economic growth using the comparative output elasticity method. Boarnet (1998) collected panel data from 1968~1988 of counties in California and defined different spatial weight matrix, he indicated that there was a strong spatial spillover effects of highway transport infrastructure between adjacent areas. Joseph，Ozbay (2006) verified the spillover effects of transportation of US states, administrative cities and counties using the space measurement methods, he thought that the directly affect of transport infrastructure decreased and the spillover effects of transportation increased with the decrease of the geographical scale.

These years, many domestic scholars studied the spatial spillover effects of transport infrastructure. HU Angang, LIU Shenglong（2009）considered that the annual contribution rate of the sum of direct contribution of China's transport investment and external spillover effects is 13.8%. ZHANG Zhi and ZHOU Hao（2012）pointed out that the spillover effects of China's transport infrastructure worked more through economic ties. LI Fengyue（2013） analyzed the mechanism of spillover effects of transport infrastructure taking counties in Zhejiang province as examples, and explained the way of spillover effects from three dimensions, residents, businesses and regions.

These studies always take the whole China and some developed provinces as research objects, confirms the spillover effects of transport infrastructure on economic growth from different aspects. However, little studies has been down for some backward-developed areas. As for the Northwest region, where economy develop is lagging behind and the strategic position is very important, transportation development relies more on highway which is of high level in accessibility. With the proposition of Silk Road Economic Belt Strategy, an urgent need for economy development is put forward, which makes it an urgent problem to be clear of the model and degree of the impact of transport infrastructure on economic growth. As a result, it is very significant for guiding the layout and construction of highway and is very meaningful for social and economic development in the Northwest to study on the promotion of highway transport on economic growth and revealing its spillover effects.

2 Basic model

2.1 Basic model theory

Cobb-Douglas production function is used to analyze the relationship between highway transport infrastructure and economic growth. Capital investment (K) is decomposed into two parts, one is the highway infrastructure investment in the region (K), another is the capital investment except the highway infrastructure stock in the region (TR). In addition, highway infrastructure investment in other regions (OTR) is also joined in to build Cobb-Douglas production function, which is converted to the following relationship formula:

$$\ln Y = \alpha_1 \ln L + \alpha_2 \ln K + \alpha_3 \ln TR + \alpha_4 \ln OTR + C + \varepsilon_t \qquad (1)$$

In this formula, Y stands for output within the region, which reflects the economic growth in the region; L stands for local human capital investment, α_1 stands for elasticity of labor force output; α_2 stands for elasticity of capital output except highway transport infrastructure in the region; α_3 stands for elasticity of input and output of highway transport infrastructure in the region; α_4 stands for elasticity of input and output of highway transport infrastructure in other regions.

An only-individuals-affected panel data model including time dummy variables is built as follows:

$$\ln Y = \alpha_1 \ln L_{it} + \alpha_2 \ln K_{it} + \alpha_3 \ln TR_{it} + \alpha_4 \ln OTR_{it} + C + \varepsilon_t \qquad (2)$$

ε_t is assumed as classical error term: the mean value is zero and the variances are the same, there is no relevant sections of related time series. That is to say, there is no correlation exists when the error term is between different individuals or at different times.

2.2 Model verification method

Panel data structure is built to analyze time series of the five provinces in the Northwest in different years. The sample contains information in three directions, individual, indicators and time (Balgagi, 2001). Variable intercept model is often used to represent the individual differences existed in individual causes when building the model. Individual effects is divided into two forms, the fixed effects and the stochastic effects. The impact is analyzed using the fixed effects estimation method and the stochastic effects estimation method. F Test is used to decide whether to use the hybrid model or the fixed effects model, then Hausman Test is used to make sure whether to establish a random effects model or a fixed effects model.

3. Variables selection and data processing

3.1 Variables selection

Relevant variables are used as substitutions in order to study the spatial spillover effects of highway transport infrastructure on economic growth in Northwest China.

GDP is taken as output value as it stands for the value of all final goods and labor force produced by the economy in a region or a country.

The number of overall employments, which can be obtained directly from Statistical Yearbook, is taken to represent labor force investment of a region.

In traditional Cobb-Douglas production function, highway equivalent mileage is obtained by weighted conversion based on traffic volume. However, as different levels of highway have different functions and service objects, this method can't reflect the differences of the proportion of GDP produced by different levels of highway to transport, also can't reflect the investment of highway infrastructure accurately (Jeffrey, 2010). As a result, the amount of highway infrastructure investment is accumulated annually to get the capital stock of highway infrastructure in the current year. In data processing, annual highway investment is transformed into constant prices of 1990 to calculate the highway infrastructure investment in the Northwest from1990~2012.

The whole social capital stock (removal of the part of highway infrastructure stock) is taken to represent capital investment except the capital stock of highway infrastructure.

3.2 Calculation of spatial weight matrix

Based on the purpose of the study, the binary adjacency matrix of the five capitals in the Northwest is built.

Referring to the relevant researches, the binary adjacency matrix is built as follows: If two provinces are contiguous (sharing a common boundary length), the corresponding weight element value is 1; On the contrary, if they are not (no common border length), then the corresponding weight element value is 0.

$$w_{ij} = \begin{cases} 1 & \textit{when} \text{ i and j are contiguous} \\ 0 & \textit{when} \text{ i = j or they are not contiguous} \end{cases}$$

In which, $i, j \in [1, N]$, i, j are serial numbers of space unit, N is the quantity of space unit.

The first row to the fifth row represents Gansu, Shaanxi, Qinghai, Ningxia, and Xinjiang respectively, then the matrix is standardized so that the sum of the elements in every row is equal to 1. The final matrix is as follows.

$$w_{ij} = \begin{bmatrix} 0 & \frac{1}{4} & \frac{1}{4} & \frac{1}{4} & \frac{1}{4} \\ \frac{1}{2} & 0 & 0 & \frac{1}{2} & 0 \\ \frac{1}{2} & 0 & 0 & 0 & \frac{1}{2} \\ \frac{1}{2} & \frac{1}{2} & 0 & 0 & 0 \\ \frac{1}{2} & 0 & \frac{1}{2} & 0 & 0 \end{bmatrix}$$

4. Empirical analysis

According to the previous modeling analysis, the sectional data of GDP, labor investment, highway infrastructure investment and capital investment except the capital stock of highway infrastructure in the Northwest from 1990 to 2012 are collected. Then the consolidated data series are established by EViews, and the compiled data are analyzed using regression method. The results are shown in Table 1.

Table 1. Results of the analysis of spatial spillover effects based on the binary adjacency matrix in the Northwest

Dependent Variable: Q		Method: Pooled Least Squares		
Sample: 1990 2012		Included Observations: 23		
Cross-sections included: 5		Total pool (banlanced) observation: 115		
Variable	Coefficient	Std.Error	t-Statistic	Prob
L	0.517083	0.569726	0.907637	0.3669
K	0.206349	0.180790	1.141373	0.2573
TR	0.132547	0.132032	1.003860	0.3178
OTR	0.151206	0.265161	0.570102	0.5703
C	-0.120751	3.596924	-0.033571	0.9733
Fixed Effects(Cross)				
_GS-C	-0.254403			
_SX-C	0.199262			
_QH-C	-0.380281			
_NX-C	-0.25989			
_XJ-C	0.461410			

The results are calculated by panel data OLS, the fixed effects and the stochastic effects. The conclusion is that the fixed effects should be used. The estimation results are shown in Table 2.

Table 2. Estimation results of the binary adjacency matrix model (1990~2012)

spillover effects	variables	panel data OLS	panel data fixed effects	panel data stochastic effects	test results
W_{con}	labor	0.358619 3.095739	0.517133 0.907687	0.378333 3.121823	From the result of fixed effects model Wald, stochastic effects model L and test Huasman , fixed effects should be used.
	Capital stock except for highway	0.281929 3.229871	0.206349 1.141373	0.278346 3.153858	
	Highway investment	0.363875 5.184601	0.132516 1.003670	0.336984 4.697073	
	W_{con}	-0.289798 -4.972228	0.151150 0.570032	-0.263612 -4.264511	
	Constant term	1.301204 3.180545	-0.120751 -0.033571	1.192487 2.679655	
	R^2	0.868028	0.946806	0.843112	

Model estimation results:

$$\ln Y = 0.517083 \ln L + 0.206349 \ln K + 0.132547 \ln TR + 0.151206 \ln OTR - 0.120751$$

（0.907637） （1.141373） （1.003860） （0.570102）
（-0.033571）

$R^2 = 0.946806$ $\overline{R^2} = 0.927209$ F=48.31221

The model estimation results indicate that when the assuming of other variables is constant, GDP grows 0.517083% when labor force input increases 1%; GDP grows 0.206349% when capital stock increases 1%; GDP grows 0.132547% when local highway infrastructure investment increases 1%,; and GDP grows 0.151206% when ecdemic highway infrastructure investment increases 1%. From these results we can see that highway infrastructure investment plays an important role in promoting local economic development, and the spillover effects of ecdemic highway infrastructure investment on local economic development is also obvious.

Goodness of fit can be obtained from the regression model results: $R^2 = 0.946806$, corrected coefficient of determination is $\overline{R^2} = 0.927209$, which shows that the sample fits the model well.

As to H_0: $\beta_2 = \beta_3 = \beta_4 = 0$, the given significant level is $\alpha = 0.05$, and the critical value of freedom k-1=3 and n-k=18 identified in the F distribution table is F(3,18)=3.16. Based on the F=48.31221 in the table, F> F(3,18)=3.16, therefore the null hypothesis is rejected, which means that the regression equation is significant. As a result, labor force input, capital stock and highway infrastructure stock together have a significant effect on GDP.

5. Conclusion

Here we may draw the following conclusions.

(1) As an important part of social capital stock, local highway infrastructure plays a significant role in promoting local economic growth. The output coefficient of local road infrastructure on economy in the Northwest is 0.1325, which is higher than the results obtained by economists using panel data of China. It's mainly caused by the relatively backward infrastructure capital stock of Northwest China.

(2)There is a significant positive spillover effect of ecdemic highway infrastructure on local economic growth. The output coefficient of ecdemic highway infrastructure on economy is positive, which mainly works between neighboring provinces. The higher the supply capacity of national and provincial highway between them is, the stronger the positive spillover effect will be, and the higher the correlation about economic growth between them will be.

References

Boarnet, M. G. Spillovers and the Locational Effects of Public Infrastructure. *Journal of Regional Science*, 38: 381–400.

Balgagi, B.H. Econometric Analysis of Panel Data (second edition). John Wiley & Sons, Chichester, United Kingdom, 2001.

Edward Calthropa. Cost-benefit analysis of transport investments in distorted economies. Transportation Research Part B, 2010, (44):850–869.

Gregory K.Ingram. World development report 1994: infrastructure for development (R)U.S. :Oxford University Press,1994.

Holtz-Eakin, D. and A.E. Schwartz, "Infrastructure in a Structural Model of Economic Growth," Regional Science and Urban Economics, 1995: 131 – 151

HU Angang, LIU Shenglong. Transportation, economic growth and spillover effects——based on the the results of spatial econometric of China's provincial data. Industrial Economy in China, 2009, (5): 5-14.

Jeffrey P. Cohen. The broader effects of transportation infrastructure: Spatial econometrics and productivity approaches. Transportation Research Part E, 2010, (46):317–326.

LI Fengyue. Space spillover effects of transportation infrastructure on regional economy——taking Zhejiang province as an example. Zhejiang Institute of

Finance, 2013.
Maudos, M.J. et al. Infrastructures and Productivity in the Spanish Regions. Regional Studies, Taylor and Francis Journals, 1996, 30(7): 641-649.
ZHANG Zhi, ZHOU Hao. Spillover effects of transport infrastructure and industry differences. Economics, 2012, 38(3): 124-133.

Legislation of Chinese Urban Public Transport

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Abstract: At present, China's urban public transport development cannot adapt to economic and social development, the majority of urban public transportation proportion is low with accelerating urbanization, growing urban population, the trend of an integral of urban and rural has become more and more obvious and the problems of urban public transport are increasingly prominent. And improving legal system of urban public transport is the basic guarantee for the healthy development. This paper will study the legislation of China's urban public transport administrative regulations in depth.

Keywords: Public management; Public transport priority; Legislation of China Urban Public transport.

1 Introduction

At present, China's urban public transport development cannot adapt to economic and social development and people's travel needs, the majority of city public transportation proportion is low. In order to fundamentally ease traffic congestion, travel inconvenience, environmental pollution, contradiction, must establish the public transport priority development ideas. Bus priority is the important content of current our country to determine the city traffic development strategy, it is the inevitable choice to solve the traffic problems in our city. Implementation of bus priority development is the important content of government public management, but how to implement, implementation of bus priority, the city government is still in the exploratory stage.

2 Legislative principles

Legislation of China urban public transport is benefit for people. In order to ensure the correct direction of public transportation development of book industry, public transportation legislation should adhere to the following basic principles .

(1) The principle of unity of coordination

Because of the laws and regulations of our country is composed of legal norm effectiveness rating of multi-level, each are not identical, this is no exception in field bus legislation. Therefore, public transportation legislation must pay attention to the harmonization and unification of the whole system of laws and regulations, except the. Level coordination between unified legal norms.

(2) The principle of social justice

Urban public transportation legislation in particular should highlight the principle of social justice. Its connotation includes two aspects: On the one hand, generation fair; On the other hand, intergenerational equity. By emphasizing the importance of the priority development of public transport, promoting low carbon travel, protect the natural ecological environment, maintenance of the earth quality, so that future generations of people can enjoy fairly and contemporary people of earth mass.

(3) The principle of public participation

In order to make the public development truly realize "people-oriented", "public transportation legislation process must follow the principle of public participation, to keep the Democratic legislation. In the United States, in order to ensure public participation in the content of the adoption and enforcement of good government provisions, any traffic (including public transport project to obtain), federal government capital funding, we must ensure that the project is to attract the public and stakeholder participation, is a comprehensive, coordinated and continuous the planning process.

3 Legislative system

At present, in the field of traffic is not independent and complete public transportation method. About public traffic regulations are relatively more, such as the "Ministry of construction on the development of urban public transport priority views" (Ministry of construction, 2004), the "urban public steam tram passenger management approach" (Ministry of construction, 2005), "on the development of urban public transport priority of several economic policy advice" (Ministry of construction and other ministries. "The State Council on 2006), the urban public transport priority development guidance" (State Council, 2012), these rules are introduced to guide China's urban public traffic construction plays an important role in guiding policy.

Because our country is vast in territory, the urban development is great, can not solve all the problems of urban public transport regulations by a public transportation method, thus the public traffic law should include the guiding opinions and suggestions to the local public transport regulations, so as to provide basis for the formulation of laws and regulations of local government policy. The main should be reflected in the local laws and regulations of the content, depth equirements, such as the bus operating range, quality of service, freight, specific measures of administration of authorization.

4 The content of legislation

Mature foreign legislative experience of public traffic, and fully consider the present situation and development of China's public transit legislation situation, city public transportation legislation in China should include the following several aspects.

(1) The nature and status of urban public transit industry

Should the public nature of clear city public transportation. In the city traffic system, as the public transport has the advantages of high efficiency, environmental protection, economy, fairness properties, has a major role in alleviating traffic congestion in the city, to meet the public demand for travel, Protect environment, energy conservation, the promotion of city traffic sustainable development. Therefore, we should establish the priority of city public traffic in city traffic development, as well as its in passenger traffic of city of the dominant position in the overall city public traffic mode; clear requirements, form the core principles.

(2) Authority government and administration functions,

Should be the main leading responsibilities clear government on the development of bus priority and bus industry, clear the authorities and responsibilities of urban public transport sector, coordination mechanism of decision making clear of transit priority. At the same time, the relevant departments to deal with the transit priority rights to make limited, to ensure the healthy and orderly development of urban public transit industry.

(3) The priority development of public funds from the security mechanism

Clear the public transportation development into the government public finance priority protection, definite proportion sources and investment funds (public transport expenditure of public finance expenditure ratio), the establishment of long-term security mechanism, clear sustainability bus priority development of fund input.

(6) The overall principle of bus lines operation and management

The main task is to the provisions of the urban public transport operation managers and their responsibilities and management right is obtained, the rights and obligations of operators. Encourage public transport operating orderly competition and limited competition, market development of the principle of public traffic. In addition, the bus operating quality, price and other content clear macro guiding principles.

(8)The subsidy policy loss mechanism of bus

To clarify the public traffic industry policy loss of content and category, accounting mechanism; clear the policy loss of subsidies, subsidies model, and the related supervision, auditing system.

(9) bus service standards and supervision mechanism

On public transport enterprises, different bus hall type service norms, establishing a fair and impartial service standards; supervise and inspection, regular inspection for bus services, a clear corporate responsibility and obligation, ensure passenger satisfactory bus service.

(13) The legal liability and penalties

Clearly in violation of public traffic law provisions of punishment and enforcement provisions; to implement the main responsibility of public transit priority setting to investigate the mechanism of corresponding.

(1) The duties and rights of operation main body

As the passengers to provide basic services for urban residents, public transit enterprises have a bounden social responsibilities and obligations. City bus operation main body should be operating in good faith oriented, committed to providing passengers with safe, efficient, convenient, punctual, comfortable bus service, satisfy all sorts of transit demand residents growing city, guarantee the efficiency and vitality, promote the rapid development of city social economy. On the other hand, as a part of urban public transit industry, every bus operation main body should the whole industry interests, compliance with industry regulations, abide by the industry norms, and orderly competition, and seek common development, promote the healthy development of public transport industry.

Single bus operation main body development, the general enterprise economy's inalienable right, these basic rights include: the right to operate independently, provide the product right, profit, to the market development and expansion of enterprise scale and other rights. Needs to be pointed out is, because of the particularity of public transportation, bus operation main body in the enjoyment of those fundamental rights at the same time, will also be more strict government control than other industries and enterprises, in order to ensure the correct direction of the development of the public transport industry. However, the bus operation main body in accepting the control at the same time, should also enjoy the financial support and policy support provided by the government, which is also of special interest in other industries can not enjoy the. Can say, the rights of the main body of public transportation operation with more particularity compared with the enterprises in other industries, this is also reflected in the specific requirements of the development of public transport industry.

(2) The rights and obligations of passengers

Bus companies charge a fee to provide bus service between the passengers and the public transit operators have formed a relationship of rights and obligations, and is restricted and legal protection. Passenger bus service is the object and the core, the bus service should establish the supremacy of passengers, passengers for this concept, to provide passengers with safe, convenient, stable service. Enjoy the bus enterprise high quality service is the basic right of publication of passengers, including time, space and quality of service requirements, such as safety, stability, on time. At the same time, every passenger has the service level of public transportation enterprise and service quality - supervision rights, when their legitimate rights are harmed, have the right to make reasonable compensation requirements.

Urban public transport service has universality and fairness, both men and women, young and old, should emphasize the wealth, health, urban and rural residual have enjoy the bus service to the right, the government and the enterprise has the obligation to provide a fair public services for all citizens and foreign staff. The bus service should pay attention to humanistic care, with relatively low fares so that the majority of wage earners can afford, to people with low incomes, old and young, the disabled and other subgroups give preferential subsidies, to provide special services for persons with disabilities, is the responsibility of the government, is the part of the special groups enjoy the basic rights issue.

References

Ian Masser, O. Sviden & M. Wegener. (1993). Transport planning for equity and sustainability. Transportation Planning and Technology

Li Ying, (2001). Liu Yan, Li Hongchang: "and the foreign legislation and public transportation to Beijing city bus development enlightenment", "capital economy", In 2001 twelfth period, December 15

Mao. Baohua and Ho. Tin-kin, (2000). On Sustainable Policy of China Urban Transportation, Review of Science and Technology, 1(2000), Beijing.

Tan Zongze (2002). "administrative law", Beijing, China University of Political Science and Law press.

Veleva, V. Ellenbecker M. (2001).Indicators of sustainable production: Framework and methodology. Journal of Cleaner Production, 2001, 9(6):519-549.

Wang Xuehui. (2008). "the construction of" harmonious administration of law and order, "Research on administrative law, the fourth issue of 2008.

Impact of a Freight Network from Railway Freight Organizational Reforms

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Abstract: The study of the changes the Freight Organizational Reforms brings to the freight demand network are important for development of railway freight traffic as it is the most source of income. This paper presents the changes through the demand network. Firstly, the collected data is used to analysis the demand of the transport market changes. This is one of the important reasons for the implementation of Freight Organizational Reforms. Secondly, by constructing virtual transport network, the differences are analyzed about the changes that transportation reforms have brought. The freight transportation reform loses the requirements of goods transport. This makes the origins and destinations of goods on the network become diverse. Accompanied by the reform, the flow and volume of traffic and goods are more complicated than pre-reform period. Before and after the reforms, comparing the range of network and wagon destination, as well as the possible path of the goods, we can draw on the conclusion that the demand network is more complicated and competitive in the future. How to organize the transport of goods more convenient and economic after reform is a serious problem.
Keywords: Freight organizational reforms; Demand changes; Demand network changes; Goods transport path problems.

1 Introduction

This paper analyzes the impact on freight demand network from the Freight Organizational Reforms. First, Freight Organizational Reforms is to adapt to changes of demand in freight transport market, to better meet customers' transportation needs and to improve competition of rail freight in transport market.

Second, Freight Organizational Reforms is the reform of transport organization of the railway transport enterprise, which is in order to change the conduct situation of freight market and to reduce freight transport deficiencies at the current process (ZHAO Xueyou, 2014).

The main connotation about the reforms includes two aspects. One is the overall objective of Freight Organization Reforms. The other is the tasks of the reforms. Among them, the overall goal of Freight Organization Reforms covers the stability of bulk material transport and the other goods (YANG Wenxi, 2014). For the former material, the protocol approach should be taken. And for the latter, the railway companies should guarantee to meet customer’s demand, the quality of transport services and the standardization of the management fees. The main task of the Freight Organizational Reforms can be divided into three parts. The first part is mainly about the innovation of the operation ways that freight organizational uses. The second part is the implement of the real goods system and the last part is railway freight transport developing to modern logistics.

Third, due to Freight Organizational Reforms, the railway freight in the operation process is different than before. An open carriage and full acceptance expanded scope of railway freight service supply area, which causing freight demand network compared with the network before is changed. Such changes include the increase of the demand network nodes, the wagon flow path, and the expansion of freight service scope, etc.

2 Freight Market Demand Changes

Economic development makes the transportation needs change a lot, which contributed to the rapid growth of the need in modern logistics industry (CUI Yaqiong, 2014). The transportation demand of small parts and items, express transportation, and some daily necessities are growing fast in recent years (DING Chuang, 2014).

About 70% income is from freight rail transport. Due to the form of macroeconomic malaise, railway freight volume continued to decline. In 2013, the national railway freight, the growth index almost decreased and presented to negative in each months except for January. Railway freight is decreased, but the logistics of the whole society achieved higher growth. Railway freight data (collected form the internet) from January to June in 2013 is as follows:

Table 1. Freight volume of six months in 2013

	Months					
	Jan	Feb	Mar	Apr	May	June
Freight Volume(10 kilo-tons)	34443	30980	33984	31218	32420	313048
Grand Total Freight Volume(10 kilo-tons)	34443	65423	99407	130625	163044	194348
Cumulative YoY Growth (%)	1.6	0	-0.9	-2.3	-3.1	-2.8
YoY Growth (%)	1.6	-1.8	-2.4	-6.5	-6.5	-0.7

Table 1 shows the exact data about the freight volume in 2013. According to table 1, we can draw the trends of freight volume in Figure 1 as follows:

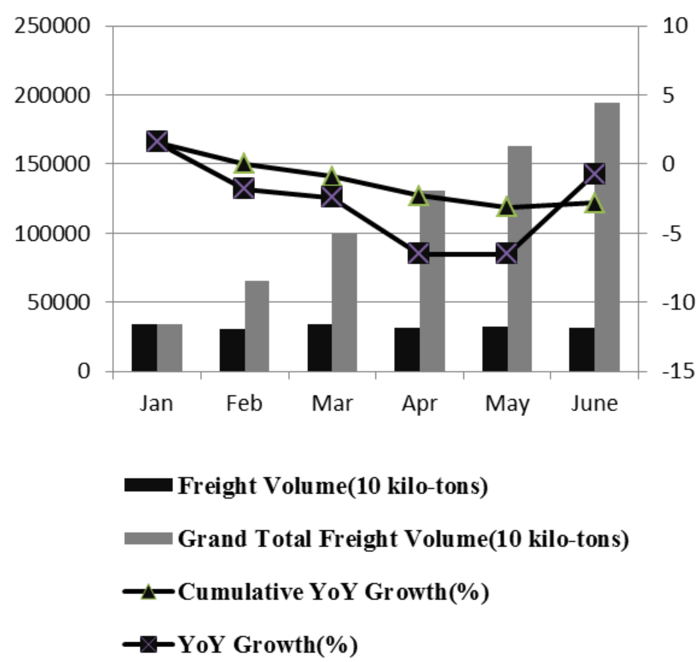

Figure 1.The trends of freight volume of six months in 2013

In the railway freight services, there is a complicated procedure in application for goods transport, which makes transport organization out of touch with the market demand. Non-standard transportation fees and capacity allocation issues also caused goods lose. After the reforms, railway transport companies fully considered all the stations and its generating demand for freight transport, which makes the increased needs of scattered white goods transportation in small and medium enterprises.

3 Demand Network Changes Analysis

In order to analyze the impact of reform, the following simple visual railway network graph is constructed. Suppose there are n stations. Among them, the freight source generating points are represented as the node set of O, and the destination stations are represented as the node set of D. In the set of O suppose that o_i (i=1, 2, 3, •••, n) refers to the non-fulcrum stations, O_i refers to fulcrum station. While the d_j (j=1, 2, 3, •••, n) and D_j refers to the non-fulcrum stations and fulcrum stations in the set of D. The bold lines and bold dashed lines represent the volume in these path are larger than the other lines.

(1)The network before Freight Organizational Reforms

Railway freight business is mainly to supply the approval to large loading points, namely adequate supply compared to the surrounding small freight stations for relatively concentrated flows. For the generated supply of the non-fulcrum station, it should be transported between the major sites. Some non-fulcrum stations will even be ignored. This kind of network is as follows:

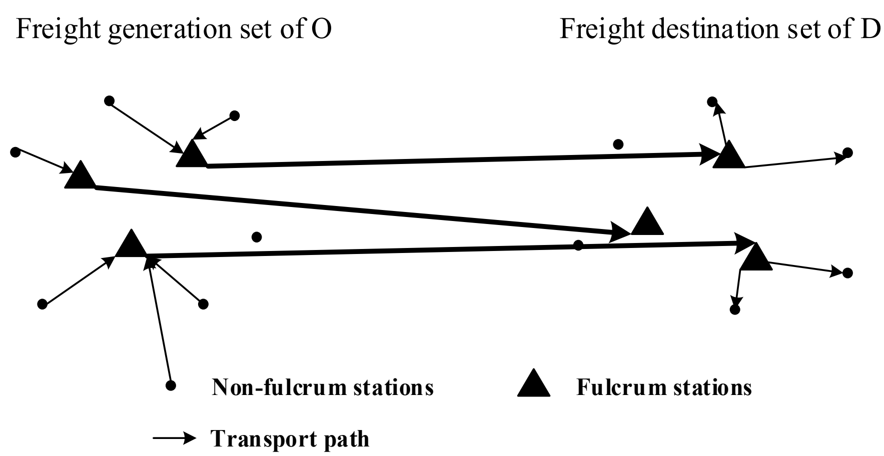

Figure 2.The railway networks before freight organizational reforms

(2) The network after freight organizational reforms

After the railway Freight Organizational Reforms, there is a comprehensive open acceptance for freight demand. For non-fulcrum stations, the supply that generated not only can be directly carried and transported to the destination, but freight sources can cycle between fulcrum and non-fulcrum stations. Therefore, the status of non-fulcrum stations has improved after the reforms, which directly led to an increase in the number of generation and disappeared sites.

Transport of goods does not to pass through the fulcrum stations on condition that the origins to the destination stations have adequate transport volume and the goods flow is concentrated. This means the origin station to destination transport is more economic than the transport path which goods must transport to fulcrum stations first.

The changes of the network are as follows:

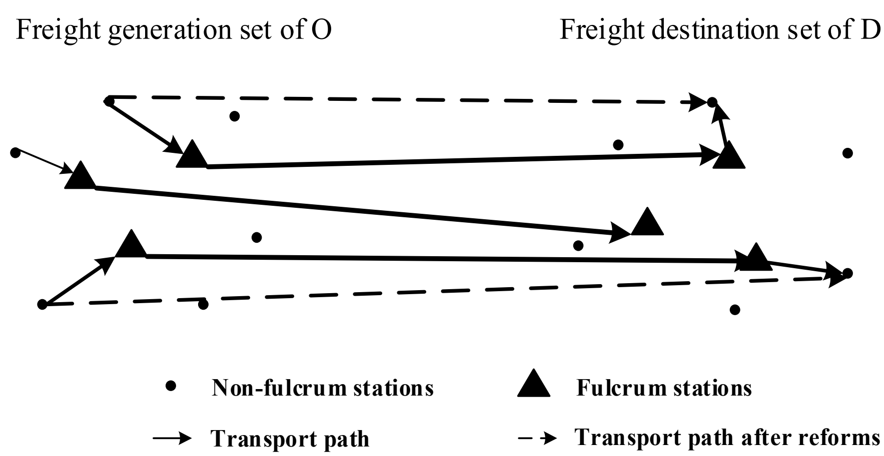

Figure 3.The railway networks after freight organizational reforms

The transportation path should be chosen from the consideration of transport cost, the shortest path and other objections. Finally, the chosen path must meet the multi-objections.

4 Discussions of Results

(1)Problem definition and description

We define the directed graph as G= (V, A). Every node $v \in V$ represent the original (or the destination) station. The arc set A define as the route, which freight train transport path contained. Each arc on the graph has a corresponding nonnegative real number W, which represent the weight of arc. The weight refers to the quantitative index related to the arc (WU Fei, 2014). P for graph G is a transport route of goods from the origins to the destinations. The path P contains a set of nodes which represent the stations the path contained. The nodes in P represent the order that goods be transported. And the shortest route can be represented as follows:

$$W(P^*) = \min\{W(P)\}$$

With the length of the P is called as follows:

$$W(P) = \sum_{a \in P}(a)$$

(2)Results analysis

Before Freight Organizational Reforms, some non-fulcrum stations are ignored because of the less freight volume generated. And some non-fulcrum stations' freight volumes which are taken into considered must be transported to fulcrum stations first. Then through the origin fulcrum stations and destination fulcrum stations, the goods can finally arrive at their place. So the possible paths can be enumerated as follows:

P (voi, v0i, vDj, vdj)
P (v0i, vDj, vdj)
P (voi, v0i, vDj)
P (v0i, vDj)

After the reforms, all the non-fulcrum stations are considered no matter how small freight volumes they generated. The reforms promoted the non-fulcrum stations status. At the same time, the numbers of the original non-fulcrum stations are increased. Therefore, in one hand the goods circulate between the non-fulcrum stations and the fulcrum stations. In other hand, goods can also be transfer directly between two non-fulcrum stations. As the result, the possible paths of the goods are enumerated as follows:

P (voi, vdi)
P (voi, v0i, vDj, vdj)
P (voi, vDj)
P (voi, v0j, vdj)
P (voi, v0i, vDj)
P (v0i, vDj, vdj)
P (v0i, vDj)
P (v0i, vdj)
P (voi, vDj, vdj)

The enumerated paths list all possible paths that goods can be transported. For different condition of goods transport, the chosen path should meet the objective function. All the analysis on this paper is based on the hypothesis of sample visual transportation network which discussed above.

5 Conclusions

Here the following conclusions can be made.

(1) It is observed that the network has changed since the Freight Organizational Reforms. Not only the scope of the service and the range of wagon destination are more lager than before, but the number of the stations that must be considered is increased.

(2) It is also observed that the path and the wagon routing have a lot of choices. The goods can be transported between the non-fulcrum stations and the fulcrum stations. Also, the origin and destination stations of the path are not just at the fulcrum stations, it can be non-fulcrum as well.

6 Recommendations for Future Research

Goods transport path problem and rail network problem are important to study so that it can be more detailed in rail freight transportation situation. And the model can be more close to the actual, such as the objective function of the path, the constraints of path chosen and routing problem. The constraints that contain the capacity constraints, flow direction, flow volume, and the demand of customer should be considered in the future research.

References

CUI Yaqiong, JIA Surong, & WANG Gongqiang. (2014). "Modern logistics situation analysis of the railway freight development". *New west: in late· theory*, (9), 74-74.

DING Chuang, ZHANG Qi, & FENG Bingjie. (2014). "Status of railway freight and marketing strategy". *Chain technology investment*, (A05), 289-289.

WU Fei, ZHAO Yutang, & YAO Wenjuan. (2014). "The Selection of Heavy Cargo Transportation Path". *Management Science and Engineering*, *2014*.

YANG Wenxi. (2014). "The thinking of market-oriented railway freight organizational reforms ". *Railway freight*, *32*(8), 28-31.

ZHAO Xueyou. (2014). "Discussion on reform of railway freight organizations". *Railway freight*, *32*(1), 10-13.

Design and Development of Units of Rail Transport Products Based on the Internet of Things

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Abstract: This paper is based on the analysis of the rail freight demand and problems, by conducting SP survey for the owner of the demand in the freight market and using cluster analysis to segment the freight market to obtain differentiated needs of each owner. And combining product hierarchy theory, this paper analyzes the design elements of frail freight products. Finally, from the perspective of the unitized rail transport product, the paper analysis three kinds of modes of transportation, including truckload, LTL, container transport, and designs and develops the form of the rail freight transport products on the internet of things. This research considering the characteristics of our railways and the market demands to create some unitized transport products in the application environment of the internet of things, which ispersonalized, diversified, and meeting the needs of shippers.
Keywords: The internet of things; Unitization; Railway product design; Clustering analysis; Market segmentation.

1 Introduction

Under the planned economy, the traditional rail freight product refers to spatial displacement of goods through the process of transportation, it is calculated in units of tonne-kilometers (Jiguang. G, 2005). With the development of market economy, multiple transportation modes system gradually improved, substantial changes occurred in the connotation of freight product. It caused a huge impact for the development of the traditional railway cargo transportation product. In order to change the situation that rail transport market rate is gradually decline, some scholars carried out a series of studies about rail transport product design and development. Literature (Yan. Z, 2014) on the basis of analysis of current situation of China's railway freight product design, based on the CS strategy, proposed a ideas about rail freight product optimization. Literature (Yuhua. G, 2011) on the basis of the rail freight market survey forecast, from a marketing point of view, use the concept of the overall product to design railway cargo transportation product. Above studies lay a solid foundation for more theoretical studies, but its products were not really designed to achieve transparency in the transport process and product tracking real time. Rise and application of the Internet of Things technology lay an important foundation for solving the problem. So this paper is based on the analysis of the rail freight demand and problems, by conducting SP survey and cluster analysis knowing the different need of shipper, and from the perspective of the unitized rail transport product,designing and developing the forms of the rail freight transport product on the Internet of things. This research for enhancing the competitiveness of rail transport, consolidating and expanding market share, improving the economic and social benefits has a great significance.

2 Internet of Things technology and its application in railway freight transport

2.1 outlined of the Internet of Things

Things English name is "The Internet of Things". Abbreviation: IOT. Known by name, the Internet of Things is " the Internet that things linked." It has two meanings: First, the core and foundation of the Internet of Things is still the Internet, and it is an extension and a network based on the Internet; Second, its client extends to any goods to exchange information.

Therefore, the definition the Internet of Things is through radio frequency identification (RFID) devices, sensors, global positioning systems, laser scanners and other information sensing device, according to the agreed protocol, to make anything connect with the Internet, and to exchange information and communication, in order to achieve intelligent identification, positioning, tracking, monitoring and management of a network (Xin. Z, 2011).

2.2 application in railway freight transport

According to the requirements of the railway cargo transportation, railway cargo transportation applications in Internet of Things technology should be independent electronic label design, things were constructed corresponding application system to adapt to different forms of freight requirements. The core problem is that RFID technology designed to identify the goods, mainly electronic tags include RFID, ZigBee, Beidou recognizes.

Applications of three types of RFID technology of The Internet of Things in railway freight transport firstly need to achieve a unit, which is the application of stereotypes storage containers, such as pallets, containers, bulk bags, baskets and other container forming a cargo unit, for different cargo units designed appropriate electronic tag, information intelligent recognition technology and PC application software development, eventually forming the corresponding The Internet of Things applications.

3 Rail freight market segments

3.1 Rail freight needs analysis

There is a big difference in the species, volume, speed between shippers, and the Rail freight demand is different. So the survey for the need of shipper and cluster analysis for the Rail freight market for rail transport product' design and research has important significance.

When shippers choose the transport products, they mainly consider the following effects factors:

(1) Freight volume. Shippers when choosing mode of transport, freight volume as an important limiting factor is essential. Because of different size cargo, its optional mode of transportation is not the same.

(2) Economy. Economic factors are important when selecting the mode of transportation, especially for the level of low-value bulk goods transportation and under the condition that various other factors are same, economic factors often play a role as the first factor.

(3) Security. the impact and consequences caused by damaged goods, can not compensate by the money, so the safety of the transport of goods is very important, especially for high value-added goods.

(4) Transport speed. Timely delivery of goods is very important for investment and conversion marketing plan, therefore, the owner of the requirements for the transportation rate is also increasing.

(5) Convenience. Freight-related procedures are or are not simple and convenient, relevant job is simple and efficient, becoming increasingly important factor when the user selects products.

(6) Transparency during transport. In a market economy,Master cargo status and location, configuration, and management to improve the level of corporate resources play an important role.

(7) Service. With the continuous development of additional products, services indicators such as "door to door" may also become a considering factor when selecting.

3.2 SP survey of the rail freight demand

According to analyzing influencing factors, using SP survey (Stated Preference Survey) method (Lianhua. T, 2013), access to cargo demand information through questionnaires, we use the principle of sampling in shen yang railway bureau' qi qi ha er freight station for each owner of the 105 questionnaires, 100 valid questionnaires were obtained.

In order to verify the reasonableness and reliability of the questionnaire design, 'use KMO and Bartlett test of sphericity test methods to verify (Ya. Z, 2014), the test results are shown in Table 3.1.

Table 3.1 KMO and Bartlett's test

KMO and Bartlett's test	
Adequate sampling of the degree of Kaiser-Meyer-Olkin	.727

Bartlett's test	The chi-square approximation	191.106
	df	21
	Sig	.000

Table 3.1 shows the KMO and Bartlett test results, which KMO value is 0.727> 0.7, indicating good validity; Bartlett spherical test results Sig value of 0.00, less than the significance level of 0.05, and therefore reject the null hypothesis Bartlett test of sphericity, validity think good fit to continue to do factor analysis.

3.3 Cluster analysis based on the rail freight market segments

China's existing rail freight transport is divided into three types, namely, truckload, LTL, containers. Transport product design and development should be combined with the owner's needs, based on the original three forms. so, in this paper, freight volume, economy, transparency, security, transportation speed, convenience, transportation, and service these seven factors as the classification index, using K-means clustering analysis method, due to sample size constraints, in this paper, decided to divided100 samples into three categories, the final clustering results are shown in Table 3.2**.**

Table 3.2 K-means final clustering center

	Cluster		
	1	2	3
Freight volume	9	3	4
Economy	8	7	8
Security	7	5	8
Transport speed	8	7	8
Convenience	7	7	7
Transparency during transport	7	8	8
Service	6	6	7

Through inter-class variance and intra-class error mean square analyzing for each impact factor, obtained significant differences between the various categories, reasonable clustering results.

3.4 Characterization of the various market segments

After the railway freight market segments, each of these factors need to be broken down to study the general characteristics of each segment of the market, in order to distinguish the different needs of various market segments of travelers. Factors in the various market segments are distributed as follows Table 3.3.

Table 3.3 Distribution of shippers' demand in the various market segments

Index	Demand / Market	Unimportant	Less important	General	More important	Important
Freight volume	Ⅰ type	0.00	0.00	0.00	36.80	63.20
	Ⅱ type	26.00	69.60	4.40	0.00	0.00
	Ⅲ type	0.00	51.30	48.70	0.00	0.00
Economy	Ⅰ type	0.00	0.00	2.60	84.20	13.20
	Ⅱ type	0.00	4.40	21.70	69.50	4.40
	Ⅲ type	0.00	0.00	5.10	58.90	36.00
Security	Ⅰ type	0.00	0.00	2.60	84.20	13.20
	Ⅱ type	0.00	0.00	4.40	30.40	65.20
	Ⅲ type	0.00	0.00	15.10	48.90	36.00
Transport speed	Ⅰ type	0.00	5.30	7.90	71.10	15.70
	Ⅱ type	0.00	4.40	21.70	56.50	17.40
	Ⅲ type	0.00	0.00	0.00	56.40	43.60
Convenience	Ⅰ type	0.00	2.60	36.80	60.60	0.00
	Ⅱ type	0.00	0.00	47.80	47.80	4.40
	Ⅲ type	0.00	0.00	15.40	71.80	12.80
Transparency during ransport	Ⅰ type	0.00	0.00	11.10	71.10	17.80
	Ⅱ type	0.00	0.00	8.70	60.90	30.40
	Ⅲ type	0.00	0.00	0.00	81.30	18.70
Service	Ⅰ type	0.00	15.80	50.00	34.20	0.00
	Ⅱ type	0.00	17.40	26.10	56.50	0.00
	Ⅲ type	0.00	0.00	12.80	84.60	2.60

Through analyzing the following diagram can be obtained, freight volume in class Ⅰ market more than the other market, were 100%, it can be explained mostly bulk cargo transport market, at the same time, in such markets, the speed of transportation and transparency during transport is relatively high proportion, were 97.4%, 97.4% and 88.9%, which can be seen for bulk cargo shippers valued economy and security of the modes of transportation, in addition, the requirements for transparency during transport is relatively high; Ⅱ type of market factors that affect the safety of the biggest, 95.6%, thus indicating that the market can focus on cargo security; in Ⅲ type of market, transparency during transport were the largest share of 100%, followed by economic factors accounted 94.9%,while the service is more than other markets, and Freight volume' proportion were smallest. Therefore, it can speculate that the market should be small pieces, LTL, the owner pay more attention to the state of real-time control for the transport of goods, and focus on transport prices and transportation services.

4 Unit of rail transport product design and development in the environment of The Internet of Things.

According to the above freight market segments and the requirements of the railway cargo transport unit, combined with the existing truckload, LTL, three freight containers in the form of rail, on the basis of the existing railway products designs and developsrail transport product in the environment of The Internet of Things.

4.1 Unit of vehicle transportation products

(1) Unit of the fast-specific bulk cargo originating direct trains. For the type of supply is fixed, stable volume of bulk cargo such as grain, cotton, mineral running specific, direct, fast trains, while a train as a unit to add electronic tags, using The Internet of Things technology for cargo location tracking, achieve transparency requirements during transport.

(2) Unit of the Cape-speed direct-specific bulk cargo originating trains. Such products are also great for freight volume shippers, but the transport speed is relatively low, these products relative to specific bulk cargo fast direct trains has low price.

(3) Unit of vehicle transportation transit trains. Such products for freight volume is relatively small, not enough to gather a direct train. while a car is a transport unit to add electronic tags, to achieve the positioning of each type of cargo tracking, to provide convenient services to shippers.

4.2 Unit of container transportation products

(1) Unit of the container transport fast trains. This column is the product for the stable supply of container transportation shippers, major transport precision, precious, fragile goods, running rapid transit trains containers, while a container for a transport Unit to add an electronic tag.

(2) Unit of the Cape-speed container transport trains. Such products compared to the previous one in terms of products, more slowly, but the price is cheaper.

(3) Unit of regular direct containers trains. This train fixed, fixed-line, regular, fixed vehicle, pricing, circulation runs between two base stations, without regrouping. so it has high speed and efficiency.

4.3 Unit of LTL product transportation products

(1) High-speed Unit of LTL transportation product. This is mainly for small-volume, high value-added transportation time demanding LTL, per packaging unit for a transport unit for tracking the goods, to ensure safe transport of goods, with the option to provide "door to door" transport services, for the owner to provide convenient.

(2) Cape speed Unit of LTL transportation products. These products mainly include transportation to the time limit is not required, according to sources, waitingthe consolidation, assembly and other job completed, running alone trains transport products.

5 Conclusions

Faced on the increasing competition in freight market and the increasingly diverse needs of shippers, rail freight market ushered in new opportunities and challenges. Given a rail shipper of product design issues, combined with the main trend of the logistics network technology development and applications, create personalized, diversification, meeting the necessary demand of shippers Unit of transport product, is the necessary development trends of rail freight market, and this is of great significance for the consolidation and expansion of rail freight market share, and the economic and social benefits improved.

References

Jiguang. G. (2005). Based on CS strategy of railway freight product design method. *Railway Transport and Economy*. 77-79.

Yan. Z. (2014). Research on design and development of China's railway freight products. *Railway Freight Transport.* 5-9.

Yuhua. G. (2011). Chinese railway freight marketing theory and the development. Central *South University.*

Xin. Z. (2011) the application and research on the Internet of things in the railway container. *Railway Transport and Economy*. 58-60.

Lianhua. T. (2013) Research on high speed railway passenger transportation product combination design method. *Beijing Jiaotong University.*

Huang. C, and Jianjun. C. (2012). Analysis of high speed railway passenger service quality, satisfaction and loyalty of the railway passenger. *journal,* 1-5.

Ya. Z. (2014). Research and application of railway freight marketing oriented data mining technology. *Southwest Jiao Tong University.*

A Systematic Evaluation Strategy of Car-Following Models

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Abstract: This paper introduces the systematic strategy of car-following (CF) models with three aspects. The general reality description is firstly used to analyze whether the CF models can describe the overall longitudinal driving behaviors really. Then the individual reality description is applied to analyze the ability of simulating individual behaviors precisely of diverse CF models. Finally, the inter-driver and intra-driver heterogeneity are analyzed for that good models can minimize the discreteness. In general, it is convenient for researcher to use the systematic strategy to evaluate the CF models.
Keywords: Car-following models; Evaluation; Systematic strategy.

1 Introduction

Car-following (CF) models, which describe the longitudinal interactions of vehicles, have been developed for almost half a century. In the early stage, the studies of CF models are focused on the model establishment. Many models are developed when researchers figure out that the existing models cannot describe some specifically macroscopic phenomena. In this period, a large number of models are proposed by researchers due to their intuitive senses. And the rule of CF models evaluation is whether the model can describe the real traffic phenomenon. However, the parameters of various CF models cannot be estimated precisely because of the lacking of measured data, especially the microscopic data. Several researchers attempt using vehicle experiments to calibrate the parameters, leading to a doubt about the quantity and quality of the data (Brackstone, 1999).

Technological advances in the field of microscopic data-collection methods have caused a considerable increase in the number of studies using trajectory data to calibrate CF models accurately (Pipes, 1953; Gazis, 1959; Herman, 1959; Brockfeld, 2004). During the calibration, two mathematical principles are widely applied: Least squared errors (LSE) and maximum likelihood (ML), and these two principles are identical in some degree. Arne (Ranjitkar, 2004; Hoogendoorn, 2005) and Wang (Wang,2010) use the value of the LSE as the standard of evaluating the CF models. And the smaller errors between simulated and measured trajectories mean better model performances. Hoogendoorn (Ossen, 2006) adopt the value of ML in the model estimation and use the likelihood-ratio test to cross-compare CF models with different complexity.

In general, the methods of using mathematical value to evaluate model performances, which represents the fitting degree of simulated and measured microscopic trajectories, are widely developed in recent years.

These methods which provide a convenient cross-comparison of different models, however, result in the deviation from the initial goal of CF models' establishment. A great CF model is one that can describe the real microscopic longitudinal behaviors precisely and the actual macroscopic phenomena accurately, not one with the maximum or minimum mathematical value. Therefore, the systematic evaluation strategy of CF models, which accord to the initial goal, is still lacked.

The main contribution of the present study is the introduction of a systematic evaluation strategy of CF models, which focuses on the model description on real behavior. And the next section will proposed the strategy in detail and the section 3, 4 and 5 will introduce the different rules of model evaluation belonging to the strategy system separately. Conclusion will be drawn and further studies will be introduced in the last section.

2 Systematic Strategy

The initial goal of CF models' development is to describe the reality of the longitudinal behaviors. Thus the basic principle of the systematic strategy of CF models evaluation is reality description. There are two methods of reality description analysis: the first one is general reality description, which describes different individual drivers with the identical parameters; the second one is individual reality description, which models individual drivers separately with the independent parameters. These two methods represent different aspects of CF models evaluation, with the same principle—reality description although.

Besides the basic principle, there is another goal focused on by some researchers and should become the developed principle—adaptation analysis. The adaptation analysis is more and more vital when the CF models are applied to a large number of individual drivers. These drivers have diverse driving styles which are called the inter-driver heterogeneity, and the same driver has distinct styles which is called the intra-driver heterogeneity. A good model should cover the inter/intra-driver heterogeneity simultaneously with great robustness. Therefore, the developed principle of adaptation analysis is inevitable.

3 Generalized CF models

The CF models can be expressed in discretized form as follows:

$$v_i(t_{k+1}) = f[h, y_i(t_k), y_i(t_k - \tau)|\theta] \tag{1}$$

Where θ denotes the set of parameters describing the car-following models; h denotes the time step used for discretization; $v_i(t_k)$ denotes the velocity of driver i at time instant t_k; $a_i(t_k)$ denotes the acceleration of driver i at time instant t_k; and $y_i(t_k)$ denotes the state that is relevant for driver i at time instant t_k.

The state of $y_i(t_k)$ includes all stimuli present in the CF models, and can use the following specification:

$$y_i(t_k)=f[v_i(t_k),\Delta x_i(t_k),\Delta v_i(t_k)] \tag{2}$$

Where $\Delta x_i(t_k)$ denotes the distance between the vehicle i and the leading vehicle; $\Delta v_i(t_k)$ denotes the velocity difference between the vehicle i and the leading vehicle.

And the calibration is to minimize the difference between the measured state $y_i^{obs}(t_k)$ and the simulated state $y_i^{sim}(t_k)$, which can be expressed as follows:

$$\begin{aligned} y_i^{obs}(t_k)&=f[v_i(t_k),x_{i-1}(t_k)-x_i^{obs}(t_k),v_{i-1}(t_k)-v_i^{obs}(t_k)] \\ y_i^{sim}(t_k)&=f[v_i(t_k),x_{i-1}(t_k)-x_i^{sim}(t_k),v_{i-1}(t_k)-v_i^{sim}(t_k)] \end{aligned} \tag{3}$$

Where $x_i^{obs}(t_k)$ denotes the measured position of vehicle i at time instant t_k; $x_i^{sim}(t_k)$ denotes the simulated position of vehicle i at time instant t_k; $v_i^{obs}(t_k)$ denotes the measured velocity of vehicle i at time instant t_k; $v_i^{sim}(t_k)$ denotes the simulated velocity of vehicle i at time instant t_k;

4 Calibrating methods

There are two main mathematical approaches to formulate the calibration problems: Least squared errors (LSE) and maximum likelihood (ML).

The LSE is one of the regression methods which can be expressed as following simply:

$$S(\theta)=\sum_{1}^{n}(Y_i^{sim}(\theta)-Y_i^{obs})^2 \tag{4}$$

Where Y_i^{sim} denotes the simulation predictions at point i, i = 1, . . . n; Y_i^{obs} denotes the data point i, i = 1, . . . n; and this reduces the calibration problem to a multi-variate nonlinear optimization problem:

$$\boldsymbol{\theta} = \arg\min S(\theta) \tag{5}$$

The ML method uses the likelihood function as the joint probability that the CF model predicts all data points:

$$L(\theta)=prob(Y_1^{sim}(\theta)=Y_1^{obs},\ldots,Y_n^{sim}(\theta)=Y_n^{obs}) \tag{6}$$

$$L(\theta)=\prod_{i=1}^{n} p(Y_i^{obs}|\theta) \tag{7}$$

When the log-likelihood function is used as follows:

$$L(\theta)=\sum_{i=1}^{n} Ln\ p(Y_i^{obs}|\theta) \tag{8}$$

And the parameters can also be solved:

$$\boldsymbol{\theta} = \arg\max L(\theta) \tag{9}$$

4.1 General reality description

For the general reality description, the CF models are calibrated for all drivers with the following approach: the measured data of the leading vehicle is served as inputs for the models. The longitudinal models calculate the acceleration of the follower, and get the velocity and position. In that case, the models can simulate the movements of each following car. Comparing the measured data points and the simulated data points, the error term can be calculated generally for all drivers, as shown in the following :

$$Error(\theta)=\frac{1}{n}\sum_{1}^{n}\frac{\sqrt{\sum[Y_i^{obs}-Y_i^{sim}(\theta)]^2}}{\sqrt{\sum[Y_i^{obs}]^2}} \tag{10}$$

Where n denotes the number of vehicles.

Considering the calculating error in the optimization, the optimal process is repeated for several times to get the distribution of the parameters θ. And in the general reality analysis, the parameters should be in the normal range, which is in line with the actual driving behaviors. If there is any parameter that is not consistent with the range, the general reality description is not good and the model cannot describe the overall longitudinal driving behaviors really.

4.2 Individual reality description

For the individual reality description, the CF models are calibrated for each driver separately with the following approach: the measured data of the leading vehicle is as inputs for the models. The longitudinal models calculate the acceleration of the follower, and get the velocity and position. In that case, the models can simulate the movements of each following car. Comparing the measured data points and the simulated data points, the error term can be calculated separately for individuals, as shown in the following :

$$\varepsilon(\theta) = \frac{\sqrt{\sum[Y_i^{obs} - Y_i^{sim}(\theta)]^2}}{\sqrt{\sum[Y_i^{obs}]^2}} \tag{11}$$

The calibrating errors are also considered and the calibration should be repeated for several times. The average values of the parameters θ are used in the simulation of the car-following behavior. Comparing the measured microscopic trajectory separately with the simulated one, the individual reality can be evaluated, with the little difference means the great individual reality description.

4.3 Heterogeneity analysis

Heterogeneity is widespread, for that human drivers are not deterministic automata. And there two aspects of longitudinal driving behavior heterogeneity: inter-driver heterogeneity and intra-driver heterogeneity.

Inter-driver heterogeneity is the diverse driving styles among different drivers, and can be figured out when the individual reality description is applied. When the different parameters of distinct drivers are compared, the discreteness of these parameters can be used as the inter-driver heterogeneity analysis. In general, the large discreteness means the large inter-driver heterogeneity and the defect of the CF model.

Intra-driver heterogeneity is the difference during the different periods of driving. For intra-driver heterogeneity analysis, the data of all the leader-follower combinations are split into two parts equally in the first. Then the part I and part II are calibrated with the method mentioned in the calibration for individual reality description. For each vehicle in the two part, the error term is defined as follows:

$$\varepsilon_J(\theta) = \frac{\sqrt{\sum[Y_i^{obs} - Y_i^{sim}(\theta)]^2}}{\sqrt{\sum[Y_i^{obs}]^2}} \tag{12}$$

Where J belongs to part I or Part II.

And through comparing the difference of $\varepsilon_I(\theta)$ and $\varepsilon_{II}(\theta)$, the intra-driver heterogenetiy can be figured out. Generally, the large difference of the distinct driving period means the model cannot simulate one driver precisely. Therefore, the intra-driver heterogeneity can also be the vital aspects in the CF models evaluation.

5 Conclusion and future work

The systematic strategy of car-following models is developed for the three levels. Firstly, the general reality description is used to analyze whether the CF models can describe the overall longitudinal driving behaviors really; secondly, the individual reality description is used to analyze the ability of simulating individual behaviors precisely of diverse CF models; finally, the inter-driver and intra-driver heterogeneity are analyzed for that good models can minimize the discreteness. For using the systematic strategy, the evaluation of the CF models can be more convenient and feasible. In the future, the specific case of several CF models evaluation should be studied and the process need to be further refined.

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Reference:

Brackstone, M., and McDonald, M. (1999). "Car-following: a historical review." *Transportation Research Part F: Traffic Psychology and Behavior*, 2(4), 181-196.

Brockfeld, E., Kühne, R. D., and Wagner, P. (2004). "Calibration and validation of microscopic traffic flow models." *Transportation Research Record: Journal of the Transportation Research Board*, 1876(1), 62-70.

Gazis, D. C., Herman, R., and Potts, R. B. (1959). "Car-following theory of steady-state traffic flow." *Operations research*, 7(4), 499-505.

Herman, R., and Potts, R.B. (1959). "Single Lane Traffic Theory and Experiment." *In Proceedings of the Symposium on Theory of Traffic Flow*, 147-157.

Hoogendoorn, S. P., and M. Schreuder. (2005). "Tracing Congestion Dynamics with Remote Sensing: Toward a Robust Method for Microscopic Traffic Data

Collection." *I Presented at 84th Annual Meeting of the Transportation Research Board, Washington, D.C.*

Ossen, S., Hoogendoorn, S. P., and Gorte, B. G. (2006). "Interdriver differences in car-following: a vehicle trajectory-based study." *Transportation Research Record: Journal of the Transportation Research Board*, 1965(1), 121-129.

Pipes, L. A. (1953). "An operational analysis of traffic dynamics." *Journal of applied physics*, 24(3), 274-281.

Ranjitkar, P., Nakatsuji, T., and Asano, M. (2004). "Performance evaluation of microscopic traffic flow models with test track data." *Transportation Research Record: Journal of the Transportation Research Board*, 1876(1), 90-100.

Wang, H., Wang, W., Chen, J., and Jing, M. (2010). "Using Trajectory Data to Analyze Intradriver Heterogeneity in Car-Following." *Transportation Research Record: Journal of the Transportation Research Board*, 2188(1), 85-95.

Rail Transit Impact on the Development of Commercial Space in Zhuhai

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Abstract: The rail transportation has been gradually becoming a main way for the urban public transportation in China. The rail transit, as a kind of large capacity, high speed, safety and punctual transportation, not only improves the accessibility of the urban traffic, but also raises the new commercial circle. It brings a huge impact to the development of urban commercial space. In recent years, with the rapid development of Zhuhai, the government has started the constructions of the rail system and the north station TOD project in order to alleviate the traffic congestion in the downtown of Zhuhai. Based on the north station TOD projects, the relationship between the rail transit and the urban commercial space had been analyzed. The rail transit impact on development of commercial space had been studied.
Keywords: TOD; Urban commercial space; Rail transit; Catalyst.

1 Introduction

In China, the cities are facing many developing problems with the development of economy, the industrial structure adjustment and the urbanization. The continuous expansions of city bring about the intense traffic demand and the serious traffic pressure. The congestion has being more and more serious. In major cities, though a variety of measures having been implemented, but it is difficult to fundamentally solve the congestion problems. In the other way, facing the grim problems of energy and land, many big cities in the developed countries almost without exception had chosen the rail transportation as the main mode of transport. Comprehensive analysis of the current social economic development and urbanizational development goals has found that the urban rail transit system basically established the leading position of the future transportation in cities.

The rail transit is not only changing the pattern of the city, but also bringing the value-added land for the rail transit site periphery. The infinite business opportunities and vitality had been brought by the formation and development of business circle. The change of traffic pattern, caused by the rapid public bus or rail transit, had brought the new pattern for domestic business development. For example, the transit-oriented development (TOD) will play a key role to promote the development of urban commercial space.

The paper analyzed the rail transit impacts on the urban spatial structure and the development of commercial space according to the Zhuhai north station TOD project according to the TOD theory and the theory of urban catalyst.

2 Related Theories

2.1 Urban Rail Transit System

Urban rail transit system is a special line public transportation system with continuous orientation ability. Its characteristic is a whole special track that is not mixed with the motor vehicles. For example, there is no any intersection, any pedestrian crossing, and any bicycle way or vehicle line. Usually, urban rail transit systems were built in the underground or above viaduct. The special pattern made the train run in the rail line freely. Urban rail transit system can run in the fully automatic operation mode. In addition, the urban rail system is divided into two kinds, heavy subway and light rail (Sebastien, 2009).

2.2 TOD

A TOD is a mixed-use residential and commercial area designed to maximize the access to public transport. A TOD neighborhood typically has a center with a transit station or stop (train station, metro station, tram stop, or bus stop) surrounded by the relatively high-density development blocks, with which the lower-density development blocks progressively spread outward from the center. TODs generally are located within a radius of one-quarter to one-half mile (400 to 800 meters) from a transit stop because it is considered to be an appropriate scale for pedestrians. Thus the last mile problem is solved.

Eight principles of design a TOD (Peter, 2014) are:

(1) Designing suitable for walking the streets and pedestrian scale blocks.
(2) The bicycle network is preferred.
(3) Improving the road network density.
(4) Developing a high quality public transport system.
(5) Using a mixture of blocks.
(6) According to the city's public transport capacity to determine the density.
(7) Through the quick commute to establish some compact urban areas.
(8) Adjusting the parking areas and the road use to increase mobility.

A typical TOD is mainly composed of the following functional structures of land use: Bus stops, core business district, office district, residential districts, and public open space (Lu).

2.3 Urban Catalyst

The theory of urban catalyst (Jin, 2006) is that the original spot catalyst integrates with new elements to form a urban large spot catalyst, or along the river or the traffic route to form a line catalyst as well as a plane catalyst that would make the design project affect a larger city area. The influence would eventually produce a reaction mechanism with the urban development.

In terms of urban design project itself, a specific construction project that can be used as a start point or a catalyst to stimulate the urban design implementation. The spot catalyst is important for the decision of implementing a phased

3 The Impacts of the Rail Transit on the Urban Space

This chapter analyzed the impacts of the rail transit on the urban space according to the urban structure and the urban commercial space. Including, the axial development of urban space, the overall urban space form changement, the rail transit has two efficacies of the agglomeration and diffusion on the urban structure, and the urban population spatial distribution change. By the joint effect of the agglomeration and the diffusion, the urban commercial space will be an urban catalyst pattern.

3.1 The Impacts of the Rail Transit on Urban Space Structure

3.1.1 Axial development of urban space

Urban development axis is mainly composed by the centrifugal effect traffics, such as railway, highway, rail transit lines, which drive the development of the surrounding land. The development axis type, quantity, direction, length, and stretching speed directly constitute all kinds of city external forms, which determined some phased development characteristics of the city developing form. The rail transit as a fast high-volume traffic type guided the urban development along the rail transport, which the corridor effect made the city construction along the rail transit line be a high density axial city development. Rail traffic impacts the urban spatial structure by the stations or sites. These stations constitute an axis, along which the urban high-density development and dotted construction have been done with a continuously expansion. Eventually, the axial development of urban space is finished and the corresponding rail transit lines have also become a city's developing axis (Bao, 2012).

3.1.2 Overall urban space form change

The different forms of rail transit network have very different impacts on the whole urban space. The grid network makes an evenly distributed urban space. The radial network has a strong center district. The ideal form is a ring network with some radial lines, which is helpful for realizing the sustainable development of urban space.

3.1.3 Urban spatial agglomeration and diffusion

Rail transit guides the spatial distribution of a city's important flow of people, logistics and economy, which has taken the role of agglomeration and diffusion for the urban space. The convenience of rail transit makes people in the industry that is on the outskirts of the city concentrate to the downtown of the city. The heavy development of land and the high density agglomeration of commercial offices and other public facilities constructed in a large-scale construction impact area have brought the agglomeration form of the urban spatial structure, which the stop station is the center. It not only helps stimulating the city's vigour and keeping a strong central region, but also promotes the formation and development of the city's secondary center. "Agglomeration" effect has some impacts on the land price. The related industries that want to improve their profit will make some decisions on the land cost and transportation cost. There are quite a number of industries and population which will spread to outside. It is called the city industry "diffusion" effect (Bao, 2011).

3.1.4 Urban population spatial distribution change

The rail transit can make the urban population migrate to the new town or the edge area of a city, which alleviates the pressure of the central downtown and drives the development of the new town or the edge area. It will ease the pressure of downtown population.

3.2 The Impacts of the Rail Transit on Urban Commercial Space

The construction of rail transit has an important impact on the location of urban commercial space which is decided by three factors including the market, the distance and the competition. The urban commercial space can be changed dramatically by the joint effect of the agglomeration and the diffusion. The impacts on the urban commercial space structure can be some gradual developing forms according to the points, the lines and the planes (Cai).

The motivation of commercial spatial structure evolution is mainly the location change of the business, which is caused by a collection effect of the market, the distance and the competition. The factor of market is the combination of consumers. The factor of distance includes the traffic conditions and the space distance. The factor of competition is mainly the number and capacity of distribution in a same industry among the commercial and radical scope (Xin Fei).

4 The Rail Transit Construction Impacts on Zhuhai's Commercial Space

Zhuhai is located in the southwestern coast of the Pearl River mouth, which is adjacent to Macau and Hong Kong. It has a population of about 2.5 million. Zhuhai's climate is warm and humid. The coastline with continuous mountains is long and beautiful. Now the current population center of Zhuhai is to the southeast of the north station, which is near the Pearl River estuary.

The Zhuhai north station TOD project is designed by the Peter Carl Thorpe who is the author of the concept of TOD design. The north station TOD project is located in Tangjiawan, 15 kilometers north to the Zhuhai downtown, where is adjacent to the southern section of Zhongshan city, Guangdong province, China.

The south and west border of the project is a mountain with rich vegetation. The east of the project is the Pearl River estuary. There are a large number of transport infrastructures in the internal layout of the project, which maintain a convenient contact with other area. The transportation infrastructure is also a part of the strategy that Zhuhai is a core developing area for future in Guangdong province.

Peter designed eight subjects for the project place, of which one subject is developed around the local and inter-city public traffic stations, including a rail transit through the project area.

There will be three kinds of public transportation including inter-city light railway, rail transit and traditional bus. The most important parts are the intersection between the rail transit and the light railway and the intersection between the rail transit and the traditional bus. This area is the highest density of development among the area in future including commercial and retail service and some residential district. A series of square and park will increase the public space along the roads.

The rail transit stations along the public transportation road will provide the transfer function with the traditional bus. The transfer stations will also be a high density area for employment, which are convenient public traffic services for people. In addition, the community services, shops and restaurants are located within a walking distance. The bus rapid transit (BRT) lines are generally perpendicular to the bus lines or along the crescent bay edges. This will provide convenience for local residents who want to go to all local or other tourist destinations in the city (Ning).

According to the project plan, the inter-city railway, the local rail transit and the BRT will converge together in the north station, which provides a convenient transportation. The north station will become a large TOD community. In this area, where will be the most urbanized area, there will be a high density of commercial, retail and high-rise residential area. There also will be a series of square, parks and other public spaces. The TOD community relying on the north station will become the point catalyst that drives the development of entire regional area.

The rail transit line extended from the downtown of Zhuhai is the most important public transportation trunk from the TOD project base to the downtown of Zhuhai. It is the main axis in the base area, which forms a line catalyst to connect the different level TODs. Along the lines, the mixed development will drive the whole project base development. Along with the economic power's increasing of the TOD base, the developing focus will shift to the secondary area of the TOD and the areas that are encircled by different public traffic lines. By spreading outward from the axis, a plane catalyst will take shape in the north station area. It is called an integral space growth pattern from point to line, then from line to plane (Yao Yafang).

The following figure shows the layout of the rail transit lines including the Line 1 and the Line 2 in Zhuhai.

Figure 1. The layout of rail transit lines in Zhuhai

5 Conclusions

The rail transit is an important part of urban public transportation, which can drive the commercial development and restructure the commercial space layout. Through the analysis of the development of Zhuhai urban rail transit and the relationship between the rail transit and the commercial space, we can draw the following conclusions:

(1) The development of rail transit has an important impact on the development of urban commercial space. The construction of rail transit will bring new business districts. The functions of the traditional business districts or the center business district (CBD) will be weakened because the rail transit changes the regional commercial status of the hub site near downtown.

(2) The development of rail transit will lead to the evolution of the urban commercial pattern, which is from point to line and from line to plane.

(3) During the rail transit construction, we should take advantage of the certain project plans and policies to guide the rail transit along the peripheral to form a good business environment.

Acknowledgement

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References

Bao Qiaoling. (2011). "Based on the influence of rail transit mountain city commercial space development thinking- In chongqing light rail line 2 as an example."

Bao Qiaoling. (2012). "The mountain city space optimization research under the influence of the rail transit- In downtown Chongqing."

Cai Guotian. "Rail transit construction to research on the effects of guangzhou retail business space."

Jin Guangjun. (2006). "Theory of catalytic effect of urban design projects the impact on the surrounding environment."

Lu Huapu. "Suitable for the study of China's urban TOD planning method."

Ning Heng. "Zhuhai north station TOD's overall design." Sustainable transport research center.

Peter Calthorpe et al. (2014). "Transit Oriented Development in China." A Manual of Land-use and Transportation for Low Carbon Cities.

Sebastien Rabuel. (2009). "French trams and "BHNS" bus rapid transit system: is closely related to the urban areas and their selection process."

Xin Fei. "Changsha city rail transit impact on commercial spatial structure studies."

Yao Yafang. "China's big cities around the new town space of TOD mode building."

Economic Integration Development of Port Cluster and Port City

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Abstract: Port city is a kind of special economic region with inner inevitable connection essentially, which determines its development practice need the integration between port and port city. Based on the studies of the economic impact of port cluster on city, especially the integration process, integration effect and integration tendency with each other in the economic development, this paper proposes that the set composed of a port cluster and city should be regarded as a large-scale system and puts forward a dynamic port economic impact model based on system dynamics, providing applied theory and methodology for the economic operation mode of port cluster and port city.
Keywords: Economic integration; Port cluster; System dynamics.

1 Introduction

With the tendency of global economy integration strengthening, the influence of port on global economic development has become increasingly strong, and the changing functions of port have made the relationship between port and urban economy get closer. As a consequence, the careful studies of the role of port cluster and its correlative development with urban economy can become the essential basis for solving a series of significant issues. Although the theory and application study on the integration of port industry and national economy in contemporary academic field is gradually deepened and has made some process, there is obviously still blank in the research on the integration process, integration effect and integration tendency between port cluster and city in the economic development. Therefore the complete analysis of the economic impact of port on the urban economy from the perspective of port cluster and the systematic analysis of the integration between port and city from the perspective of city can lay a research foundation for the applied theory of the economic operation mode of port cluster and port city.

2 Port Cluster

2.1 Defining a port cluster

It is because of the unique geographical position and the relevant business that the cluster phenomena of port industry have become more and more clear. There are acknowledged port clusters in Rotterdam, the Lower Mississippi and Durban, which shows that the cluster theories can be used as a tool to analyze the development status of port and port-related industry. Haezendonck defined a port cluster as 'the set of interdependent firms engaged in port related activities, located within the same port region and possibly with similar strategies leading to competitive advantage and characterized by a joint competitive position vis-à-vis the environment external to the cluster (Haezendonck, 2001) '. By studying the experts' advice comprehensively, a port cluster is defined as 'a population of mutually related business units, associations, universities, research institutes and public (-private) organizations centered around a distinctive economic specialization, engaged in port related activities, located within the same port region with similar strategies leading to competitive advantage and characterized by a joint competitive position vis-à-vis the environment external to the cluster'.

2.2 Constructing a port cluster

The first step to identify a port cluster is to decide on the economic specialization of the cluster. In the case of seaports the core specialization is the arrival of goods and ships. All activities related to the arrival of goods and ships are included in the port cluster.

The second step is to identify the business organizations and non-business organizations included in a port cluster. Business organizations consist of at least five broad groups in a port cluster: cargo-handling firms, transport firms, logistics firms, manufacturing firms, trading firms, etc. Non- business organizations consist of associations and public (-private) organizations.

The third step is to identify relevant port cluster region. All clusters have 'geographical borders', even though in many cases these are not well defined. The relevant region generally includes the primary port area, the business district of the port city, secondary nodes in the proximity of the primary seaport (Klink, 1995) and municipalities in the vicinity of the port with a concentration of port service activities.

2.3 Measuring a port cluster performance

The issue of how the performance of port clusters can be measured is important for cluster scholars. The net present value of the future value added generated in the cluster is the best indicator of the performance of a port cluster. This indicator cannot be calculated. However, once time series of the value added generated in a port cluster become available, the influence of various variables on the performance of clusters can be analyzed. For instance, variables such as expenses for harbor administration, and the number of new port establishments are likely to influence the future value added generated in the cluster. The value added generated in year t can be written as:

$$VA_p(t) = \sum_{i=1}^{n} Va_i(t) \qquad for \quad i = \{1 \ldots n\} \tag{1}$$

Where: VA is the total value added of a population P consisting of n firms,
Va_i is the value added of firm i in the cluster P.

The performance of the cluster can be written as:

$$CP_p(t) = VA_p(t) + \frac{VA_p(t+1)}{1+r} + \cdots + \frac{VA_p(t+n)}{(1+r)^n} \tag{2}$$

Where r is the discount rate used to calculate the net present value over the period t to n.

3 The Economic Integration Analysis of Port Cluster and Port City

3.1 Port cluster activities with industry classifications

According to the industry standard, the port cluster activities with industry classifications are shown as Figure 1.

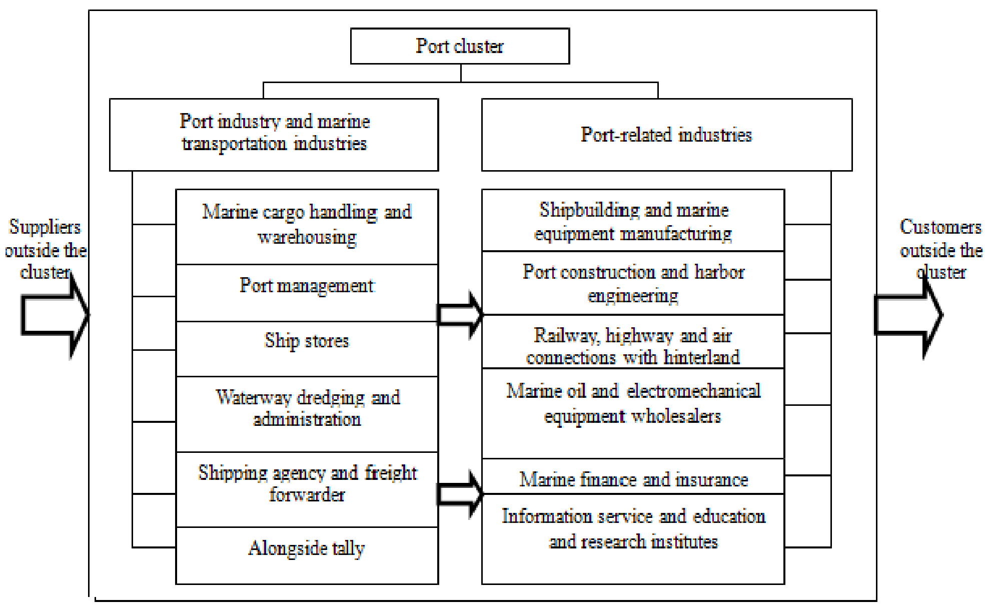

Figure 1. Port cluster activities with industry classifications (SISIRC, 1999)

3.2 The economic impact of port cluster on port city

In general, the total impact of a port cluster on the local urban economy can be divided into the direct, indirect and induced impact. The direct impact is referred to the economic impact generated by port itself and marine related activities on the local and national economy, which mainly arises from local port user industries. The indirect impact is generally defined as all activities in the region which are economically dependent on the primary activity (Davis, 1983), which comes from port capital spending on new port construction, expansion or rehabilitation projects. The induced impact includes economic activity that comes from household purchases of goods and services made possible because of wages generated by the direct and indirect activities.

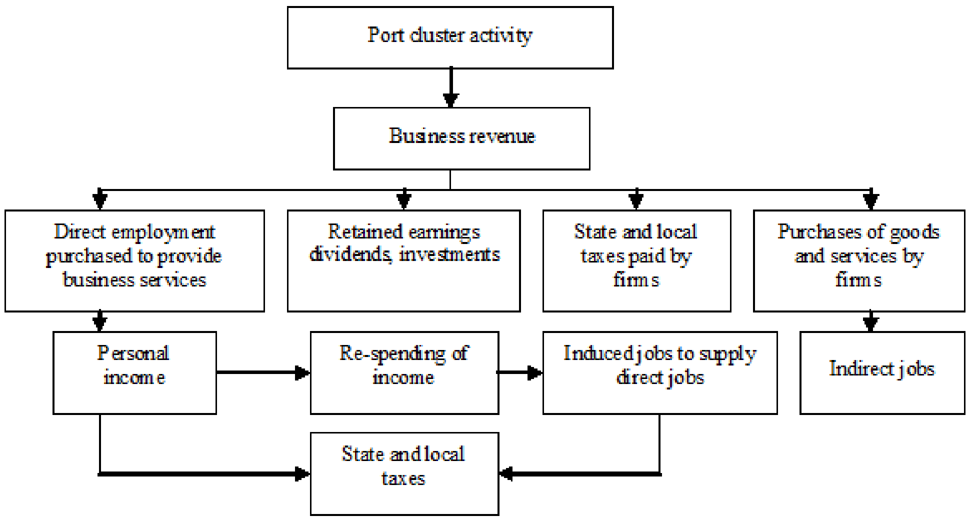

Figure 2. Flows of economic impacts through the economy

Figure 2 graphically demonstrates how seaport activity impacts urban economy. As indicated, the marine cargo and vessel activity initially generate business revenue to the firms supplying marine services. This revenue is used to purchase employment (direct jobs) to provide the services, to pay stockholders and for retained earnings, and to purchase goods and services from local firms, as well as national and international firms (creating indirect jobs with these firms). Businesses also pay taxes from the business revenue. Furthermore the employees hired by the firms receive wages and salaries (personal income), a portion of which is saved, while another portion is used to buy goods and services such as food, housing, clothing, health care, etc. These purchases create a re-spending impact throughout the economy, known as the personal income multiplier. As a result of these local purchases, additional jobs (induced jobs) are created in the local economy. Finally, taxes are paid by individuals employed with the firms providing the services for the marine terminals.

3.3 The economic integration analysis of port cluster and port city

Engaged in the retrospect of port development process, we will be aware of the reason why the scholars come to attach weight on the degree of relationship between port and city, the significant effects produced by port on urban and regional economies, as well as the integration between each other during the economic development. Also it must be admitted that the supporter of prosperous ports should be the growth of urban and regional economies, which embodies the development strategies of 'prospering city on the port and making port serve the city'. Given the close linkage between port and urban economy, the followings should be emphasized to well deal with the economic integration between port cluster and port city: (1) it is essential that the idea of 'port cluster serving urban economy' should be demonstrated clearly and port cluster operation should take the development of urban and regional economies as final goal; (2) a unblock and high-effective integrated transportation system around the port should be established in the city. It has been approved by lessons in the transportation practice all over the world that the construction of port should be carried out in accordance with that of integrated transportation system; and (3) there is much necessity to definite the port development direction where the construction of modern logistics hub is a strategic target.

4 Methodology of Economic Integration of Port cluster and Port City

4.1 Research review of methodology

After discussing the economic integration of port cluster and city, the next step is to find an appropriate methodology to estimate the impacts. However, there is no standard methodology that accurately measures the economic impact of a port cluster. It has been observed that the economic impact of port cluster on city is clearly characteristic of dynamic. As time goes by, some integration factors will enlarge, transfer or disappear due to the social and economic effect, such as the advance of technology, the difference of government policy orientation and the adjustment of industrial structure. Thus there will be a corresponding change in the economic impact of port cluster on city, and all needed is to analyze the changing tendency and find out its inherent law. What's more, it is evitable that the integrated supplement effect between port and urban economy will lead to the existence of abundant nonlinear relation in the integration with each other, and the application of system analysis is required to solve the problem because the accumulated effect caused by the correlation is non-additive.

4.2 Dynamic model based on system dynamics

System dynamics (SD) is a methodology for studying and managing complex feedback-control systems. In fact it has been used to address practically every sort of feedback system. System dynamics provides a common foundation that can be applied wherever we want to understand and influence how things change through time, which uses concepts drawn from the field of feedback control to organize available information into computer simulation models. A digital computer as a simulator, acting out the roles of the operating people in the real system, reveals the behavioral implications of the system that has been described in the model in order to see how the structure and decision-making policies in a system create its behavior. Hereby we regard a port cluster and the city as a large-scale system, and the analytic procedures on principle of system dynamics stimulation model are as follows:

(1) Definition of system objectives. The objectives of establishing the dynamic economic impact model are to study the dynamic changes of the economic impact of a port cluster on the city and the economic integration with each other.

(2) Identification of system boundary. There are two types of variables in the model, one is the state variables —— gross domestic product, port throughput volume, port throughput capacity, cluster natural resource, port pressure and fixed assets investment to cluster, and the other is the supplementary variables —— cluster-generated gross domestic product (GDP), cluster-generated employment, cluster revenue and cluster itself investment.

(3) Ascertainment of causality. The essence of model establishment is to analyze the causality, only through which can we understand the whole structure of the system and as a result find out the correlation among variables (Figure 3.).

(4) Establishment of system dynamics model. The causality diagrams and flow diagrams are presented through causality analysis of system elements, forming the model by means of the software of VENISM (Renan Jia, 2002) which is the special software package for system dynamics.

(5) Computer simulation. The results of model test on computer can be used to analyze the approaches to system improvement or to draw up several alternative plans as reference for decision-makers.

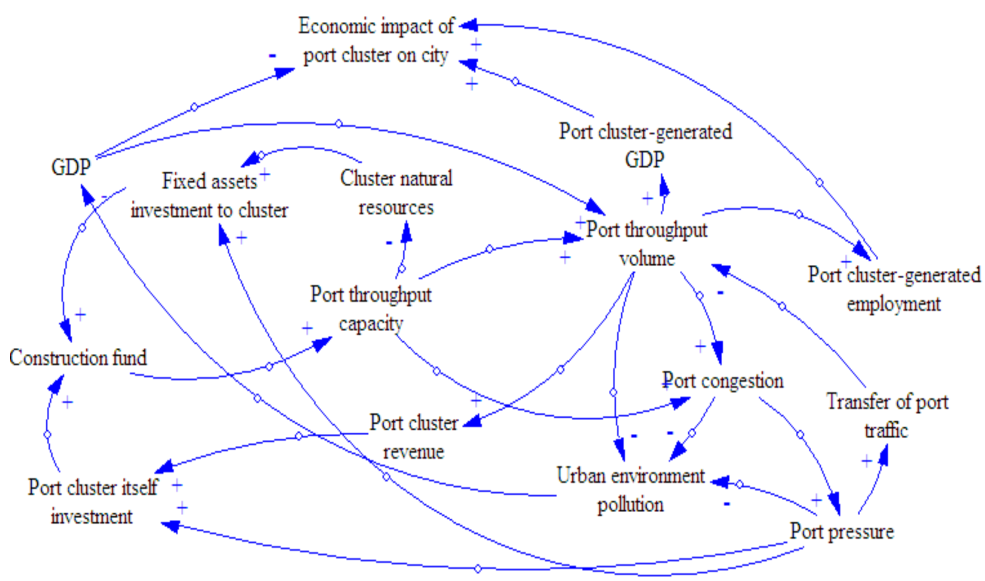

Figure 3. The total causality of economic integration between port cluster and port city

5 Conclusions

A good integration is the key to develop port cluster and urban economy, so further study on the operation mode of port cluster, the effective models and algorithms measuring the economic integration between port cluster and city, and then the definition of applied theory for the economic operation mode of each other are both of academic and practical significance, especially for the development of port resources and improvement of port competitiveness.

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References

Davis, H. C. (1983). "Regional port impact studies: a critique and suggested methodology." *Transportation Journal,* vol. 23, pp. 61-71.

Haezendonck, E. (2001). "Essays on strategy analysis for seaports." Leuven, Garant, 136.

Klink Van, H. A. (1995). Towards the borderless main port Rotterdam – an analysis of functional, spatial and administrative dynamics in port systems. Amsterdam: Thesis publishers.

Renan Jia. (2002). System dynamics- analysis of feedback dynamic complexity, Higher Education Press, Beijing, pp. 152-159.

Shanghai International Shipping Information Research Centre (SISIRC). (1999)."The statistical index system for the economic impact of Shanghai shipping and related industries on urban economy", Shipping Management, Oct.

Evaluation of the Service Quality for an Urban Rail Transit Station Based on Characteristics of the Elderly

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Abstract: The aging of population has become a global trend, and the traffic problem of the older people has become the focus of the society. With the large-scale network of the urban rail transit, there is a certain gap between the existing station facilities and the traffic demand of aging society. This article analyzed travel characteristics of older people through surveys and questionnaires. Based on the characteristics and travel demands, service quality index system for urban rail transit station is established. The service quality of the several stations in Shanghai is evaluated through comprehensive evaluation model. Finally, in order to improve the safety and convenience for older people's travel, some suggestions for improving facility and services of station are proposed.
Keywords: Urban rail transit station; Characteristics of the elderly; Evaluation of service quality.

1 Introduction

Since 1980s, Shanghai has been the oldest city in China. By the end of 2013, the population of aged 60 and above accounted for 27.1% of the total population. The degree of the ageing is nearly twice that of china's national average. According to the prediction of Population and Development Research Institute of Shanghai Academy of Social Sciences, the peak of aging population will appear in the 2030s. And then the elderly population in Shanghai is expected to be more than 5,000,000. With the implementation of free public transport service, the frequency of elderly traveling is increased. The proportion of elderly to take rail transit is also increased. Mao Haixiao and Ren Futian analyzed the travel characteristics of older people. They proposed some suggestions from development of public transportation and construction of barrier free facilities for the elderly (Mao Haixiao and Ren Futian, 2005). Zhang Zheng gave the travel behavior characteristics of the elderly in Beijing city. He predicted the effect of aging population on future structure of residents travel in Beijing (Zhang Zheng, 2009). Yue Xiang studied the universal design of public transport facilities in Berlin, and proposed some special design advice for the disabled and elderly people (Yue Xiang, 2013). But there was little research about how to improve the quality of serving aging people in urban rail transit stations. So this article studied the related problems of service quality in urban rail transit station based on the characteristics and travel demands of the elderly.

2 Travel Behavior and Travel Problems of the Elderly

We investigate some elderly people in Yangpu district and Hongkou district. And the elderly around Siping Road station, Wujiaochang station and Hongkou football stadium station are the main surveying people. The research results are as follows.

2.1 Travel characteristics of the elderly

(1) Psychological and physiological characteristics of the elderly

The old people cannot be as intensive as young people. Their response to the outside world is slow and their action is not flexible. They are easily in danger even in ordinary circumstances. For the psychological aspect, the elderly are more likely to feel they are failures. They want to be taken care of, but they have strong self-esteem. They don't want to be despised because of age and physical reasons.

Action ability and endurance of the elderly are not as good as that of the young (Zhang Zheng, 2009. Xu Zhiyong, 2012). When solving the problems of safety and convenience of elderly travel, we should consider the psychological and physiological needs of the elderly.

(2) Traffic characteristics of the elderly

As for the trip purpose, the elderly travel gradually from survival to enjoying good quality of life (Mao Haixiao and Ren Futian, 2005). Exercise, food shopping and sending their children to school accounted for higher proportion in numerous travel purposes. And then, going to hospital and visiting friends are as follows. The purposes of travel by rail transit are mainly shopping, visiting friends, participating social activities and going to the hospital.

2.2 Existing problems of the elderly travel

On the basis of research data, there are a lot of difficult matters for the elderly in rail transit station, such as walking up and down stairs, standing trouble in platform, going in and out of toll gate machine, listening to broadcast, finding the corresponding export etc. The ratio of various difficulties can be found in Figure 1.

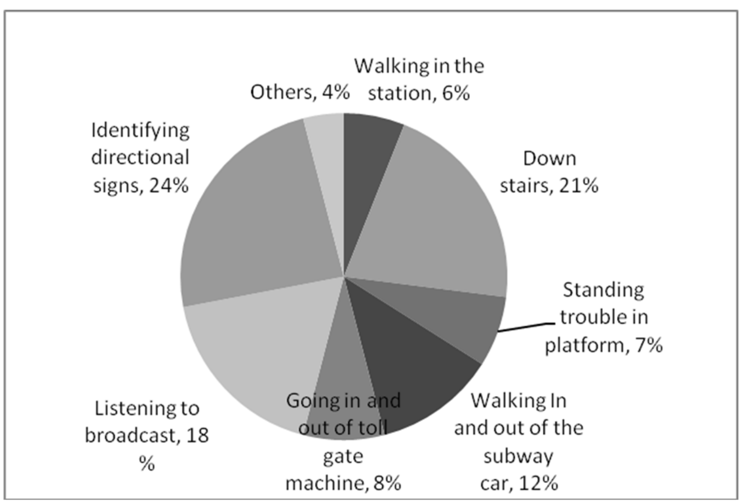

Figure 1. Behavioral difficulties of the elderly

3 Establishing Evaluation Index System

Through the above analysis of the existing problems on the travel characteristics of the elderly, we established the evaluation index system of service quality of urban rail transit station. The index systems is also combined with the relevant experts' advices (Fan Qianqi, Pu Qi and Yin Congcong, 2013; Zhao Ye, Wang Jinsong and Chen Fa'an, 2013). It is divided into three layers. The first layer is comprehensive index A. Safety index B_1、convenience index B_2、speed index B_3 and amenity index B_4 are the second layer. Each of the second level indicators can be divided into the third level indexes of C_{11}-C_{14}, C_{21}-C_{25}, C_{31}-C_{33}, C_{41}-C_{43}. All the indexes are shown in Table 1.

Table 1. The evaluation index system of service quality

The First layer	The second layer	The third layer	
The evaluation index system of service quality of urban rail transit station based on characteristic of elderly A	safety index B_1	C_{11}	setting rationality of barrier free lift
		C_{12}	setting rationality of safety handrail
		C_{13}	skid resistance surface
		C_{14}	safety in waiting area on platform
	convenience index B_2	C_{21}	convenience of ticket checking machine
		C_{22}	layout rationality of guiding sign
		C_{23}	visibility of electronic information
		C_{24}	toilet position in station
		C_{25}	convenience of information consultation
	speed index B_3	C_{31}	walking time
		C_{32}	transfer time at station (for transfer station)
		C_{33}	ticket waiting time
	comfort index B_4	C_{41}	cleanliness at station
		C_{42}	layout rationality of seat and its number
		C_{43}	comfortable at station queuing area

4 A Case Study of Service Quality Evaluation at Urban Rail Transit Station

Considering multiple factors, this study uses AHP to analyze the problem. This method is systematic, simplicity and practicality. It can analyze the nature and influence factors of complex decision problems. And quantitative information is taken into account to make thought process mathematical, so as to provide a simple decision-making method for multi-objective, multi-criteria problems.

4.1 Computing the index weight

By consulting the experts in the field of urban rail transit, we establish the comparative judgment matrix (A-B, B_1-C, B_2-C, B_3-C, B_4-C). These judgment matrixes present the situation of the comparative weight of this layer's relative factors, aiming at some factors of the upper layer. AHP adopts the 1~9 marking method, brought forward by Satie, to constitute the judging matrix. And then we calculate the weight of each index, along with the consistency check of judging matrix.

The judgment matrix of the A-B is as follows (Table 2).

Table 2. A-B judgment matrix

A	B_1	B_2	B_3	B_4
B_1	1	3/2	4	3
B_2	2/3	1	8/3	2
B_3	1/4	3/8	1	3/5
B_4	1/3	1/2	5/3	1

Calculating the maximum characteristic value of judgment matrix by using MATLAB software, we get $\lambda_{\max} = 4.006$.

Then, we calculate the consistency index C.I. of judgment matrix (formula 1), and get the the consistency ratio C.R. using the following formula 2.

$$C.I. = \frac{\lambda_{\max} - n}{n-1} \tag{1}$$

$$C.R. = \frac{C.I.}{R.I.} \tag{2}$$

In the function, n is the order of matrix. The random consistent index R.I. is shown in Table 3. When the $C.R. \leq 0.1$, we think the judging matrix has satisfying consistency. Otherwise, we should adjust it.

Table 3. The average random consistent index R.I.

N	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	12
R.I.	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.52	1.54

The calculation process is as follows.

$$C.I. = \frac{\lambda_{\max} - n}{n-1} = \frac{4.006 - 4}{4-1} = 0.002;$$

$$C.R. = \frac{C.I.}{R.I.} = \frac{0.002}{0.9} = 0.0022 \langle 0.1$$

So we think the judging matrix has a satisfying consistency. Therefore, the weight vector of each indicator using MATLAB software is $A = (0.443, 0.295, 0.105, 0.156)^T$

With the same methods, we establish the other judgment matrix B_1-C, B_2-C, B_3-C, B_4-C. The results of weight are as follows:

$B_1 = (0.213,0.262,0.346,0.179)^T$; $B_2 = (0.208,0.281,0.228,0.109,0.174)^T$

$B_3 = (0.625,0.238,0.136)^T$; $B_4 = (0.167,0.333,0.500)^T$

The final index weights are as follows:

W=(0.0944,0.1161,0.1533,0.0793,0.0614,0.0829,0.0673,0.0322,0.0513,0.0656, 0.0250,0.0143,0.0261,0.0519,0.0780)^T

4.2 Computing the index score

Taking Siping Road Station as an example, this paper studies the evaluation method for service quality. Siping Road Station is the transfer station of line 10 and line 8, where is heavy traffic. Among the indicators in the third level of index system, 3 indicators are quantitative indicators, while 12 indicators are qualitative indicators. The scores of the quantitative index are got by survey at the station. The scores of the qualitative indicators are got from the data of questionnaire for the elderly passengers.

The walking speed is about 0.9m / s for the elderly. The average walking time is about 2min18s from Exit 1 or Exit 2 to platform (excluding ticketing time). According to early study and practical situation of stations in Shanghai, the score of walking time is shown in Table 4 (Zhao Ye, Wang Jinsong and Chen Fa'an, 2013).

Table 4. Scores of walking time index

Walking time	Score	Walking time	Score
0 min 00 s ~ 1 min 00 s	10	3 min 00 s ~ 3 min 30 s	5
1 min 00 s ~ 1 min 30 s	9	3 min 30 s ~ 4 min 00 s	4
1 min 30 s ~ 2 min 00 s	8	4 min 00 s ~ 5 min 00 s	3
2 min 00 s ~ 2 min 30 s	7	5 min 00 s ~ 6 min 00 s	2
2 min 30 s ~ 3 min 00 s	6	>6min 00 s	1

As for internal transfer time, score of each index is valued at the same way with Table 4. And the total transfer time from Line 10 to Line 8 is 42s at the walking speed of 0.9m / s for the elderly.

As for ticket waiting time, the average ticket waiting time is 52s based on field research on the elderly without Bus Card. The score of various ticket waiting time is shown in Table 5 (Zhao Ye, Wang Jinsong and Chen Fa'an, 2013).

Table 5. Scores of ticket waiting time index

Ticket waiting	Score	Ticket waiting	Score
0 min 00 s ~ 0 min 30 s	10	2 min 30 s ~ 3 min 00 s	5
0 min 30 s ~ 1 min 00 s	9	3 min 00 s ~ 3 min 30 s	4
1 min 00 s ~ 1 min 30 s	8	3 min 30 s ~ 4 min 00 s	3
1 min 30 s ~ 2 min 00 s	7	4 min 00 s ~ 5 min 00 s	2
2 min 00 s ~ 2 min 30 s	6	>5min 00 s	1

The sores of the other 12 qualitative evaluation indexes are scored by passengers one by one during the questionnaires. Using the same ten score system, the highest score is "10". The elderly gives the score according to their degree of satisfaction. Then we analyze the overall data of the investigation and get the final score. Combined with the above quantitative indicators, the scores of different indexes of this station are summarized in Table 6.

Table 6. Service quality evaluation of Siping Road station
(For the elderly passengers group)

Index	Score	Index	Score
setting rationality of barrier free lift	3.5	convenience of information consultation	7
setting rationality of safety handrail	8.5	walking time	7
skid resistance surface	9	transfer time at station (for transfer station)	10
safety in waiting area on platform	9.5		
convenience of ticket checking machine	9	ticket waiting time	9
layout rationality of guiding sign	8	cleanliness at station	9
visibility of electronic information	8.5	layout rationality of seat and its number	7.5
toilet position in station	8	comfortable at station queuing area	9

So we get the score of service quality of Siping Road Station for the elderly is 8.019. According to the value of evaluation, the service quality of Siping Road station is good.

The service quality of other stations can be evaluated by this method. So we can find the gaps between the service quality and the demands of the elderly. Some measures should be taken so as to provide better services for the elderly. The measures include improving the convenience of barrier free elevators, setting non-skid floor and sitting area at the right position. Guiding signs should be designed more scientific and reasonable. The amount of information, text size, pattern and color should also be considered. At the same time, we should enhance the public awareness of respecting the elderly through media publicity. Subway staff and passengers in the station are willing to help the elderly so that the elderly travels smoothly by urban rail system.

5 Conclusions

Population aging is the inexorable trend of economic development and social progress. This paper made a quantitative evaluation for the service quality of urban rail transit station based on characteristics of the elderly, taking Siping Road station as an example. Some related suggestions are put forward. With the increase of the elderly travel frequency, there are still many issues need to be further studied. We hope to create a humanized travel environment for the elderly.

References

Chen Hong and Feng Liwei. (2009). Study on the design of urban mass transit visual guide system in aging city (Shanghai). *Market Modernization*, 31: 34-36.

Fan Qianqi, Pu Qi and Yin Congcong. (2013) "Comprehensive evaluation of passenger service quality for urban rail transit based on passengers' Perception." *Urban Mass Transit*. 16(11): 49-52

Mao Haixiao and Ren Futian. (2005). "Research on characteristics, problem and improvement suggestions of traffic for Chinese old people." *Journal of Chongqing Jianzhu University.*7: 30-33

Xu Zhiyong. (2012). "Urban Transport Strategies of Aging Society in China." *Computer and communications,*30(2): 46-49.

Yue Xiang. (2013). Berlin universal design of urban public transport facilities and its enlightenment to China. *Journal of Chifeng University*. 6: 26-29

Zhang Zheng. (2009). "Study on analysis method of the elderly travel behavior characteristics." Beijing: Beijing Jiaotong University

Zhao Ye, Wang Jinsong and Chen Fa'an. (2013). "Empirical research of comprehensive evaluation of urban rail transit station service levels based on passengers' feeling perspective." *Transportation Science & Technology.* 4: 121-123

Reform of a Public Transport Operating Model in Luotian County Based on Game Theory

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Abstract: Inappropriate planning and operation of bus system in small and medium-sized cities has severely hampered the development of the public transport industry. This paper takes the public transport system of Luotian county of Hubei province as an example, and uses game theory to analyze the behavior of the government, the bus company and the bus owner's under uncertain information. Basically, this paper provides a method for better solving the distribution contradiction problems of buses owners interest group under the new operating system. Study results also have a reference value for small and medium-sized cities of our country. This paper also provides a decision support system for the reform of public transport system of small and medium-sized cities.

Keywords: Public transport system reform; Asymmetric game patterns; Luotian county.

1 Introduction

The urban public transportation is an important infrastructure of city which related to the sustainable development of the city and the people's interests. As the increasing population and the rapid growth of the car ownership, the urban traffic has become a more serious problem.

With the improvement of government reform and the socialization process, the traditional public transport operation mode is clearly unable to respond to the needs of society effectively. At present bus operation and management of small and medium-sized cities in our country are worrying as follows: 1. Policies are hysteretic and law enforcement cannot find strong evidence. 2. Each department acts on its own and responsibilities are not clear, which lead to low efficiency and poor macro-control ability. 3. Integration of government administration with enterprise which lead to the competition is not strong. 4. The bus fare mechanism is not scientific and the service quality is not high. 5.Law frame and compensation mechanism of finance are still not perfect.6.Lacking of effective supervision mechanisms (CHEN Pu, 2012).

The main reason caused these problems is that the public transport operating system does not appropriate, at the same time the government did not play a dominant role. So many cities began to explore the reform of the public transportation operation model. The key to reform is adequately introduce the competition mechanism.

2 Social Conditions for Reform Are Gradually Mature

The social conditions here are on a perspective of a wide range, including factors such as government, enterprises and the public.

In terms of government, the main factor that affects it's functional transformation is financial burden. How to reduce the governmental financial burden and arrange the limited funds to where the need is greatest becomes a direct reason why the government returned partly public service supply power to enterprises.

In terms of the public, the public transport is running monopoly by the state-owned enterprises which lead to low bus service quality and the poor efficiency. It not only can't meet the demand of the public travel but also often operates at a loss, thus the government has to increase financial support.

Therefore, in the cases of international economic environment gradually open, in order to guarantee the quality of bus transportation service and at the same time to intensify competition of private enterprises, it is necessary to introduce the privatization mechanism to bus operation to achieve the optimal allocation of resources.

3 Public Transport System Reform of Luotian

The thoughts of the Luotian public traffic operation reform is to transform from the original affiliated management mode to share-holding management mode. Through the reform to establish relative state-owned control and enhance the government leadership and control force to the development of the bus company. At the same time, establishing and improving market access and exit mechanisms to realize the return of the vehicle ownership and management rights. Then making uniform standard and unified management for all vehicles and drivers. Rights and interests are redistributed and signed up in the process of reform. Whether the interests of all parties can realize game balance or not is critical to the success of a reform （ZHANG Shuquan,2012）.

According to the ideas of the game theory in this paper, a model of the information uncertainty will be established to analysis the behavior regularity the government, the bus company and the original buses owner.

3.1 Model assumption.

Assumption 1: For convenience of analysis , the model assumes that the bus reform relates to two different groups, one is profit group which get more profits under the original system, the other is none profit group which get less. In this case, affiliated bus owners are belong to profit group and bus company is belong to none profit group. Assumption 2: None profit group preferential make choose in reform. And assume that the both game players to take some strategy has nothing to do with the proportion of the decision makers.

Assumption 3: Both sides are free to give selection strategy, and there is no external intervention force .

Assumption 4:Both sides are bounded rational. They can calculate their own cost effectiveness, and there does not exist the possibility that one side accepted the game because of cheat. In addition, both the game sides achieve equilibrium only for their expected income and cost of one reform policy.

To facilitate the research, all of these assumptions are ideal.

3.2 The establishment of non-symmetrical game model.

Under the condition of the above assumptions, using the non-symmetrical game models structure to set up a model as shown in figure 1.（HE Chaoping，2006）. Profit group 1 stands for bus company and fist choose to reform or not.

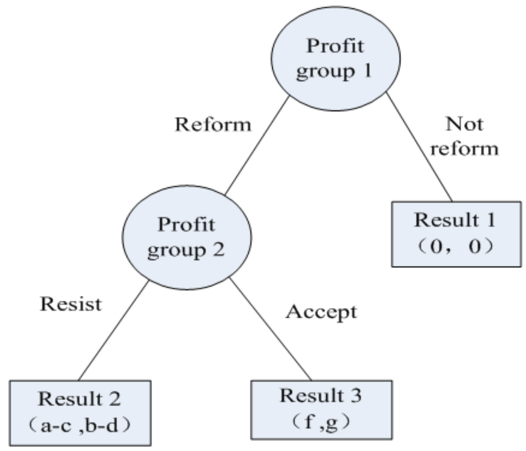

Figure 1. Non-symmetrical game model of bus reform

Assuming that the original utility of both the interest groups are 0. "a" stands for the utility that brought about if group 1 chooses to reform. "b" stands for the utility that brought about if group 2 resists the reform. "c" stands for a loss group 1 suffered when group 2 resists the reform. "d" stands for cost of resistance. "f" and "g" each stands for the utility of profit group 1 and 2.

The probability of profit group 1 chooses the reform strategy is x($0<x<1$).The probability of profit group 2 chooses the resistance strategy is y($0<y<1$).Utility of both game players as shown in table 1:

Table.1 Utility of both game players under non-symmetrical game model

utility	Game player 2	resist	accept
Game player 1	probability	y	1-y
reform	x	(a-c, b-d)	(f, g)
not reform	1-x	(0, 0)	(0, 0)

According to the table.1, it can be calculated that the expected utility of player 1 when it took reform strategy is:

$$E_{1m} = y(a-c)+(1-y)f = (a-c-f)y+f$$

The expected utility of player 1 if it didn't take reform strategy is:

$$E_{1n} = 0$$

The average expected utility of player 1 is:

$$\overline{E_1} = xE_{1m} + (1-x)E_{1n} = x[(a-c-f)y + f]$$

The expected utility of player 2 if it resisted the reform is:

$$E_{2\mathrm{m}} = x(b-d)$$

The expected utility of player 2 if it accepted the reform is:

$$E_{2\mathrm{n}} = xg$$

The average expected utility of player 2 is:

$$\overline{E}_2 = yx(b-d) + (1-y)xg$$

According to the replicated dynamic equation formula of the asymmetric evolutionary game model, it can be calculated that the replicated dynamic equations of two players' expected utility are (MIAO Ruili, 2012) :

$$F_{1(x,y)} = \frac{d(x)}{d(t)} = x(E_{1m} - \overline{E}_1) = x(1-x)[f + (a-c-f)y] \qquad (1)$$

$$F_{2(x,y)} = \frac{\mathrm{d}(y)}{d(t)} = y(E_{2m} - \overline{E}_2) = y(1-y)x(b-d-g) \qquad (2)$$

3.3 Discussion and results of model

game player 1. For Eq. 1, if a-c>0, then a-c-f>-f ; and 0≤y≤1, so f+(a-c-f)y＞0 always stands up. And because of 0≤x≤1, the solution of $F_{1(x,y)}=0$ is x=1.The game player 1 choose the evolutionary stable strategy.

If a-c≤0, when f+(a-c-f)y=0, then y= -f/(a-c-f); that means if y= -f/(a-c-f) , no mater what value the x is,$F_{1(x,y)}=0$ permanent stands up,and it is an evolutionary stable strategy. If y≠-f/(a-c-f), x=0 or x=1 is the evolutionary stable strategy. To be specific, x=1 is the evolutionary stable strategy when 0<y< -f/(a-c-f), and x=0 is the evolutionary stable strategy when -f/(a-c-f)<y<1.

game player 2. For Eq. 2, if b - d > g, it will eventually converge to (0, 1) no matter how the initial state is, so the game 2 will eventually in the condition of resistance, and all the game player 1 will not reform. In the end, the new system can not be applied.

If b - d < g, it will eventually converge to (1, 0) no matter how the initial state is, namely the game player 1 will eventually in the state of reform, and the player 2 will accept reform. When b - d - g = 0, $F_{2(x,y)}$ always equal 0, it will be evolutionary stable strategy no matter what value y is. The phase diagram of asymmetric evolutionary game is in figure.2.

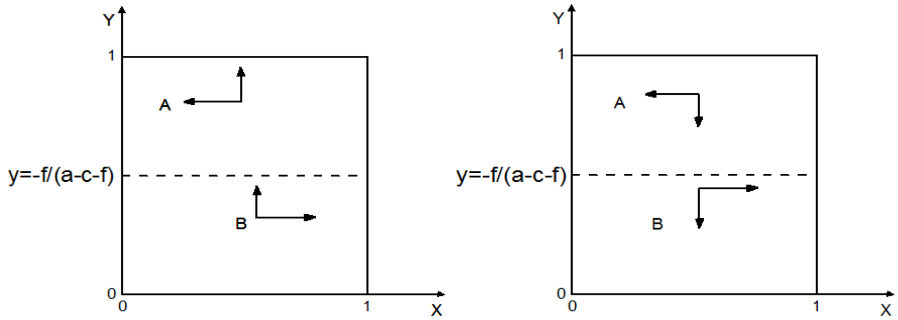

Figure 2. Phase diagram about asymmetric evolutionary game for b-d>g and b-d<g

4 Conclusion

Through the analysis and discussion of the model, three conclusions are summarized.

1. If new public transport operation patterns could bring profits to both the bus company group and the original buses owners group, the reform would be easy to get success. It is apparent even without the game model. While it gives an inspiration that government must first consider whether the new system is beneficial to non-profit group, this is the most basic prerequisite for a successful reform. At the same time if the new system can improve the profit group interests than under the original system, it will contribute to the success of the reform.

2. If the affiliated owners get more profits when they boycott the application of a new system than accept it, they will not accept the reform, so the reform will be met with resistance. Even if the bus company could get more profits under the new system and the government took forced reform measures, affiliated buses owners will take strike and other boycott measures to block the public transportation reform. Such bus reform is failure, even threaten the social stability.

3. Raising the cost of boycott or giving preferential policies to affiliated owners who accepted the reform will enhance the success of reform. For example, government can stop giving financial subsidies to opponents, or give economic compensation and higher priority of route selection to the supporters. These steps can accelerate reform to a great extent.

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Reference

Brendan Finn. Etts Ltd. (2005). Study of systems of private participation in public transPort-Helsinki metro politan area.

CHEN Pu (2012). Bus Operation And Management Of Small And Medium-sized City.

Cullinane s.(2002).The relationship between Car ownership and Public transport Provision: :a case study of HongKong . Transport policy, 9(1).

E.S.Savas.(1987). Privatization:The Key to Better Government.Chatham, NJ:ChathamHouse, 3
GUO Huiquan.(2006). Try to analysis thedefinition of the losses of the state-owned bus enterprises and the countermeasures. Urban public traffic. vol.6,
HE Chaoping.(2006). Research On The Management System Of Urban Public Transportation.
MIAO Ruili.(2012). Modern Business Trade Industry. Vol.01, 2012, pp.1.
WANG Hongzhan.(2009). Investigate the role of local government in the city bus system reform- Take Yuyao for an example. Shanghai Jiao Tong University.
ZHANG Shuquan.(2012). Journal of Hunan Finance and Economics University. Vol.28, 138.

An SMDP-Based Optimization Model for Railway Passenger Ticketing

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Abstract: Although the Passenger Railway has developed rapidly, the ticketing is still on a first come, first served basis. Gradually, we find it always induced the seats unoccupied and reduced the system rewards because of the halfway-station requests. This paper presents the Railway Passenger Ticketing Optimization Model based on Semi-Markov Decision Process (SMDP) to increase the system rewards. Especially, we propose "the seats risk-rewards" to indicate the system value at risk by different ticketing decisions. Furthermore, this study provides not only the optimal strategy of the seats utilization, but also the system maximum long-term rewards.
Keywords: Ticketing decisions; Semi-Markov Decision Process (SMDP); The seats risk-rewards; System rewards.

1 Introduction

With the massive Passenger railway constructed and operated, the demands of passengers continue to increase and a large number of new technologies have emerged (Liang et al., 2011; Liang et al., 2010). In this work, our research focuses on the seats reusing (Mao et al., 2004; Zhou et al., 2003) and the system rewards improving in Passenger railway. In general, we classify the ticketing requests services in two categories: Long Distance Requests and Short Distance Requests. We accurately defined the economic gain of railway passenger as system rewards as well.

In the development history of the railway passenger, there are three important phases. Firstly, Railway Ticketing System (RTS) has facilitated passengers travel (Feng, 2009). However, the RTS has not implemented the intelligent decision. Secondly, Tickets Distribution Plan (TDP) generated to assist the railway passenger (Ma et al., 2001). It is a strategy to allocation a number of tickets to every station along the way to sale. According to the principle Tickets Distribution Plan, the long-distance passengers' demands have priority over short-distance demands, which permits to effectively combine the short-distance demands in order to improve the load factor. Under the TDP, the essence of ticketing is based on a strategy of first come-first serve. Intelligent decision is also not applied in the tickets sale process. Thirdly, Revenue Management is successfully applied in the aviation field (Goasvi et al., 2002). However, because of the complex railway network, multi-site, travel distance different and other characteristics, it is necessary for railway to combine with its own characteristics in order to improve the system rewards.

Generally, the railway economic revenue is primarily from tickets sale (Zhang et al., 2006). However, little literature gives the intelligent optimization strategy about seats utilization to enhance railway economic revenue. In this paper, we discuss a kind of optimal decision model by dynamic analyzing the possible tickets array for one seat along the whole way in order to maximize the system rewards, in the period of tickets sale.

To describe briefly and accurately, we propose "seats risk-rewards" to indicate the system value at risk (Zhou et al., 2008). Seats risk-rewards mean the value of the remainder short-distance tickets. It can be explained that a long-distance ticket is cut into several short-distance tickets to sale. After one of these short-distance tickets has been sold, the seats risk-rewards indicate the summation of all the remainder short-distance tickets value. System rewards can be presented by tickets-rewards subtracting seats risk-rewards.

According to the above analysis, our work is organized as follows. The ticketing strategy and procedure is described in Section II. In Section III, we presented the optimization model. The specific analysis of the Semi-Markov Decision Process model (SMDP) for Railway Passenger Ticketing is in Section IV. The simulation with analyze about the optimal model is in Section V. Finally, we summarized the research in this article and presented future work in Section VI.

2 Ticketing Strategy and procedure

In terms of first come first serve, the seats are liable to lead to vacant. Because short-distance passengers occupied tickets, the demands of long-distance passengers rarely could be content. In comparison to the conventional way, our strategy based on the SMDP is effective for the ticketing decision.

This paper provides a number of assumptions: every station which uses the optimal model is controlled by its own virtual station, receptively. The virtual station records the number of the remained tickets in real time. Moreover, it makes the decisions about all the purchase requests. Besides this, we suppose that: no ticket reservation been canceled, no request been postponed scheduled, no refund request, all passengers had to buy one ticket for once request, the person who was denied would be directed to purchase other trips ticket, and all the demands would be treated sequentially by virtual station. There are two levels of tickets: long-distance (h) and short-distance (l).

Figure1 shows that the procedure of the purchase requests in station A. In the primary stage, each ticketing agent transmitted every ticket purchase request to virtual station to process. The virtual station handles only one request at one time. It will array a series of requests randomly which generate simultaneously and are treated sequentially. Except for the limited capacity for a train, the available tickets are also limited. In regard to the different O-D demands, the new tickets will be generated by the seats reusing. It can effectively enhance the tickets-rewards and the tickets utilization. The main idea of our Semi-Markov Decision Process model (SMDP) for Railway Passenger Ticketing Model is to decide whether to accept or not a purchase request from a passenger at a time for effectively utilizing the value of all the seats. In this study, not only we have considered traffic volume, but also analyzed the system rewards in an optimal decision.

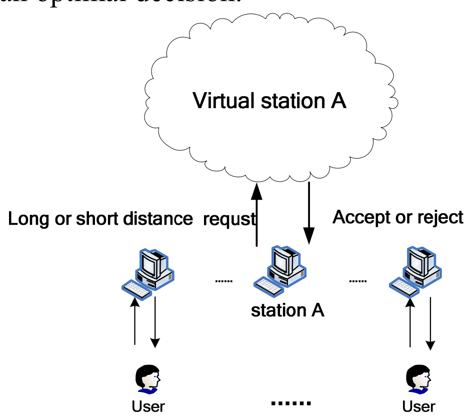

Figure 1. The ticketing procedure in station A

3 Optimization Model

Before we throw out the specific model, there are several definitions need to be described.

(1) In our model, the optimal model is applied only in the originating station.

(2) We define the destination-station which is not the Terminal station as halfway-station. We denote the number of halfway-station as Z, $Z \geq 1$.

(3) The destination-station which is affiliated in one local Railway Bureau is considered as short-distance (l).

(4) The destination-station which crosses Railway Bureaus is considered as long-distance (h).

In our model, two basic kinds of requests are provided, namely, short-distance and long-distance requests. For brevity, four stations (z_1~z_4) are set along the whole line. We consider only one class of seats and the unlimited station are z_2 and beyond. In comparison to the traditional ticketing policy in station z_2~z_4, the originating station z_1 uses the optimal model to sale tickets. As the following descriptions, we focus on the ticketing optimal decision in station z_1.

Figure 2 explains the characteristic about the four stations. Because of station z_2

affiliated in one local Railway Bureau, the request type is short-distance when the destination is station z_2. The travel from z_1 to z_3 and z_4 is regarded as long-distance, since z_3 and z_4 are cross Railway Bureaus. In order to comply with the Rail Tickets distribution principle, the demands which destination is terminus station (z_4) will be directly received. Thus, we only analyze the travel in which the destination except z_4. The arrival rates of requests l or h follow the Poisson distribution with mean rates λ_l and λ_h, respectively.

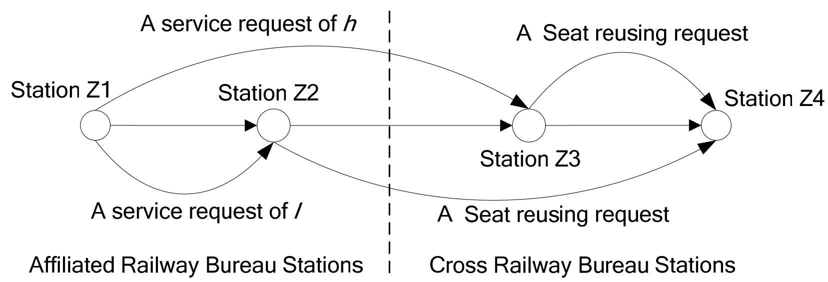

Figure 2. Illustrate about the stations and seats reuse

In order to understand the relationship between the halfway-station (z_2 and z_3) requests and the seats reuse, we give the explanation as follows. When a halfway-station request was received, a new ticket was generated which from the halfway-station to beyond (Shi et al., 2009; Shi et al., 2008). The whole process of the optimal policy decisions can not only control the seats reuse, but also improve the load factors and system rewards.

4 SMDP-Based optimization policy decisions

4.1 System states

We present request-events as well as the system states in this section. The system states can reflect the system rewards impacted by ticketing decisions. A request of purchase tickets l or h can be considered as an incoming event. Thus, in the system model, we define two events:

(1) Receive or reject a long-distance request (e.g. A passenger want to go from z_1 to z_3), denoted by e_h;

(2) Receive or reject a short-distance request (e.g. A passenger want to go from z_1 to z_2), denoted by e_l;

The number of purchase request l and h which has been received are denoted as n_l and n_h, respectively. Thus, the system states can be expressed as following:

$$S = \{ s \mid s = < n_l, n_h, e > \} \quad (1)$$

Where $e \in \{ e_l, \quad e_h \}$ indicates the collection of all the events.

4.2 Decision-making

It is critical for our model to make ticketing decision. When a passenger arrived at a ticket window and proposed a particular type of ticket request, two type of decisions can be selected by the model: reject and receive, which are denoted by $a(e)$=0 ,and $a(e)$=1 . Accordingly, the decisions can be expressed by a set:

$$A = \{ a_{\langle s,e \rangle} \mid \quad a_{\langle s,e \rangle} \in \{0,1\} \}$$

4.3 System rewards

In this study, the seats risk-rewards caused by the short-distance tickets is particularly problem resolved by our optimized model. With the following discuss in this section, we focus on Single trains to research system rewards, which contains two factors: The ticket-rewards and seats risk-rewards.

Let $x(s,a)$ as the ticket-rewards, when the system selects decision *a* with state *s*. $x(s,a)$ is shown as follow:

$$x(s,a) = \begin{cases} 0, & e \in \{ e_h, e_l \}, a = 0 \\ R_h, & e = e_h, a = 1 \\ R_l, & e = e_l, a = 1 \end{cases} \quad (2)$$

Where $R \in \{ R_l, \quad R_h \}$ denote the value of a ticket, as an *l* or *h* purchase request is accepted, the system can obtain income R_l or R_h .

The seats risk-rewards can be evaluated based on the probability of the various seats reuse array and the corresponding rewards, denoted by *q* and β , respectively.

Consequently, we have

$$y(s,a) = q \bullet \beta \quad (3)$$

Let the parameter $\tau(s,a)$ indicates the time duration between two adjacent policy decisions and it follows an exponential distribution. Therefore, the average rate of passengers arriving for tickets can be computed as:

$$\gamma(s,a) = \tau(s,a)^{-1} = \lambda_h + \lambda_l \quad (4)$$

According to above analyses, the Semi-Markov Decision Process (SMDP)-Based Optimization Model, the whole system rewards $z(s,a)$ in the duration of $\tau(s,a)$ can be built as following:

$$z(s,a)=x(s,a)+y(s,a) \tag{5}$$

Where $x(s,a)$ and $y(s,a)$ are already defined in the previous.

Applying the system rewards equivalent (5), we can deduce the maximum long term rewards as following:

$$v(s)=\max\left\{z(s,a)+\eta\sum_{i\in S;i=s-1}p(i\mid s,a)v(i)\right\} \tag{6}$$

Where $\eta=\dfrac{\gamma(s,a)}{\varphi+\gamma(s,a)}$, φ indicates the discount rate. Denote $p(i\mid s,a)$ as the state transition probability, with the decision *a* and the current state *s*.

According to these equivalents above, the ticketing failure probability $P_{failure}$, defined as the ratio of the number of rejected requests and the total number of requests, is thus given by

$$P_{failure}=\frac{\sum_{n_l}\sum_{n_h}\left(\left(1-a_{j1}\right)\pi_{j1}+\left(1-a_{j2}\right)\pi_{j2}\right)}{\sum_{n_l}\sum_{n_h}\left(\pi_{j1}+\pi_{j2}\right)} \tag{7}$$

where a_{j1}, $a_{j2}\in A$ are the decisions adopted at states $\langle n_l,n_h,e_l\rangle$ and $\langle n_l,n_h,e_h\rangle$, respectively. The short-distance and long-distance requests steady-states probabilities can be indicated as π_{j1} and π_{j2}, respectively, with $j1=\langle n_l,n_h,e_l\rangle$, $j2=\langle n_l,n_h,e_h\rangle$.

5 Performance evaluations

In this section, we will provide the performance of our optimal model using a simulator written in matlab. In the simulation, we set the requests arrival rates of requests *l* and *h* are 3 and 5 per unit time, respectively, and the discount factor φ=0.1.

The ticketing failure probability of request *h* under various arrival rates of purchase requests are shown in fig.3. We have evaluated the ticketing failure probability of long-distance passengers under different number of total tickets (K=600 and K=1000) with different arithmetic: SMDP and Greedy. By using Greedy arithmetic, it always adopted any kind of requests without considered the risk probability. We further increase the total number of tickets from 600 to 1000. We can gain better results by the higher number of tickets. A higher ticketing failure probability is achieved when the long-distance request arrival rate increases. For example, we need reserve some tickets for the requests which want to terminal station. Compared with Greedy arithmetic, the ticketing failure probability is lower by using SMDP, when we set a same total number of tickets. It can be seen that the SMDP is an efficient optimal model which can reasonably allocate *l* and *h* tickets.

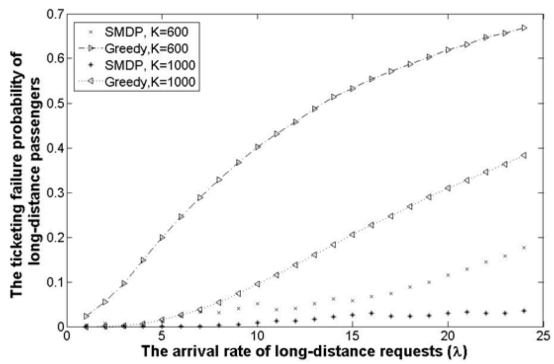

Figure 3. The ticketing failure probability of request *h* under various arrival rates

In fig 4, we can easily find the distinguished performance in system rewards by using the SMDP optimal model compared with the Greedy arithmetic. The change of the number of total tickets affects the system rewards with the same arrival rate. With increasing arrival rate for request *h*, the system rewards are enhanced by an exponential distribution for both SMDP and Greedy. Although, the SMDP model could get more excellent results than Greedy did.

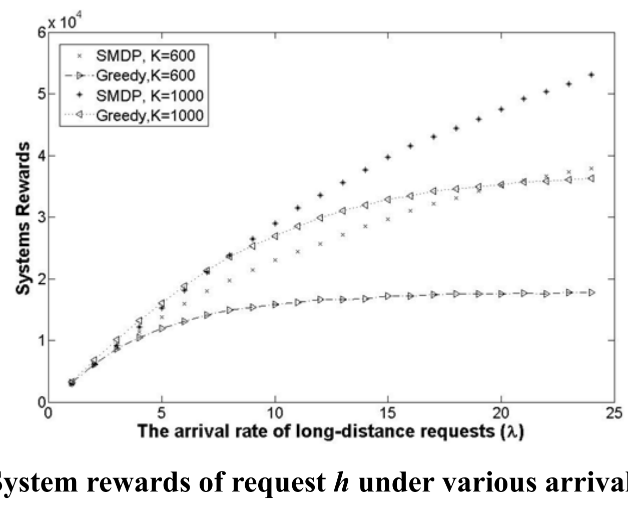

Figure 4. System rewards of request *h* under various arrival rates

6 Conclusions

In this paper we have proposed a new idea to provide insight to formulate an optimal Railway Passenger Ticketing model based on SMDP for the problem of seats reuse of the tickets from origin station to halfway point. By simulation with matlab, we have obtained the ticketing failure probability of long-distance (h) passengers and the whole system rewards considering the seats risk-rewards with various arrival rate of request h. Further study will focus on deducing the details of the seats risk-rewards on different optimal decisions. In addition, we will investigate the ticketing and travel guidance in railway passenger traffic passage.

Acknowledgment

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References

Feng Fei, (2009). "The System of Tickets Allocation for Railway Ticketing and Reservation. " *Railway Transport and Economy*, 7(7), 88-91.

Goasvi, A., Bandla, N., Das, T.K. (2002). "A Reinforce of Learning Approach to a Single Leg Airline Revenue Management Problem with Multiple Fare Classes and Overbooking." *IIE Transactions*, 34, 729-742.

Liang, H., Huang, D., and Peng, D. (2010). "On Economic Mobile Cloud Computing Model." in *Proceedings of the International Workshop on Mobile Computing and Clouds (MobiCloud in conjunction with MobiCASE)*.

Liang, H., Huang, D., Cai, L.X., Shen, X.M.,and Peng, D.Y. (2011)."Resource Alloaction for Security Services in Mobile Cloud Computing." *IEEE infocom*, 191-195.

Ma Jianjun, Xu Hong, Hu Siji,et al. (2001). "The Theory and Design Method on Seats Allotment System of Passenger Trains and implementation by Computer." *Journal of the China Railway Society*, 23(6),6-10.

Mao Weihua, Zeng Zhiyuan. (2004). Research ticket system and implementation of reusable seats, *Railway Computer application*, 13(12),16-18.

Shi Feng, Chen Yan, Zhou Wenliang, Deng Lianbo. (2008). "The planning and evaluation methods based on users equilibrium analysis on tickets distribution of passenger train." *China Railway Science*, 11(6), 98-103.

Shi Feng, Zhou Wenliang, Chen Yan, Dong Longyun, Xie Qingchun. (2009). "Research of Optimal Dynamic Railway Seats Share Strategy." *Journal of the China Railway Society*, 31(2), 98-103.

Zhang Xiumin, Zhao Dongmei, Wen Shudong. (2006). "Revenue Management of Railway tickets." *Railway Transport and Economy*, 28(7), 7-9.

Zhou Liang-jin, Liu Qiang, Wang Yuanyuan. (2003). "Analysis and Research for Repeat Using Seats in TRS." *Railway Computer Application*, 12(12),6-7.
Zhou Xiaohua, Zhang Yan. (2008). "A new Methods and applications of value at risk (VaR) calculation." Management Journal , 819~823.

Analysis of Social Risk Causes of Rail Transit Construction Projects Based on DEMATEL-ISM

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Abstract: In order to prevent social instability of rail transit construction projects effectively, 15 factors caused rail transit social risk were extracted. Using the integration of decision-making trial and evaluation laboratory (DEMATEL) and the interpretive structure model(ISM), a structural model of risk cause system was established. The causes were divided into 4 categories: root causes, controllable causes, key causes, direct causes. The results show that safeguarding the fundamental interests of the masses is the key to control the social risk of the rail transit construction.
Keywords: Rail transit; Social risk; DEMATEL; ISM; Causes.

1 Introduction

In recent years, rail transit construction projects bring great benefits for society. Meanwhile, since the complexity of the project and the management, the construction also brings a lot of problems especially social conflicts, which seriously affects social stability. Social risk assessment work will play an important role. Domestic research on social risk all concentrate on risk assessment method aspect, e.g. Wu put forward a comprehensive evaluation method of the combination of entropy weight and AHP method to evaluates the social risk of city transportation construction projects (Wu et al. 2009), and Yang set up a social risk evaluation index system of critical projects with three levels (Yang, Luo 2010), while quite a few research mentions about social risk causes.

The occurrence of risks is the result of multiple combined forces and to some extent corresponds with the complex environment. Relationship of each element in the risk causes system is the premise and foundation of social risk evaluation. Therefore, 15 factors caused rail transit social risk were extracted. In order to study the risk causes relationship of each element in the system further, using the integration of decision-making trial and evaluation laboratory and the interpretive structure model, a structural model of risk cause system was established, to provide the reference for the social risk assessment and risk management in the future.

2 Analysis of Social Risk Causes System of Rail Transit Construction Projects

The rail transit construction projects are large-scale projects with the characteristic of high workload, long duration, high technique, complex construction and management condition, and various interest groups involving, hence it leads to the perplexing relationship among factors, and forms an open, complex, stochastic and dynamic system.

To accurately analyze the social stability risk causes in the system, this paper studies social risk events that have occurred in the procedure of project construction, combining with the characteristics of rail construction projects, and comprehensive analysis of the relevant research results, 15 factors which cause the social risk were extracted from the four aspects of social environment, economic, ecological environment and system. (See Table 1)

Table 1. Social risk cause of rail transit construction projects

Social Risk Cause of Rail Transit Construction Projects	
Ecological Cause	S_1: Pollution from construction
	S_2: Soil and water loss
Economical Cause	S_3: Unemployment caused by project
	S_4: Low compensation of land expropriation
Social Cause	S_5: The wage arrears of workers
	S_6: Traffic risks caused by project
	S_7: High rate of Construction safety accident
	S_8: The resettlement difficulties
	S_9: National cultural conflict
	S_{10}: Negative public opinion
	S_{11}: Low degree between construction and opinion fusion
	S_{12}: Social conflicts caused by project
System Cause	S_{13}: Untimely and Opaque Information publicity
	S_{14}: Imperfect social risk management system
	S_{15}: Imperfect accountability system

3 An Integrated Modeling Method Based on DEMATEL-ISM

DEMATEL, also known as the decision-making trial and evaluation laboratory, is developed by the American Bastille National Laboratory (Li, Zhang 2014). It builds the direct influence matrix using the logical relationship between elements, suitable for studying the interactions between factors of complex systems. Interpretative Structural Modeling, which is to use known but messy relationships between system elements to reveal the internal structure of the discrete, unordered, static system (Jiang 2013), is also a method for complex system research (Zuo et al. 2012).

Plenty of researches suggest that the effectiveness of the hierarchical division of system structure is obviously weaker than ISM approach while applying DEMATEL method solely. However, large amount of computation exist when there are many factors in the system while using the ISM method alone. In view of the fact that there are many similarities between the DEMATEL and the ISM method, the combination of the two can not only reduce the complexity of computation, but also create a clear hierarchical structure to analyze complex system (Xie 2014). Zhou Dequn (Zhou, Zhang 2008) first put forward the construction method of hierarchical structure of the integrated DEMATEL-ISM system, and gives the theoretical basis and algorithm of the integration. According to Zhou Dequn's (Zhou, Zhang 2008) research, the modeling steps are as follows. (Figure 1)

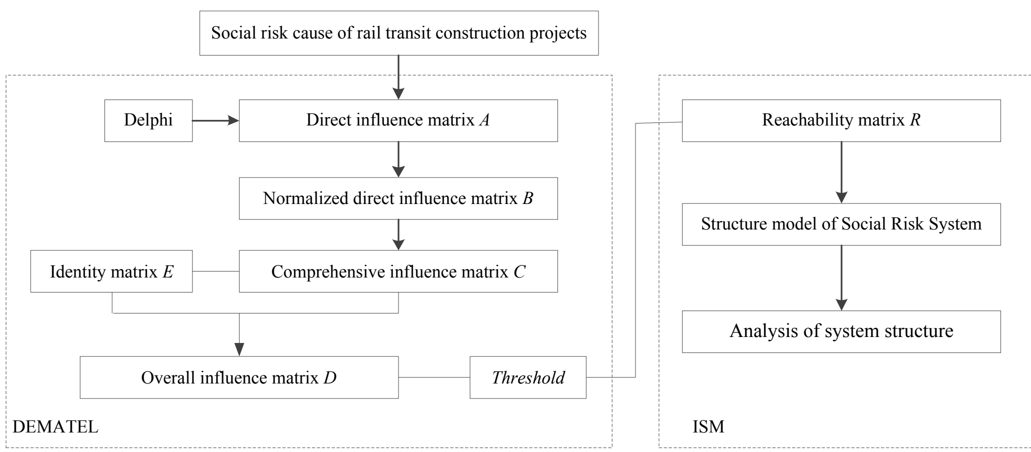

Figure 1.Modeling steps

3.1 Establishing Direct Influence Matrix

15 factors of causation system in table 1 are scored using Delphi by 20 experts in Rail transport Construction area. They compared each factor in pairs and scored them from 0 to 3 according to the degree of direct influence, representing no direct relation, weak relation, general relation and strong relation. Relations between factors were defined according to formula 1.Then the influence matrix A was established; $A = \left(a_{ij}\right)_{n \times n}$.

$$a_{ij}=\begin{cases}3, & \mathrm{k}\geq 13\\ 2, & 7\leq \mathrm{k}\leq 12\\ 1, & 1\leq \mathrm{k}\leq 6\\ 0, & \mathrm{k}=0\end{cases} \tag{1}$$

with k : number of person who holds that S_i impacts S_j .

$$A=\begin{pmatrix}
0&2&0&0&0&0&0&0&0&1&1&2&0&0&0\\
0&0&0&0&0&0&0&0&0&1&1&2&0&0&0\\
0&0&0&0&0&0&0&3&0&2&2&3&0&0&0\\
0&0&0&0&0&0&0&3&0&1&1&2&0&0&0\\
0&0&0&0&0&0&0&0&0&2&0&2&0&0&0\\
0&0&0&0&0&0&0&0&0&1&1&1&0&0&0\\
0&0&0&0&0&0&0&0&0&1&2&1&0&0&0\\
0&0&0&0&0&0&0&0&0&0&1&3&0&0&0\\
0&0&0&0&0&0&0&2&0&0&1&3&0&0&0\\
0&0&0&0&0&0&0&0&0&0&2&2&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&3&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&3&3&0&0&0&0\\
0&0&0&1&1&0&2&0&0&0&0&0&2&0&0\\
0&0&0&0&0&0&3&0&0&1&0&0&0&2&0
\end{pmatrix}$$

3.2 Establishing Comprehensive Influence Matrix

Normalize direct influence matrix then we get normalized direct influence matrix B .

$$B=\left(b_{ij}\right)_{n\times n}=\left(\max_{1\leq i\leq n}\sum_{j=1}^{n}a_{ij}\right)^{-1}A \tag{2}$$

According to matrix A , summation of the third row elements is biggest. Based on matrix B , comprehensive influence matrix C can be defined using formula 3;

$$C=B+B^2+\cdots B^n \tag{3}$$

consider $\lim_{n\to\infty}\left(B\right)^{\mathrm{n-1}}=0$, so

$$C=B\left(E-B\right)^{-1}=\left(c_{ij}\right)_{n\times n} \tag{4}$$

Then comprehensive influence matrix can be defined using MATLAB programming, when E represents identity matrix.

$$C=\begin{pmatrix}
0 & 0.200 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.120 & 0.144 & 0.307 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.100 & 0.1200 & 0.256 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.300 & 0 & 0.200 & 0.270 & 0.511 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.300 & 0 & 0.100 & 0.150 & 0.355 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.200 & 0.040 & 0.252 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.100 & 0.120 & 0.156 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.100 & 0.220 & 0.186 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.100 & 0.330 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.200 & 0 & 0 & 0.120 & 0.396 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.200 & 0.260 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.300 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.300 & 0.300 & 0.1680 & 0 & 0 & 0\\
0 & 0 & 0 & 0.100 & 0.100 & 0 & 0.200 & 0.030 & 0 & 0.110 & 0.135 & 0.132 & 0.200 & 0 & 0\\
0 & 0 & 0 & 0.020 & 0.020 & 0 & 0.340 & 0.006 & 0 & 0.152 & 0.113 & 0.108 & 0.040 & 0.200 & 0
\end{pmatrix}$$

3.3 Defining Overall Influence Matrix

Comprehensive influence matrix shows the degree of influence and relation between factors in the causation system. And the influence of each factor to itself can be shown by identity matrix E. Overall influence matrix D can be defined using formula $D = C + E = \left(\mathrm{d}_{ij}\right)_{n\times n}$.

3.4 Defining Reachability matrix

Based on overall influence matrix D, reachability matrix can be defined as $R = \left(r_{ij}\right)_{n\times n}$. And according to practical situation of Rail Transport Construction, consider threshold $\lambda = 0.15$. When $\mathrm{d}_{ij} \ge \lambda$, $r_{ij} = 1$; while $\mathrm{d}_{ij} < \lambda$, $r_{ij} = 0$.

$$R=\begin{pmatrix}
1&1&0&0&0&0&0&0&0&0&0&1&0&0&0\\
0&1&0&0&0&0&0&0&0&0&0&1&0&0&0\\
0&0&1&0&0&0&0&1&0&1&1&1&0&0&0\\
0&0&0&1&0&0&0&1&0&0&1&1&0&0&0\\
0&0&0&0&1&0&0&0&0&1&0&1&0&0&0\\
0&0&0&0&0&1&0&0&0&0&0&1&0&0&0\\
0&0&0&0&0&0&1&0&0&0&1&1&0&0&0\\
0&0&0&0&0&0&0&1&0&0&0&1&0&0&0\\
0&0&0&0&0&0&0&1&1&0&0&1&0&0&0\\
0&0&0&0&0&0&0&0&0&1&1&1&0&0&0\\
0&0&0&0&0&0&0&0&0&0&1&1&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&1&0&0&0\\
0&0&0&0&0&0&0&0&0&1&1&1&1&0&0\\
0&0&0&0&0&0&1&0&0&0&0&0&1&1&0\\
0&0&0&0&0&0&1&0&0&1&0&0&0&1&1
\end{pmatrix}$$

3.5 Establishing Structural Analysis Model

The reachable set R_i, the antecedent set A_i, and intersection 错误!未找到引用

源。 in the causation system can be calculated by using ISM while the reachability matrix is defined. Then factor S12 can be defined according to formula $R_i \cap A_i = R_i$. Remove the corresponding rows and columns of the reachability matrix in order to find new summit factors in the reachability matrix left. Followed by analogy we can get an analytical result of the hierarchy of the reachability matrix in order to establishing a structural analysis model in the end. As shown in Figure 1.

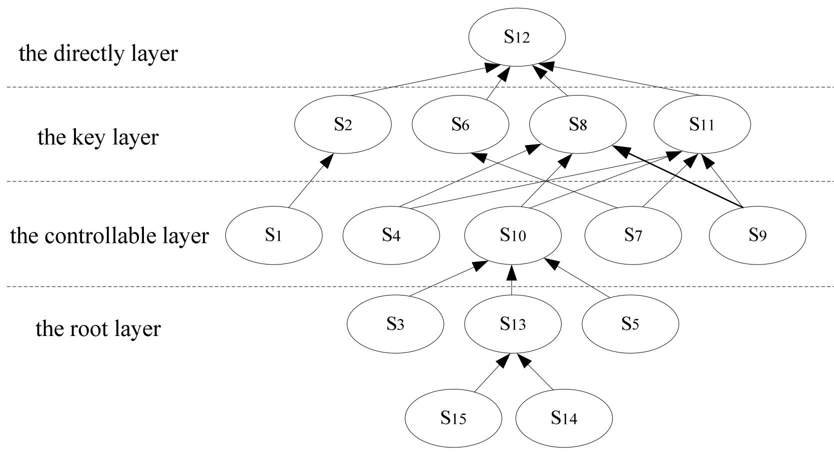

Figure 2.Structure Model of Social Risk System

4 Analysis of System Structure

Social risk causes system of rail transit construction projects with multilevel hierarchical structure can be divided into 4 layers from bottom to top: the root layer, the controllable layer, the key layer, and the directly layer (as shown in Figure 2).

(1)From root layer to controllable layer

As can be seen from Figure 2, imperfect accountability system (s_{15}) and risk management system (s_{14}) is likely to cause the manipulation, opaque information publicity (s_{13}), and the spread of negative public opinion (s_{10}). Although from different aspects of the factors, both unemployment caused by projects (s_3) and the wage arrears of workers (s_5) are the public opinion direction, and their result may lead to the negative opinion (s_{10}).

(2)From controllable layer to key layer

We also can be seen from Figure 2, negative public opinion (s_{10}) and low compensation of land expropriation (s_4) might affect the public mood, reduce the resettlement difficulties (s_8) and low degree between construction and opinion fusion (s_{11}).

Pollution from construction (s_1), such as water pollution and garbage pollution, would cause soil and water loss (s_2). Construction safety accident (s_7) may trigger traffic risks (s_6). National cultural conflict (s_9) can increase the resettlement difficulties (s_8). Construction and opinion fusion (s_{11}) also be affected by the construction safety accident (s_7) and national cultural conflict (s_9).

(3) From key layer to directly layer

As shown in Figure 2, social conflicts (s_{12}), the most direct manifestations of social risk, are influenced by all the factors in the key layer. Concretely, oil and water loss (s_2) will trigger the conflicts (s_{12}) between projects owner and the local environmental protection department; the contradiction (s_{12}) between projects owner and the traffic department may arise by traffic risks (s_6); the resettlement difficulties (s_8) would make projects owner conflict (s_{12}) with local people; the backlash of the masses may be initiated by low degree between construction and opinion fusion (s_{11}), and reduce social conflicts (s_{12}).

5 Conclusions

By the thinking of system analysis, this paper uses the method of integrated DEMATEL and ISM, puts forward the multilevel hierarchical structure and the relationship within the social risk causes system of rail transit construction projects. At the same time, root causes, key causes, controllable causes and directly causes of the social risk system were proposed. The results show that safeguarding the fundamental interests of the masses is the key to control the social risk of the rail transit construction.

The method of integrated DEMATEL and ISM not only avoids the subjectivity of the traditional analysis methods, such as fault tree analysis and analytic hierarchy process, but also ensures the system structure hierarchical and unambiguous. It should be noted that the judgments of relationship between factors in the system are based on experts' experience, and there is still a certain amount of subjectivity. The focus of future research is to realize objective relation judgment of the factors.

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References

Jiang L., Zuo Z. Y. (2013) "Analysis of city rail transit system operation safety based on ISM". *China Safety Science Journal*, 23(06), 172-176.

Li C., Zhang S. B. (2014) "Critical factors for capital structure of rail transit PPP projects based on fuzzy DEMATEL." *Urban rapid rail transit*, 27(01), 72-75.

Wu X. G., Wang R., Chen Y. Q. (2009). "Social risk management of large-scale urban traffic construction project." *J. of HUST. Urban Science Edition*, 26(4), 25-28.

Wang Z. Y. (2010) "Research of key construction project social stability risk analysis and evaluation." *Construction management*, (7) ,48-50.

Xie H. T. (2014) "Analysis of the cause-effect interactive relations of the construction foundation pit collapse accidents." *Journal of Safety and Environment* , 14(04), 151-155.

Yang L., Luo E. X. (2010) "Study on social risk indicator system for large project." *Science-Technology and Management* , (02), 43-46.

Zuo Z. Y., Xie W. Z., Shao C. F. (2012) "Optimization of regional logistics system for the Bohai ring based on ISM." *Logistics Technology* , 31(5), 120-122.

Zhou D. Q., Zhang L. (2008) "Study on hierarchy of complex system based on integration DEMATEL/ISM." *Journal of Management Science in China* , 11(02), 20-26.

Trade Credit Term Decisions under Centralized Decisions

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Abstract: In this article, we studies the optimal trade credit term decision under the centralized decision making in an extended economic ordering quantity framework. We divide the trade credit policy into two parts: $T \le M_j$ and $T > M_j$. The objective of this research is to determine the optimal credit term to maximize the joint total profit per unit time. Furthermore, numerical study and sensitivity analysis are presented to illustrate the results of the proposed model and to draw managerial insights.
Keywords: Trade credit; Credit term; Centralized decision; Sensitivity analysis.

1 Introduction

In business operations, due to the uncertainty of the procurement, production and sales aspects, business will be a shortage of funds. China's small and medium -sized enterprises have capital constraint, it is difficult to solve this problem. This will not only hinder their own development, also affect the profit of other companies in the supply chain. Now, there are two common ways: First is the bank credit; the second is trade credit. The first study is a bit of more, the second way is relatively lake. So, this paper studies of the second way.

Trade Credit is an important coordination mechanism between manufacturers and retailers. It can share the cost, transfer the risks and regulate the benefits. Trade credit term is the length of time allowed retailer to delay payment, it is the core concern of credit term decisions. This paper study the issue of trade credit term decision under a centralized decision-making, how to set the optimal trade credit term to make the supply chain system's profit maximization, and the sensitivity analysis of trade credit term.

2 Literature review

When the buyers and suppliers exchange goods/services, they usually have to agree on trade terms. These trade terms consist of delivery and prices and payment conditions. Now trade credit for goods/services is a very common business practice, the optimal length of trade credit is the core concern of credit term decisions.

Shi and Zhang (2010) incorporated default risk into the supplier's decision. Numerical study suggested that the optimal trade credit term increases with the buyer's capital cost, and decreased with the supplier's capital cost, the demand rate, the probability of default, and the buyer's inventory holding costs. Abad and Jaggi (2003) introduced cooperative behavior, modeled a set of Pareto-efficient solutions. The particular solution depended on a profit-sharing parameter that the supplier and the retailer establish through negotiation. Jaber and Osman (2006) relaxed the lot-for-lot assumption. Jaggi et al. (2008) investigated the supplier and the retailer both offer trade credit. Assuming the supplier's credit period as given, they presented an algorithm to jointly determine the retailer's optimal cycle time and credit period. Kouvelis and Zhao (2012) modeled no cooperative behavior but introduced stochastic demand. Using a capital-constrained newsvendor model, the authors found that trade credit was always advantageous for the supplier. Gupta and Wang (2009) formulated a model to investigate the relationship between cash discount and discount period. A smaller cash discount implied a longer discount period. Charharsoogi and Heydari (2010) introduced cooperative behavior and uncertain lead times. Sarmah et al. (2007) compared trade credit and quantity discount contracts in an economic order quantity framework. Trade credit was more efficient if the supplier's cost of capital is lower than the buyer's cost of capital; otherwise quantity discounts were more efficient. Lee and Rhee (2010) considered quantity discount, buy backs, two-part tariffs, and revenue sharing in a newsvendor framework.

In these literatures, the trade credit term were considered as the unilateral decision problem of manufacturer rather than from the perspective of the entire supply chain. Therefore, this paper sets up a two-echelon supply chain that contains single manufacturer and a single retailer to study the optimal trade credit term decision under the centralized decision making.

3 The mathematical model

3.1 Assumptions and notation

The following assumptions were made in developing the proposed model:

(1)There is a single supplier and a single buyer in this model.

(2)The production rate is greater than the demand rate and shortages are not allowed.

(3)The supplier adopts a lot-for-lot policy.

(4)The retailer has no initial money, but his/her sales revenue can put in the bank to obtain interest. When the time to pay supplier for goods, the retailer's sales revenue less than need to pay ,he/she should take stock pledge measure to pay.

(4)The supplier cost of capital is less than the retailer, this ensures that manufacturers have the ability to provide the trade credit.

(5)The retailer holding cost is less than the purchase cost, if the holding cost is higher than purchasing cost, the retailer don't want to keep any inventory.

Notation:

D - Retailer's demand rate per unit time

h - Retailer's unit stock holding cost of good quality items per unit time excluding interest charges

A - Supplier's setup cost per setup

S - Retailer's ordering cost per order

M_j - The length of the trade credit period offered by the supplier

T - The length of replenishment cycle of the retailer

I_e - Retailer's interest earned per dollar per unit time

I_p - Retailer's interest charged per dollar in stocks per unit time

I_m - Supplier's capital opportunity cost per dollar per unit time

π_j - Retailer profit, supplier profit and total profit($j = r, s, 1, 2$)

p, w, c - Retailer selling price, supplier wholesale price, supplier production cost($p > w > c$)

Then assumption that $I_p > I_e$, $I_p > I_m$, $pI_e > wI_m$.

3.2 Modeling

In the trade credit, as the credit term is longer or shorter than the length of replenishment cycle of the retailer, we have the following two possible cases:① $T \le M_j$ and ② $T > M_j$. These two cases' inventory and capital model for the retailer are depicted in Figure.1.

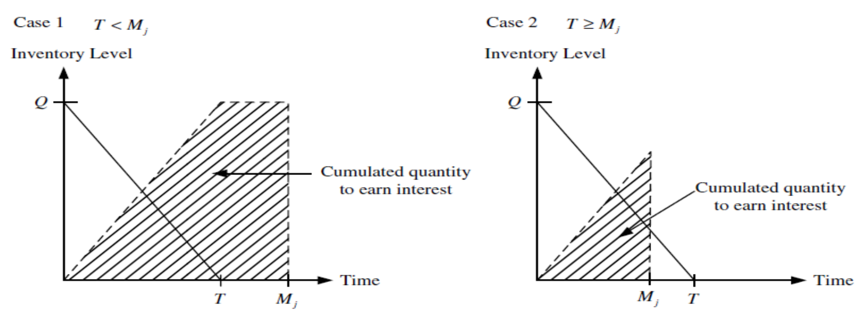

Figure 1. Inventory and capital model for the retailer under trade credit

Profit function of the retailer:

Retailer's profit= sales revenue- ordering cost – inventory cost –cost of financing+ interest of sales revenue

$sales\ revenue\ = (p-w)D$, $ordering\ cost\ = S/T$, $inventory\ cost\ = hDT/2$.

When the $T \le M$, retailer dose not financing so has no cost of financing, $interest\ of\ sales\ revenue\ = pDI_e(M - \frac{T}{2})$

When the $T > M$, $cost\ of\ financing\ = \frac{wD(T-M)^2 I_p}{T}$,

$$interest\ of\ sales\ revenue\ = \frac{pDI_e[M^2 + (T-M)^2]}{2T}$$

Retailer's profit:

$$\begin{cases} T \le M, & \pi_r = (p-w)D - \dfrac{S}{T} - \dfrac{DTh}{2} + pDI_e(M - \dfrac{T}{2}) \\ T > M, & \pi_r = (p-w)D - \dfrac{S}{T} - \dfrac{DTh}{2} - \dfrac{wD(T-M)^2 I_p}{T} + \dfrac{pDI_e[M^2 + (T-M)^2]}{2T} \end{cases} \quad (1)$$

Profit function of the supplier：

Supplier's profit = sales revenue - opportunity cost -set-up cost

$$\text{Supplier profit}: \pi_s = (w-c)D - wI_m MD - A/T \quad (2)$$

Total profit function of the system：

$$\begin{cases} T \le M, & \pi_1 = (p-c)D - \dfrac{A+S}{T} - \dfrac{DTh}{2} + pDI_e(M - \dfrac{T}{2}) - wI_m MD \\ T > M, & \pi_2 = (p-c)D - \dfrac{A+S}{T} - \dfrac{DTh}{2} - \dfrac{wD(T-M)^2 I_p}{T} + \dfrac{pDI_e[M^2 + (T-M)^2]}{2T} - wI_m MD \end{cases} \quad (3)$$

3.3 Solution procedure

According to the total profit function of the system (3), we can get the first derivative and the second derivative of the function as following:

$$\frac{d\pi_1}{dT} = \frac{A+S}{T^2} - \frac{Dh + pDI_e}{2} \quad (4)$$

$$\frac{d^2\pi_1}{dT^2} = -2\frac{A+S}{T^3} < 0 \quad (5)$$

$$\frac{d\pi_2}{dT} = \frac{A+S+DM^2(wI_p - pI_e)}{T^2} - \frac{Dh}{2} + \frac{D(2pI_e - wI_p)}{2} \quad (6)$$

$$\frac{d^2\pi_2}{dT^2} = -2\frac{[A+S+DM^2(wI_p - pI_e)]}{T^3} < 0 \quad (7)$$

By (5) and (7) shows that the profit function's second derivative is below zero, we can know that the total profit function of the system is a concave function. Furthermore, from(4)and(6)we get the $\frac{d\pi_1}{dT}|_{T=M} = \frac{d\pi_2}{dT}|_{T=M}$, therefore the profit function in the $T > 0$ is a concave function rather than piecewise concave function.

Setting $\frac{d\pi_1}{dT} = 0$ and $\frac{d\pi_2}{dT}$=0, we can get the optimal replenishment cycle time when $T \le M$ and $T > M$.

$$\begin{cases} \dfrac{d\pi_1}{dT}=0, & T_1^*=\sqrt{\dfrac{2(A+S)}{Dh+2pDI_e}} \\ \dfrac{d\pi_2}{dT}=0, & T_2^*=\sqrt{\dfrac{2[A+S+DM^2(wI_p-pI_e)]}{Dh+2D(pI_e-wI_p)}} \end{cases} \quad (8)$$

In the case $T \le M$, due to $pI_e < wI_m$, we can know that the longer the credit term, the system's profit will be smaller, so the optimal M is

$$M_1^* = T = \sqrt{\frac{2(A+S)}{Dh+2pDI_e}} \quad (9)$$

In the case of $T > M$, we can get the $T > M \Rightarrow M < \sqrt{\dfrac{2(A+S)}{Dh}}$, therefor the optimal credit term is

$$M_2^* = (I_p - I_m)\sqrt{\frac{2(A+S)}{D}} * \frac{1}{\sqrt{hI_p{}^2 + wI_pI_m(2I_p - I_m)}} \quad (10)$$

By the above get:

$$\begin{cases} T \le M\text{时}, & \pi_1^* = [p-c+M(pI_e-wI_m)]D-\sqrt{2D(A+S)(h+2pI_e)} \\ T > M\text{时}, & \pi_2^* = [p-c+wM(I_p-wI_m)]D-\sqrt{(h+wI_p)[2D(A+S)+wI_pM^2\mathrm{D}^2]} \end{cases} \quad (11)$$

4 Numerical studies

In this section, we solve the problem described in this paper, for numerical study with the parameters set as follows: $D=100$, $A=100$, $S=90$, $p=100$, $w=40$, $c=20$, $h=5$, $I_e=0.01$, $I_p=0.06$, $I_m=0.05$.

According to the(11)get the relationship between credit term and total profit of entire channel is depicted in Figure.2. So we can get the optimal trade credit term is $M^*=0.12$, the maximum profit is $\pi^*=7472$ and the optimal replenishment cycle time is $T^*=0.72$. This result is consistent with the section 3. Under the trade credit financing, business can increase the order to increase its sales revenue, but the cost of financing also increase, so businesses need to proceed from the total profit to give the optimal trade credit term.

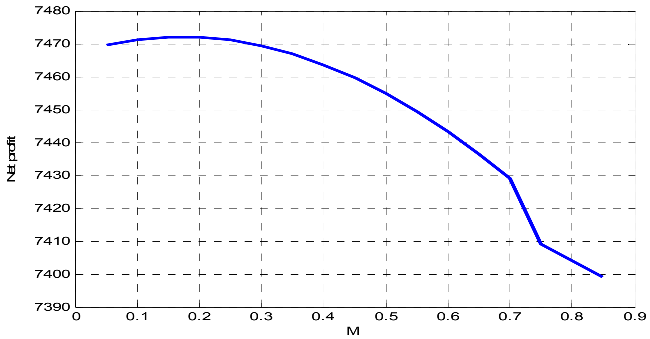

Figure 2. The relationship between credit term and total profit of entire channel

On this basis, we use sensitivity analysis to investigate the impacts of some factors on trade credit term decisions. These factors contain h, D, I_p and I_m, we let h, D, I_p and I_m within a reasonable range by a certain step change, then analyze these variables how affect trade credit term decisions.

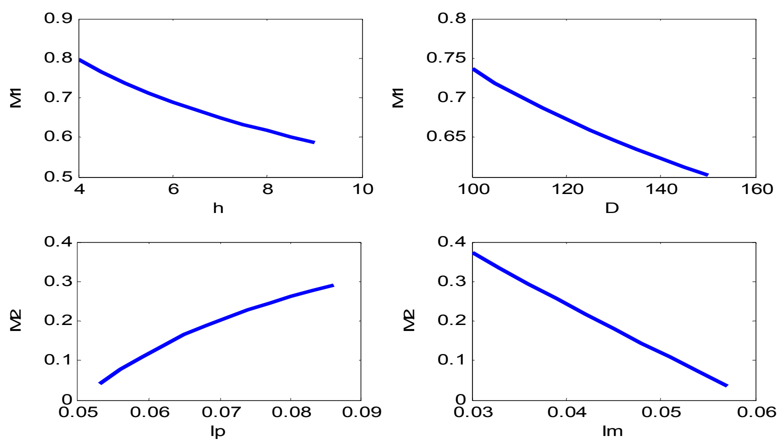

Figure 3. Credit term sensitivity analysis of h, D, I_p and I_m

The sensitivity analysis results are shown in Fig.3, We can draw the conclusions from Figure.3 as following:①Retailer holding cost impacts the retailer's ordering, in response to the supplier's credit term. So a higher holding cost leads to a shorter term, because the retailer’s inventory cost increases with his holding cost, a longer term in the case of a higher holding cost. ②A higher demand rate leads to a shorter credit term. We argue that a longer term for retailers with a higher demand rate, may bring in more orders, but it also leads the supplier to a greater level of default risk, so a shorter term will be preferred.③The retailer has a higher capital cost, which indicates his financing is more constrained, the supplier has to grant a longer term in this case. ④The supplier with greater financing capacity tends to grant longer term.

5 Conclusions

Trade credit is a major component of short-term financing for business all over the world, and the optimal length of trade credit is the core concern of trade credit term decisions. This paper studies the optimal trade credit term decision in an extended EOQ framework, and makes the numerical study. We get the relationship between credit term and total profit of entire channel and the sensitivity analysis of h, D, I_p and I_m .

As for future research, our model can be extended to decentralized supply chain, multi-echelon supply chains. Also, it can consider deteriorating items and default risk into the proposed model.

References

Abad P. L., Jaggi C. K 2003. "A joint approach for setting unit price and the length of the credit period for a seller when end demand is price sensitive." *International Journal of Production Economics 83*, 115–122.

Charharsoogi, S. K., Heydari J. (2010). "Supply chain coordination for the joint determination of order quantity and reorder point using credit option." *European Journal of Operational Research 204*, 86–95.

Gupta D., Wang L. (2009). "A stochastic inventory model with trade credit." *Manufacturing & Service Operations Management,* 11 (1), 4–18.

Jaber M. Y., Osman I. H. (2006). "Coordinating a two-level supply chain with delay in payments and profit sharing." *Computers & Industrial Engineering 50*, 385–400.

Jaggi, C. K., Goyal, S. K., Goel S. K. (2008). "Retailer's optimal replenishment decisions with credit-linked demand under permissible delay in payments." *European Journal of Operational Research 190*, 130–135.

Kouvelis, P., Zhao, W. (2012). "Financing the newsvendor: Supplier vs. bank and the structure of optimal trade credit contracts." *Operations Research 60 (3)*, 566–580.

Lee C. H., Rhee B. D. (2010). "Coordination contracts in the presence of positive inventory financing costs." *International Journal of Production Economics 124*,331–339.

Sarmah, S. P., Acharya D., Goyal S. K. (2007). "Coordination and profit sharing between a manufacturer and a buyer with target profit under credit option." *European Journal of Operational Research 182*, 1469–1478.

Shi X. J., Zhang S. (2010). "An incentive-compatible solution for trade credit term incorporating default risk." *European Journal of Operational Research 206 (1)*,178–196.

Production Function of a Railway Transportation Economy Analysis Method of Transfer

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Abstract: Production function is the econometric model used to study the business relationship between input and output. In this paper, it uses Cobb-Douglas (C-D) production function as based model, and it uses regression analysis and Solow residual as the theoretical support. It simulates the production function model of railway transportation. Through the empirical study and quantify the railway transport enterprise production function analysis, we can reveal factors affecting investment in the railway transport enterprise output volume. This research is helpful for future.

Keywords: Transportation economy; Production function and cost function.

1 Introduction

Our country has vast land and rich resources, but the allocation of resources are out of balance, so we should develop the railway transportation industry. Because it can provide strong service, it can support for last development of our country's economy and society. We research the relationship between the national economy and the production factors of rail transportation. It can provide guidance for scientific advice in the development of railway transport. It discusses the application of the production function in analysis, forecasting and investing. At last it can provide a reference for the production and management decision-making.

2 Cobb-Douglas production function (C-D)

C-D production function is very widely used in economic production function model, and it is very suitable for the analysis and research of the production development of large enterprises. C-D production function was originally by American mathematician Cobb and economist Paul Douglas, they studied the capital of the United States between 1899 to 1922 impact on national income and labor force by historical material. When the assumption of constant technology is the same, we can simulate for the output and the relations of capital and labor force.

2.1 The mathematical model of C-D production function

The first winner of the Nobel Prize economics professor J.Tinbergen thinks that as time progresses, the production function's curve should exhibit a trend to move to the right level. That is the same number of labor force and the amount of capital should get the output as time increase, the level of technology should be varied. Based on the above, an enterprise may be increasing, decreasing or the same, then the C-D production function as follows:

$$Y = A(t)L^{\alpha}K^{\beta}\mu \qquad (1)$$

Y: the output of an enterprise; $A(t)$:Comprehensive technical level, change over time; L: the number of input labour; K: the amount of capital invested, generally refers to the net value of fixed assets; α:Law firms; β:Law firms; μ:Random perturbation terms, including in addition to comprehensive technical level, the number of labor, the capital of three factors, all other unpredictable factors influence on output, in order to simplify the model, this article does not consider random perturbation terms.

Type (1) is a common C-D production function model. The model adopts the comprehensive technical level of change, and it didn't make any assumptions on law firms, so it is usually referred to as free schema model.

2.2 C-D Production function of the basic indicators

This paper uses one of the most basic margin analysis to analyze C-D production function in economic. The main factors of production are marginal product, elasticity and returns to scale, as follows:

(1) The marginal output of labor MP_L

$$MP_L = \lim_{\Delta L \to 0}\frac{\Delta Y}{\Delta L} = \frac{\partial Y}{\partial L} = \alpha A(t)L^{\alpha-1}K^{\beta}\mu = \alpha\frac{Y}{L} \qquad (2)$$

(2) The assets of the marginal output $\mathrm{MP_K}$

$$\mathrm{MP_K} = \beta\frac{Y}{K} \qquad (3)$$

(3) Labor unit of output MP_{LM}

The average wage of railway transportation industry in our country as the SA_L RMB, the investment on labor each unit of currency can be output to labor unit of output:

$$MP_{LM} = \frac{MP_L}{10^4 \bullet SA_L} \tag{4}$$

(4) Asset unit of output MP_{KM}

$$MP_{KM} = \frac{MP_K}{10^8} \tag{5}$$

(5) The marginal rate of substitution of labor for assets

In the C-D production function, the work of the marginal rate of substitution of capital MRS_{LK} refers to in the case of the production/output unchanged, an additional unit of labor can reduce the inventory of fixed assets, at this time because the output Y is constant, K can be assets as function of labor L:

$$MRS_{LK} = -\lim_{\Delta L \to 0} \frac{\Delta K}{\Delta L} = -\frac{\partial K}{\partial L} = \frac{\alpha K}{\beta L} \tag{6}$$

(6) The output elasticity coefficient of labor and assets EL 、 EK

$$EL = \frac{\frac{\partial Y}{Y}}{\frac{\partial L}{L}} = \frac{\partial Y}{\partial L} \bullet \frac{L}{Y} = MP_L \bullet \frac{Y}{L} = \alpha \tag{7}$$

$$EK=\beta \tag{8}$$

(7) Scale reward change

Assume that labor and fixed assets and to expand the production of lambda times to Y

$$\frac{Y'}{Y} = \frac{A(t)(\lambda L)^{\alpha}(\lambda K)^{\beta}}{A(t)L^{\alpha}K^{\beta}} (\lambda > 1) \tag{9}$$

3 Railway transportation production function simulation

Railway transport is a large service companies, and its production function is key function that relationship between output and input key. In this section, we use C-D production function as the basis model. It can be used as railway transport simulation and test, and it also can calculate and analyze the related indicators.

3.1 Railway transportation C-D production function

（1）Y：Output, railway transportation industry output value can be a transportation revenue or reduced turnover, consider conversion turnover H is the railway transportation industry to meet the national economy development the most visible expression of transport demand, this paper USES it as the full value of the railway transportation industry.

（2）A（t）: Comprehensive technical level, the management level, labor force quality, the introduction of advanced technology such as decision, type (10) adopted the comprehensive technical level of change, considering the research period, remained stable development of national economy and railway transportation in our country, think comprehensive technical level A (t) and over time, steady development using the type function as A comprehensive technical level of development:

$$A(t) = A_0 * \gamma' \tag{10}$$

A_0: The base of comprehensive technical level; γ': Comprehensive technical level of the average development speed; t: Relative to the time span of the base period during the reporting period.

（3）L: Labor number, generally the number of employees or staff total wages, considering the research period, our country labor force decline of railway transportation, and increasing its total wages, these two indicators were used respectively to simulate and compare.

（4）K: Fixed assets, the use of railway transportation industry of the net value of fixed assets each year.

（5）μ: Random disturbance, to simplify the model, μ=1

Based on the above, the free mode, railway transportation, the normal form of the C-D production function is:

$$H = A(t)L^{\alpha}K^{\beta} = A_0 * \gamma' L^{\alpha}K^{\beta} \tag{11}$$

Under the condition of constant scale reward, railway transportation, the normal form of the C-D production function is:

$$H = A_0 * \gamma' L^{\alpha}K^{1-\alpha} \tag{12}$$

3.2 Railway transport simulation of C-D production function

Based on the index data, production function to simulate and test of the railway transportation industry, briefly describes its principle is as follows.The simulation of the C-D production function

According to the constant return free mode and scale (actual it is the size of remuneration changes due to the change of the comprehensive technical level) in the two cases, introduces the following two methods respectively.

(1) Direct estimate method

Direct estimation refers to completely based on the historical data, not to any scale returns hypothesis, according to certain mathematical method to estimate parameters, a brief introduction to its steps are as follows.

Transform the C-D production function:

In order to get the function of linear form, type (11) on both sides for logarithmic transformation, have to function as follows:

$$\ln H = \ln A_0 + \ln \gamma * t + \alpha * \ln L + \beta * \ln K \tag{13}$$

$$\begin{cases} Y = \ln H \\ a = \ln A_0 \\ b_1 = \ln \gamma \\ b_2 = \alpha \\ b_3 = \beta \\ x_1 = t \\ x_2 = \ln L \\ x_3 = \ln K \end{cases} \tag{14}$$

Type (13) can be turned into:

$$Y = a + b_1 x_1 + b_2 x_2 + b_3 x_3 \tag{15}$$

Type (15) as a ternary linear function, can take advantage of the multiple linear regression of related theory and method to estimate its parameters.

Estimated parameter: similar to a yuan linear regression, multiple linear regression parameter estimation is also based on the least squares principle, go into the derivation process here.

Reduction simulative function parameters: according to the type (13), through a simple reverse, easy type (11) of each parameter of the experience value is:

$$\begin{cases} \tilde{A}_0 = e^{\tilde{a}} \\ \tilde{\gamma} = e^{\tilde{b}_1} \\ \alpha = \tilde{b}_2 \\ \beta = \tilde{b}_3 \end{cases} \tag{16}$$

Free mode, the railway transportation industry experience C-D production function of the sample regression function is:

$$\tilde{H} = e^{\tilde{a} + \tilde{b}_1 \bullet t} L^{\tilde{b}_2} K^{\tilde{b}_3} \tag{17}$$

(2) Strength form estimate method

Strength form estimation is in a constant scale reward ($\alpha + \beta = 1$) conditions, the type (12) on both sides of the exponential, it turned into a binary linear function, on the basis of drop yuan, according to the principle of least squares estimate parameter, the specific steps similar to direct estimation method, go here, its experience regression function are as follows:

$$\tilde{Y} = \tilde{\alpha} + \tilde{b}_1 x_1 + \tilde{b}_2 x_2 \quad (18)$$

$$\tilde{H} = e^{\tilde{a} + \tilde{b}_1 \bullet t} L^{(1-\tilde{b}_2)} K^{\tilde{b}_2} \quad (19)$$

4 Conclusions

This paper describes parameter estimation and hypothesis testing that free mode and constant returns to scale method. Then few years of study can be selected, it uses the railway converted turnover as output value, and it uses the number of employees in the transportation industry employees, total wage and net fixed assets as input elements. At last it uses SPSS software for the production of railway transportation function model to simulate and test. According to the test results of the two models, it selected constant returns to scale case studies as a basis for the subsequent. Then it calculates the relevant indicators and draws the relevant conclusions. For example, it can research the number of employees employed for transportation and net fixed assets; and it also research the comparison of fixed assets brought into outputs and inputs to bring the total wages; at last it research on the labor force relationship between the size of elastic modulus than the elastic coefficient assets.

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References

Fang Tao, (2001). “Railway transportation production function and factor level empirical research.” Chengdu: southwest jiaotong university, 25-35

Liu wenjin, (2003). “An empirical analysis of the production function and application.” Journal of railway transportation and economy, 2 (5),16-19

Huang yajun, (2009). “Microeconomics.” Beijing: higher education press, 5(3), 121-156

Implications of Foreign Policy to the Development of Railway Freight

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Abstract: According to foreign study on the policy development of railway freight transportation, this paper present that the developed countries adjust transportation structure and encourage various transportation modes to balanced develop by laying down integrated transportation and environmental protection policy. On the basis of analysis on current situations of the railway freight market and referring experiences of the foreign policy of integrated transportation, tax policy and transport subsidy, it introduces a strategy on promoting the development of China railway freight transportation.
Keywords: Freight turnover; Railway freight transportation; Transportation policy.

1 Introduction

Along with variety of industrial structure and the increasing competitiveness of other transport modes, the railway freight transportation maintains the steady growth in the volume and turnover volume. Nevertheless, the railway freight transportation facing severe challenges because of the decreasing of transportation market share. Besides, the sustained growth of car ownership contribute to the serious traffic congestion to many countries, uncoordinated development of transportation structure, which bring obstacles to the sustainable development of transportation. Therefore, we can learn and reference the methods of solving these issues form those countries, such as providing subsidy to environmental friendly transportation modes, increasing the tax on vehicle transportation, limiting vehicle transportation development and so on.

Table 1.2002-2012 the trend of Chinese freight market share change

Year	Railway	Road	Waterway	Airlift	Pipeline
2002	13.82%	75.25%	9.56%	0.01%	1.36%
2003	14.33%	74.14%	10.10%	0.01%	1.41%
2004	14.59%	72.96%	10.98%	0.02%	1.45%
2005	14.46%	72.06%	11.80%	0.02%	1.67%
2006	14.15%	71.98%	12.21%	0.02%	1.64%
2007	13.81%	72.04%	12.36%	0.02%	1.78%
2008	12.78%	74.12%	11.39%	0.02%	1.70%
2009	11.80%	75.32%	11.29%	0.02%	1.58%
2010	11.24%	75.52%	11.69%	0.02%	1.54%
2011	10.64%	76.28%	11.52%	0.02%	1.54%
2012	9.52%	77.78%	11.19%	0.01%	1.49%

Table 2.2002-2012 the trend of Chinese freight turnover market share change

Year	Railway	Road	Waterway	Airlift	Pipeline
2002	30.89%	13.38%	54.28%	0.10%	1.35%
2003	32.02%	13.18%	53.32%	0.11%	1.37%
2004	27.78%	11.29%	59.66%	0.10%	1.17%
2005	25.82%	10.83%	61.89%	0.10%	1.36%
2006	24.71%	10.98%	62.46%	0.11%	1.75%
2007	23.46%	11.20%	63.39%	0.11%	1.84%
2008	22.76%	29.80%	45.57%	0.11%	1.76%
2009	20.67%	30.45%	47.13%	0.10%	1.66%
2010	19.49%	30.59%	48.24%	0.13%	1.55%
2011	18.49%	32.25%	47.34%	0.11%	1.81%
2012	16.80%	34.26%	47.02%	0.09%	1.83%

2 Integrated Transport Policy in Foreign Countries

Most of the countries keeping the similar objectives of integrated transport policy, which are speeding up transportation development for promoting economy, raising transportation efficiency, ensuring social equality, developing backward areas, protecting environmental and using resource more efficiently. To achieve the objectives, the developed countries pay much attention to the balanced development of various transportation structures. From the view of sustainable development of transportation, the railway is widely accepted because of more environmental protection and energy saving.

The White Paper On European Transport Policy For 2010 emphasized on comparison of different modes of transport especially mentioned the waterway and railway should occupy a larger market share. Finally to break the strong situation of road transport, create comprehensive transportation system with coordinated development of various modes of transport, and solve various transportation issues. In order to achieve the goal of sustainable development and social equality, the European Union provides support to the transport mode which helps to the goal. At the same time, gradually adjust the transport policy along with the deeper understanding on developing law of transportation and social economy.

The UK proposed the concept of low carbon transportation in the white paper of Our Energy Future Creating A Lowcarbon Economy in 2003, which is worldwide accepted. In decade, the UK focuses on the study of low carbon emission transportation. Compare with the other transportation modes, the railway transportation is hardly affected by weather conditions and low pollution, which is the lowest carbon and most efficient transportation way thus acquire to a large number of policy support.

Japan's Transport Ministry published a paper The Direction of Integrated Transportation Policy on The Basis of Long-term Prospect in 1980. The objective of the paper is that developing overall public transportation system to instead the vehicles society. The main measures are speeding up the railway on mail lines, developing urban rail and aviation network, and making full use of the railway, shipping and other transportation systems.

From the foreign comprehensive transportation policy that we can see, abroad countries pay more attention to balanced development of various transport modes. Moreover, the transportation policy is adjusted constantly along with the social and economic changes. They attaching importance to railway development, meanwhile, ensure the sustainable development of transportation.

3 Foreign Tax Policy

Tax is the regulation of the economy running. Through to increase or decrease tax can affect the economic interests of the various modes of transportation, which guiding transport enterprise or individual economic behavior.

In German, the overall level of burden is less than one percent of the income of transportation even though the enterprises undertake the full amount of tax. There are mineral oil taxes, ecological protection tax, vehicles tax and road use fees in the German transportation tax. The railway transportation did not need to pay the vehicle tax and road use fees. To restrict road transportation, German government decides the vehicle tax to large trucks according to the weight, the discharge of harmful substances and noise emissions, and the highway use fees to heavy truck according to the using time.

The main taxes that the U.S. freight railway undertaking are corporate income tax, fuel tax and property tax. For the fuel tax, the federal and state offer some privilege to railway and levy lower tax rate.

There are three added-value tax standards in Italy, 21% standard rate, 10% beneficial tariff and 4% special beneficial tariff. Italy rail transport implement 10% beneficial tariff, and in some special cases it can be tax-free. The passenger and freight railway transport within the international and European Union are both duty-free.

The UK takes the lead in levying climate change tax by 2011 Finance Act. The article stipulates that beside electricity for residents, it must pay the climate change tax to all electricity using. To support the railway transportation, the act clear that the British treasury has the power to extend the passenger and freight railway operators' climate change immunity.

4 The Foreign Policy of Subsidies

Because railway freight transportation undertake the transport of life necessities and key material, which has public good characteristics. The most obvious manifestation of railway public good is the transport prices deviate from the transportation value, need government subsidies to make up for the loss. Beside, along with the concept of environmental protection is gradually strengthened, many countries pay more attention to the development of low carbon transportation. Environmental subsidies are the most direct means to encourage low carbon transport.

4.1 Public welfare subsidy

Transportation companies are the business entities of the transport sector; meanwhile it is taking the busy transportation task. It not only hopes to gain profit from transport activities, but also to complete the public transport service requirements. Therefore, the companies could not fully charge in accordance with market principles.

Russia affords the transportation companies subsidies on the transportation of ensuring national security, disaster relief, emergency transportation and other necessary personnel and material transport that having completely social significance. To the transportation that government supporting for food, pesticides, fertilizers and other materials, the railway charges the regular fare, and to the part which needs policy relief, the government directly give subsidies to the carrier.

After the Dutch railway reformed, the allowance was decreasing yearly. Instead of the objective of profit, the railway service has social benefits. The new mode is that the government provides the allowance according to the contract which signed with operators. Moreover, Dutch also provide the allowance to the projects which having significant effect about economic and social development. For example, the specialized freight railway line between Dutch and Germany border which receive 150 million-250 million euro operating subsidy per year from the government.

The Sweden government first isolated profit line and losses line. As the representative for losses line, the local government implemented concession that received appropriate subsidies. Such approach achieved a clearly definition about public railway service and commercial service.

4.2 Environmental subsidies

The EU Transport Commission is the coordinating agency of various transport modes in Europe. Since the organization was founded, one of the main businesses is constantly engaged in lay down the integrated transport policy from the level of the overall European Union and the concrete implementation. According to the statistics at that time, the proportion of road traffic CO2 emission occupies 84% among all the transportation modes. Thence, the European Union started to pay more attention on the development of Eco-friendly transportation mode.

The Marco Polo program directly support to non-automotive transportation in the form of subsidies, which have significant effect on transportation modes transfer. At present, the program has funded more than 150 projects, of which transportation modes transfer projects occupy 83%. The Marco Polo program affirmed environmental benefits of rail and waterway transportation, that is the most directly and efficiency measure to promote transportation modes transfer in Europe.

In the initial stage of the railway reform, there are three allowances of UK government providing, freight facilities subsidy, line usage fee subsidy fund and company-neutral income support fund. Among the three allowances, the major objective of freight facilities subsidy is encouraging the freight transportation to transfer from roadway to waterway. Switzerland was the first country to establish an integrated transport infrastructure fund which imposes high tolls to heavy freight trucks. Most of the income earned is included in integrated transport infrastructure fund to the new railway line project investment.

Since the 1970s and 1980s, the rapid development of road traffic in Japan. It brings environmental and energy crisis, while accompanied by the negative impact of traffic accidents, road congestion and so on. The Japan government carried out a transportation preferential policy. The purpose of the policy is to promote the transfer from long-distance freight transport to take railway and waterway transportation modes, which supporting the development of railway freight transportation from the level of national aspect. The Japan Railway Freight company think of that the supporting from national policies bring into play affect to construction of high density of Japan freight corridor.

There are some other mainly subsidies around the world. For instance, after twentieth Century 80 years, the U.S. derate the tax which are necessary but unprofitable rail lines, meanwhile encouraged to sell the unprofitable rail lines to subsidize the main business line; in order to mitigate the traffic congestion, traffic accidents, air pollution and reduce the road noise, the French government decided to provide the allowance to support the development of railway. After calculation, the number of subsidy is about equal to the effect of energy saving and environmental protection.

5 Freight fare policy

In the fierce competition of the transport market, freight fare not only reflect the value of freight transport product, but also regulate the relationship between supply and demand, which is the most direct factor of owners choosing the transportation modes.

The railway freight fare in Italy is completely decided by the cargo transportation department of the national railway group of Italy independently. Railway Company has relatively high autonomy on freight fare.

The freight fare making and adjustment of French railway is completely by French state-owned railway company, it has high autonomy. The freight fare is made by according to its category, feature, characteristics and transportation condition, the French railway freight fare is the price by agreement, if the customer agrees, the company can sign agreement with the customer, and there is no need for approval by other departments. Flexible price making mechanism is the guarantee of stable development of railway cargo transportation.

American railway cargo transportation has several forms such as price by agreement, freight fare released, combined transportation freight fare and local line freight fare. Price by agreement is the main form of American railway cargo freight, 80% of the UP's volume is agreed by contract, On the basis of basic freight fare, Railway Company can negotiate and sign transportation contract with the consignor. When the consignor disagrees with the railway company, freight fare released can be used, which can also be adjusted, National Transportation Safety Board has certain appropriate regulations on freight fare which is mainly used on the cargo lacking competition, for those competitive cargo, policy regulations are much less.

In Brazil after the privatization of railway, freight fare by agreement is implemented, transportation service price cap is set by making transportation agreement and is duly adjusted by according to the change in inflation rate. On the premise of effective competition, operator has the right to make its price autonomously, different freight fare can be adopted by different transportation demand of different consignors, franchised operators are allowed to sign transportation agreement freely with the consignors under special circumstances by different demand and margin cost pricing.

In 2003, the Russian Government enacted Transportation Development Strategy of Russian Federation, in which it states Russian Railway Company should change the methods of changing freight fare and adjusting price list in order to adapt to the need of market development. On the aspect of cargo transportation, for the cargo imported and exported, the sea port fare rate should be emphasized and freight fare comprehensive adjustment method should be made.

6 The enlightenment of transportation policy abroad to China

The sustainable development of transportation modes is very dependent on the support of national policy. Because the railway has advantages of large volume, high stability, small influence by climate, and low carbon and environmental protection, so it received lots of national attention. Currently, Chinese government provide certain orientation to support the railway transportation, but lack specific support policies and measures, which is one of the main factors to contribute to the low share in the railway freight market.

6.1 Comprehensive transportation policy in China

In China, the research on comprehensive transportation system came later, Ministry of Transportation of the People's Republic of China was established in 2008, which represents comprehensive transportation system development in China has entered organizational and institutional phase, but Ministry of Railway is always independent of other four transportation forms until march, 10, 2013, by according to organizational reform and functional transformation of the State Council, government functions are separated form enterprise, the administrative function of drafting railway development planning and policy which belonged to Ministry of Railway was handed over to Ministry of Transportation, since then China has really initiated the comprehensive transportation system research and management.

The comprehensive transportation policy making can refer to the practices abroad, thoroughly consider various transportation forms from the perspective of comprehensive transportation system. Transportation development fund should be collected and used, the usage of this fund shouldn't be confined on construction, which should always be used to subsidize operation, all transportation forms should be encouraged to develop in balance. Furthermore, on the aspect of environmental protection, the term of encouraging environmental transportation should also be made, ensuring sustainable development of transportation.

6.2 China's railway taxation policy

China put an emphasis and support the construction and development of railway, the taxation policy was implemented in 1994 which exempt corporation income tax of some railway state owned enterprises with multiple businesses, but in 1998 the taxation policy was reinstated. In 2001, to support the development of western region, during the construction period or Qing Zhang Railway, corporation income tax was also being exempted. During the process of railway funding institution reform, for supporting Daqin company reconstruction and IPO, 7.9 billion RMB corporation income tax it should pay was exempted. But in recent years, the favorable policy given to the railway company has been less and less, there is rarely any tax preference regarding railway operation.

Under the circumstances of emerging green transportation concept, railway transportation as low carbon transportation form should be supported and preferred. The investment and technology transformation are concerning environmental protection, safe operation, energy saving and emission reduction, in taxation deduction and exemption policy can be increased in the projects of railway investment, more social capital can be attracted to the investment of railway, promoting the development of railway transportation. On operation, due to the effect of energy saving and environmental protection the fuel tax exert, thus fuel tax can be collected from road transportation and other forms, slow down their development and create a space of development for railway transportation.

6.3 Railway subsidy policy in China

Railway transportation shoulder the transportation mission of public interest, basic return of investment can almost not be realized. Due to the features of public interest, cross-subsidies are adopted inside the railway, subsidizing the loss of public interest transportation by operational transportation profit, but the government has not specific subside policy on public interest railway., which causes that the operational target, financial boundary and assessment criteria are not specific, there is no direct connection between operational activities and performance, operational effectiveness is low, effective stimulation, supervision and assessment mechanism cannot be established which hinders the organizational reform of railway cargo transportation. Indian railway didn't separate the governmental functions from the enterprises, which undertook enormous public interest transportation tasks, for balancing and lowering the consumer prices, regarding the necessities of fruit, vegetables, papers, cotton and organic fertilizer, Indian railway offered a freight fare which was lower than its cost. In result, the economic loss for transporting those cargo is 0.5672 billion Rupee.

As an entity in the market, railway transportation companies undertake public-interest transportation task which doesn't comply with corporate behavior, government should define the commercial and public-interest features of railway cargo transportation, the economic loss due to public-interest transportation should be subsided. Different loss should be assigned to different entities, the loss of supporting agricultural cargo should be subsided by Ministry of Agriculture and the loss due to relief supplies should be shouldered by Ministry of Civil Affairs. The source of subsidies funding could also refer to foreign practices, tax and fees should be collected from the transportation mode which has negative effect on environment such as road transportation.

6.4 Railway freight fare policy in China

To avoid monopoly and promote the healthy development of national economy, in the initial period after the founding of this nation, under the planning economy system, administrative method was adopted to make and adjust railway cargo transportation freight fare, which management was centralized and uniform freight fare was implemented, under the market economy system, uniform freight fare does not reflect the true value of service of railway transportation products, the transportation department which has the right to make price cannot allocate the transportation resources by adopting market mechanism, the price level loses its function of adjusting the demand and supply of cargo transportation, compared with flexible and diversified road transportation mechanism, railway transportation losing its market share is inevitable .

Freight fare is the most significant factor which affects railway cargo transportation, flexible price making policy can correct the defective relations between transportation cost and freight fare, transportation enterprise should have the right of appropriately floating the freight fare, strategy of multiple forms of freight should be implemented. When it was put into practice, certain period, certain region certain cargo could be allowed to operate in market-oriented way, gradually open it up all around after learning the lessons.

7 Conclusions

The supports from government policies play an important role on the development of railway freight transportation. However, it was difficult to achieve the goal of high freight turnover if only relayed on the policy support. Except the policy support, the railway transportation has gained success on the aspects of infrastructure planning and construction, Operation organization mode and freight product marketing. It should closely follow the cargo transport market and logistics trend to constantly improve market competitiveness in the future.

Reference

Cui Yanping, Hou Jing (2013). “Discussion on the German Railway Reform.” *Railway Transportation and Economy,* (07), 94-97.

Liu Zhaoran.(2013). “Inspiration of EU Multimodal Transport Policy on China's Development of the Railway-Waterway Transportation.” *Railway Transportation and Economy,* (05), 56-60.

Luo Qingzhong, Jia Guangzhi, Chang Jing (2013). Foreign Railway Reform.*China Railway Publish House*.

Min Huang, Jianping Zhang (2007). Inspiration of Development Strategy of Foreign Transportation. *Economic Press,* China.

Xiong Yongjun, Luo Qingzhong, Zhu Jichang (2001). Railway Reform, *China Railway Publish House*.

Xu Wenhui. “Research on Non-commercial Problems of Railway Reform.” *Railway Transportation and Economy,* 2003 (6), 45-48.

Yan Dong, Wenlong Guo, Yan Chai (2004). Development and Reform of Comprehensive Transportation. Chinese Science and Technology Press.

Particular Cultivation for Outstanding Talent in the Transportation Industry

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Abstract: Transportation industry is basic industry and service industry of the economic and social development, transportation outstanding talent is the fundamental guarantee to support the development of transportation, the realization of the scientific development of transportation relies on sufficient amount, structural optimization, excellent quality and reasonable distribution of professional talent team. As a featured college, that provides service for the rapid developing transportation industry, should take the initiative to serve the country's strategic needs and the needs of industries and enterprises, support and play its leading role in developing the national economy to meet the urgent need of transportation industry outstanding engineering talent. Aiming at current common existing problems of talent development and personnel training, systematically analyze training excellence transportation needs and quality standards of excellence talents, explore and summarize the terms of the training objectives, training programs and training model to build transportation training excellence system that is able to provide a good reference for transportation training excellence.
Keywords: Transportation; Excellent talent; Cultivation system.

1 Introduction

Transportation industry is the basic industries and service industries of economic and social development. With emphasis on the construction of comprehensive transportation system, accelerating the development of transportation industry is an important material prerequisite for the accelerated development of the urbanization and the sustained and healthy development of economic society. The next decade is a critical period of national transportation strategy transformation and accelerating the development of modern transportation, transportation development will face a very arduous task, until 2020, we should have greatly enhanced the quality and efficiency of development, have vigorously promoted the ability and level of service, and have built a safe, smooth, convenient, green and economical transportation system.

Transportation outstanding talent is the fundamental security to the support of the transportation industry, to achieve scientific development of transportation relies on the adequate amount, structural optimization, good quality, reasonable distribution of talent team, strengthening the construction of transportation industry outstanding talent team and enhancing the guarantee capacity of outstanding talent will profoundly affect the progress and efficiency of the development of modern transportation. The development of the transportation industry puts forward higher requirements and challenges to our country's higher education, especially higher engineering education. Faced with the country's economic and social development needs of transportation excellence talent, As a featured college, that provides service for the rapid developing transportation industry, should shoulder the responsibilities and tasks, play its supporting and leading role, cultivate outstanding talent of transportation industry which is in the urgent need in the development of national economy.

Transportation industry talent team construction should be closely combined with the feature of industry development stage and talent demand characteristics of regional economic development, and fully in accordance with the new situation and new development of modern transportation requirements, aiming at prominent problems existing in talent development, overall planning, highlight the keystone, promote steadily and enhance the relevance and global transportation industry talent development. Cultivating excellence talents should fully follow the law of growth, working institutional mechanisms of innovation and talent, with emphasis at the urgent need of talent, high-level and highly skilled talent, as a whole to promote all types of talent team construction, construct a all-round, multi-level, professional, international transportation professional talent team with high-quality.

2 Current problems in talent development and cultivation in transportation industry

Transportation engineering education in China has good foundation after years of development, has formed a reasonable transportation industry education structure and system. Basically meet the large demand for various levels of society, various types of engineering and technical personnel. We have made great achievements in the development of service industry. At the same time, many problems still exists in transportation industry talent development and talent training.

The problems of talents development in transportation industry currently can be summarized as the following three aspects: firstly, the relative shortage in advanced and skilled personnel. In the face of increasingly complex natural conditions and even more serious resources and environment restriction, solve the relative scarcity of talented person in major transportation engineering construction, transport services, security, energy conservation and environmental protection science and so on; A serious shortage of high-skilled talents, high-skilled talents with technicians and more than skill level is much lower than the national average and the goals. Secondly, the professional and regional distributions are not reasonable. Existing talent, especially with senior professional and technical positions, mainly focused on the field of traffic engineering technology research and development, design and construction. However, these talents in the conservation and management, transportation services, security and environmental protection and other areas are failing. Thirdly, the use of high-level talent is unreasonable. The phenomenon that "Executive" and "official position" lead to the invisible drain of talent is serious; the sustainable development of the talent problem is outstanding.

Taking characteristic university in high levels of transportation industry as a case study, there are some problems of talent training showing in four aspects: firstly, the course system setting can't meet the requirements of cultivating innovative talents. Professional backbone course is weak, and the organic link is not enough. It focus on a single course of systematic, specificity and specific laws, but of course, the connection between the integrity and common law have been neglected, and lacking of knowledge integration and integrated applications is difficult to meet the system requirements of innovative talents knowledge system. Secondly, single training model, training methods behind. Especially the teaching mode and teaching method are still "force-feeding", dominated by teachers, take the student as the main body of research teaching mode has not been fully established; Lack of effective implementation of the operational level, driving force is not enough. The majority of students learn passively rather than actively, this way of imparting knowledge imprisoned the students' thinking and development, it is difficult to effectively stimulate students interest in learning, leading to students' initiative and energy is not enough. Third, the comprehensive quality education still needs to intensify. On ability training, we design more about what we learn, but why and how to design is relatively less, lack of systematic education of Disciplines and scientific research methods, lack of scientific research training system. On the engineering quality training, lack of overall design of engineering quality training from the perspective of professional. Fourth, the Industry-university joint training in engineering education is insufficient. Especially the higher education system reform, industries and enterprises are unable to effectively participate in the training process, resulting in the physical practice is absent or weak.

3 The requirements and quality standards

3.1 Transportation talents training demand

Our road to brand-new industrialization with Chinese characteristics, building an innovative country, reinvigorating China through human resource development and other series of major strategic made an urgent request of higher engineering education reform and development. The urgent need is to train a large number of engineering talents with the capacity of support industries development, innovation and international competitiveness. Transportation is the basic industries and service industries of the economic and social development. Over the next decade is the critical period for the national transportation strategy transformation and accelerate the development of modern transportation. To greatly enhance the quality and efficiency of development as well as the ability and level of service, the aim is to build a safe, smooth, convenient, green and economical transportation system. In order to achieve transportation scientific development, we need to rely on adequate quantity, reasonable structure and excellent quality of talents. Transportation development is faced with a very arduous task, which made an urgent demand for transportation talents training.

Transportation talents' training is to strengthen the awareness needs of active service for national strategic and industry business. It requires establishing the concept of training talents with morality first, capacity importance and all-round development. And it also requires innovation the mechanism of the universities and industry and enterprises in joint training, reforming the talents training model of the engineering education, enhancing the ability of students' engineering practice, creative capacity and international competitiveness. Transportation professionals needs to master basic theory and method of transport organization, which equip them with strong engineering application capability to undertake transportation production work in various positions. And also they must be capable of responding quickly to principle and method of operation of new technologies and equipment, which enable them to make the application of innovation based on the new technologies and equipment. In addition to master the transportation expertise, it also needs to be familiar with management, economics, safety engineering control theory, information theory and other disciplines' basic theory and method, so that they have an integrated transportation systems thinking and have the need of the ability to actively adapt to social and economic development and transportation continued rapid.

Transportation talents training on the basis of summarize the national historical achievements of engineering education and reference the foreign experience is to identify the importance of national transportation area talents training strategy which is focused on: first, we must pay more attention to engineering education in severing national development strategies. Second, we must pay more attention to work closely with industry. Third, the more attention should be paid to overall quality and social responsibility. Fourth, the internationalization of engineering talents training also should be paid corresponding attention. The integration and cross of the transportation professionals' knowledge with management science, economics, security science and computer science needs to be taken fully account of when training the transportation professional talents. These enable students to form a transportation professional knowledge system based on the ability to disciplinary. The students should be strengthened in the general education model of professional training, which improved their overall quality and innovation and enhanced students' social adaptability.

3.2 The quality standards of cultivation for transportation talents

"National Long-term Education Reform and Development Plan" takes the "excellent engineer education training program" as a strategic important task in new era about the reform and development of higher education. Through the closed cooperation of education and industry, the universities and enterprises, in the background of practical engineering, as the main line of the engineering technology, the engineering awareness and engineering quality as well as the ability of engineering practice of students are improved. Training a large number of many types of excellent engineers who are creative to adapt to business development demand, rapid economic and social development, and can meet the international requirements of technology and engineering application.

The primary issue of the higher engineering education is to clear the quality standard of training the excellent engineering, namely to solve the problem of what human should be cultured. Higher engineering education is not yet created by "excellent engineer", but to create "excellent engineer" for the potential to build a good foundation. The so-called "excellence" is the pursuit of the development of quality standards and a concept, its basic characteristics reflected in the talents training objectives, training an important element of the specifications, organizational processes and pathway in the way of education. Excellent idea can be summarized to reflect goal of quality education concept, a wide range of the positioning, the "student-centered" model concept and the approach view of the characteristics of school.

(1)The goal of quality education

The quality of traditional knowledge and the once popularized ability quality concept are converted into a comprehensive view of the quality which included the knowledge and capability. That is to say, the personnel training is focus on the ultimate goal that to promote the overall development of students.

(2)A wide range of positioning

As a high level of industry characteristics universities, outstanding engineering talents training specifications positioning, not only to cultivate creative talents of various projects, but also to develop academic, engineering and management of complex interdisciplinary top creative talent. The development needs of the industry and business should be met in training talents to adapt to the country's economic and social development, and the need of internationalization and globalization should also be accomplished.

(3)The "student-centered" model concept

In reaching a variety of external training objectives and specifications location, the contribution about students' self-development must be taken as the core, so as to implement a wide range of training mode, highlight the dominant position of students, promote students' personality expertise and student self-development.

(4)The characteristics of school of approach concept

The featured high-level university not only to cultivate innovative talents as the fundamental tasks, but the functional disciplines should be reflected, so as to highlight the scientific research and social service functions that should be carried out tightly around personnel training. It is necessary to guide the teaching with scientific in training of personnel. The research-based training approach will be run through the entire process of personnel training, which means that it advocates "explore", "question", "advocating" and "hard-work and pioneers" to improve students' ability to learn, practice and innovation ability.

4 The cultivation system for excellent students in transport industry

The key point of training excellent students lies in how to train good persons. This means what kind of training modes and training pathways should be taken, and also means the design and innovation of training elements such as personnel targeting, training programs and training modes.

(1)The scientific training objectives

The training objectives and positioning is the guiding principle of training programs. With the rapid development of transportation, the demand for excellent students in different types and levels is increasing. The majors relating to transportation should fully understand and grasp the characteristics of the industry trends and this demand. Combined with their characteristics and level types, these majors should set and improve the distinctive training targets on the basis of reflecting the students' competence.

Students are required to master the basic theory and a relatively broad knowledge in their area, to have the ability to solve practical engineering problems with innovation and research capabilities for engineering and technical work to assume senior professional or managerial jobs. On this basis, the training system aims at the rail transportation industry's urgent demand for innovative talents, closely tracking the forefront of rail transportation, and vigorously educating the engineering, complex and research-oriented creative students. The integrated key technologies and management requirements shall be taken into account such as bridge and tunnel stations around the line, EMU and overloaded trains, traction power supply, communication signal, operations and scheduling, etc.

(2)Systematical and matching training program

Training program takes the achievement of training objective as basic guiding principle, decomposes the capacity according to the capacity target matrix and capacity achievement matrix, takes the project awareness, the practical ability and innovation on the basis of general engineering education as priority, optimizes the specific curriculum, and updates the teaching content. Transportation Excellent Training Program shall highlight the characteristics of this industry, relying on long-term research cooperation, taking bilateral advantages, and designing the curriculum content, the training process models, as well as the pathway of students' self-learning and personality development all together. From the perspective of universities, the key is to grasp the rules of personnel training and students' growth.

(3) Innovative and diverse cultivation mode

Cultivation mode plays a key role in cultivation process for excellent talent in transportation industry. The single cultivation mode with course inculcation as principle is necessary to be broken through, in the cultivation process for excellent talent. The coalition of college and enterprise is carried out to make sure the cultivation is open to enterprise, society and world. Based on the combination strategy with production, teaching and research, the diverse cultivation mode is jointly created with question-inquiry, research-training and engineering-practice as orientation. The diverse cultivation mode ensures the development of individual strong point, and enforces the capability to study initiatively, exploring and research, engineering practice and innovation, which broadens their internationalization visions.

5 Conclusions

Transportation outstanding talent is the fundamental guarantee to support the development of transportation, the realization of the scientific development of transportation relies on sufficient amount, structural optimization, excellent quality and reasonable distribution of professional talent team. Enhancing the guarantee capacity of outstanding talent will profoundly affect the progress and efficiency of the development of modern transportation. The development of the transportation industry puts forward higher requirements and challenges to our country's higher education, especially higher engineering education. With economic and social development needs for transportation excellence talent, the featured college providing service for the rapid developing transportation industry, should shoulder the responsibilities and tasks, play its supporting and leading role, cultivate outstanding talent of transportation industry which is in the urgent need in the development of national economy.

Transportation talents' training is to strengthen the awareness needs of active service for national strategic and industry business. It requires establishing the concept of training talents with morality first, capacity importance and all-round development. Transportation industry talent team construction should be closely combined with the feature of industry development stage and talent demand characteristics of regional economic development, and fully in accordance with the new situation and new development of modern transportation requirements, aiming at prominent problems existing in talent development, overall planning, highlight the keystone, promote steadily and enhance the relevance and global transportation industry talent development. Excellent idea can be summarized to reflect goal of quality education concept, a wide range of the positioning, the "student-centered" model concept and the approach view of the characteristics of school. The scientific objectives, systematical and matching training program and innovative besides diverse cultivation mode are the basic elements of effective cultivation system for excellent talent in transportation industry.

References

HAN Xu-dong，YANG Tao，LI Jun-peng(2014). Academic Standards for the Outstanding Engineer Program in railway Industry-A Case Study of Southwest Jiaotong University. JOURNAL OF SOUTHWEST JIAOTONG UNIVERSITY(Social Sciences), 06: 123-127.

HE Xiaoping, ZHAO Xin(2014). The training mode for professional talents in transportation industry. Forum in Education and Teaching, 50:149-150.

HE Xiaoyan(2012). Research and Practice in the Particular Education-training Plan for Outstanding Engineer——A Case Study of Southwest Jiaotong University. Forum in Education and Teaching, 33:231-233.

LI Shuqing, REN Qiliang(2011). Several Ideas on Training Plan for Outstanding Engineer in transportation industry. Journal of Chongqing Jiaotong University(Social Sciences), 02:108-110.

PENG Qiyuan，MA Si，WEN Chao(2011). Reform and Practice in the Development of Talents for Traffic & Transportation Industry, JOURNAL OF SOUTHWEST JIAOTONG UNIVERSITY(Social Sciences), 06:5-10.

Southwest jiaotong university(2014). The process report for outstanding Engineer training.

The ministry of transport of the People's Republic of China (2011). The medium and long-term talent development plan outline in highway and waterway transportation.

WANG Shengwei(2014). Research and practice in training mode for outstanding Engineer in regular institution for higher learning. Modern marketing, 05:78-79.

WANG Yongsheng(2011). Research and practice in training mode of Outstanding Engineer in high-level characteristic university. Chinese Higher Education, 06:15-18.

XU Lei, PENG Jinshuang(2014). The exploration and practice in training mode of Outstanding Engineer in transportation industry. Electronic World, 06:214.

ZHANG Anfu, LIU Xingfeng(2010). Some ideas on the implementation of training plan for outstanding Engineer. Higher engineering education research, 04:56-59.

Customer Satisfaction Evaluation of Rail Door-to-Door Transport Service

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Abstract: The customer satisfaction evaluation characteristics of rail door-to-door transport service is analyzed in this paper. Establishment of timeliness, charge, goods integrity, complaint, information, order acceptance, cargo taken, cargo delivery, other service to the first-level indexes of satisfaction evaluation indexes system by LSQ model for reference. Fuzzy comprehensive evaluation method and the relevant parameters are combined on processing evaluation result. Finally, the feasibility of value calculation method is verified according to evaluate rail freight point Y.
Keywords: Door-to-door service; Evaluation index; Evaluation method.

1 Introduction

Rail door-to-door transport service is coordinated to promote rail logistics development and well satisfy customer demand. It takes rational utilization of nonmetal resource, improvement for take-distribution network as well as active expansion to their business (Wang, 2014).It extends service into management, also blend rail freight and logistics together as a complete business process, not only to broaden business thoughts, but to increase transport market share. Due to its conduct is guided under customer demand. There provides reference for service improvement. In addition, current rail service-related indexes are overly one-sided or lack of market to participate, difficult to reflect difference in evaluation object and service environment. On the great of significance for the customer satisfaction evaluation in rail door-to-door service.

2 Rail Door-to-door Service Customer Satisfaction Characteristics

Rail door-to-door transport service as the third-party logistics, mainly has the following characteristics evaluation of customer satisfaction:

(1) The comprehensive evaluation index; which can accurately reflect the satisfaction of customers. Rail door-to-door transport service possess inseparable feature of general logistics service, namely the production and consumption is at the same time. So it is reasonable to select indexes based on service process.

(2) Service results; since the rail transport door-to-door service is the logistics service extends the arrival end to the sending. It focuses on convenience, accuracy

and standardization, makes reducing customer perception for service. Comparing with process, customers are more concerned about service completion.

(3) Information; since the reduction of customer perception, makes it possible to deliver service information to customer, which is an important factor for evaluation.

(4) Different customer evaluation; the service must adhere to the customer voluntary principle. Customers are divided into shipping and receiving, only being able to enjoy the "arrival gate", "station-to-door" service, namely service and corresponding service object according to the flow of goods.

3 The Construction for Evaluation Indexes

Rail door-to-door transport refers the whole process, begins with collection in designated place, transportation, until delivery to the consignee (Ye,2011). There order acceptance, cargo taken, goods in transit transport, cargo delivery, also charge, information, complaint, claim service based on the general service process. While it considers the inseparability, lacks evaluation indicators about service result. Relatively complete customer logistics service evaluation is LSQ model at present, in which nine indicators are summarized based on the investigation in numbers of the United State large third-party logistics companies. That is staff communication, order release amount, information quality, order process, goods accuracy rate, cargo soundness, goods quality, error processing, timeliness (Mentzer,2001). Combined with the concrete conditions of China's rail door-to-door service, selected the indexes from process and results, specific analysis shown in Figure 1.

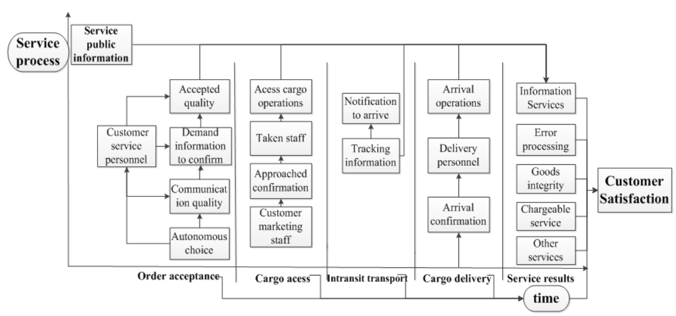

Figure 1.The process for constructing satisfaction evaluation indexes

The first-level indicators selected are timeliness, chargeable service, goods integrity, complaint, information, order acceptance, cargo taken, cargo delivery, other service. According the service process to continue and refine first-level into second-level indicators, each indexes and interpretation as shown in Table1.

Table1. Rail door-to-door service satisfaction indexes and interpretation

First-level	Second -level indexes	Interpretation
Timeliness	1Order processing 2Cargo taken 3Cargo delivery 4Claim processing 5Complaint 6Information release	Timeliness is reliable to fulfill cargo transportation. It is the core element for customer evaluation overall service. Second-level indicators are selected according to timeliness requirement.
Charge	1 Channel 2 A quotation	The door-to-door transport service-related charge and a quotation are established by using a one-time charge ticket to facilitate customer payment, also to fairly charge the transport supervision fees.
Goods integrity	1Delivery-arrival integrity 2 Claim way 3 Claim result	It is decisive to get service result and propose cargo damage or loss based on cargo integrity. It reflects rail error handling capability.
Complaint	1 Complaint channel 2 Complaint way 3 Complaint result	If the commitment and actual transportation generate deviation, it would raise questions even complaint. Customer satisfaction is decided on the treatment, the important factors of evaluation quality.
Information	1Public information 2 Check-track inquiry 3 In transit transport inquiry 4 Cargo arrival notice	Information is customer requirement to modern service as well as rail public, marketing platform. Rail main provide public information and arrival notice, not only to facilitate customer to get transport and arrival information, but to reflect error processing convenience.
Order acceptance	1Communication quality 2Demand confirmation 3Formalities 4Autonomous choice	Customer can raise demand on network and on-site orders, etc. The staff handles the request though communication, negotiation and other remedies. Order acceptance is the accuracy factor to build image in entire service process.
Cargo taken	1Contact service 2Handling operation 3 Metering service 4 Ticket transfer	There are three aspects, logistics order processing. Second is contact process, reflecting the response to customer demand. Third is logistics service process, main including loading and unloading, metering, ticketing transfer operations, customers can directly feel the specification and accuracy, embody the sender service capabilities.
Cargo delivery	1Contact service 2 Handling operation 3 Ticket transfer	Delivery service process includes handling, ticketing transfer operations. It is the terminal of entire service process, reflecting the rail in the "last mile" service capabilities.
Other service	1Warehousing 2Pack 3Agency 4 Handling 5Distribution	Rail door-to-door service also provide other logistics service. But rail logistics in the development stage, over here evaluating together.

According to the characteristic of customer difference evaluation, evaluating between sending and arrival terminals, on the one hand to facilitate calculation, on the other hand, to clearly analyze evaluation results. Distinguish the evaluation index into consignee and shipper, shown in Figure 2, Figure 3.

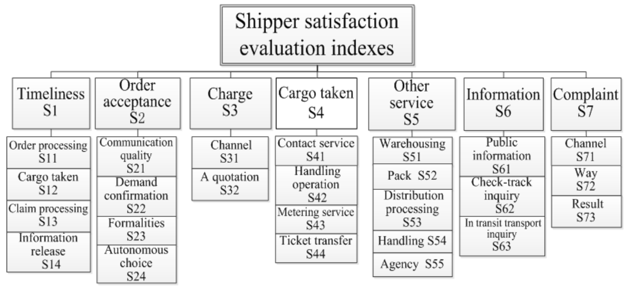

Figure 2.Shipper satisfaction evaluation indexes

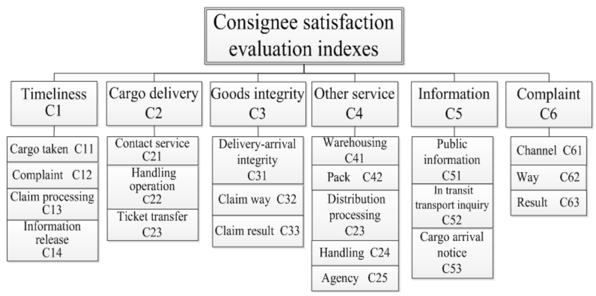

Figure 3.Consignee satisfaction evaluation indexes

4 Evaluation Method of Rail Door-to-door Service Customer Satisfaction

This text uses mature fuzzy comprehensive evaluation method to obtain result. Compared with others, it is suitable for indirectly quantitative indicators, while the indicators in the paper mostly are difficult to quantify. In addition, each evaluation values of indicators can be analyzed by fuzzy relevant parameters. It is conducive to understand customer evaluation and propose corresponding suggestions.

Each indicator is quite different on the importance extent. Therefore, it is critical to get weight. In order to simplify the calculation process and reduce confusion judgment, making customers to give the weight directly to reflect the wish. The indicators are divided into the shipper and consignee, weights got from investigation.

The five reviews table $V=\{v_i\}=\{v_1,v_2,v_3,v_4,v_5\}=\{10,8,6,4,2\}$. The survey results are normalized to obtain membership fuzzy evaluation matrix. Refer to equations by (1), $\sum_{i=1}^{7} r_{ijt}^{s}=1$;

$$R_i^s=\begin{bmatrix} r_{i11}^s, r_{i12}^s, r_{i13}^s, r_{i14}^s, r_{i15}^s \\ \cdots\cdots\cdots \\ r_{iM1}^s, r_{iM2}^s, r_{iM3}^s, r_{iM4}^s, r_{iM5}^s \end{bmatrix} \tag{1}$$

Weight fuzzy sets $w_i^s=\{w_1^s,w_2^s,w_3^s,w_4^s,w_5^s,w_6^s,w_7^s\}$; and fuzzy synthetic B_i^s evaluation vector, that is $B_i^s=W_i^s\circ R_i^s$, $\circ$ for the fuzzy composite operator.

After evaluating the above calculations, the result is a vector $B_i^s = [b_{i1}^s, b_{i2}^s, b_{i3}^s, b_{i4}^s, b_{i5}^s]$. In order to more clearly understand the result to obtain a specific value, then use the comprehensive parameters. While highlight the role of the rank, using the square of membership power b_{i2}^s can obtain weighted evaluation parameters, namely

$$\alpha_i^s = \frac{\sum_{t=1}^{5} (b_{it}^s)^2 v_t}{\sum_{t=1}^{5} (b_{it}^s)^2} \tag{2}$$

Refer to equations in the text by (2), α_i^s for shipper satisfaction evaluation index value.

These results can be clearly seen that each values of the shipper satisfaction first-level indicators. Considering the impact on the results, the processing method that is first-level indexes multiplied corresponding weights, to obtain the total evaluation value, as:

$$\alpha^s = \sum_{i=1}^{7} w_i^s \cdot \alpha_i^s \tag{3}$$

5 Analysis of Example

Survey shipper and consignee data of rail freight point Y, get 92 effective weight evaluation on network on-site and etc, half of shipper.100 customers selected to evaluate, 94 are valid, 49 are shipper, 45 are consignee, while cargo taken, cargo delivery and complaint service according be chosen whether or not, making investigation and assessment. Since calculating the membership terms, there is no significant impact on the results. Survey results are summarized in Table 2.

Table 2.Evaluation index weight values and corresponding scores

Respondent	Shipper																								
First-level	S1				S2				S3		S4				S5					S6			S7		
Weight	0.177				0.162				0.145		0.157				0.139					0.121			0.099		
Second-level	S11	S12	S13	S14	S21	S22	S23	S24	S31	S32	S41	S42	S43	S44	S51	S52	S53	S54	S55	S61	S62	S63	S71	S72	S73
weight	0.282	0.287	0.241	0.19	0.327	0.214	0.214	0.245	0.443	0.557	0.244	0.263	0.284	0.209	0.181	0.199	0.217	0.211	0.192	0.298	0.364	0.338	0.345	0.323	0.332
Extremely	5	3	1	16	34	45	17	46	9	15	5	5	3	8	20	17	19	15	26	24	26	21	2	2	2
Satisfied	40	16	2	28	14	4	30	3	7	28	15	15	17	12	20	27	26	32	17	25	22	25	2	2	1
Generally	4	0	0	5	1	0	2	0	28	6	0	0	0	0	9	5	4	2	6	0	1	3	0	0	1
Not satisfied	0	1	1	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dissatisfied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Respondent	Consignee																					
first-level	C1				C2			C3			C4					C5			C6			calculation
weight	0.184				0.166			0.178			0.155					0.161			0.156			(1)
Second-level	C11	C12	C13	C14	C21	C23	C24	C31	C32	C33	C41	C42	C43	C44	C45	C51	C52	C53	C61	C62	C63	$R_1^s=\begin{bmatrix}0.102 & 0.816 & 0.082 & 0 & 0\\ 0.15 & 0.8 & 0 & 0.05 & 0\\ 0.25 & 0.5 & 0 & 0.25 & 0\\ 0.327 & 0.571 & 0.102 & 0 & 0\end{bmatrix};$
weight	0.281	0.265	0.262	0.192	0.33	0.371	0.299	0.402	0.289	0.309	0.178	0.192	0.232	0.211	0.187	0.257	0.38	0.363	0.212	0.328	0.46	(2)
Extremely	30	0	0	20	10	11	12	21	0	0	24	22	20	18	26	25	23	25	0	1	0	$B_1^s=[0.194,0.689,0.043,0.075,0];$
Satisfied	15	1	1	25	13	10	11	23	1	1	21	23	23	24	19	20	20	18	2	1	2	(3)
Generally	0	1	0	0	0	2	0	0	0	0	0	0	2	3	0	0	2	2	0	0	0	$\alpha_1^s=\frac{\sum_{t=1}^{5}(b_{1t}^s)^2 v_t}{\sum_{t=1}^{5}(b_{1t}^s)^2}=8.094;$
Not satisfied	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
Dissatisfied	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Satisfaction value	Extremely 9-10	Satisfied 7-9	Generally 5-7	Not satisfied 3-5	Dissatisfied 1-3

Calculate results based on survey data and formula (1) (2) (3), as follows, both shipper and consignee are satisfactory to the rail door-to-door service from Figure 4. However neither the value of charge service for shipper nor cargo delivery service for consignee is high according to the survey. The suggestions that rail point Y could amplify charge channel and strengthen normative of cargo delivery.

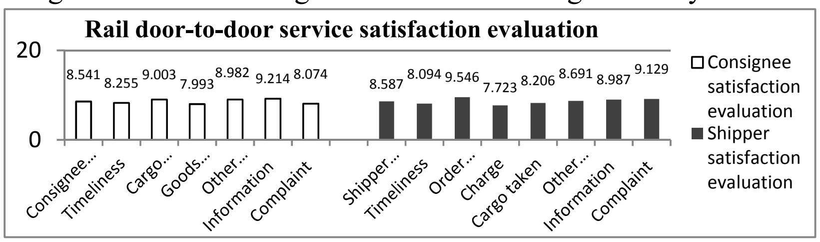

Figure 4.Rail freight point Y satisfaction evaluation values

6 Conclusions

Rail door-to-door service evaluation feature conclude its property, the greatest satisfaction of passengers. It is the development goal and the cause to optimize continually. Acquiring service evaluation indexes system and calculating the rail freight point Y satisfaction value by fuzzy comprehensive evaluation method. It recommends that extend charge channel and enhance normative of cargo delivery. Then verify the method with relevant parameters. Analyzing the changes of customer demand from satisfaction evaluation and rail door-to-door transport experience, so as to guide rail transport development faster and meet society needs better.

Acknowledgement

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References

Ke Taotao. (2006). "Study on affecting factors of customer satisfaction for the third party logistics enterprise." *Logistics Technology.*10, 43-45.

Mentzer J.T.,Flint D.J.,Hult G.T.M. (2001)"Logistics Service Quality as a Segment Customized Process." *Journal of Marketing*.4, 82-101.

Wang Guilin. (2014). "Research on door-to-door related issues of railway freight." *Southwest Jiaotong university master degree thesis.*

Ye Weiming. (2011). "Door-to-door cargo railway transportation practice and discussion." *Railway freight.* China Academic Journal, Freight, 9, 9-12.

Impact of Rural Road Infrastructure on Poverty Reduction—Based on the Analysis of Sichuan Province

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Abstract: By analyzing the correlation between road infrastructure construction in different regions of Sichuan Province and poverty, it can be found that when road density is low, the poverty rate is relatively high, then further analysis tells that rural road construction influence the changes of the structure of peasnats' income and improve their viability. On this basis, we make suggestions to increase rural road infrastructure construction in the poverty-stricken areas.
Keywords: Rural roads; Poverty alleviation; Sichuan.

1 Introduction

Transportation which plays a linking role in the economic ties has a vital influence on the division of labor, the trade development, the agricultural production layout and the urban distribution. Rural road is a important basic condition to develop rural economy, to speed up the adjustment of agricultural industrial structure, to increase the income of peasants continuously, and is an important link to promote harmony, to narrow the differences, to promote the integration between urban and rural areas, and is the solid foundation on which to build a new socialist countryside. Relative lag-behind of rural infrastructures, especially underdeveloped road is one of the common characteristics in the poor areas. Rural highway has the widest service recovery and links the poverty areas most frequently, and is also the infrastructure which should be selected to improve in the first place in rural areas.

2 Field Data

Until 2012, in Sichuan province, it has accomplished a investment of 17.3 billion RMB, 22 thousand kilometers newly-built roads and 8967 kilometers newly-expanded roads. All of these programs have brought that 92.26% of the towns are accessible by taking roads and 137 highway bridges, which cover that all newly-built and newly-expanded rural roads (including both concrete roads and asphalt roads) have reached 8471 kilometers, local rural roads have reached more than 9621 kilometers and the roads between neighbors have reached 8471 kilometers. Since 1980s, the state, facing the reality that infrastructure construction in poverty-stricken areas is weak, has enrolled the rural infrastructure construction in the top list of poverty development. As the Sichuan Poverty Alleviation Monitoring

Statistics Yearbook says, the government has invested 9735 million RMB into the preferential poverty counties from 2005 to 2010, including 2310 million RMB to road construction up to 23.8% in and the ratio of 2009 is 34% and 22.2% in 2010. The concrete data is shown in the chart below.

Table 1 The Investments into Road Construction of Si Chuan Preferential Poverty Alleviation Counties(YUAN)

Year	Road Investment	Total Investment for Poverty-alleviation	Ratio(RI/TIP)
2010	507717449	2284305454	22.2
2009	941729918	2751444448	34.2
2008	284711613	1895675962	15
2007	201785900	1251092134	16.1
2006	229472072	778158104	29.5
2005	149093200	774474500	19.3
合计	2314510152	9735150602	23.8

3. Data Analysis

It has been proved that road constructions can improve regional economic growth. (World Bank, 1994, p15). From Chart 2, we can see road construction has a certain relationship with poverty population reduction chronologically. For example, when the Ganzi county's road coverage rate is low, its poverty rate is high; when Chengdu county's road coverage rate is high, its poverty rate is low. The influences of road construction on mitigating poverty are always classified into two kinds, one is direct influence and the other is indirect influence. The direct influences show as saving transportation time, including the time taken on the way to workplace, school, hospital and supermarket and saving money like saving the motor vehicle fuels thing. The indirect influences always mean the increase of income and other benefits brought and various income source and employment stucture by boosting economic growth, which can alleviate the weakness when the economy comes to shocks. (Grootaert，2002)

Table 2 The road density and regional economic condition through the whole province in 2012

Area	Road Density		Per Capita (yuan)	Percentages of Regional GDP（%）			the Proportion of Poverty Families Accounted for the Whole Families（%）
	Calculated on the Territorial Area（KM/Hundred Square KM）	Calculated on Population（KM/Ten Thousand People）		Primary Industry	Secondary Industry	Tertiary Industry	
Whole provice	60.515	32.606	29608	13.8	51.7	34.5	18.6
Chengdu	185.115	19.331	57624	4.3	46.3	49.4	7.9
Zigong	158.023	19.389	32787	12.4	59.8	27.8	18.1

Panzhihua	66.616	41.897	60391	3.5	75.9	20.6	16.5
Luzhou	109.149	26.076	24317	13.9	60.6	25.5	15.6
Deyang	134.564	20.745	35945	15.2	60.2	24.6	8.9
Mianyang	97.231	35.885	29080	16.3	52.5	31.2	13.5
Guangyuan	107.535	55.341	18672	19.6	47	33.4	26.8
Suining	174.262	22.845	20908	22	52.6	25.4	18.0
Neijiang	200.405	23.549	26341	16.7	62.4	20.9	22.2
Leshan	71.395	26.263	31942	11.9	62	26.1	20.9
Nanchong	171.370	27.357	18757	22.9	51.7	25.4	27.5
Meishan	105.124	21.079	26168	17.5	57.2	25.3	20.0
Yibin	138.704	33.454	27865	14.6	62.3	23.1	20.0
Guang'an	162.948	20.976	23410	18.6	52.2	29.2	14.1
Dazhou	120.693	28.171	20685	21.9	53.3	24.8	24.8
Ya'an	40.845	39.553	26157	15.2	58.7	26.1	21.0
Bazhong	133.918	41.418	11823	23.8	42.9	33.3	18.9
Ziyang	181.942	29.047	27283	21.9	55.7	22.4	16.7
A'ba	15.498	143.087	22525	15.5	50.1	34.4	23.4
Ganzi	17.739	255.803	15753	24.6	38.9	36.5	47.0
Liangshan	37.774	47.326	24668	19.5	52.4	28.1	23.9

Source: Sichuan Traffic Yearbook (2013) and Poverty Alleviation Monitoring Statistics Chronology of Sichuan Province (2012)

3.1 The influence of rural road construction on income structure

There are two methods that road construction influences on the income of planting industry. One is that, thanks to the accomplished road construction, the peasants save money while they buy and sell agricultural products, so that they have improved the productivity. The other is that the accomplished road can build the relationship between peasants and markets so that they can adjust the planting pattern to increase productivity. What's more, it can stimulate non-agricultural development and offer jobs for non-agricultural population, which would make the income source and labor resource diverse. One of the most important factors that lead town companies to success is that there are the fundamental roads and other infrastructures spread across the rural areas.(World Bank, 1994,p 3)

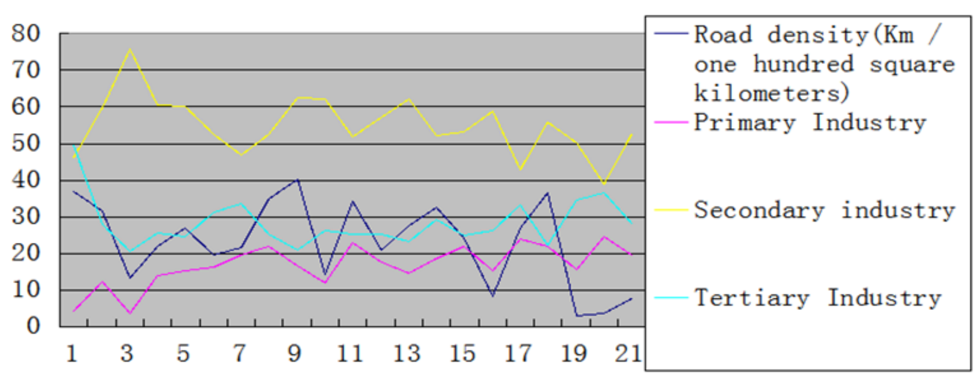

Figure 1.the Relation between Regional Road Density Rate and Industrial Structure

Based on the data of Industrial Structure and road density in the Table 2,plotted discounted diagram shown in Figure 1, we can find the line of Road Density goes the opposite direction against the line of the proportion of Primary Industry's GDP, while keeps the same trends with the line of Tertiary Industry. Then we come to the conclusion that the higher the road density is, the more the proportion of tertiary industry' GDP in regional GDP is and the less ratio of primary industry is, the more easily non-agricultural businesses survive and the more advanced the industrial structure is.

3.2 the influence of road infrastructure construction on raising economic viability of peasants

Road infrastructure construction can make it more convenient for poor people to get education and medical care, make it come true that more professional technicists and teachers come to serve local people, improve the infrastructure quality like hospital and school. And it is also good for poor people to enhance human capital and make it convenient for relatives and friends visiting that raise up social capital. Seen from Figure 2, the correlation between labor training and road density is high, which means road construction is beneficial for labor transfer and employment in poverty-stricken areas and has a positive influence on mitigating poverty.

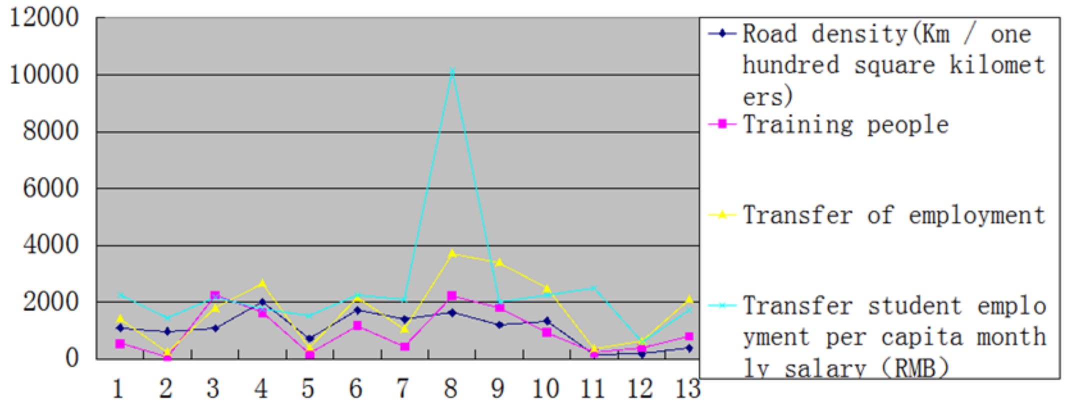

Figure 2. the correlation between road density and the number of training people

Source: Poverty Alleviation Monitoring Statistics Chronology of Sichuan Province (2012)

4 Conclusion and discussion

It is a significant way to increase peasants' income that to construct rural roads. It has been proved that it is a valid approach to get rid of poverty and make moderately prosperous life that to speed up rural roads construction and improve rural traffic conditions. One of the most important reasons that lead to rural economic lagging behind is the weakness of transportation and limited information coming in. However, to speed up rural roads construction not only can break the closing condition, facilitate the exploitation of rural nature resources which turn the soil, mineral, forests, water and tourists resources into productivity, but also can open and expand information and goods channels which bring rural natural products and agricultural products into circulation to increase peasants' income and make well-off life, and drive the rural areas to get rid of poverty eventually.

It is an arduous task for new period poverty-relief that to promote roads construction. The transport agencies in different regions would have to put road-construction as the strategic focus, formulate a practical scheme, take efficient measures to carry out rural roads construction effectively, striving to make contributions to getting rid of poverty and living a well-off life in poverty-stricken areas.

Acknowledgement

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References

Ali I．and E．Pernia．2003．Infrastructure and Poverty Reduction—What is the Connection?ERD Policy Brief Series No．13，*Economics and Research Department*，Asian Development Bank．

Baoguo Wu, the Discussion of the Approaches Adopted to Mitigate Poverty.*China Party and Government Cadres Forum*,2008,（5）：25-27.

ESCAP．2001．Policy Issues forthe ESCAP Region：Balanced Development of Urban and Rural Areas and Regions within the Countries of Asia and the Pacific．Bangkok．

Huiying Wen, Jingbo Liu, the Analysis of the Effects that Rural Roads Construction has on Rural Economic Development.*Transportation standardization*, 2010 (13)

Jocelyn A．Song co．2002．Do Rural Infrastructure Investments Benefit the Poor?World Bank Working Paper 2796，Washington，D．C．

Kristin Komives，Dale Whittington and X un Wu．2001．Infrastructure Covemge and the Poor：A Global Perspective．University of NorthCarolina at Chapel Hill．

Wenchang Zhang, FengjunJin, Jie Fan, Transportation Domain. Bei Jing: Science Press, 2002.

Wuguo Si，to discuss Agriculture and Agricultural Economics Structural Adjustment from the Perspective of Transportaion.the Town Economics, 2003,

Wen Li, the Rural Road Construction and the Poverty Relief[M]. Bei Jing: China Financial Economics Press, 2006．

Zhongying Ma, the Analysis of the West Road Development from the Perspective of New-period Villages.Xi An: the Chang'an University, 2010.

Operation Cost Research of Railway Freight Transportation Enterprise Based on the Advanced Activity-Based Costing Theory

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Abstract: Based on the theory of activity-based costing, this paper studies the detail cost composition and cost behavior of railway freight transportation enterprise. According to the analysis, this paper purposes an advanced activity-based costing theory. Firstly, it analyzes the exact process of transportation operations. Then, it divides the cost elements into the related cost centers. At last, based on the cost centers, this theory allocates the cost elements into specific processes. Finally, this paper puts forward the calculation steps.
Keywords: Railway transportation enterprise; Operation cost; Cost accumulation; Cost allocation.

1 Introduction

Cost is the monetary expression of resource consumption during the process of products production or manpower supply of an enterprise. It also is an important basis of decision making, budgeting, controlling and performance evaluation. As for a railway transportation enterprise, according to the particularity of its production, there are lots of differences in analysis and calculation of operation cost, comparing with the manufacturing enterprise. Calculating and ensuring the operation cost of a railway transportation enterprise is not only an important constituent part of transportation benefit assessment, but also an obbligato content of decision-making and analysis of profit and loss.

2 Basic conceptions and research status

According to the particularity of its production, the study on railway freight transportation operation cost has to turn some basic conceptions in manufacturing enterprise into transportation field. According to different angles and standards, operation cost could be divided into different types. For examples, there are some classification standards like economic content, economic use, effects during the manufacturing process or the relationship between different cost objects (Li Xingrong, 2007). For the transportation enterprise, the operation cost projects are set as follows: material, fuel, salary, energy, depreciation and other cost.

Cost behavior is the dependence relationship between the variable ultimate cost and portfolio under certain conditions (Zhang Yanan, 2010). Specific to transportation enterprises, their cost behavior means the correlation between the operation cost and the transportation production (generally expressed in tonnage mileage). With the change of output, there are lots of forms of the cost. The same as manufacturing enterprise, the operation cost of transportation costs are divided to fixed cost, variable cost and mixed cost.

Currently, there are more researches on enterprise cost segregation but lacking of theories about railway transportation enterprises. Li studied on the operation processes and expenses dividing of the railway cost in our country, but he didn't take the directed research on the transportation enterprises (Li Dai'an, 2001). Based on the problem of high-speed railway's loss, Ma studied on the calculating methods about high-speed railway cost and put forward the concepts and characteristics about comprehensive transportation cost of high-speed railway (Ma Chongyan, 2014). According to ABC (activity-based costing) theory, Duan had a research on the cost drivers of cost projects in passenger and freight transportation and purposed the BP neural network model for cost forecast (Duan Jie, 2011).

In this paper, the theoretical basis is also the ABC theory. But it analyzes the exact process of transportation operations and divides the cost elements into the related cost centers. Based on the cost centers, this theory allocates the cost elements into specific processes. In a word, it takes both the cost center and the cost processed into considered, when analyzing the cost projects. This advanced theory makes up the lack of calculation in railway freight transportation enterprise cost.

3 Processes of railway freight transportation operation

The production of railway freight transportation is displacement. The whole operation processes are made up with various middle operations. During them, there are both output of production (Total weight of ton-km, Train kilometers) and resource consumption (material, fuel, salary and so on) which leads to cost spending (Liu Yunguo, 2001).

The construction of general transportation enterprises is the same as railway administration. In the structure, there are production departments (e.g. train operation depot, signal depot etc.) and auxiliary departments (e.g. finance, executive office and so on). The processes of railway freight transportation organization are as fig.1.

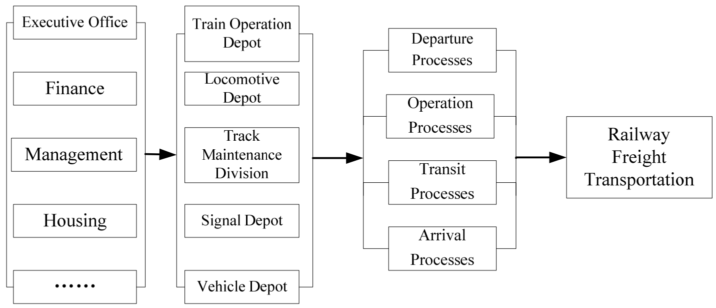

Fig.1 Processes of railway freight transportation organization

4 Accumulation and allocation of cost projects

According to the accounting theory, this paper sets the locomotive depot, train operation depot, vehicle depot, track maintenance division and signal depot as cost centers. As the current research, we briefly divide the cost projects which change with the turnover into variable cost. The cost projects which do not change with the turnover or the variable quantity of which is light are divided into fixed cost. The method of cost accumulation which according to the cost centers is as Tab.1.

Tab.1 Cost accumulation method which according to the cost centers

	Variable Cost Projects	Fixed Cost Projects
Locomotive Depot	Locomotive aided repairing, Locomotive temporary repair, Locomotive repair, Locomotive overhaul, Locomotive servicing work, Fuel and oil of locomotive, Piece rate wage, Piece rate labor cost	Salary bonuses, Labor cost, Wage surcharge, Depreciation cost of locomotives and equipment, Office allowance, Travelling expense, Labor protection cost, Rental expense, Other expenses
Train Operation Depot	Piece rate wage, Piece rate labor cost	Salary bonuses, Labor cost, Wage surcharge, Office allowance, Travelling expense, Labor protection cost, Rental expense, Other expenses, Car use cost
Vehicle Depot	Freight vehicle examination cost	Salary bonuses, Labor cost, Wage surcharge, Depreciation cost of equipment, Device detection cost, spares of means of production, Office allowance, Travelling expense, Labor protection cost, Rental

		expense, Other expenses, Car use cost
Track Maintenance Division		Salary bonuses, Labor cost, Wage surcharge, Depreciation cost of equipment, Maintenance and repair materials cost, Track maintenance machine cost, Office allowance, Travelling expense, Labor protection cost, Rental expense, Other expenses, Car use cost
Signal Depot	Communication expense of stations and lines, Maintenance cost of signal and electrical equipment	Salary bonuses, Labor cost, Wage surcharge

The changes of variable cost are related with some elements (like rotation volume of freight transport), which are called cost drivers. Specifically, cost drivers are the standards or indexes of resource allocation. They are the basic reasons of resource consumption. The cost drivers during the whole railway freight transportation processes are as Tab.2.

Tab.2 Analysis of cost drivers during the railway freight transportation processes

Operation Processes	Detail Processes	Cost Driver	Resource Requirement	Responsible Department
Departure Processes	Freight departure	Sending freight weight	Salaries of freight transportation staff, Cost of stations and related structures	Train Operation Depot, Vehicle Depot
	Shunting operation	Shunting operation hour	Salaries of shunting staff, Maintenance cost of shunting locomotive, Fuel, Oil	Locomotive Depot
Operation	Locomotive	Locomotive	Maintenance cost of	Locomotive

Processes	traction assignment	running kilometers	locomotive, Cost of locomotive oil, Cost of locomotive fuel, Salaries of locomotive crew	Depot
		Engine hours	Depreciation expense of locomotive each hour	
		Total weight of locomotive ton-km	Cost of locomotive servicing	
	Freight vehicle assignment	Freight locomotive hour	Depreciation expense of freight vehicle	Vehicle Depot
		Freight vehicle kilometers	Maintenance cost of freight vehicle, Cost of freight train examination	
	Track assignment	Total weight of train loading	Maintenance cost of tracks, Energy charge in electrified railways, Depreciation expense of maintenance equipment	Track Maintenance Division
	Signal assignment	Train kilometers	Depreciation expense of signal equipment, Maintenance and operation cost of signal equipment	Signal Depot
	Station operation assignment	Train kilometers	Train cost of arriving, departure and passing through	Train Operation Depot
Transit Processes		Transit weight of freight	Transit and loading and unloading cost of freight	Train Operation Depot
Arrival Processes	Freight Arrival	Arriving freight weight	Salaries of freight transportation staff, Cost of stations and related structures	Train Operation Depot, Vehicle Depot
	Shunting operation	Shunting operation hour	Salaries of shunting staff, Maintenance cost of shunting locomotive, Fuel, Oil	Locomotive Depot

Based on the analysis before, we could see that the contents of cost projects were still complex. When dividing them into the operation processes, we ignore or combine the cost projects which take less resources or expenses. The cost allocation of railway freight transportation enterprises is as follows.

Tab.3 Cost allocation of railway freight transportation enterprises

Operation Processes	**Cost Driver（Independent Variable）**	**Variable Cost Projects（Dependent Variable）**
Departure and Arrival Processes	Arriving and Departure freight weight	Freight transportation cost of station
Transit Processes	Transit weight of freight	Transit cost of station
Operation Processes	Locomotive running kilometers、single locomotive running kilometers	Maintenance cost of locomotive, Cost of locomotive oil, Cost of locomotive fuel, Depreciation expense of locomotive, Salaries of locomotive crew
	Engine hours	Depreciation expense of locomotive each hour
	Shunting operation hour	Maintenance cost of shunting locomotive, Salaries, Fuel, Oil
	Freight vehicle kilometers	Maintenance cost of freight vehicle, Cost of freight train examination
	Freight vehicle hours	Depreciation expense of freight vehicle in each freight vehicle hours
	Total weight of locomotive ton-km	Cost of locomotive servicing
	Total weight of train loading	Maintenance cost of tracks, Energy charge in electrified railways, Depreciation expense of maintenance equipment
	Train kilometers	Depreciation expense of signal equipment, Maintenance and operation cost of signal equipment

5 Calculation steps of operation costs

As the discussed above, this paper purposes the division and description of railway transportation enterprise production processes, the analysis of variable cost and fixed cost, the method of accumulation and allocation of cost and the analysis of cost drivers. Based on them, the calculation steps of operation costs are as follows:

(1) Ensure the unit expense, which means finding out the unit expense of a given operation process.

(2) Calculate the operational volume. We have to calculate out the operational volume which is related to the unit expense.

(3) Calculate the variable cost. For a given process, multiply the unit expense and the operational volume. The result is the variable cost of that operation process.

(4) Calculate the whole cost of a freight transportation product. When given a freight transportation product, after calculating out the variable cost, we add up the fixed cost allocation. The result is going to be the whole cost of the product.

6 Conclusions

The calculation of operation cost of railway freight transportation is a key problem of enterprise benefit evaluation. Based on the theory of activity-based costing, this paper studies the division and description of railway transportation enterprise production processes, the analysis of variable cost and fixed cost, the method of accumulation and allocation of cost and the analysis of cost drivers. Then, it gave out the cost calculation steps of a transportation product. The advanced ABC theory could describe the structure of cost projects exactly and provide decision supports of cost structure optimization. However in this paper, the division of cost projects is subjective and it leaves out some cost projects.

Acknowledgement

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References

Duan Jie (2011). "Research on Transportation Cost Predication of Railway Construction Project". *Beijing Jiaotong University*.

Li Xingrong and Guo Zhenyan (2007)."Research on the Enterprise Knowledge Economy and Cost Accounting". Science and Technology Consulting Herald, (3): 145-145.

Li Dai'an and Fan Xiujun (2001). "Chinese Railway Cost Calculation System". Chinese Railway,10:7-11+4

Liu Yunguo(2001). “Study on the Case of Railway Transportation Enterprise of ABC”. Accounting Research, (2): 31-39.

Ma Chongyan (2014). “Research on High-speed Railway’s Transportation Cost”. Southwest Jiaotong University.

Zhang Yanan (2010). “Representing and Reasoning about Costs Using TOVE Ontology and Resource Consumption Accounting”. Shanghai Jiaotong University.

Railway Freight Transportation Economic Benefit Cost-Volume-Profit Analysis

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Abstract: Cost-volume-profit model is applied to analyze the railway freight transportation economic benefit, based on the cost data of railway enterprises. Through Cost-volume-profit model, the relationship between transportation costs, freight transportation unit price and freight transport is obtained, then the freight transport and freight transportation unit price at break even point are drawn. Then the key factors affecting transportation profits are clarified and sensitivity coefficients of which are explored. The risk resistance capability of railway enterprise is assessed. This paper can provide adequate data indicators for the railway enterprise managers to make strategic decisions.

Keywords: Cost-volume-profit analysis; Railway transportation; Economic benefit; Sensitivity analysis.

1 Introduction

It is particularly important for railway transportation enterprises to improve the economic benefits. There are strong links between railway transportation economic benefit and effecting factors and it is essential to clarify the relationship and identify the key influencing factors. The existing studies for the railway transportation economic benefit mainly focus on cost accounting and evaluation system, while rare in quantitative relationship between cost, profit, freight transportation unit price and transport.

Li Daian divided railway operations into different sections, calculated variable unit cost of work in each section and got the total cost of railway transportation (Li Daian, 1999). Liu Yunguo applied Activity Based Costing to railway enterprise, analyzing cost divers of operations, accounting the total cost according to the quantity of work (Liu Yunguo, 2001). Zhao Zhiwen established a prediction model of railway transportation cost, based on through PB neural network theory and Activity Based Costing theory (Zhao Zhiwen, 2007).Wen Nuan established an assessment index system, utilizing the analytic hierarchy process to evaluate the economic benefit (Wen Nuan, 2011).Xia Huaiwei made a comprehensive appraisal to railway transportation economic benefit through principal component analysis, identifying the critical factors influencing the economic benefit(Xia Huaiwei, 2001). Zhang Likun evaluated the benefit of Railway PDL by DEA-C^2R evaluation model, in perspective of economic and social efficiency (Zhang Likun, 2010).

Most of the exciting researches assessed railway transportation enterprises economic benefits in macroscopic level, while absent in exploration of mathematical formula of profits. This paper applies CVP model to the study of railway transportation economic benefits, identifying the key factors influencing the economic benefit, assessing the risk resistance capability of enterprise, proposing effective measures to improve the economic benefit.

2 Fundamentals of Railway Transportation Economic Benefit CVP Analysis

Several variables are involved in railway economic benefit CVP model, such as fixed cost of transportation operations (Abbreviated as F), variable cost(Abbreviated as TV), variable unit cost(Abbreviated as V), freight transport (Abbreviated as Q), freight transportation unit price(Abbreviated as P), sales revenue(Abbreviated as S), transportation enterprise profit(Abbreviated as M). The equation between these variables is shown as formula (1).

$$M = S - F - TV = P \times Q - F - V \times Q \tag{1}$$

Formula (1) is the basic mathematical equation of CVP model, which clearly indicates the mathematical relationship between cost, transport and profit. All the CVP analysis derives from the formula.

2.1 Analysis of Freight Transportation Cost Behavior

Cost behavior analysis is the premise of CVP analysis. The product of railway transportation is transport. The transportation cost can be gathered as the fixed costs and variable costs. The fixed costs mainly includes labor cost (which not covers the piece wages), depreciation cost, daily management funds and so on while the variable costs are expenditures varying with operation volume, such as the piece wages, locomotive overhaul fees, locomotive medium-term repairing fees, locomotive servicing fees and so on.

2.2 Analysis of Break Even Point

The freight transports at Break Even Point are these make the sales revenue equals to the transportation total cost. Break Even Point Analysis is helpful for the freight transportation manager to define the relation between freight transport, sales revenue and the profits. The freight transport and sales revenue at Break Even Point (Abbreviated as Q_B and S_B) can be calculated from formula(2)and formula(3).

$$Q_B = F / (P - V) \tag{2}$$

$$S_B = P \times Q_B \tag{3}$$

2.3 Analysis of Profit Target

The volume of freight transport (Abbreviated as Q_W) targeting the profit target (Abbreviated as M_T) can be derived from the formula (1), just by replacing M with M_T in computational formula (4). The variations on variables have influences on target profit, which can be acquired by Profit Target analysis. These are references for the transportation manager as they make decisions.

$$Q_w = M_t + F \big/ (P - V) \tag{4}$$

2.4 Sensitivity Analysis

Railway freight transportation activities are varying constantly. The critical values of freight transportation unit price, transport and fixed cost, which affect the profits of transportation enterprise, can be calculated by formulas, from formula (5) to formula (8), which all derive from formula (2) concerning Break Even Point. Specific to different influencing variable, influence degree each are distinct. The influence degree can be measured by sensitive coefficient, calculated through formula (9). If the sensitive coefficient of a variable is positive, it indicates that the variable has a positive correlation with profit. And vice versa. The larger a sensitive coefficient is, the larger influence degree is.

The minimum allowed unit Price $P_{\min} = V + F / Q$ (5)

The maximum allowed variable unit cost $V_{\max} = P - F / Q$ (6)

The minimum allowed freight transport $Q_{\min} = F / P - V$ (7)

The maximum allowed fixed cost $F_{\max} = (P - V) \times Q$ (8)

The sensitive coefficient $SC_v = \Delta M\% / \Delta v\%$ (9)

In formula (9), SC_v means the sensitive coefficient of a certain variable, $\Delta M\%$ means the percentage change in profit, $\Delta v\%$ means percentage change in the variable.

2.5 Relevant Decision-making Indexes

A series of decisions are necessary in transportation operation, which can determine the development direction of a transportation enterprise in short or long term. The decision-making indexes related to CVP include Contribution Margin (Abbreviated as CM), Safety Margins (Abbreviated as MS) and Degree of Operating Leverage (Abbreviated as DOL). Contribution margin indicates the profit transportation product contributing to transportation enterprise while the Safety Margins reflects the security of transportation enterprise operations. Degree of Operating Leverage, which indicates the impact of changes in sales revenue on profit, is a measure of operation risk. These indexes demonstrate profitability of transportation product and production capacity of transportation enterprise. Transportation operation plan are made based on these indexes. The calculation formulas for these indexes are form formula (10) to formula (14). Q_{MS} means the safety margins transport, $MS\%$ means rate of safety margin, and Q_P means the planned transport.

$$CM\% = \frac{CM}{M} \times 100\% \tag{11}$$

$$Q_{MS} = Q - Q_B \tag{12}$$

$$MS\% = \frac{Q_{MS}}{Q_P} \times 100\% \tag{13}$$

$$DOL = \frac{CM}{CM - F} \tag{14}$$

3 Numerical examples

The paper applies the CVP model to a freight transportation enterprise, estimating the economic benefit in aspects of cost behavior, break even point, profit target, sensitive analysis and DOL, exploring the relationship between freight transport, sales revenue and freight transportation price, identifying the key factors affecting the economic benefit of this transportation enterprise.

3.1 Cost Behavior of railway transportation

The annual volume of the railway is 3000 million tons, while the annual freight transport is 416323 million ton kilometers. The sales revenue is 10511 million yuan throughout the year and the transportation unit price is 252.47 yuan/million ton kilometer. The total costs are gathered as fixed cost and variable cost, shown in table 1. The detail expenditures of transportation operations can be seen in table 2.

Table 1. Cost Items of Freight Transportation Enterprise

Cost behavior	Cost items
Fixed costs	salary, bonus and subsidiary of workers, labor cost (which not covers the piece wages), depreciation cost of locomotive, administrative expenses, travel expense, workers insurance expense, lease rentals and other expenditures
Variable costs	salary, bonus and subsidiary of workers, piece wages, locomotive small-auxiliary-repairing charges, locomotive temporary-repairing fees, locomotive overhaul fees, locomotive medium-term repairing fees, locomotive servicing fees, locomotive fuel oil fees

Table 2. Detailed expenditures of transportation operations

Cost items	Fixed cost	variable cost	Subtotal
1 Cost of labor	18,276,122.00	6,598,959.51	24,875,081.51
2 Direct productive cost	5,631,146.88	20,194,270.07	25,825,416.95
3 Manufacturing service costs	2,486,669.82	-	2,486,669.82
Operation cost summation	26,393,938.70	26,793,229.58	53,187,168.28

3.2 Decision-making Indexes of Railway Transportation

The cost volume profit analysis diagram can be drawn according to the financing data of the transportation enterprise, shown in figure 1. The CVP indexes concerning economic benefit are all in table 3.

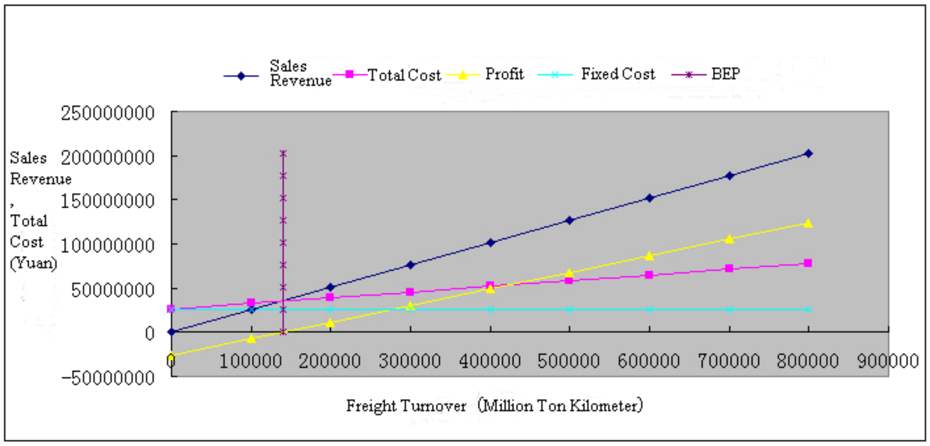

Figure 1. Cost volume profit analysis diagram

Table 3. CVP indexes of transportation enterprise

Items	Indexes	Values
Break Even Point (BEP) Analysis	contribution per unit	188.11 yuan / million ton kilometer
	Rate of contribution margin	74.51%
	Rate of variable cost	25.49%
	Freight transport at BEP	140310.99 million ton kilometers
	sales revenue at BEP	35424315.65 yuan
	safety margin transport	276012.01 million ton kilometers
	Rate of safety margin	66.30%
	completion rate of transport at BEP	33.70%
Transport for target profit	$Q_w = \frac{M_t+F}{P-V} = \frac{M_t+2639.39\times10^4}{252.47-64.36} = \frac{M_t+2639.39\times10^4}{188.11}$	
Sensitivity Analysis (10% Level)	sensitivity coefficient of transportation unit price	2.02
	sensitivity coefficient of variable unit cost	-0.52
	sensitivity coefficient of fixed cost	-0.51
	sensitivity coefficient of transport	1.51
Analysis Of the factors effecting the profits	minimum allowed unit price	127.76 yuan / million ton kilometer
	maximum allowed variable unit cost	189.07 yuan / million ton kilometer
	maximum allowed fixed cost	78314519.53 yuan
	minimum freight transport	140311 yuan / million ton kilometer
	DOL	1.51

3.2.1 Break Even Point of railway transportation

The freight transport at BEP is 140310.99 million ton kilometers, occupying 33.70% of the current freight transport, indicating that the transportation enterprise can achieve balance of profit and loss by competition 33.70% of the current freight transport. The sales revenue at BEP is 35424315.65 yuan while the safety margin ratio is 66.30%. These indexes values demonstrate the transportation operation is in good condition and the enterprise has the certain anti-risk ability. The production capacity is rationally used and the possibility of loss is smaller.

3.2.2 Sensitivity Analysis of Variables Concerning Railway Transportation

Sensitivity analysis rests on the assumption that as the other indexes remain unchanged, the freight transportation price, variable unit cost, fixed cost and freight transport respectively increase by 10%, and the target profit is 5192.06 million yuan (when the freight transport is 416323 million ton kilometers). The sensitivity coefficient of each index is shown in table 3. The sensitive coefficient of freight transportation price ranks the first, about 3 times as that of variable unit price. the sensitive coefficient of freight transport takes the second place while the fixed cost is the last. the freight transport and transportation unit price have a positive effect on the profit and the fixed cost and variable unit cost effects the profit negatively. Improving the transportation price and freight transport are effective ways to promoting profit. On the other hand, reducing the fixed cost and variable unit cost are significative.

3.2.3 Critical Value of Factors Affecting the Profit

The critical values of transportation price, variable unit cost, fixed cost and transport are calculated. As the transportation price reduces to 127.76 yuan (reduces by 49.79%), the sales revenue equals to the total cost. The price leaves no margin of profit. The actual transportation price should higher than it otherwise the enterprise will made a loss. The current price is secure since the critical value price occupies 51.21% of the current price. The enterprise made no profit as the variable unit price increases by 194.75%, from 64.36 yuan to 189.07 yuan. There is equal effective if the fixed cost increases from 26393938.70 yuan to 78314519.53 yuan (increases by 196.71%) or 33.70% of the current freight transports are completed. At present the freight transportation unit price and fixed cost are reasonable, the freight transport is considerable. The enterprise is less likely to suffer a loss based on the analysis of factors influencing the profit.

3.2.4 Degree of Operating Leverage Analysis

The degree of operating leverage of this enterprise is 1.51, means that the earnings before interest and tax (EBIT) will increase by 1.15% as the freight transport increase by 1%, vice versa. It can bring the financial risks as well as the benefit on financial leverage. The larger the Degree of Operating Leverage is given, the higher the operation risk and benefits are. Degree of Operating Leverage is an important reference for the enterprise manager to make strategic decisions.

4 Conclusions

The paper expounds the principles of CVP model and presents the relevant indexes in CPV. Then the CVP model is applied to a transportation enterprise, which can provide some references for the enterprise manager. The cost items of the enterprise are gathered as fixed cost and variable cost. The freight transport at the BEP is calculated, and the sensitivity coefficient of factors effecting profit are drawn. Risk resistance capability of the enterprise is assessed though safety margin and Degree of Operating Leverage.

In conclusion, CVP analysis help the manager to cognize the operation condition and the weaknesses need to improve of the transportation enterprise, providing ideas and approaches for the improvement.

Acknowledgement

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References

Li Daian and Xu Gang (1999). "Study on China Railroad Costing System (CRCS)". *Journal of the China Railway Society*, 21(6): 96-100.

Liu Yunguo (2001). "Study on the Application of ABC in Chinese Railway Transport Enterprises". Journal of Accounting Research, (2): 31-39.

Wen Nuan and Zhou Yaodong(2011)."Research on Economic Evaluation of Transportation Companies Based on AHP", International Conference on Engineering and Business Management(EBM2011),2702-2705.

Xia Wei Huai(2011). "Comprehensive Evaluation and Competitive Strategy of Chinese Railway Transportation Enterprise's Economic Benefit". Journal of Changsha Railway University, 19(2): 92-96.

Zhang Likun(2010)."DEA evaluation of passenger dedicated line efficiency". Railway Operation Technology,16(4): 8-10.

Zhao Zhiwen and Lu Qinyao(2007). "Study on the Prediction of Railway Freight Transport Cost Based on Activity-based Costing and BP Neural Networks". Railway Transport and Economy, 28(12): 20-22.

Exploration of "Alliance of Agriculture and Community" Based on Third-Party Trading Enterprises

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Abstract: With the constant improvement of urban and rural distribution network, "Alliance of Agriculture and Community" has became a highway for agricultural products to flow to the city residents, but there are still a lot of resistances in the process. This paper analyzes the problems of "Alliance of Agriculture and Community" in our country and introduces a new operating model which based on the third-party trading enterprises, then researches its development advantages and suggests the corresponding advice and countermeasures.
Keywords: "Alliance of Agriculture and Community"; Agricultural cooperatives; The third-party trading enterprises; Direct selling.

1 Introduction

As "Medium and long-term plan on development of logistics industry (2014-2020)" published by the state council points out, with the increasing demand for bulk agricultural products logistics and fresh agricultural products cold chain logistics, there is an urgent need for more perfect, convenient, efficient and safe consumer goods logistics distribution system. As an important part of urban and rural distribution, the problem how agricultural products go into the city should gain the corresponding attention. With documents issued by government to support agricultural cooperatives to establish the sales outlets in urban community, "Alliance of Agriculture and Community" do emerge. It's a new sales model of agricultural products after "Alliance of Agriculture and Supermarket" and it implements the farmers and the urban community's directly communication, providing a convenient channel for agricultural products' going into the city and citizens' gaining fresh agricultural products. The direct selling model based on the third-party trading enterprises break the traditional model and introduce professional trading enterprises to improve the sale effect by strengthening professionalism of each link.

2 The Domestic Status of Traditional "Alliance of Agriculture and Community"

The traditional "Alliance of Agriculture and Community" is an agricultural products sales model of building sale stores in the city communities through agricultural cooperatives, making the products directly docking with the community consumers. In recent years, Beijing, Shanghai, Guangdong, Jiangsu and other provinces have tried this pattern positively and have achieved remarkable success in reducing the product price, meeting consumers' demands and improving the level of service. As that this model is still in the early stage, there are many difficulties and problems.

2.1 The main effects of "Alliance of Agriculture and Community"

Firstly, farmers improve their incomes distinctly. The model is, for the most part, a way to expand the sales channels and methods of agricultural cooperatives, achieving the direct supply of agricultural products from the fields to the table, and avoiding the unnecessary circulation. This way saves up to 20%~30% of the circulation costs. A survey found that those agricultural cooperatives which organize "Alliance of Agriculture and Community" improve their incomes distinctly, increasing revenue by 20% and enhancing the farmer's enthusiasm.

Then, citizens gain more convenient life. Agricultural cooperatives build sale stores in the city communities, saving the time of purchase of citizens, and offering protection for freshness of agricultural products. What's more, the product price in the sale stores is generally lower than the supermarket and other external markets (SHI 2014). These community stores supply cheap and healthy agricultural products to citizens, improving the quality of their life.

Lastly, the model may promote the upgradation of agricultural cooperatives. In the past, agricultural cooperatives lacked effective operating standards, and farmers didn't change the traditional product model to meet the market demand in time. "Alliance of Agriculture and Community" provide a good direct marketing platform of agricultural products for agricultural cooperatives, consolidating the development foundation for them. In addition, farmers learned that how to adjust the production structure and realized the importance of the quality of agricultural product according to the sale, cultivating their sense of marketing and quality.

2.2 The protruding problems of "Alliance of Agriculture and Community"

Firstly, the lack of social support. The smooth implementation of "Alliance of Agriculture and Community" involves many aspects of society, it needs the support from relevant departments of commerce and industry, taxation, finance, and so on. At present, the social awareness of this model is not enough, limiting its promotion seriously. For example, some community administrations refuse the stores because they think that these stores are not conducive to their management. Besides, higher taxes or a heavy rent for the land and other issues has seriously reduce the farmers' work enthusiasm.

Then, the lack of funds and equipment. The traditional "Alliance of Agriculture and Community" is dominated by agricultural cooperatives, and the set-up of stores puts forward some requirements for storefront, equipment and personnel. It often takes liquidity, and it bring huge pressure to agricultural cooperatives. Freshness is the key to agricultural products sales, but most agricultural cooperatives are still in the early stage, facilities which include packaging, storage, transportation and test equipment remains to be improved, bringing certain challenges to the product quality and safety.

Lastly, the lack of management ability. Management ability is a big defect of agricultural cooperatives in the process of direct selling. Financial management, e-commerce, logistics distribution all have the certain requirements for labor personnel. Based on the economic power of agricultural cooperatives, they can't provide a higher level of treatment to attract relevant management talent, so it make the lack of talent an important restricting factor of the development of "Alliance of Agriculture and Community" (ZHENG 2013).

3 The Advantage Analysis of the Model Based on the Third-Party Trading Enterprises

3.1 Compared with the model that farmers achieve sales by themselves

As a traditional way to sell agricultural products, this model that farmers achieve sales by themselves avoid the circulation in the middle, and bring agricultural products to consumers directly. This model has large limitation, small scale and single products, it's always very popular in those underdeveloped areas, and farmers are difficult to grasp the market dynamics and adjust production structure timely (WEN 2013). But "Alliance of Agriculture and Community" based on the third-party trading enterprises encourage agricultural cooperatives in different scale to strengthen exchanges and cooperation and form agricultural cooperative federation, and it can rich the type and quantity of agricultural products to meet the market demand. The third-party trading enterprises can receive agricultural products from the planting base directly with professional storage and transportation vehicles, ensuring the freshness of agricultural products in the entire circulation. The enterprises tend to have complete information processing ability to realize the information communication and feedbacks between each link, providing accurate market dynamics and market demand to the farmers.

3.2 Compared with the model of "Alliance of Agriculture and Supermarket"

"Alliance of Agriculture and Supermarket" requires agricultural cooperatives to make a treaty with the supermarket, achieving long-term supply of agricultural products to the supermarket and the win-win between farmers and supermarket. But under this sale model, the supermarket concern the appearance more, freshness of agricultural products, etc. Some farmers cannot meet the high standard and most agricultural cooperatives can't accept the non-cash transactions which widely used in supermarkets. There aren't too high standards of agricultural products under the model based on the third-party trading enterprises, it only needs to pass the quality inspection from the third-party enterprises. Besides, the third-party trading enterprises will be responsible for the store's location, purchasing of cold storage facilities, worker's recruitment and the supply of capital flows, etc. The model solves the lack of capital and management experience of agricultural cooperatives effectively, and achieves a sales platform of agricultural products which is more convenient than the supermarket.

4 The Key for "Alliance of Agriculture and Community" Based on the Third-Party Trading Enterprises

Although that it's the third-party trading enterprises who complete the sale of agricultural products, it doesn't gain any excess circulation, but provide a more professional and efficient agricultural transport condition when compared with the model based on agricultural cooperatives, ensuring the safety of agricultural products. On the other hand, the dominance of trading enterprises lead to the significantly decreasing participation of farmers in sales link. While farmers is a group that is sensitive to sales revenue, in order to maintain the effective connections of each link, it is particularly critical that timely information feedback and the establishment of reasonable interest distribution mechanism. In addition, with the continuous improvement of living standards, community residents give higher expectations to the product variety and quality safety of agricultural products. Only with stable rich supply sources, safe and efficient logistics distribution, and professional store sales, can it gain the expected effect that the model should have and truly realize the optimization and upgradation of traditional "Alliance of Agriculture and Community" operation model. New model based on the third-party trading enterprises is shown in figure 1.

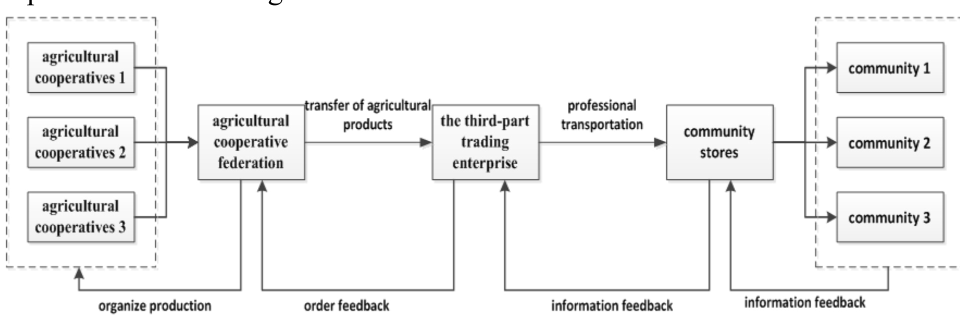

Figure 1. "Alliance of Agriculture and Community" based on the third-party trading enterprises

5 Countermeasures and Suggestions

"Alliance of Agriculture and Community" is a system process involving multiple elements. In order to promote the new model based on the third-party trading enterprises effectively, this paper put forward the following countermeasures and suggestions.

Firstly, deepen the social cognition on "Alliance of Agriculture and

Community". It's a kind of agricultural products sales model which brings many benefits to multiple entities. The government should take effective measures including television, network to promote the advantage of the model and enhance people's understanding of "Alliance of Agriculture and Community". In this way, we can create a good develop environment for it and mobilize the enthusiasm of multiple entities.

Then, strengthen the support from relevant departments to "Alliance of Agriculture and Community". Policy support is an important premise of its rapid promotion (LI 2012). The government should strengthen the capital support, provide the third-party trading enterprises certain preference and support in respect of taxation and land, and offer certain subsidies when enterprises purchase agricultural product storage, transportation facilities. In this way, more trading enterprises will be involved.

Lastly, attach great importance to the government supervision and strengthen cooperation. At present, agricultural cooperatives, the third-party trading enterprises and community market are not mature, so it is important to gain the government's supervision and support. The government can encourage farmers to form agricultural cooperative federation actively and conduct joint sales, find and solve problems through the supervision of the production and management in planting base, the management and construction of community stores and information sharing between farmers and enterprises, and coordinate business cooperation and profit distribution between enterprises and agricultural cooperatives to build the long-term cooperation mechanism.

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References

LI weihua. (2012). "Necessity of Organization and Circulation in Producing and Selling Agricultural Goods". *Logistics Technology.*

SHI hexin, MI zhiguang, HOU ruifeng. (2014). "Optimal selection research of Alliance of Agriculture and Community". *Urban and Rural Development.*

WEN yu. (2014). "Discussion on the Development of China's Agricultural Products Direct Marketing Modell". *Practice in Foreign Economic Relations and Trade.*

ZHENG liwen. (2013). "Alliance of Agriculture and Community: status, problems and countermeasures". *China Price.*

Analysis of Transportation and Economic Development in Jiangxi

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Abstract: Jiangxi economic development is inseparable from the transportation industry, transportation industry plays an important role in economic development in Jiangxi Province, this paper use 1978-2012 transportation data, analyze the Jiangxi railway transport, road transport, sea transport, air transport, and the use of correlation analysis, gray correlation analysis, elasticity analysis and other analysis of the intrinsic link the province's transportation and economic development; the use of gray prediction model, transportation and economic development in Jiangxi Province were forecast, plan ahead and be prepared to predict the situation in Jiangxi Province in 2013-2020 transportation and economic development in Jiangxi Province, making use of the good momentum of economic development in the country, and to catch up others. To find the problems and the adverse impact on economic development in Jiangxi Province, To build the global economy play a key role in the development of large-capacity channel, the layout of the road network and promote coordinated economic development , to make transportation industry has become a new economic growth point of Jiangxi Province.
Keywords: Correlation analysis; Gray correlation; Elasticity analysis; Gray prediction model.

1 Introduction

In recent years, Jiangxi economy continued to maintain a rapid development momentum. In 2012, the province's GDP reached 1.294888 trillion yuan, an increase of 10.65% over the previous year, for many years to achieve a growth rate of more than 10%. Transportation as a special material production sectors, by specializing in cargo and passenger transportation services business, social production, distribution, exchange and consumption to be normal in all aspects, with social infrastructure, public services and material production, and it is has multiple properties. As a critical infrastructure, it is a prerequisite for the social and economic development and the spread of civilization; as a public good, it is through personnel exchanges, inter-regional exchange of goods to contact the household, spatial displacement of people and things, to support economic sectors building and interpersonal area. By

2012, the annual completion of various modes of transport Cargo traffic 1.2702 billion tons, an increase of 13.8% over the previous year, cargo turnover 344,896,700,000 tons km, an increase of 14.8% over the previous year; passenger transport volume 84,459 million, compared with last year growth of 6.7%, Passenger turnover 97.9844 billion person-kilometers, an increase of 1.8 percent over the previous year. Although transportation industry to continue to develop in Jiangxi, the exact size of the national economy the demand for transportation, and transportation research role in promoting the national economy is still seriously lagging conducted at different stages of development, for the transportation and economic development understanding of the relationship is also largely remain in the sensual rather than rational level, stay on qualitative rather than quantitative level, which will seriously affect the development of Jiangxi, and transport development strategy of science and rationality. If you can not follow the development of transportation and infrastructure for the interaction between the economic development of the national economy to provide the necessary support and protection, it will seriously hinder the development of the national economy. Therefore, the study of transportation and economic development in Jiangxi relationship is of great practical significance.

2 Correlation Analysis

This article is taken from the Statistical Yearbook of Jiangxi,since 1978-2012 years of data, as shown in Table 1:

Table 1.the traffic situation and economic development in Jiangxi

Year	Z1	Z2	Z3	X1	X2	X3	X4	Y1
1978	1184	30245	6630					87
1980	1335	29651	4937					111
1990	1581	33203	4937	2990626	1703696	17593	24893	428
1995	1579	34915	4937	3926003	2390630	22179	30113	1169
2000	2197	60292	5537	7469297	4530738	23601	35821	2003
2005	2307	62300	5560	8816426	6039555	33270	41722	4056
2006	2307	128234	5716	9477604	6564562	36759	43239	4820
2007	2458	130691	5716	10269219	7167001	40046	43782	5800
2008	2549	133847	5716	22898520	8070117	80332	66261	6971
2009	2612	137011	5716	23509074	8072337	85718	70674	7655
2010	2734	140597	5716	27386993	9127645	100339	76633	9451
2011	2734	146631	5716	30040231	9625564	111576	79138	11702
2012	2734	150595	5716	34489670	9798488	127020	84459	12948

Source: Jiangxi Statistical Yearbook

Remarks:Railway mileageZ1,Highway mileageZ2,Inland navigable mileageZ3, Cargo turnover X1, Passenger turnover X2, Cargo traffic X3, passenger trafficX4,GDP of jiangxiY1

Running SPSS software , the following results:

Table 2. Jiangxi GDP and Highway mileage's correlation

		Y1	Z1	Z2	Z3
Y1	Pearson correlation	1	.896**	.918**	.285
	Significant (bilateral)		.000	.000	.345
	N	13	13	13	13
Z1	Pearson correlation	.896**	1	.924**	.214
	Significant (bilateral)	.000		.000	.482
	N	13	13	13	13
Z2	Pearson correlation	.918**	.924**	1	.342
	Significant (bilateral)	.000	.000		.253
	N	13	13	13	13
Z3	Pearson correlation	.285	.214	.342	1
	Significant (bilateral)	.345	.482	.253	
	N	13	13	13	13

**.In the .01 level (bilateral) significant correlation.

Table 2 shows, Jiangxi GDP and Highway mileage has the highest correlation, the correlation coefficient was 0,918, followed by Railway mileage, the correlation coefficient was 0,896, and finally to Inland navigable mileage, only 0,285, relatively fast-flowing water in Jiangxi Province, side of the lake surrounded by mountains, mostly hilly topography, rivers can takes little, so the correlation coefficients is low.

Table 3. Various types of index's correlation

		Y1	X1	X2	X3	X4
Y1	Pearson correlation	1	.967**	.968**	.949**	.967**
	Significant (bilateral)		.000	.000	.000	.000
	N	11	11	11	11	11
X1	Pearson correlation	.967**	1	.989**	.933**	.994**
	Significant (bilateral)	.000		.000	.000	.000
	N	11	11	11	11	11
X2	Pearson correlation	.968**	.989**	1	.889**	.997**
	Significant (bilateral)	.000	.000		.000	.000
	N	11	11	11	11	11
X3	Pearson correlation	.949**	.933**	.889**	1	.906**
	Significant (bilateral)	.000	.000	.000		.000
	N	11	11	11	11	11
X4	Pearson correlation	.967**	.994**	.997**	.906**	1
	Significant (bilateral)	.000	.000	.000	.000	
	N	11	11	11	11	11

**.In the .01 level (bilateral) significant correlation.

As seen from Table 3, the highest correlation coefficient is Cargo traffic, followed by passenger traffic and cargo turnover, and finally is the passenger turnover. All the correlation coefficient more than 0.9, has the higher correlation, This shows that economic development is inseparable from the transport industry development of Jiangxi Province, the two are closely related.

3 Grey Relational Analysis

Correlation analysis is based on the probability theory of stochastic processes, by comparison between the array of factors to determine the degree of correlation between variables, is a static study. The Grey Relational Analysis is based on gray system,Compare the time series between the factors to determine which is the dominant factor in high-impact,Is a dynamic process.

Hypothesis the system features action sequences is economic time series behaviorY i = {Yi(n)}, Y i is economic factors, Action sequences related factors is traffic behavior time series Xi={Xi(n)},Xi is transportation factor, n is time, ε_{ij} and r_{if} represent of Yi and Xi Grey Relational and grey relative correlation,Y i and X i Comprehensive Grey Relational is ρ_{ij} (θ is distinguish factor):

$$\rho_{ij} = \theta\varepsilon_{ij} + (1+\theta)r_{if}$$

Now use the data of Jiangxi Province from 1990 to 2012 statistics, Calculates the GDP of Jiangxi Y1, Cargo turnover X1, Passenger turnover X2, Cargo traffic X3, Passenger traffic X4's Comprehensive Grey Relational and sequencing see Table 4(θ = 0.5):

Table 4. Grey Relational table

	X1	X2	X3	X4	
Y1	0.417892344	0.354093	0.36838	0.333333	X1>X3>X2>X4

From the Comprehensive Grey Relational and sequencing, the greatest impact on GDP of Jiangxi Province is Cargo turnover X4, followed by Cargo traffic X3; combining correlation matrix comprehensive analysis, Cargo turnover X4 and Cargo traffic X3 for the gross regional product of Jiangxi Province has significant role in promoting.

4 Elastic analysis

Relative proportions traffic growth rate and economic growth rate, called the transport elasticity coefficient, which reflects the development of the transport sector is to adapt to the development of the national economy,And the degree of adaptation. To maintain a sustained, rapid and coordinated development, transportation must rationalize the relationship.so that the development and growth of the national economy and maintain transportation has proper proportional relationship.

According to GDP of Jiangxi Province is calculated ,to calculate cargo turnover and Cargo traffic turnover elasticity ,various transport and the total shown in Table 5:

Table 5. elasticity coefficient table

Year	Cargo traffic	The people Airlines	Railway	Highway	Water transport
2006	0.56	0.74	0.58	0.52	0.79
2012	1.30	0.67	-0.63	1.47	0.61
Year	Cargo turnover	The people Airlines	Railway	Highway	Water transport
2006	0.40	0.78	0.24	1.07	0.05

From Table 5, the Cargo transportation from 2006 to 2012,the elasticity coefficient from0.56 to 1.30, while cargo turnover from 2006 to 2012, the elasticity coefficient from0.40 to 1.39. In 2012, Cargo transportation turnover volume and elasticity in 2012 is greater than 1, This shows that the traffic is growing faster than economic growth, transportation development presents a balanced development of the national economy, it adapt to the development of transport in general;At the same time, we can see very rapid development in Jiangxi Highway,it is greatly adapt and meet the needs of economic development in Jiangxi Province, it is worth mentioning that the situation in Jiangxi Railway, 2012, Cargo traffic and cargo turnover are negative, This explains Jiangxi railway transportation is very tight, which restricts economic development in Jiangxi Province, to compared 2012 to 2006, Elasticity has been a substantial increase, indicating that transport during the six years has been rapid development,but most of elasticity is still less than 1, This explains the development of the overall transport can not meet the economic development in Jiangxi Province. To further detailed analysis, we can see the development of the four modes of transport fastest is highway transportation, highway Cargo traffic elasticity coefficient from 0.52 to 1.47, its cargo turnover elasticity coefficient from 1.07 to 2.24, We can see highway transport development speed faster than the speed of rail and waterway transport, which shows the development of rail and water transport is far can not meet the needs of economic development.

5 Grey Prediction Model

Gray prediction method is a discrete data as a continuous variable,Discrete values achieved in the change process, showing its regularity. Using Matlab is preferred to achieve gray prediction process. When using Matlab gray prediction program, can be fully in accordance with the prediction model for solving steps, namely

Step1: the original data accumulation;

Step2: Architecture cumulative order matrix and vector;

Step3: Solving gray parameters;

Step4: The parameter data into to predict models to predict.

Using 2005-2012 data with Jiangxi Province transport-related cases, running matlab software, the results are as follows:

Table 6. Transportation predictive value

Year	Z1	Z2	Z3	Y1	X1	X2	X3	X4
2005	2307	62300	5560	4056	8816426	6039555	33270	41722
2006	2307	128234	5716	4820	9477604	6564562	36759	43239
2007	2458	130691	5716	5800	10269219	7167001	40046	43782
2008	2549	133847	5716	6971	22898520	8070117	80332	66261
2009	2612	137011	5716	7655	23509074	8072337	85718	70674
2010	2734	140597	5716	9451	27386993	9127645	100339	76633
2011	2734	146631	5716	11702	30040231	9625564	111576	79138
2012	2734	150595	5716	12948	34489670	9798488	127020	84459
2013	2885	154031	5716	15529	43773924	10783312	160750	98995
2014	2965	158319	5716	18328	52225196	11521973	191815	109960
2015	3047	162727	5716	21631	62308124	12311231	228883	122140
2016	3132	167257	5716	25529	74337727	13154555	273115	135669
2017	3219	171913	5716	30129	88689841	14055646	325895	150696
2018	3308	176699	5716	35558	105812865	15018462	388875	167388
2019	3400	181618	5716	41966	126241770	16047231	464025	185929
2020	3495	186674	5716	49529	150614808	17146472	553698	206523

6. Conclusion

Through correlation analysis, gray correlation analysis, elastic analysis, the transportation and economic development in Jiangxi Province there is a high correlation; compared with 2006, 2012 has been great development, but rail transport also stress, can not meet the economic development. Finally, this paper also made a prediction for the transport of Jiangxi , in 2020, the GDP of Jiangxi Province has 4.952915 trillion yuan.Jiangxi Province transportation will get a larger development.

References

Liu Jianqiang, He Jinghua .J. (2002). *Empirical Study of Transportation and the National Economy*. Transportation Systems Engineering and Information Technology, 2 (1): 82-86.

Ciren Ouzhu .J. (2002). on relationship between transportation and national economy,Tibet University,17 (1): 72-74.

LIU Binglian, Zhao Jintao .J. (2005).Empirical Research China Transportation and Regional Economic Development causation. China Soft Science,(6): 101-106.

Shi Shuping .J. (2006).Explore the relationship between China's regional economy and transportation factors.Postgraduates Zhongnan University,(2): 82-89.

Ling Qi .J. (2001).Relationship between Fujian Transportation and Regional Economic Development .Fujian Normal University (Philosophy and Social Sciences), (2): 20-26.

M. (2014). Jiangxi Statistical Yearbook, Beijing: China Statistics Press.

Game Model of Taxi Service Pricing Based on Deregulation

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Abstract: This thesis, based on the characteristics of the taxi industry, to investigate the game model of pricing the taxi industry in relax regulation conditions. By analyzing the relationship, establish in Stackelberg bi-level programming model. Among them, the upper programming for the maximization of social welfare, lower planning is to maximize the interests of Taxi Company. The model considered the taxi operation of actual loading mileage. Considering the solving of bi-level programming model is complex, this Article uses genetic algorithm to solve the upper limit value after relax regulation Then combining case, the pricing game model is studied. The calculation shows that the model can effectively respond to the pricing process. At the same time, the algorithms can effective computational models.

Keywords: Transportation economy; Pricing model; Bi-level programming; Taxi regulation; Generic algorithm.

1 Introduction

Since the 1970s, each country began to relax or relieve economic regulation of the industry to different degrees. At present, China taxi industry is in the strict regulations, there are many regulatory failure phenomena, such as deformity allocation of industry profits between taxi venture and taxi driver, the contradiction of supply and demand between consumers and operators. Taxi fare is an important mean to allocate passengers' resources and coordinate industry participants' Interests and needs. Douglas (1972) analyzed the inverse relationship of the average passenger waiting time and taxi-load rate, and made a model that combine taxi market demand with the average trip costs and waiting time Cairns and Liston Heyes (1996) pointed out that the price of a taxi service regulation is important for produced balance, and notted that only a sub-optimal pricing in travel costs and taxis are forced to be controlled that can be achieved. In recent years, China has also started a taxi fare determined method. Chen Qian and Wang Wei (2005) raised calculation method of the taxi fares under the control of the total amount and related costs formulated by analyzing the taxi supply and demand. Zhen Yangzhong (2006) Using Logit Model PSM function to create a competitive market model under rental prices system, which get a starting price within two kilometers.

These pricing schemes are not taken the problem of regulatory process that how to regulate the price of a taxi problem into account, in view of the method of economics, this article, studies China's urban taxi industry regulation from the point of view of social welfare and industry cost, and establishes price regulation game model through analysis of the process of price regulation that the government and the taxi company's game relationship, so as to provide a theoretical basis for government to determine the regulation of the taxi industry, and provide some ideas and methods for the reform of the taxi industry, which promote taxi industry's healthy development.

2 Basic assumption of pricing model udder Industry deregulation

The government and the taxi company carry out the main-second decision-making relationships Stackelberg game. Between the two game relationship can be described as: regulator (government) act first, than implement appropriate regulatory instruments (price regulation means); taxi company after the operation, according to the regulator’s (government) actions to adjust the company's business strategy.Taxi companies and taxi drivers are for the passenger service, ignoring the internal distribution of benefits between the two conflicts. Consider the two unity gain profits.

Assume that the government's regulation means of the taxi industry are that government subsidies taxi industry by operating mileage q through fiscal tax, set cost per operating kilometer of m, the corresponding transfer payment is mq.

According to the theory of economics, supply and demand balance in the taxi industry and to consider the cost of transfer payments and shadow, the passengers remaining $U(q)$ can be expressed as:

$$U(q) = \int p(q)dq - qp - \lambda mq \tag{1}$$

Where, q is the taxi operating mileage $\int p(q)dq$; as effectiveness of taxi passengers; qp as a taxi passenger travel costs. $\lambda > 1$, λmp as government transfer payments and the resulting shadow costs.

Cost is convex function based on microeconomics, assuming that the costs of taxi companies are:

$$c(q) = c_0 + c_1 q + c_2 q^2 \tag{2}$$

Where: $c_0 > 0, c_1 > 0, c_2 > 0$. c_0 is the taxi company's fixed costs; c_0, c_1, c_2 can be calibrated based on historical data in taxi industry.

Taxi Company's profit is expressed as $\pi(q)$:

$$\pi(q) = pq - c(q) + mq = pq - c_0 - c_1 q - c_2 q^2 + mq \quad (3)$$

The function of Government regulation:

$$\max Z = \int_0^q p(q)dq - qp(q) - \lambda mq + pq - c_0 - c_1 q - c_2 q^2 + mq \quad (4)$$

Taxi company objective function is:

$$\max \pi = pq - c_0 - c_1 q - c_2 q^2 + mq \quad (5)$$

3 Game model analysis of considering taxi actual loading mileage

The game between government and the taxi company is divided into two stages, stage one: regulator adjusts the decision variables m in order to achieve maximum social welfare; Stage two: the taxi company takes action to change their operational programs (operating mileage ***q***) to achieve taxi companies the maximum profits.

In realistic mode, Taxi change between real-load an no-road stages, assuming that demand function related to the real-load and no-load mileage , Passenger demand function is: $Q_i = f(p,k)$. where $k = Q_i / (Q_i + V)$; p represents the price of services of unit operating mileage ; k represents taxi loading rates; Q_i represents the taxi real-load mileage; V_i represents taxi no-load mileage.

According to principles of economics, passenger demand function can be expressed as:

$$Q_i = ap^{\varepsilon} \quad (6)$$

Where, a represents undetermined coefficients; ε represents the price elasticity.

Passengers inverse demand function is:

$$p = (Q_i / a)^{1/\varepsilon} \quad (7)$$

The passenger utility function is:

$$U_i = \int_0^{Q_i} p(Q_i)dQ - P(Q_i)Q_i - mQ_i = \int_0^{Q_i} (\frac{Q_i}{a})^{\frac{1}{\varepsilon}} dQ_i - (\frac{Q_i}{a})^{\frac{1}{\varepsilon}} Q_i - \lambda m Q_i \quad (8)$$

The sum of the passengers' utility:

$$U(q) = \sum_{i=1}^{q} \left[\int_0^{Q_i} (\frac{Q_i}{a})^{\frac{1}{\varepsilon}} dQ_i - (\frac{Q_i}{a})^{\frac{1}{\varepsilon}} Q_i \right] - \lambda m \sum_{i=1}^{q} Q_i \quad (9)$$

Considering the real-load and no-load mileage, the single taxi costs can be expressed as:

$$C_i = \sum_{j=1}^{m} C_j (Q_i + V_i) \tag{10}$$

Where, C_i is the taxi operating costs (yuan); $\sum_{j=1}^{m} C_j$ is the taxi average cost per operators kilometers (yuan / km); m is the number of different cost structure, q is the number of taxi passengers.

The total cost of the taxi company can be expressed as:

$$C = \sum_{i=1}^{q}\sum_{j=1}^{m} C_j (Q_i + V_i) \tag{11}$$

The taxi company's total profit:

$$\pi(q) = \sum_{i=1}^{q} (\frac{Q_i}{a})^{\frac{1}{\varepsilon}} Q_i - \sum_{i=1}^{q}\sum_{j=1}^{m} C_j (Q_i + V_i) + m\sum_{i=1}^{q} Q_i \tag{12}$$

Optimal objective function of Government regulation can be expressed as:

$$\max Z = \sum_{i=1}^{q}\left[\int_0^{Q_i} (\frac{Q_i}{a})^{\frac{1}{\varepsilon}} dQ_i - (\frac{Q_i}{a})^{\frac{1}{\varepsilon}} Q_i\right] + \sum_{i=1}^{q} (\frac{Q_i}{a})^{\frac{1}{\varepsilon}} Q_i - \sum_{i=1}^{q}\sum_{j=1}^{m} C_j (Q_i + V_i) + (1-\lambda) m \sum_{i=1}^{q} Q_i \tag{13}$$

Government and the taxi company master-slave game, assuming the government to consider the social welfare maximization to make optimal decisions on the basis of profit maximization of the taxi company, the game between the Government and the taxi company is expressed by mathematical model as follows:

Upper level (*U1*): is formula (15). $s.t\ Q_i = f(p, m)$

Lower Planning (*L1*):

$$\max \pi(q) = \sum_{i=1}^{q} (\frac{Q_i}{a})^{\frac{1}{\varepsilon}} Q_i - \sum_{i=1}^{q}\sum_{j=1}^{m} C_j (Q_i + V_i) + m\sum_{i=1}^{q} Q_i \tag{14}$$

$$s.t: \pi(q) \ge \pi_0,\ \ Q_i \ge 0, 0 \le k \le 1,\ \ p = (Q_i / a)^{\frac{1}{\varepsilon}}$$

Where, π_0 represents the minimum operating profits of taxi company.

4 Model solutions

For the above model for genetic algorithm design:

(1)Encoding. This process is the first step in the design process of the algorithm, in many cases is encoded in binary form.

(2)The definition of fitness function. Fitness function in relation to the evolution of the population, in algorithmic process fitness is non-negative; the value of the fitness is the bigger the better for algorithm.

(3)The control parameter. Hybridization probability p_c : The p_c higher the population Introduced faster, but the lost speed of received good genes will be increased accordingly, p_c become low that make the search for obstacles. Generally take $p_c = 0.4 \sim 0.99$ .Population size *n*: *n* large, will increase the computational difficulty, ***n*** is small, the search space is limited, the situation may arise not converge. Experts suggest that the scale is $n = 20 \sim 200$. Mutation probability p_m : In order to stabilize the population, after individual variation, it will not have too much difference with the parent; p_m value should be small, generally $p_m = 0.001 \sim 0.1$.

(4)Generating the initial population. Usually generated initial population randomly. The produced needs to check whether it meet constraint, if the constraint is not satisfied need to re-generate the initial population.

(5)Genetic manipulation.

A choice. Select a few larger values of fitness form parent, let not participate in genetic manipulation, used to replace several of the next generation of smaller fitness value. The larger value will be inherited to offspring form remaining Individual. b. hybridization. Hybridization is good genes of parent Inherite to the next generation, and generate new individual contains more complex gene. c. variation. For each generated offspring mutate in a certain p_m 。

(6)Determination of algorithm terminates. When evolution of the group is stable, the process of population evolution ends.

5 Case Studies

Applying the above model to a simple case for analysis. Selected data was generated from the “2007-2009 GuangZhou city taxi monthly cycling operating table ". Basic data are shown in Table 1 and Table 2.

Table 1. Component of unit operating mileage of vehicles

Monthly average operating days	Daily average operating hours	Daily average operating mileage	Daily average passenger mileage	Daily average passenger occupancy rate
28 d	18 h	342.66 km	237.61 km	69.34/%

Table 2. Component of unit cost of vehicles

Type	Component of costs	costs/(yuan / Month)
direct costs	Depreciation, Fuel, Maintenance, Insurance, Intelligent Management System service fees, Accident damages, Driver's social insurance, ect	10608.94
indirect costs	Management salaries, Vehicle license fee for the right to operate, Administrative expenses, utilities, Hospitality, Consumables, Rent, communication expenses, conference fees, advertising fees, intangible assets and long-term assets, insurance, other administrative expenses	2764.98

The corresponding values required by model can be calculated as follows,

When *m*=23, unit cost of vehicles can be obtained, 10608.94 +2764.98 =13373.92 (yuan/ Month)

So, we get unit operating mileage of vehicles , 13373.92/（28*237.61）=2.01（¥/ Month）

According to relevant literature, the value of the price elasticity coefficient ε is from 1.0 to 1.4, here take the middle value 1.25.Generally, the value of the shadow costs is from 1.1 to 1.5, here take the middle value 1.25.Based on the above calculation, the corresponding data can be obtained, as is shown in Table 3.

Table.3 Data required for model calculation

no-load ratio	Operating costs per kilometer	price elasticity coefficient	shadow costs	total number of taxis
30.66%	2.01yuan/ km	1.2	1.25	18858 Vehicles

Algorithm settings are as follows,

(1)The model is binary coded, the optimal storage strategy and roulette way are combined to makes the algorithm convergence.

(2) Groups size, hybrid probability and mutation probability are $n = 50$, $p_c = 0.5$ and $p_m = 0.005$, respectively.

(3)The model chooses forms of two-point crossover, each select two parents to hybridize with probability 0.5.

(4) The algorithm would generate initial individuals 60 randomly, first check whether it can meet the corresponding constraints, if not, then, need to return to re-generate the initial group.

Based on genetic algorithms to calculate the *p* was 2.51 yuan, that is, the average rate per kilometer is 2.51 yuan.

Through the above analysis, we can see the average rate per kilometer is 2.51 yuan. Clearly, it is possible to reach an equilibrium state, which can achieve the regulatory objectives of maximization of the government's social welfare and taxi companies' own interests at the same time.

6 Conclusions

China's taxi industry regulations are too strict, need to relax. Given the current situation of the taxi industry and inadequate competitive market conditions, the government should take reasonable means of price regulation, allowing a degree of competition to protect consumers from price gouging and improve social welfare. Through analysis of price obtained from the bi-level model, it can be concluded that, setting price regulation is a feasible method in today's circumstances where the regulations are too stringent, it also can provide a reference for government policy. Government regulation on prices, in fact, is a long-term process, the paper only discussed a single static problem under price regulation, but did not do further research on dynamic situation, which is the future research directions.

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References

Cairns, R. D,Liston-Heyes ,C（1996）"Competition and regulation in the taxi industry" Journal of Public Economics. 59: 1-15

CHEN Qian, WANG Wei,HUANG Juan. (2005) " The Study of Distance-accounting Taxi Price under Demand". Urban Transport of China. 3(3):14-18

Douglas. W（1972）"Price regulation and optimal service standards: The taxicab industry" Journal of Transport Economics and Policy,20: 116-127

LAO Chao-hui,WU Qun-qi(2013). " Analysis on Characteristics and Government Regulation of Taxi Industry". Journal of Highway and Transportation Research and Development. 30（6）：132-135

Mu Chen，Zhao Xiangmo(2013)."Agent Based Simulation Methods of Pricing Taxi Operation system". Electronic Test. (13):39-42

XIAO Jian, DAN Bin, ZHANG Xumei(2007). "Bi-level Programming Model and Genetic Algorithms for the Selection of Vendors". Journal of Chongqing University (Natural Science Edition). 30(6):155-158

YANG Zhong-zhen, WANG Lu(2006). " Model analysis of the taxi starting price in a city". Journal of Dalian Maritime University. 32(6):38-41

Modeling and Application of an Early Warning System of China's Foreign Trade Container Shipping Market

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Abstract: To provide effective analysis tools, an early warning system is proposed for China's foreign trade container shipping market. Firstly, by analyzing volatility mechanism of foreign trade container shipping market, a set of monitoring indicators is presented, including container throughput, freight index CCFI and PMI new export orders index et al. The monthly samples of the indicators from 2005 to 2014 are collected. Secondly, the warning threshold and interval of each indicator are determined by the combination method of statistical analysis and expert scoring. According to the design principle of early warning signal system and the indicator state division method, the early warning signal system of China's foreign trade container shipping market is proposed. To monitor the long-term market wave trend, an early warning index model is further proposed by the method of synthetic index, in which the indicator weights are determined by the principal component analysis method. Finally, the comparison results between the system operating and the real market volatility further demonstrate the validity of the proposed system.
Keywords: Foreign trade container; Shipping; Early warning; Signal system; Index; Throughput.

1 Introduction

China's waterborne transport realized the high speed development in the last two decades. Until now, it has not yet formed a complete long-term cycle of fluctuation. Due to lack of enough cyclic statistics, it brings great difficulties for in-depth research on cyclical fluctuation. In 2008, the international financial crisis swept over the world. As a highly internationalized industry, China's foreign trade container shipping market got very big impact with a sharp fall of freight rates and a negative growth of throughput. Since then, the short-term fluctuations of China's foreign trade container shipping market loom large. Experts and scholars began to pay more attention to the study of monitoring and early warning of it.

In the existing literatures, an early warning model of port economics is proposed by the climate index method (Zhu Chao, 2005), in which an early warning indicator system is presented and major monitoring problems are discussed. The literature (Gan Aiping, 2011) investigates the interrelationship of macroeconomic growth and shipping cycle by empirical analysis. The strategies are also proposed to deal with China's future shipping cycle. The literature (Zhu 2011) proposed leading indicators for China's foreign trade container throughput. A composite leading index for China's foreign trade container throughput is proposed by the principal component analysis method (Zhu, 2013). In recent years, some climate indexes are also Su successively released by many research institutes (Table 1). These indexes provide useful quantitative analysis tools for monitoring the short-term market fluctuations in waterborne transport industry.

Overall, the monitoring and early warning of China's waterborne transport industry is still in its infancy stage. The related theoretical analysis and monitoring technology should be further improved. Therefore, an early warning signal system and the index model of China's foreign trade container shipping market is mainly proposed.

Table 1.The existing climate indexes in China's waterborne transport

Name of Index	Model or method	Initial release time	Release cycle	Index provider
The Yangtze river shipping climate index	Diffusion index	April, 2004	Quarterly	Changjiang River Administration of Navigational Affairs
China Shipping Prosperity Index (CSPI)	Composite index	December, 2009	Quarterly and Monthly	Shanghai International Shipping Institute
Shanghai Shipping Index (SSI)	Composite index	March, 2010	Monthly	China Center for International Economic Exchanges
CSSI and CPSI index	Composite index	July, 2010	Weekly	China Waterborne Transport Research Institute

2 Early Warning indicators and warning thresholds

To effectively monitor container shipping fluctuations, it is not enough to only consider indicators in China's foreign trade container shipping market. The scope should extend to other closely related fields, such as the whole container logistics chain, the macroeconomics at home and abroad, the situation of foreign trade, the upstream and downstream industries and so on. According to analysis of the fluctuation mechanism in china's foreign trade container shipping (Zhu, 2011), the throughput, freight, import and export volumes, supply capacity of container ships and cargo demand are all critically important to monitor the container shipping market. Base on it, the six early warning indicators are chosen, which include the growth rate of China's coastal container throughput (CCCT), China's export container freight index (CCFI), Howe Robinson Containership Index (HRCI), the growth rate of China's import and export volume (CIEV), China's PMI new export order index (NEOI) and American consumer confidence index from the Conference Board (ACCI).

The monthly statistics of these indicators are collected. The sample data ranges from January 2005 to December 2014. On the one hand, the warning thresholds of these indicators are calculated by the statistical characteristics, such as the mean, median, maximum, minimum and variance of the sample data (Abraham, 1983). On the other hand, the expert scoring method is adopted for determining the thresholds. The final warning thresholds are comprehensively derived by these two methods. The thresholds results are shown in Table 2, where the blue, watchet, green, yellow and red light areas respectively denote the different indicator status of overcooling, cooling, normal, heating and overheating.

Table 2. Early warning indicators and warning thresholds

Indicators	Light Area				
	Blue	Watchet	Green	Yellow	Red
CCCT	⩽1.4%	1.4%, 8.0%	8.0%~19.9%	19.9%~24.0%	>24.0%
CCFI	⩽946	946~1028	1028~1124	1124~1157	>1157
HRCI	⩽400	400~600	600~1100	1100~1300	>1300
CIEV	⩽ -9.1%	-9.1%~7.1%	7.1%~24.1%	24.1%~32.6%	>32.6%
NEOI	⩽45.5	45.5~49.5	49.5~53.5	53.5~56.0	>56.0
ACCI	⩽ 52	52~75	75~100	100~107	>107

3 Early Warning signal system and index model

There are five steps to model the early warning signal system of China's foreign trade container shipping market.

Step 1. Selecting Indicators. Generally, about six early warning indicators are selected. The coincident indicators are comprised the majority of the selected indicators. Meanwhile, the leading or lagging indicators are also permitted. The six early warning indicators are selected as shown in Section 2.

Step 2. Determining thresholds. For each indicator, four threshold values are should firstly determined. Then five kinds of status, which include the overcooling,

cooling, normal, heating and overheating intervals, are divided by the four thresholds from high to low. These intervals are represented as the blue, watchet, green, yellow and red light areas, respectively. The warning thresholds of the six proposed indicators in the above section are shown in Table 2. The state of the indicators in 2014 is shown in Figure 1.

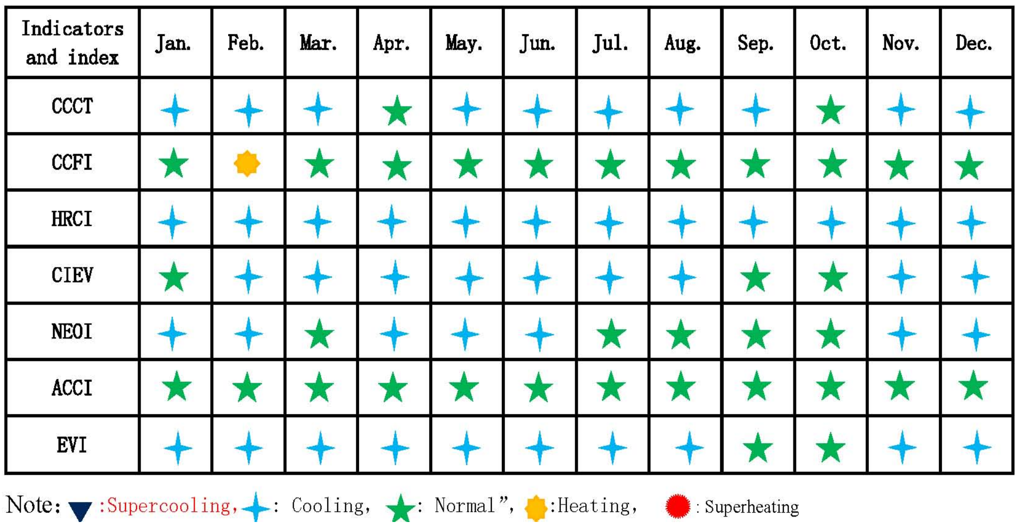

Figure 1. Early warning signals of the indictors and the index EVI.

Step 3. Calculating early warning index. First of all, the blue, watchet, green, yellow and red light areas are set to the values from 1 to 5, respectively. Then, there is a score for each indicator in a month. The value of early warning index is derived by adding up all scores of indicators, in which the indicator weights are determined by the principal component analysis method. Figure 2 shows the curve of early warning index (EWI) of China's foreign trade container shipping.

Step 4. Building signal light system. According to the historical trend and statistics analysis of the EWI, the warning intervals are determined by expert scoring method as shown in Table 3 and Figure 2. Based on it, the state of the index can be shown as different kinds of lights in every month. The last column of Figure 1 depicts the state of EWI in 2014.

Table 3. Early warning indicators and warning thresholds

Index	Light Areas				
	Blue	Watchet	Green	Yellow	Red
EWI	<10.8	10.8~15	15~21.9	21.9~25.5	>25.5

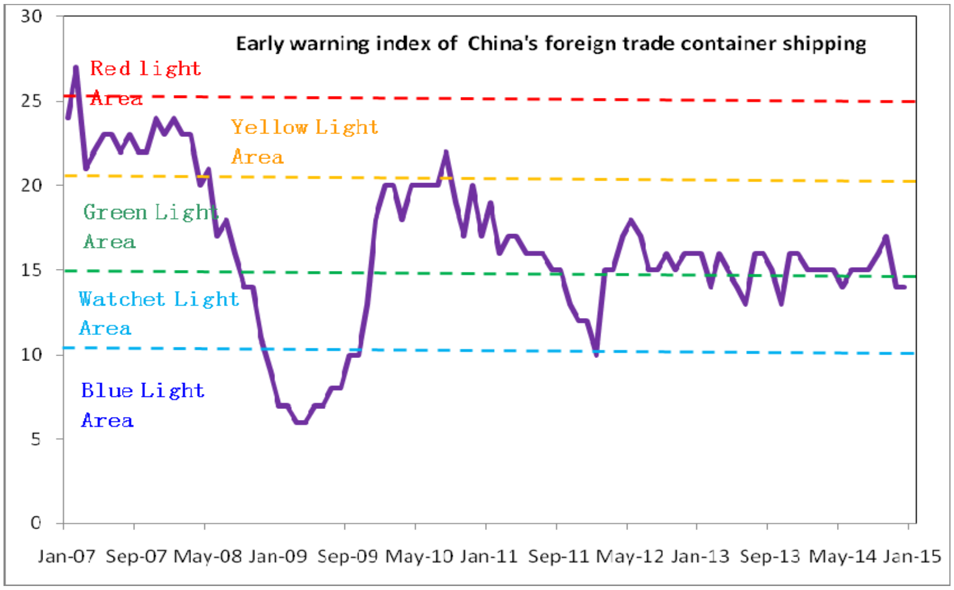

Figure 2. Early warning index of China's foreign trade container shipping

4 Application of EWI

As shown in Figure 2, China's foreign trade container shipping is in the heating state during 2007. The EWI reached the maximum value of 27 and showed the overheating state in February. During this period, China's foreign trade economy developed at a high speed. The growth rate of the import and export volume mostly stayed above 25%. From the container perspective, the growth rate of throughput also stayed above 20%. Moreover, the insufficient container ship capacity resulted in amazing increase of container freight. Soaring charter rate made the HRCI index reached the maximum value of 1407 in September, 2007.

The EWI slowed dramatically with the advent of the international financial crisis of 2008. The china's foreign trade container shipping fell into the overcooling state and the EWI dropped down to the bottom with the minimal value of 7 in February, 2009. China's coastal container throughput decreased with the negative growth, and the CCFI index also fell to below 800 points. The whole container shipping market was at its lowest.

China's container shipping began to rapidly rebound in 2010. The EWI recovered to pre-financial crisis levels in August. However, the shipping market started to fall again since 2011. The EWI slumped into the cooling state once again. In recent two years, China's foreign trade container shipping market is between the state of normal and cooling, and the EWI swing around the value of 15. From the indicators perspective (Figure 1), only two indicators (CCFI and ACCI) are in the norm state. Other four indicators are all in the cooling state in 2014.

From above analysis, the EWI has effectively reflected the fluctuation of China's foreign trade container shipping market in recent years. It can play a warning role in the process of the container shipping market fluctuations.

5 Conclusions

A set of monitoring indicators for China's foreign trade container shipping market is presented. The warning thresholds are given by the export scoring method. Based on it, the EWI and signal system are proposed. The practice of trial operation proves the EWI can truly reflect the fluctuation of China's foreign trade container shipping market. So it is a useful tool to monitor the short-term fluctuation. In further research, the monitoring indicators of other sub-industries, such as dry bulk cargo shipping, crude oil import and inland waterway transport, can also be investigated. Accordingly, the early warning indexes of the sub-industries could also be given. Then, a whole early warning system of China's waterborne transportation can be proposed.

References

Abraham B., and Ledolier J. (1995), *Statistical Methods for Forecasting (2nd Revised Edition),* Wiley, New York.

Gan A. P., Qu L. C., Zhen H., and Zhang L. W. (2011). "Shipping development countermeasures based on the relationship between economic growth and shipping cycle during the twelfth five-years." *Shipping Management,* 2011, 33(7), 5-8.

Zhu C., and Feng X. J. (2005). "Early warning system and method of port economics." *Shipping Management*, 26(7), 11-14.

Zhu J. S. (2011). "Fluctuation analysis and leading indicator determination for coastal container throughput of China." *Shipping Management,* 33(6), 11-14.

Zhu J. S., and Tian Y. J. (2013). "Leading indicator for the Foreign Trade Container Throughput in China Water Transport." *Proceeding of The 2nd International Conference on Transportation Information and Safety*, 2397-2403.

Effect of Corporate Social Responsibility on Enterprises' Sustainability: Empirical Evidence from Listed Companies in the Transportation Industry

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Abstract: Empirical data from related listed companies are then adopted to analyze and test the actual effect of corporate social responsibility on the enterprises' sustainability. Findings show that in each dimension of CSR, the impact on sustainability is fair operation, labor practices, consumer issues, environment, responsibility for governance and community development from high to low in turn. As to economic development and human rights, there is no significant impact on sustainability, and human rights can affect sustainability negatively. Therefore, it is an effective way to promote transportation enterprises' sustainability by enhancing CSR, performing CSR in stages and ensuring the priority of implementation of part enterprises' CSR.
Keywords: Corporate social responsibility; Sustainability; Transportation industry.

1 Introduction

Transportation, the critically basic industry concerning national economy and the people's livelihood, has always played the fundamental and leading role in our national development strategy. For its weightily status, in the 12th Five-Year Plan, our government has put forward the overall goals that on the base of the principal "appropriate advance", we should build convenient, safe, economic and efficient comprehensive system of transport to provide powerful support and guarantee for national economy and social development. And enterprise is the important component part and carrier in transportation, and it is reported that the transportation enterprise has shouldered over eighty percent traffic, which means that the developments of transportation companies directly decide the movement of transportation industry.

To certain extent, the development of transportation enterprises relies on growth of transportation, which doesn't imply that the more rapid, the better. Growing too fast may cause such problems as shortage of funds and generate finance crisis, while growing too slow may also set the enterprise in survival crisis by inefficient use of resources. Taking account of this point, many scholars regarded that companies should gain profit and take other stakeholders' benefit and relevant social responsibilities in to account simultaneously. However, at present such problems as environmental pollution, waste of resources, transportation security problems are looming large. For example, on November 29, 2013 in Dongying, Shandong province, the logistics poisonious parcels cause deaths. All these problems focalize on CSR. How can transportation enterprises, one of the most critical economic arteries of national economy, fulfill their social responsibilities? which are the comparatively important social responsibilities? Figuring out these questions will be of great benefits to instruct making relevant policies, fulfill social responsibilities, and thus promote their sustainability.

2 Literature Review and Research Hypothesis

Corporate social responsibilities (CSR), originated from *Management Philosophy* written by England scholar Sheldon in 1924. In 1971, Committee for Economic Development pointed out that CSR were composed by three concentric circles and formed the CSR Concentric Circles Model. Carroll (1979) put forward CSR four-dimension model, including economic responsibility, legal responsibility, moral obligation and discretional responsibility. Carroll (1991) further revised it as a pyramid model. With the proliferation of stakeholder theory, some study combined it in the model. For instance, Ramanathan (1976) held that CSR could be divided into four parts, i.e. client, personnel, community and vulnerable groups. WBCSD (2003) stated that CSR contained employee benefits, environment protection, community participation, supplier relations and other aspects. Comparing with western countries, researches in our country got behind. By far, the definition and connotation haven't reached a consensus. The domestic CSR researches still judged and expanded on the base of the foreign categories. For example, Xu et al. (2007) considered that Chinese CSR has nine dimensions, i.e. economic responsibility, legal responsibility, environment protection, client orientation, people foremost, public welfares, employment, business morality, society stability and progress.

The measurement adopted in this paper is the sustainable growth rate (SGR) raised in the angle of finance which was also used by Van Horne (1988).

Therefore, it's of great necessity to conclude the relevant researches on the relation between CSR and financial performance. Although the empirical researches on CSR and financial performance starting from 1970s, Margolis and Walsh(2003) have analyzed the 127 empirical researches from 1972 to 2002 and have found out that there are 54 holding the positive relation opinions, 7 of negative relation, 28 of no correlation and 20 of no agreement. Quite a few scholars such as Ruf et al(2001), have discussed the reasons which caused the varied results and all considered that this may boils down to that they haven't taken the industry, scale, quality and others into account and the measurement are too simple or inconsistent. Researches got the results that CSR can drive and constrain sustainability. Li (2006) deemed that CSR, embodying the operation philosophy and value, was a key variable to enterprise sustainability. Hu (2004) analyzed the impact factors of sustainability, the main content of CSR and illuminated CSR's practical significance to sustainability, pointed that CSR is the ethical basis of sustainability finally.

This paper deemed that the sustainability of transportation enterprises should based on the fulfillment of society responsibilities such as responsibility governance, economy development, human rights, labor practice, environment, fair operation, customer problems, community development and so on. For instance, increasing investment on green economy, low carbon, energy saving and staff training will not decease profits but enhance enterprise prestige. Good image is beneficial to elevate customers' evaluations and thus can gain more opportunities, strengthen competitive power and further increase company performance. The CSR in transportation enterprises and their different dimensions are able to influence sustainability positively. On the basis of analyses above, this paper raised the following hypothesis.

H1: transportation enterprises' CSR can influence sustainability positively.

H1a: transportation enterprises' responsibilities for governance can influence sustainability positively.

H1b: transportation enterprises' economic development can influence sustainability positively.

H1c: transportation enterprises' human rights can influence sustainability positively.

H1d: transportation enterprises' labor practices can influence sustainability positively.

H1e: transportation enterprises' environment can influence sustainability positively.

H1f: transportation enterprises' fair operation can influence sustainability positively.

H1g: transportation enterprises' consumer issues can influence sustainability positively.

Hy1h: transportation enterprises' community development can influence sustainability positively.

3 Research Design

3.1 Sample Data Collection

Given that the 2008 global financial crisis may cause some minor errors, data selected in this paper are coming from the *2009-2011 Annual CSR Development Report of Transportation Industry* developed by Kuang (2012) in DLMU CSR and sustainability research center, because this report renders a comprehensive and detailed evaluation and is praised with great authority and reference value.

3.2 Variables and Model Design

3.2.1 CSR

Despite that scholars have defined CSR in different angles, these classification are on account of stakeholder theory. CSR assessment system from the *2009-2011 Annual CSR Development Report of Transportation Industry* are applied in this paper as measurement. This system lists the social expected eight core topics, containing responsibility governance, economic development, human rights, labor practice, environment, fair operation, customer problems and community development. All the results will be in hundred marks and their sum is the final score.

3.2.2 Sustainability

Van Horne(1988) put forward SGR as the following.SGR=(net profit margin ×asset turnover ×equity multiplier ×retained earning rate)/(1-net profit margin ×equity multiplier ×asset turnover ×retained earning rate).This measurement fully disclosed enterprise finance activities and operation activities, manifesting best growing ability under the constraints of current external environments and internal resources.

3.2.3Model Design

In order to test the hypothesis, we set up the following model 1.

$$SGR_{it} = \beta_0 + \beta_1 CSR_{it} + \beta_2 NFPS_{it} + \beta_3 ROA_{it} + \beta_4 GROW_{it} + \beta_5 INDRA_{it} + \beta_6 FIRST_{it} + \beta_7 ZHSHA_{it} + \sum YEAR_{it} + \varepsilon_{it} \quad (1)$$

In this paper, Dependent Variable is SGR and Independent Variables is CSR and its eight dimensions, i.e. the governance of responsibility (ZRZL), economic development (JJFZ), human right (RQ), labor practice (LDSJ), environment (HJ), fair operation (GPYY), consumer issues (XFZWT) and community development

(SQFZ). Besides, in reference to the existing literature, such as Chen et al. (2008) and Tang (2009), we also take other factors reflecting enterprise finance and governance into consideration. Specifically, they are net cash flow per share (NFPS), ROA (return on assets), growth rate of operating profit (GROW), independent director rate (INDRA), share proportion of the largest shareholder (FIRST), stock proportion restriction (ZHSHA) and YEAR.

4 Data Analysis

4.1 Descriptive Analysis of Sample

The listed companies in transportation industry which published CSR reports from 2009 to 2011 as are chosen as research samples, among which there are 27 CSR reports in 2009 and 80 reports come from 2010 and 2011. After deleting 17 data with missing values, 100 complete data are carefully preserved. The minimum value of CSR is 3.65 while the maximum value is 63.04, basically reaching a preferable level of above 60, which reveals the poor situation of CSR on the whole. The deviations of other CSR indexes are also big and the mean value of JJFZ, RQ and GPYY are 0.469, 0.289 and 0.646 respectively, which is consistent with the current reality of CSR.

4.2 Regression Analysis

In table 1, we have a estimation on model 1. In model1, the regression coefficient of CSR is above zero (significance level $P<0.05$), which indicates that the transportation enterprises' CSR can influence sustainability positively and thus hypothesis 1 is verified. Furthermore, we discussed the relations between 8 specific indexes and sustainability, seen in regression 2 and regression 9. Except JJFZ and RQ without obvious regression coefficients, the regression coefficients of ZRZL (significance level $P<0.01$), LDSJ(significance level $P<0.05$), HJ (significance level $P<0.01$), GPYY (significance level $P<0.05$), XFZWT (significance level $P<0.01$) and SQFZ (significance level $P<0.1$) are all above zero. Obviously, in the present fulfillment of CSR, only responsibility for governance, labor practices, environment, fair operation, consumer issues, community development can boost the sustainability efficiently. In the rank of impact factor, they are GPYY (0.054), LDSJ (0.043), XFZWT (0.041), HJ (0.032), ZRZL (0.026) and SQFZ (0.020) from high to low. However, the JJFZ and RQ don't impact evidently on CSR, RQ impacts CSR negatively. Henceforth, the hypotheses 1b and 1c are not verified and hypotheses 1a, 1d, 1e, 1f, 1g and 1h are all verified.

Table 1. Regression Analysis

Dependent variable: SGR									
Variable	Total samples								
	model1	model2	model3	model4	model5	model6	model7	model8	model9
CSR	0.003**								
	2.316								
ZRZL		0.026***							
		3.600							
JJFZ			0.009						
			1.620						
RQ				-0.015					
				-0.879					
LDSJ					0.043**				
					2.361				
HJ						0.032***			
						3.286			
GPYY							0.054**		
							2.068		
XFZWT								0.041***	
								3.084	
SQFZ									0.020*
									1.922
R^2	0.542	0.584	0.487	0.479	0.523	0.563	0.526	0.568	0.500
F	10.890***	10.120***	9.770***	10.320***	9.730***	11.240***	9.450***	10.790***	10.170***
OBS	100	100	100	100	100	100	100	100	100

Notes: (1) T value illustrates T statistic after a Robust standard error correction; (2) * * *, **, * illustrates_respectively 1%, 5% and 10% significance level; (3) In the regression analysis, this paper also concluded such control variables as ROA, GROW, INDRA, FIRST, ZHSHA, CONS and YEAR. Owing to the limited space, they were not listed specifically in the table.

5 Results and Discussion

In terms of different impact of eight dimensions on SGR, CSR can be ranked as fair operation, labor practices consumer issues, environment, responsibilities for governance and community development from top to bottom. However, the economic development and human right do not impact evidently on sustainability, and human right impacts sustainability negatively. This may be due to the macro-environment which affects the economic development and leads to instability of the great economic development from 2009 to 2011. The human right may be paid insufficient attention in transportation industry, which probably generates the negative effect.

Therefore, on account of conclusions mentioned above, this paper believes that good performance on responsibility for governance, labor practices, environment, fair operation, consumer issues, community development will be definitely beneficial to long- term and sustainability, which in turn requires enterprises to infuse such ideas into management system and behaviors to enhance CSR performance. The different dimensions of CSR influence SGR variously. In terms of the impacts, from top to bottom, they can be ranked as fair operation, labor practices, consumer issues, environment, responsibilities for governance and community development. Therefore, in accordance to different phrases and key points, enterprises can perform CSR efficiently and thus boost sustainability.

6 Recommendations for Future Research

Taking into account the difficulties in collecting the data, we only selected the samples up to 2011, the sample is relatively small, future research may collect the latest data to validate the conclusions in this study. In addition, the study was cross-sectional study, a longitudinal study can be considered to be conducted in future study.

Acknowledgement

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References

Carroll,A.B.(1979). "A Three-dimensional Conceptual Model of Corporate Performance." *Academy of Management Review*,4(4),497-505.

Carroll,A.B(1991). "The Pyramid of Corporate Social Responsibility: Toward the Moral Management of Organizational Stakeholders." *Business Horizons*, 39(18),25-29.

Chen,X.S. Chen,X.J.(2008). “the Empirical Study on the Profit Quality and Sustainability Capacity of China Listed Companies.” *Shanghai Journal of Ecnomics*,5,88-93.(in Chinese)

Ramanathan, K. V. (1976). “Toward a theory of corporate social accounting.” *Accounting Review*, 516-528.

Kuang,H.B.(2012).“2009-2011 Annual CSR Development Report of Transportation Industry”. (in Chinese)

Higgins,R.C.(1977).“How Much Growth Can a Firm Afford?” *Financial Management*,6,7-16.

Hu,X.Q.(2004).“Sustainability and CSR.” *Journal of Chongqing University of Posts and Telecommunications(Social Science Edition)*,16(2),123-125.(in Chinese) (in Chinese)

Li,P.L.(2006).“Research on CSR and Sustainability.” *Modern Finance and Economics*, 10. (in Chinese)

Margolis J D, Walsh J P.（2003）. “Misery loves companies: Rethinking social initiatives by business.” *Administrative science quarterly*, 48(2): 268-305.

Ruf B M, Muralidhar K, Brown R M, et al.(2001) “An empirical investigation of the relationship between change in corporate social performance and financial performance: A stakeholder theory perspective”. *Journal of business ethics*,32(2): 143-156.

Tang,Q.Q., Xu,X., Cao,Y.(2009).“Stock Incentive, Research Input and Enterprise Sustainability.” *Journal of Shanxi University of Finance and Economics*, 8,77-84.(in Chinese)

Van Horne,J.C.(1988).“Sustainable Growth Modeling.” *Journal of Corporate Finance*,1,19-24.

World Business Council for Sustainable Development.(2002).“Corporate Social Responsibility.” *The WBCSD’s Journey*,2.

Socioeconomic Determinant Analysis of Influencing the Urban Transit Share in China

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Abstract: In recent years many cities in China are making great progress in developing urban public transportation. Meanwhile the share of public transit is becoming one of the main indexes in evaluating the level of public transport development. Based on the quantitative analysis of different type of cities, this paper reveals the internal relationship between the public transit share and social economic conditions. Firstly the range of factors influencing public transit share or transit usage is determined based on domestic and international literature review. Secondly, the trend of domestic public transit ridership and social economic factors in recent 25 years is examined as the fundamental to build models. Thirdly, the paper chooses 30 cities of different types and scales as the objects of study, and builds structural equation models to quantify the impacts of changes in several determinants on public transit share. In the end the paper illustrates how and to which extent the social and economic factors influence the change of public transit share.
Keywords: Transit share; Socioeconomic determinants; Structural equation model; Factor analysis.

1 Introduction

With the advent of the 21st century, the rapid economic development has led to increasingly serious traffic jams in metropolises, and an effective way to address to the problem is to vigorously develop the urban public transit system.(Yang, 2006) In 2005, General Office of the State Council forwarded the *Advices to Give Priority to the Development of Public Transport (No.46 Document by General Office of the State Council [2005])* released by the Ministry of Housing and Urban-Rural Development of the People's Republic of China and the National Development and Reform Commission, which confirmed the priority of public transit in urban transportation and drew wide attention from cities in China to the development of public transit. In December 2012, the State Council issued the *Guidance of the State Council to the Prior Development of Public Transport (No.64 Document by the State Council [2012])*, in which the State Council clearly pointed out that, "An urban motorized transportation system dominated by the public transport should be constructed by improving the transportation capability, service level, competitiveness and attraction of the public transport. At the same time, the walking and bicycling conditions should be refined…The public transit share should be increased so as to define the dominant role of public transit in urban transportation." These policies have brought precious opportunities for the development of the urban public transportation. One of the major purposes to vigorously development the urban public transport system is to improve the public transit share in the daily transportation so as to alleviate the urban transport pressure. Therefore, it is of vital guiding significance for urban and transportation planning to analyze various socioeconomic factors influencing the public transit share and reveal the internal relationship between the public transit share and the socioeconomic conditions.

Most research into the public transit share appear in foreign literatures. Since the 1990s, there has been a systematic study of the public transit share, focusing on various factors which might influence the public transit efficiency, and the relation between these factors. The previous research could generally be divided into two types, namely research into the endogenous factors and the exogenous factors. The analysis of the endogenous factors mainly focuses on ticket price (Sale, 1976; Kain, 1996), service supply level (Liu, 1993; Kohn, 2000), service quality (Cervero, 1990; Syed, 2000; Avedel, 1995); while the analysis of the exogenous factors focuses on spatial factors, public finance factors and socioeconomic factors. Among them, the analysis of spatial factors and public finance factors mainly features regression analysis. (TCRP, 1996; Crane, 2000; Morral, 1996; Kain, 1996), while the analysis of the socioeconomic factors is mainly conducted through the aggregate model to study the sensibility of public share rate to various factors. For example, Liu (1993) and Chuang (1997) though that the employment rate and the regional development level have the greatest influence on the public transit share. Gomez-Ibanez (1996) found out the elastic coefficient of the employment rate to the public transit share in the downtown area is 1.24~1.75, which is higher than that of the income level, the regional population and other factors to the public transit share. He even deduced that the income level and the suburbanization have a negative influence on the public transit rate, which should be balanced through improving the service level and reducing the ticket price. Liu and Kain (1995 & 1996) studied the interplay between the auto ownership and the public share rate, but their conclusions are relatively vague.

Generally speaking, the research content into the factors influencing the public transit share is diversified and the existing research findings are referential to the formulation of transportation policies to some extent. However, due to the limit of research scope and data acquisition, the existing research findings tend to target at a specific region or city, thus lacking universality. In particular, the foreign urban development characteristics, socioeconomic conditions and transportation system vary greatly from those in China and the importance degree of these factors to China is fundamentally different. Therefore, it is necessary to enhance the quantitative analysis of various influencing factors based on the practical situation in China so as to promote the positive interaction between the formulation of public transit policies and the public transit operation efficiency.

2 Macro-level Trend Analysis of Transit Ridership and Socioeconomic Development

The development of the public transit system has a close bearing on the steady socioeconomic development in the urban area. This part conducts an overview of the urban public transit and socioeconomic development trend in China and analyzes to find the major factors influencing Annual passenger boardings and the public transit efficiency.

2.1 Data source and selection

The data in this part mainly are obtained mainly from *China Statistical Yearbook* issued by National Bureau of Statistics on an annual basis. The statistical data cover the economic and social conditions of various cities in China from 1987 to 2012. Based on these data, this paper calculates and processes relevant indexes.

The urban public transit passenger boardings and the annual per capita transit trips are confirmed as the indexes indicating the urban public transit development level. According to the previous research and the data accessibility, macro factors influencing the public transit development can be classified into three types, socioeconomic development level, public transit system construction level and mechanized development level.

Table 1. Index classification and selection

Classification	Indexes	Unit
Socioeconomic development level	Gross domestic product (GDP)	100 million RMB
	Urban population	10,000 persons
	Urban employees	10,000 persons
	Urban land for construction	km^2
	Population density	10,000 persons/km^2
	Employment density	10,000 persons/km^2
	Per capita income	RMB
Public transit construction level	Standard operating bus vehicles	Set
	Length of operating bus lines	km
	Standard bus vehicle ownership ratio	set/10,000 persons
	Proportion of transit in municipal investment	%
Automatized development level	Road network mileage	km
	Per capita road area	km^2/person

	Private auto ownership	10,000 sets
	Private auto ownership ratio	ets/10,000 persons
	Proportion of road in the municipal investment	%

2.2 Analysis of the public transit and socioeconomic factors development trend

Over the past 25 years, China’s urban socioeconomic level has been greatly improved and the scale of the urban population and land use has kept expanding. The growth of annual passenger boardings is closely related to the expanded scale of urban population and employment. (Figure 1) Though urban population did not show significant growth, the growth curve of urban employment almost coincided with the growth curve of annual passenger boardings. On the other hand, the growth of annual passenger boardings is closely related to the rapid development of the transit system. Also, it can be seen that, as annual passenger boardings increased, standard operating bus vehicles and length of operating bus lines also kept on growing. Especially after 2005, the scale of operating bus lines registered a rapid increase.

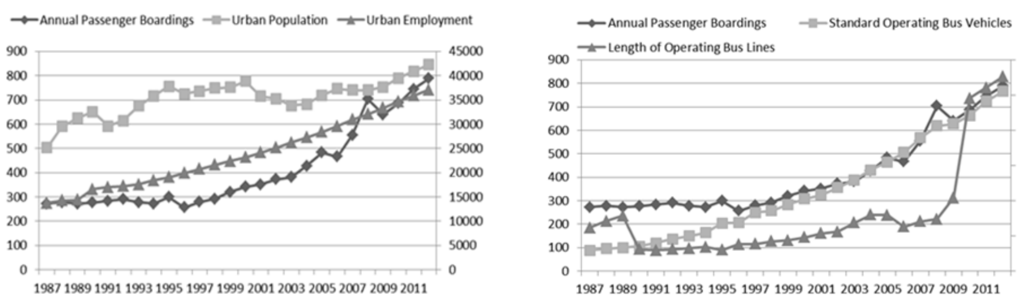

Figure 1. Trend of passenger boardings, population, employment and transit supply

Annual per capita transit trips acts as an index to indicate the public transit service efficiency. Its growth magnitude was not that significant. Around 2000, it even fluctuated, which suggested that, despite the significant growth of socioeconomics and annual passenger boardings, the transit service efficiency still failed to be increased by a large margin and the transit trips still did not hold great attraction to the public. (Figure 2)

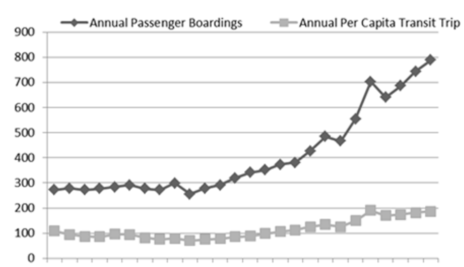

Figure 2. Trend of annual passenger boardings and annual per capita transit trips

From Fig. 3, it can be seen that the development trend of annual per capita transit trips, bus vehicles per 10,000 persons and proportion of transit in municipal investment almost coincided with each other. In some sense, it indicated that, despite of the significant increase of annual passenger boardings, the annual per capita transit trips still developed slowly, which inhibited the competitiveness and attraction of the public transit. And it also can be seen that the density of population and employment is decreasing steadily.

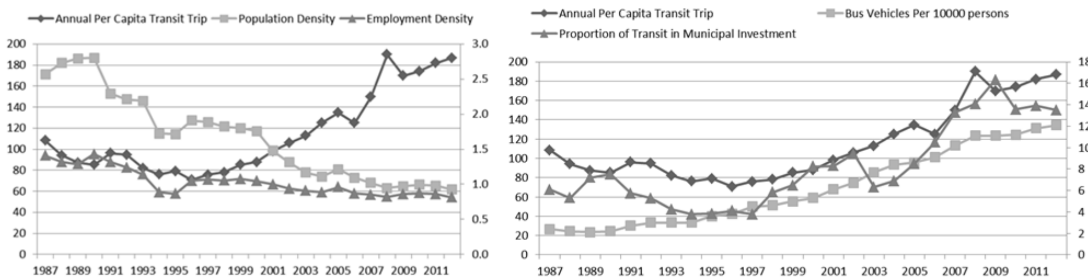

Figure 3. Trend of annual per capita transit trips, population, employment and transit

2.3 Correlation analysis of public transit and socioeconomic development

This part analyzes the correlation between major socioeconomic factors, and annual passenger boardings and annual per capita transit trips, respectively. The first group is to demarcate the correlation coefficient between annual passenger boardings and socioeconomic aggregate indexes and analyze their significance. From Table 4, it can be seen that annual passenger boardings were significantly positively related to GDP, urban population, construction land area, standard operating bus vehicles and length of operating bus lines. This is in line with the general development rules of public transit.

Table 2. Correlation of transit ridership and socioeconomic indexes

		GDP	Population	Construction land	Standard operating bus vehicles	Length of operating bus lines
Transit ridership	Pearson Correlation	.980**	.631**	.930**	.960**	.828**
	Sig. (2-tailed)	.000	.001	.000	.000	.000
**. Correlation is significant at the 0.01 level (2-tailed).						

The second group is to analyze the correlation between annual per capita transit trips. From Table 5, it can be seen that annual per capita transit trips are significantly positively related to standard operating bus vehicles and private cars per 10,000 persons, but are negatively related to employment density and per capita road area. It should be noted that the public transit operating efficiency often has a negative influence on private cars per 10,000 persons, while a positive influence on employment density. From Table 5, it can be seen that variables have a strong correlation to each other, which suggests that the endogenous correlation among the macroscopic data index variables results in the interaction among variables. The discrete study of the urban area will resolve this problem.

Table 3. Correlation of transit ridership per capita and socioeconomic indexes

		Population density	Employment density	Bus vehicles per 10000 persons	Private cars per 10000 persons	Road area per capita
Annual per capita transit trips	Pearson Correlation	-.722**	-.564**	.909**	.913**	.904**
	Sig. (2-tailed)	.000	.003	.000	.000	.000
**. Correlation is significant at the 0.01 level (2-tailed).						

3 Socioeconomic factor analysis

Based on the data of 30 cities related to their socioeconomics, public transportation, mechanized development and residents' trips, an analytical model is established. First, the factor analysis is conducted of all index data. Multiple variables are simplified so as to decompose the original variables and find out the potential types. Those indexes showing strong correlation are classified as one type. The correlation between different types of variables is relatively low. The method has now been widely applied to various fields.

In order to obtain the potential factors influencing the public transit share and further study the relation between various factors and the public transit share, the factor analysis can be conducted to obtain the factors influencing the public transit share.

First, 22 socioeconomic description indexes undergo KMO test (Kaiser-Meyer-Olkin Measure of Sampling Adequacy) and Bartlett's Test of Sphericity. The test results are shown in Table 4:

Table 4. KMO test and Bartlett's Test of Sphericity

Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.697
Bartlett's Test of Sphericity Approx. Chi-Square	463.2
df	231
Sig.	0.000

KMO value is 0.697, which is close to 0.7. This suggests the result of the factor analysis is good. The value of Bartlett's Test of Sphericity is 463.2 and it reaches a significant level under the degree of freedom (df) of 231 and the significance level of 0.000. This suggests that there are common factors existing in various influencing factors, so the factor analysis is suitable.

Principal component method is the mostly-commonly used method to extract common factors in the factor analysis. Varimax rotation is adopted to rotate the extracted common factors so as to achieve a satisfying explanation. Arrayed according to the eigenvalues, four common factors are extracted. (Table 5)

Table 5. Extraction of socioeconomic factors and their explanation of the original variables

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	%of Variance	Cumulative %	Total	%of Variance	Cumulative %
1	8.465	38.477	38.477	4.564	20.744	20.744
2	3.285	14.933	53.411	3.262	14.828	35.571
3	1.877	8.534	61.944	2.640	11.999	47.571
4	1.504	6.838	68.782	2.586	11.753	59.323

The facto analysis results are shown in Table 6. It can be seen four common factors can be extracted from 22 socioeconomic factors participating in the factor analysis. The first common factor contains five items (including gross road network area, land use scale, length of the road network, auto ownership and bridge and road investment). Its eigenvalue (4.564) and contribution rate (20.744%) are the highest, which suggest that its explanation proportion of the variance of all social factors is the highest and it can be regarded as the road scale factor. The second common factor contains five items (general financial revenue, per capita income, disposable fiscal revenue, GPD and per capita GDP). Its eigenvalue (3.262) and contribution rate (14.828%) are just behind the first common factor. It can be regarded as the urban socioeconomic factor. The third factor contains four items (including bus vehicles ownership per 10,000 persons, length of operating bus lines, scale of standard operating bus vehicles, annual passenger boardings and per capita transit trips). Its contribution rate is 11.999% and it can be regarded as the transit supply factor. The fourth common factor contains three items (including time consumption of private car trips and transit trips and the average time consumption of trips). Its contribution rate is 11.753%, so it can be regarded as a trip time consumption factor.

Table 6. Analysis results of the socioeconomic factors

Socioeconomic factors and factor items	Factor loading	Eigenvalue	Contribution rate (%)
Common Factor 1		**4.564**	**20.744**
Gross road network area	0.930		
Land use scale	0.921		
Length of the road network	0.893		
Auto ownership	0.812		
Bridge and road investment	0.777		
Common Factor 2		**3.262**	**35.571**
General financial revenue	0.750		
Per capita income	0.713		
Disposable fiscal revenue	0.664		
GDP	0.642		
Per capita GDP	0.564		
Common Factor 3		**2.640**	**47.571**
Bus vehicles per ownership per 10,000 persons	0.891		
Length of operating bus lines	0.709		
Scale of standard operating bus vehicles	0.704		
Annual passenger boardings	0.644		
Common Factor 4		**2.586**	**59.323**
Time consumption of private car trips	0.893		
Time consumption of transit trips	0.874		
Average trip time consumption	0.807		

In the following a structural equation model will be established based on the correlation between socioeconomic factors and public transit rate to analyze the influence of various factors on the public transit share and the interaction among various factors.

4 Structural equation model of transit share and socioeconomic factors

4.1 Introduction of the structural equation model

The structural equation model is a statistical approach to analyze the relation among variables through the variable covariance matrix. It is also called covariance structural analysis. The structural equation model is a diversified statistical approach to test the relation between observational variables and latent variables, latent variables and latent variables. Generally speaking, a group of variables are assumed to have the causal relationship. The latent variables can be expressed by a group of explicit variables to stand for the linear combination of certain explicit variable. By testing the covariance among the explicit factors, the coefficient of the linear regression model can be estimated to verify whether the assumed statistical model is feasible to the research process. If it is feasible, the relational expression between the assumed potentials is reasonable.

(1) Model composition

The structural equation model is to test the combination of the factor model and the causal model. Part of the factor model contained is called the measurement equation, which is used to describe the relation between latent variables and indexes. Part of the causal model is called the compositional equation, which is used to describe the relationship between latent variables.

The most common situation of the structural equation model is that both the exogenous variables and the endogenous variables are both latent variables. At the moment, both exogenous variables and the endogenous variables have the measurement equation. The model is shown below:

Measurement equation:

$$y = \Lambda_y \eta + \varepsilon \quad (1)$$

$$x = \Lambda_x \xi + \delta \quad (2)$$

Structural equation:

$$\eta = B\eta + \Gamma\xi + \zeta \quad (3)$$

Where:

x stands for the vectors composed by the exogenous explicit variables;

y stands for the vectors composed by the endogenous explicit variables;

Λ_y stands for the factor loading matrix of y on η;

Λ_x stands for the factor loading matrix of x on ξ;

ε stands for the error items of the endogenous explicit variables;

δ stands for the error items of the exogenous explicit variables;

B stands for the coefficient matrix, which is used to describe the interaction between the endogenous latent variable, η;

Γ stands for the coefficient matrix, which is used to describe the influence of the exogenous variable, ξ, on the endogenous variable, η;

ζ stands for the residual items of the structural equation, which is used to reflect the part of η that cannot be explained.

(2) Model parameter estimation

A complete structural equation model should contain eight parameter matrixes: Λ_y, Λ_x, B, Γ, Φ, ψ, Θ_ε and Θ_δ. Among them, Γ stands for the covariance matrix of the latent variable, $\xi;\psi$ stands for the covariance matrix of the residual item; Θ_ε and Θ_δ stand for the covariance matrix of ε and δ, respectively.

If the theoretical model is proved, $\sum(\theta)$ equals to the general covariance matrix, $\sum$, namely $\sum(\theta)=\sum$, and the variance and covariance of the observational variables (namely indexes of endogenous and exogenous variables) are both the functions of the model parameters. Methods like maximum likelihood (ML) estimation and generalized least squares method (GLS) are usually adopted to estimate the model.

(3) Model evaluation

Model evaluation is related to the data fitting degree of the model. The most commonly-used fitting index to evaluate the model is the chi-square test (χ^2) of the goodness of fit, which can be directly deduced through the value of the fitting unction. The size of the chi-square is related to the sample scale, so the goodness of fit index (GFI), the amended goodness of fit index (AGFI) and the root mean square error of approximation (RMSEA) appeared subsequently. The evaluation index can be chosen according to the data characteristics, sample scale and assumed condition adopted for the test.

4.2 Modeling and effect analysis

The correlation analysis between the socioeconomic factors and the public transit share can be expressed by the relation between the endogenous and exogenous factors of the structural equation and the relation between the latent variables.The path diagram is used to show the structural equation model. The endogenous variables are expressed by ovals and the observational variables are expressed by rectangles. If two latent variables are related to each other, they will be connected by the double-headed arrow. If two latent variables are in a causal relationship, they will be connected by the single-headed arrow. The arrow points to the outcome variable. If a latent variable can be expressed by several observational index variables, the latent variable can be regarded as the observational factor. The single-headed arrow can be used to connect the latent variable and the observational variables to show that the latent variable can directly influence the value of the observational variables.

If there are too many estimation coefficients after all indexes are put into the model, the model might be hardly recognizable. The model relationship is simplified through the stepwise regression method to eliminate the insignificant factors influencing variables to improve the model structure step by step. The model is demarcated in the Amos software. The result is shown in Fig. 2.

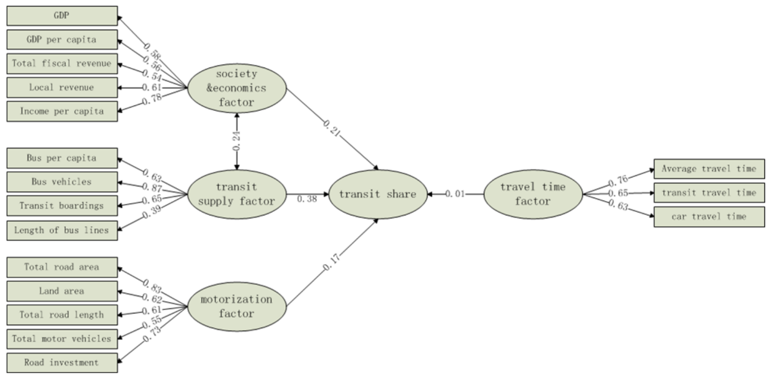

Figure 4. Structural equation demarcated results

Five major characteristics indexes are compared with the ideal value to confirm the fitting precision of the model. The fitting index of the model is shown in Table 7. Through comparison, it can be seen that the fitting index is basically within the ideal scope, which indicates good model fitting degree and certifies that the assumption of the theoretical model is correct. In other words, the socioeconomic factors are correlated to the public transit share.

Table 7. Test of goodness of fit of the model

Evaluation indexes	Model evaluation indexes	Suggested value
Chi-square value/degree of freedom	3.346	Vary with samples
Good of fit index (GFI)	0.843	>0.9
Adjusted goodness of fit index (AGFI)	0.911	>0.9
Root mean square residual (RMR)	0.452	<0.5
Root mean square error of approximation (RMSEA)	0.081	<0.08

The model demarcated results show the interaction between the changes of different factors and the public transit share.

The public transit supply factor has the greatest influence on the public transit share. The correlation coefficient is 0.38, which suggests that the improvement of the public transit bus lines and the expansion of the public transit scale can effectively improve the public transit share. The second influencing factors are urban socioeconomic factor and the road scale factor. Their correlation coefficient of the two to the public transit share is 0.21 and 0.17, respectively. This suggests the urban socioeconomic development level and the road scale can influence the public transit share to some extent, but the influence is not significant. The correlation coefficient between the trip time consumption and the public transit share is 0.01, which suggests that the former is not significantly correlated to the latter.

The correlation coefficient of the urban socioeconomic factors to the public transit supply factor is 0.24. This suggests that socioeconomic development can enhance the development intensity of the urban public transit and increase the public transit scale.

5 Conclusions and prospects

This paper studies the relation between various socioeconomic indexes all over China and in some cities and the public transit share. Through the correlation analysis, factor analysis and establishment of the structural equation model, the following conclusions are obtained:

(1) From the macroscopic perspective, population scale, land use scale and GDP are closely related to the annual passenger boardings; the standard operating bus vehicles, population and employment density are factors closely related to the operation efficiency (per capita transit trips);

(2) As to the social factors influencing the public share, there are three major factors, namely urban socioeconomics, road scale and public transit investment and supply;

(3) Through establishing and demarcating the structural equation model, the factor with the greatest influence on the public transit share is the public transit supply factor, which is followed by the urban socioeconomic factor and the road scale factor.

Due to limited data, the unified model and analysis is just targeted at some domestic cities. The follow-up research should discuss based on cities of different types. Different models should be established to discuss different influence of different factors on cities of different types.

References

Abedel-Aty, Mohamed A., and Paul P. Jovanis. (1995). “The Effect of ITS on Transit Ridership.” ITS Quarterly, Fall, 21-25.

Cervero, Robert (1990). Transit Pricing Research: A Review and Synthesis. Transportation, 17, 117-139.

Chung, Kyusuk. (1997). Estimating the effects of employment, development level, and parking availability on CTA rapid transit ridership: from 1976 to 1995 in Chicago. Metropolitan Conference on Public Transportation Research: 1997 Proceedings. May 30, University of Illinois, Chicago, 255-64.

Crane, Randall. (2000). The impacts of urban form on travel: an interpretive review. Journal of Planning Literature, 15: 3-23.

Gomez-Ibanez, Jose A. (1996). Big-city transit, ridership, deficits, and politics. Journal of the American Planning Association, 62(1), 30-50.

Kain, John F. and Zhi Liu. (1996). Econometric analysis of determinants of transit ridership: 1960-1990. Prepared for the Volpe National Transport Systems Center, U.S. Department of Transportation, May 25.

Kohn, Harold M. (2000). Factors affecting urban transit ridership. From the Bridging the Gaps Conference, Canadian Transportation Research Forum, Charlottetown, Prince Edward Island, Canada, June 6.

Liu, Zhi. (1993). Determinants of public transit ridership: analysis of Post World War II trends and evaluation of alternative networks. Cambridge, MA: Harvard University, September.

Morral, John, and Dan Bloger. (1996). The relationship between downtown parking supply and transit use. ITE Journal, 66(2): 32-36.

Sale, James. (1976). Increasing transit ridership: the experience of seven cities. Prepared for the Urban Mass Transportation Administration, U.S. Department of Transportation, November.

Syed, Sharfuddin J., and Ata M. Kahn. (2000). “Factors analysis for the study of determinants of public transit ridership.” Journal of Public Transportation, 3(3), 1-17

Transit Cooperative Research Program. (1996). Transit and urban form. TCRP Report Number16, Volume 1.

Yang, Xiaoguang, Zhou, Xuemei. and Teng, Jing (2006). Research and practice on public transportation and urban development, Tongji University Press.

Task Allocation Algorithm of Concurrent Engineering for Railways

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Abstract: In the management process of railway construction, here comes the problems such as involving too many projects, complex business, varying lengths of business cycles, employees and staff capacity varies greatly, which increase the difficulty of management and reduce the efficiency of human resources. It's meaningful to manage the process of railway construction. For the traditional management mode, managers always assign the task directly and manually, which not only increases the administrative burden, but also makes the distribution plan lack of scientificity and rationality, especially for parallel projects, presenting particularly prominent problems. According to "Railway Construction Project Management program guidance" formulated by the former Chinese Railways Construction Management Division it sorted out the management program of railway construction projects and understood the main task type, task attributes etc. meanwhile, studied the existing task allocation algorithm, building a new task allocation model used a multi-dimensional evaluation method and Rough set theory to evaluate the suitability of candidates and fully considered the properties and state of tasks and candidates to improve the scientificity and rationality of distribution plans. On the basis of the above we gave the realization steps of parallel engineering task allocation algorithm for railway.
Keywords: Railway construction; Task allocation; Concurrent engineering; Rough set theory.

1 Introduction

This paper analyzes the process of parallel railway construction project management, finding problems such as managing too many projects, complex business, varying lengths of business cycles, lots of employees and staff capacity varies greatly, etc. Managers always assign the task directly and manually when they distribute tasks in the traditional way, which not only increases the administrative burden, but also makes the distribution plan lack of scientificity and rationality.

To meet the need of modernized management for railway, appropriate task allocation algorithms should be applied to the management of railway construction project, making the task be assigned to appropriate staffs within a predetermined time, so as to improve the efficiency and rationality of task allocation.

This paper analyzed the characteristics of tasks of railway project management, and fully considered the important factors affecting the assignment, and then proposed an allocation algorithm based on multi-dimensional evaluation. It took the expert scoring as the basis for evaluation and applied Equalization method to deal with the original data, Rough set theory to work out the weights of attributes directly affecting task allocation.

2 Railway Project Management Features

2.1 Parallelism and complexity

Large railway construction projects management units always manage many construction projects. So, at the same time, there are always multiple projects need to be managed. The progress requirements of each project are often different and the project management tasks are heavy and complex, increasing the management difficulty greatly.

2.2 Diversity and dynamics of influence factors

Many factors affect task distribution, such as the type and load of tasks, the interests and ability of members, the workload and work experience of the staff. So it’s necessary to consider variety of factors synthetically.

Some factors show their dynamics. In the process of task allocation, new projects always come out at any time, the number and requirements of tasks are constantly changing, the staffs’ joining and leaving is also dynamic. The traditional way to assign the task is essentially static, so it can’t adapt well to dynamic characteristics in the management process. Therefore, it’s is particularly necessary to design a task allocation algorithm of concurrent engineering for railway.

3 Task Assignment Algorithm Designing

The objective of task allocation is to assign the suitable tasks to appropriate staff within a predetermined time. So assignment can be divided into two steps to realize. First, within the stipulated time, select the task with the highest priority. Second, select the most appropriate staff to undertake this task.

When we evaluate the scoring of members and task with subjective scoring, it’ quite necessary to unleash members’ autonomy and reduce subjectivity as possible.

3.1 Scoring designing

According to "Railway Construction Project Management program guidance", the tasks are divided into: document approval, data collection, sending and receiving files, documents signing, document generation, on-site inspection, organizational work, material application, etc. A ~ H can represent the task category in railway construction projects. Meanwhile, select M people with relevant work experience as members of expert group. Task = {t1, t2, ..., tn} represents task items need to be assigned.

Task parameters:

(1) Task load: Define the task workload $Lti = INTti * Fti * Hti$, $INTti$ expresses the intensity of task *I*; *Fti is* the frequency of task *i*; *Hti* represents the time-consuming of task *i*.

(2) Project weights: Tasks of projects belong to key projects and projects with high emergency should be assigned first, so define the project weighting factor pj,

$0 \le pj \le 1.0$.

(3) Assignment Priority: Define the task assignment priority level $D_{pi} = t_{pi} * (1 + pj)$, D_{pi} determines the priority level of task allocation, *tpi* is priority score of the task.

Expert Group was selected to score for task parameters, set a standard scoring range of 0 to 100. Vector [S_{lk1}, S_{lk2},…, S_{lkj}] represents the scoring of expert *l* for the attribute *j* of class *k*. Use the Trimmed Mean to process the vector can obtain the scoring of attribute *j* as follows.

$$\overline{S_{lkj}} = \frac{\sum_{l=na+1}^{n-na} S_{lkj}}{n - 2na} \tag{1}$$

Here, *n* represents the number of scores; *a* represents the coefficient of Trimmed Mean, $0 \le a \le 0.5$; "*Slk*1, *Slk*2,…, *Slkj*" is the array of scoring data in ascending order.

Staff parameters

(1) Personnel load: Define the Personnel load $Li=L0+L_k$, $L0$ shows the current workload of the staff, L_k is the load of task *k* to be assigned.

(2) Staff capacity: Define staff capacity Cap_{ik}, the expert group mark Cap_{ik} for the staffs to be assigned.

(3) Personnel interest: Define Personnel interest Int_{ik}, the staff score for self-interest for each task category.

(4) Staff experience: Define staff experience Exp_{ik}:

$$Exp_{lk} = \frac{\mathrm{NUM}_{lk}}{\sum \mathrm{NUM}_{lk}} * 100 \tag{2}$$

Here NUM_{lk} represents the number of history tasks completed of category k for staff l, SUM_{lk} represents the total number of history tasks completed of category k for all staff to be assigned. Here shows two main tables:

Table 1. Task Attribute Table

Attributes \ tasks	Intensity (*INTti*)	Frequency (*Fti*)	Hours (*Hti*)	Priority (*tpi*)	Project weight (pj)	Task load (*Lti*)	Distribution priority (*Dpi*)
ti	Scoring	Scoring	Scoring	Scoring	Empiric		

Table 2. Staff attribute table

Attributes \ staff	Workload L_0	Capacity Cap_{ik}	Interest Int_{ik}	Experience Exp_{ik}
hi	Scoring	Scoring	Scoring	

3.2 Weight calculation based on Rough set theory

Rough set theory researches incomplete and uncertain knowledge and data .It can learn and conclude from ambiguous and imprecise data. It doesn't need any prior knowledge. Therefore it has been successfully applied into fields such as expert systems, machine learning, pattern recognition, decision analysis, etc.

This paper used rough set theory to calculate the weights of staff properties directly affect task allocation such as staff capacity, personnel interests, staff experience, etc. According to the weights it calculated the assessment value of the staff for the task distribution . Concepts of rough set theory refer to literature (Banerjee M, 1996).

To determine the importance of certain attributes or attribute set, we need to get rid of some other property from the table, and then examine changes of the classification. If the removing of the property will accordingly change classification, so it indicates high importance of the property, on the contrary, indicates low importance of the property. This can use positive region of the rough set to describe.

Consider the task allocation decision table shown in Table 3.

Table 3. Task allocation decision table

U	Workload	Capacity	Interest	Experience	Assign or not
1	light	low	very	general	yes
2	heavy	strong	little	general	yes
3	heavy	general	general	little	no
4	heavy	general	little	little	no
5	light	low	very	little	no
6	heavy	general	little	general	yes

Quantify table 3, and then table 4 can be obtained.

Table 4. Quantized decision table

U	L	C	I	E	d
1	2	0	2	1	1
2	0	2	0	1	1
3	0	1	1	0	0
4	0	1	0	0	0
5	2	0	2	0	0
6	0	1	0	1	1

The universe U composed of elements of NO.1 to NO. 6, the condition attribute set C = {L, C, I, E}, the decision attribute set D = {d}。

U/ind(L,C,I,E)={{1},{2},{3},{4},{5},{6}},U/ind(d)={{3,4,5},{1,2,6}}, $POS_c(D)$={1,2,3,4,5,6}, $r_c(D)$=Card($POS_c(D)$)/Card(U)=6/6=1. Remove attribute L and then $U/ind(C,I,E)$={{1},{2},{3},{4},{5},{6}}, $POS_{c-L}(D)$={1,2,3,4,5,6}, r_{c-L}(D) =6/6=1. After removing C, $U/ind(L,I,E)$ ={{1},{2,6},{3},{4},{5}}, $POS_{c-C}(D)$ = {1,3,4,5}, $r_{c-C}(D)$ =4/6=2/3. After removing I, $U/ind(L,C,E)$ = {{1},{2},{3,4},{5},{6}}, $POS_{c-I}(D)$={1,2,5,6}, $r_{c-I}(D)$= =4/6=2/3. Finally remove E and then $U/ind(L,C,I)$={{1,5},{4,6},{2},{3}}, $POS_{c-E}(D)$={2,3}, $r_{c-E}(D)$=2/6=1/3.

We can conclude that attribute E is the most important because it changes positive region of U/D most, attributes C and I follow, attribute L is redundant. It reflects that we very concern about relevant work experience of the staff, meanwhile the interest and capacity are also taken into account, however the workload tend to be ignored。This paper considered humanity and efficiency and taken the workload into consideration, which was also in line with the actual situation.

Generally, decision-makers always have prior knowledge for each condition attribute and the weight of attributes can be used to measure the relative importance.

The attribute importance in rough set theory can express the influence of the properties to the decision, but it can't reflect the prior knowledge of decision-makers.

This paper combined rough set theory with prior knowledge of decision-makers and then combined synthesis attribute weight gotten from a combination of objective weight with weight from subjective prior knowledge, realized the unity of prior knowledge and objective situation. Normalize the attribute importance of each attribute:

$$q_j = \frac{r_c(\mathrm{D}) - r_{c-j}(D)}{\sum_{j=1}^{n} r_c(\mathrm{D}) - r_{c-j}(D)} \tag{3}$$

Here, $r_c(\mathrm{D})$ represents dependency of decision attribute on condition attribute, $r_c(\mathrm{D})-r_{c-j}(\mathrm{D})$ tells the importance of attribute j, q_j represents the objective weight of j, $q_j \in (0,1.0)$. Use rough set theory can get objective weight and subjective weight can get by expert experience. Suppose the weight of the objective weight is θ.

For Table 3，suppose the subjective weight of each attribute p_i is: p_L=0.2， p_C =0.3, p_I=0.1, p_E=0.4. The attribute importance can be obtained as follows：

$r_c(\mathrm{D})-r_{c-L}(\mathrm{D})$=0; $r_c(\mathrm{D})-r_{c-C}(\mathrm{D})$=1/3; $r_c(\mathrm{D})-r_{c-I}(\mathrm{D})$=1/3; $r_c(\mathrm{D})-r_{c-E}(\mathrm{D})$=2/3

Get the objective weight of each attribute： q_L=0; q_C=0.25; q_I=0.25; q_E=0.5;

So the synthesis weight is：

$P_L=\theta\times0+0.2(1-\theta)\theta=0.2-0.2\theta$, $P_C=\theta\times0.25+0.3(1-\theta)=0.3-0.05\theta$

$P_I=\theta\times0.25+0.1(1-\theta)=0.1+0.15\theta$, $P_E=\theta\times0.5+0.4(1-\theta)=0.4+0.1\theta$

Suppose: θ=0.6, so： P_L=0.08， P_C=0.27， P_I=0.19, P_E=0.46

Here get the synthesis weight of each attribute that directly affect the task allocation.

3.3 Task allocation algorithm

The aim of task distribution is to assign tasks to appropriate staff within stipulated time. Therefore, task allocation can be divided into two steps: first, select a certain task within stipulated time. Second, assign this task to the most appropriate people. So we can determine the assignment order and then assign the task with high priority. Staff that gets the highest score should be assigned firstly.

Task allocation algorithm steps:

step1. Select scoring expert group $Zi:Z1$ is made up of N persons with relevant work experience, taking responsible for the task load scoring; $Z2$ consists of M project manager, taking responsible for staff capacity scoring; $Z3$ is composed of n staff to be assigned and they score for self-interest for each task category.

step2. Select the task items need to be completed from current projects, suppose the task set is T, staff set is H. Score for task load and the staff ability then equalize and normalize the scoring data.

step3. Combine the data from step2 with the project weighting factor *pj* (adjustable) to calculate the allocation apriority score of the task item and choose the task item with the highest score.

step4. According to the relevant data from step2, calculate the task allocation suitability score of the staff for the chosen task item of step2.

step5. Assign the chosen task item from step2 to the staff with the highest suitability score. Then remove the assigned task item from set T and update T and H according the changes of project and staff. Repeat step1 to step 5 until the end.

To consider the one with a heavier workload should have lower task assignment priority, so their fitness to the task is inversely proportional to their workload; likewise, abilities, interests and experience play an active role in the allocation.

Define:

Load matching degree： $LoadFit(i,k) = 100 * 1 / (\mathrm{L}_{ik} * \sum_{l=1}^{n} (1/L_{lk}))$;

$L_{ik} = L_{ik}0 + L_{ik} = (\sum_{t=1}^{m} L_{it}) + L_{ik}$, L_{ik} is the total load if staff i undertake task k ;

Capacity matching degree: $CapFit(i,k) = 100 * Cap_{ik} / (\sum_{l=1}^{n} Cap_{ik})$;

Interest matching degree: $IntFit(i,k) = 100 * Int_{ik} / (\sum_{l=1}^{n} Int_{lk})$;

Experience matching degree: $ExpFit(i,k) = 100 * Exp_{ik} / (\sum_{l=1}^{n} Exp_{lk})$;

Defined the task set T = {t1, t2,..., tn}, staff set H={h1, h2, ..., hm}, task category set S = {a, b, c, d, e},so the synthetic matching degree for task *k* of staff *i* can be defined as:

$$Fit(hi,tk) = LoadFit(i,k)\ P_L + CapFit(i,k)\ P_C + IntFit(i,k)\ P_I + ExpFit(i,k)\ P_E$$

$$= Fit(hi,tk) = LoadFit(i,k)\ P_L + CapFit(i,k)\ P_C + IntFit(i,k)\ P_I + ExpFit(i,k)\ P_E$$

Date of task set T and staff set H is shown in the table blow. Data in the table has been equalized and normalized. Suppose the value of experience matching degree is: 15.27, 20.45, 24.46, 16.49, 23.33.

Table 5. Data table of assigned task

Attributes / tasks	Intensity	Frequency	Hours	Priority	Project weight	Task load	Distribution priority
t1	30	50	10	17.65	0.25	7.32	21.88
t2	10	20	30	23.53	0.10	2.93	25.88
t3	40	20	60	11.76	0.15	23.42	13.52
t4	70	40	20	5.88	0.30	27.32	7.64
t5	100	20	40	41.18	0.20	39.02	49.42

From Table 3, the task set T allocation sequence is: $t5 \to t2 \to t1 \to t3 \to t4$, so t5 should be assigned first, suppose the staffs' load as table6 shows; $P_L = 0.08$, $P_C = 0.27$, $P_I = 0.19$, $P_E = 0.46$. The value of matching degree can work out from the scoring data in table5.

Table 6. Data table of staff

Attri / staff	$L0$	Equalized		Matching degree（normalized）				$Fit(hi,tk)$
		Cap	Exp	$CapFit(i,k)$ 0.27	$IntFit(i,k)$ 0.19	$ExpFit(i,k)$ 0.46	$LoadFit(i,k)$ (0.08)	
a	8000	60	40	16.90	13.79	15.27	24.59	16.17
b	15000	45	55	12.68	18.97	20.45	13.11	17.48
c	20000	75	30	21.12	13.04	24.46	9.84	20.22
d	6000	80	75	22.54	25.86	16.49	32.79	21.21
e	10000	95	90	26.76	28.34	23.33	19.67	24.92

It can be seen from the table that t5 should be preferentially assigned to staff e according to values of synthetic matching degree. Staff e showed obvious advantage in both interest and experience. Meanwhile the synthetic weight of workload was very low so workload affected the value of synthetic matching degree quite lightly. The result of allocation algorithm was in line with the actual principle of task distribution.

4 Conclusions

The parallel railway project management is very important. An efficient and pragmatic task allocation algorithm should be applied into it. This paper considered the difference of projects and the staff property and gave a constructive task assignment strategy for Concurrent Engineering for Railway.

5 Recommendations for Future Research

Personal property directly affects the execution of tasks, so more factors of the staff should be taken into consideration. Meanwhile, the practical situation of the projects always changes, so it's necessary to adjust the related parameters according to the actual situation.

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References

Banerjee M and Pal S K. (1996). "Roughness of fuzzy set." Information Science, 93(3), pp.235-246.

E Ming-Cheng, et al. (1996). "Research on implementation strategy of Concurrent Design." China Mechanical Engineering, 17(3):33—36.

Mathieu Leboulanger, the Global Age of Feedback. (2007). Across -Cultural Study on C2C Markets and Online Trust Building.

Pawlak, Z. (1991). "Rough sets-theoretical aspects of reasoning about data." Kluwer Academic Publishers, Dordrecht.

Qian Song-Die, et al. (1990). "Operational Research." Beijing: Tsinghua University Press.

Zan Huang, Daniel D. Zeng, H sinchun Chen. A. (2005). "Unified Recommendation Framework Based on Probabilistic Relational Models.". SSRN.

Price Optimization of Express Rail Freight Transportation in a Competitive Context

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Abstract: Faced up with the severe competition in the market, the express rail freight transportation management needs appropriate pricing mechanism to improve the efficiency and benefit. The bi-level pricing model is established, including the lower layer model of cargo flow modal split based on the consignors' choices, and the upper layer one aiming at maximizing the benefit of railway enterprises. The improved heuristic algorithm is used in the solution of the bi-level model. The example shows that the express rail freight transportation product has a strong competitive advantage among all the products of other transportation modes with optimum price.
Keywords: Express freight transportation; Pricing; Stochastic user equilibrium; Price sensitivity.

With the gradual deepening of railway express freight system reform, in addition to coal, military supplies and the special transportation outside, railway freight tariffs by government pricing will change into government guidance and limit management. This created the conditions for the research in express cargo freight. With the gradual improvement of the market economy in our country, our express freight transport market has undergone significant changes and be the explosive growth too. Various modes of cargo transport competing has become increasingly intense. So it's time to establish a price making and regulation mechanism in order to meet the fast growing freight market

The literature (Tang, B. 2014) study on the current development of railway freight transport organizations development status and problems, and proposed to optimize express freight organizations, freight market segments and establish freight prices mechanisms to adapt to market competition ; The literature (Hui, S. Q. 2014) have determined the index weights of fast freight pricing factors of weight, thus for the railway enterprises to provide decision-making basis and reference standard in railway freight tariff pricing process, and put forward to improve the railway express freight transport price proposal. The literature (Ma, S., Chen L.J. 2011, and Gao Z. Y. 2001) study on how to pricing for railway freight when various modes of freight transport compete, and establish programming model which taking the maximum benefit of transportation enterprises and the minimum generalized cost of freight transport, then solve that by price sensitivity analysis.

The existing mainly researched from the perspective of qualitative analysis of railway express freight transportation market oriented price making, and there is a lot of achievements and experience about railway passenger pricing. But it has not been able to establish the optimization model of express freight transportation market pricing from the quantitative point of view. So it's going to set a bi-level programming model which is established to optimize fast freight pricing to meet the needs of shippers and maximize the benefits of making the rail freight product at the same time.

1 Probability of cargo owners' selection

Under competitive conditions, there being multiple modes of transport of goods between the two places, fast cargo shippers will choose a transportation way, the generalized cost (not only refers to the tariff, including transportation duration, convenience, reliability and safety and other factors) of which is the smallest. Logit model which is based on random utility theories used to describe the probability of various cargo shippers select modes of transport. Suppose the $n(n = 1, 2, \cdots\cdots, N)$ kinds of goods mode of transport cost function f^n and the utility function V^n are:

$$f^n = w_1 t^n + w_2 u^n - w_3 c^n$$
$$V^n = -\theta f^n \quad (1)$$

Where: t^n、$u^n$and c^n——the n-th mode of transport cargo length, price and ease of transport; w_n——the right of mode of transport time, the price and convenience in the cost function of the weight; θ——conversion parameters between cost function and utility function.

Under the conditions of market economy，when choosing shortcuts cargo transport between the two places, the owners will always choose the way which have the largest utility (generalized minimum cost). Accordingly, the selection probabilities of owners can be derived for each mode of transport for goods:

$$P_n = \frac{expV^n}{\sum_n expV^n} = \frac{\exp(-\theta f^n)}{\sum_n \exp(-\theta f^n)} \quad (2)$$

If the total shortcut freight volume between the origin and destination is Q, then the freight volume of the various transport ways should meet Logit model, namely:

$$q^n = QP_n = Q \cdot \frac{expV^n}{\sum_n expV^n} = Q \cdot \frac{\exp(-\theta f^n)}{\sum_n \exp(-\theta f^n)} \quad (3)$$

2 The distribution mode of cargo flow based on the owners' selection probability

Under normal circumstances, the owner will always choose between two generalized least-cost and efficient transport of goods transport, but after most of owner selected a transport way, with the cargo volume increasing to a certain value, the time of transport will be longer, the quality of service and convenience will decrease, causing the increase of generalized cost, then some owners will give up the road transport and select other methods. Finally, between the different freight transport ways reach a state of stable equilibrium of freight distribution.

This equilibrium can be described as follows: in all the options of fast freight transport modes between the two places, various generalized cost of transportation that have been adopted by goods shippers are generally equal, and not greater than the owner has not been used in the fast freight travel mode.

Based on this theory, a mathematical programming model is used here to describe a variety of cargo transport methods between the two places under the conditions of coexistence, the cargo distribution model based on the selection probability of consignor is ($M1$):

$$\min Z(q) = \sum_{n} \int_{0}^{q_n} f(x)\, dx$$

$$\text{s.t.} \ \sum_n q^n = Q, \ n \in N \qquad (4)$$

This function f(x) means the generalized cost function of cargo transport modes between the two places .And we use the negative utility to express the generalized cost of cargo transport modes. The utility value includes the random utility value and the determined utility value (V^n), so the generalized cost function can use a logarithmic form:

$$f(q^n) = \frac{1}{U} ln q^n - V^n \qquad (5)$$

Also need to prove the equivalence and the uniqueness of solution between the model ($M1$) and the user equilibrium condition. The Lagrange function of the model is:

$$L(q_n, \ \mu) = Z(q_n) + \mu(Q - \sum_{n \in N} q_n) \qquad (6)$$

And the original model's (M1) first-order condition is equivalent to the Lagrange function $L(q_n, \mu)$ on the conditions of minimal, i.e.

$$\frac{\partial L}{\partial q_n} = -\frac{1}{U} ln q_n + V_n - \mu = 0$$

According to the constraint condition is:

$$q_n = \frac{\exp\{U(\mu+V_n\}}{\sum_m \exp\{U(\mu+V_n\}} \cdot \mathrm{Q} = \frac{\exp\,(UV_n)}{\sum_m \exp\,(UV_n)} \cdot \mathrm{Q},\ \ \mathrm{m} \in \mathrm{M} \qquad (7)$$

So, the solution of the model (M1) satisfies the Logit separation function. So the proof of equivalence is finished. In addition, the objective function and the constraint set is convex, so this model is a convex programming problem, there will be a unique solution.

3 The bi-level programming model based on the benefit of transportation enterprises

Model (M1) describes the problem about the cargo traffic distribution between the different ways of express freight transportation, but that only considered the cargo owners. On that basis, we constructed a bi-level programming to reach a predetermined target and seek the optimal freight prices of railway express freight transportation. In this paper, we assume that the target is the largest freight income of the railway express freight transportation enterprises.

Here, a bi-level programming model is constructed as follows (M2) to describe the freight price optimization problems between the different cargo transport modes.

(M2) $\quad (\mathbf{U})\ \max F_1 = q^1 u^1 \mathrm{L}_{ij}$

$$s.t.\ \ u^{1(\min)} \le u^1 \le u^{1(\max)}$$

Type q^n from the lower model (flow assignment model that front):

$$(\mathbf{L})\ \min Z(q) = \sum_n \int_0^{\mathrm{q}^n} f(x)\, dx$$

$$\mathrm{s.t.} \sum_n q^n = Q,\ \ n \in N$$

$$\mathrm{q}^n \ge 0,\ \ n \in N$$

Note that this is non-convex bilayer programming problem, it is difficult to get a global model of the optimal solution, but it can get better solutions, in order to make the calculation simple, this paper uses heuristic algorithm for solving bilayer programming.

4 The algorithm steps of the bi level programming model about price's optimization

In solving the bi level programming model, the key problem is to find the response function of q^n which contacts the upper and lower of the model .Here we through the assumption of the initial cargo transport price values:$u^{n(0)}$, and get the volume of freight transport $q^n(u^{n(0)})$ by solving the lower model, finally conclude the derivative relations between cargo flow and freight price about the n's transport ,thus the reaction function can be linear approximation to:

$$q^n(u^n) = q^n\left(u^{n(0)}\right) + \frac{\partial q^n}{\partial u^n}(u^n - u^{n(0)}) \tag{8}$$

Through this type into the upper model, converting it into a linear optimization problem is to get the optimal solution of the upper model with traditional optimization methods .Once again taking the optimal solution into the lower model ,we get a new cargo allocation scheme .Repeating the above steps until convergence in the bi level programming model ,then we get a optimal solution.

5 Case Study

This numerical example is given to show the application of railway express freight price optimization model and algorithm in multi model transportation environment. When several different cargo transport modes exist in A and B under the competition, how to through the quantitative analysis of reasonable of China Railway Express freight transport price formulation in order to make the railway freight transport efficiency at the same time the goods transportation more bearing.

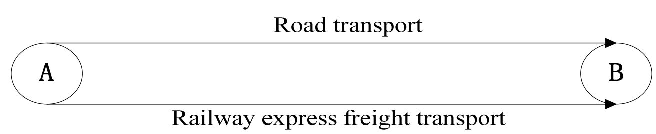

Figure 1. Analysis of examples

There are two kinds of mode of transportation mainly existing in the express freight market with high added value from A to B; here is the railway and highway transportation. Through the front analysis we know, different modes of transport the generalized transport cost function using the following exponential form:

$$f(q^n) = a(q^n)^b - V^n, n = 1,2$$

In the formula, V^n represents the utility value of the cargo transport mode determined .Here a and b respectively values 3 and 0.4. At the front has been the utility function of different modes of transport can be described by the formula (1) to be said:

$$V^n = -\alpha_1 t^n - \alpha_2 u^n + \alpha_3 c^n, n = 1,2$$

Assuming that in the operation process of the freight transport market, the transportation time of railway and highway, convenient and safety remains unchanged, and the volume of high value-added fast freight between A and B is known as 25000 tons. Here the railway freight unit price for (Yuan / ton - km), so the total freight range (17.3, 40) yuan / ton, respectively in table 1-1:

Table 1. Parameters of mode of transport

Cargo transport mode	Transportation cost（YUAN）	Transportation time/h	α_1	α_2	α_3	c^n	L_{ij}/km
Railway	$u^n \cdot L_{ij}$	1.7	3.00	3.75	2.00	6.053	340
Highway	30	1.5	3.00	3.75	2.00	6.053	---

(1) Initializing. Set the initial price between A to B of railway express freight transportation values of $u^{1(0)} \cdot L$ for 20 yuan, and set i to be 0;

(2) In all modes of transport, the freight, time and convenience as established under the premise, substituting it into the lower cargo traffic assignment model, get the cargo traffic in the equilibrium condition of Railway Express Freight Transport bearing: $q^{1(0)} = 14922.0312$;

(3) Draw the derivative relations between cargo traffic and Cargo transport prices under the multi model transport conditions between A and B.$q^1 = 23888.7792 - 448.3374 \cdot u^1$;

(4) Take the reaction function into the target function of the upper model, and solve the upper programming problem: $y^{1(0)} = 26.934$yuan；

(5) Get the iteration step with one-dimensional search method. $\alpha^{(0)} = 0.9605$; Updated, and get a new railway freight transport price $u^{1(1)} \cdot L = 26.6604$yuan;

(6) The convergence judgment. Assuming the iterative precision ($\delta = 0.01$), to determine the existence of$\left(u^{1(1)} - u^{1(0)}\right) \cdot L \leq \delta$. If not, makes the$i = i + 1$, and go to the second step to continue operation.

Though the initial prices of the freight transport are different, finally get the optimal railway express freight transport price and cargo traffic distribution scheme: optimal transport prices is 26.66yuan, cargo traffic by rail transport is 11952.73ton, and railway freight transport income 318549.78 yuan.

The calculation results show that, though the initial railway freight different the final optimal solution is approximate. And this optimal solution can effectively guarantee the railway express freight benefit, also can get higher cargo sharing rate is 47.808%.

6 Conclusion

This article has taken the interests of the two aspects of cargo owner and freight transportation enterprise in consideration, and gives a bi level programming model to describe how to formulate a reasonable railway express freight price when various cargo transport modes between the two places to compete. In this model, we not only consider the security of cargo owners' minimum generalized freight cost, but also consider the railway express freight department can make to achieve greater economic benefits in the express freight transportation market.

The results show that: the selection probability of the cargo transport modes that the owners made is sensitive to the generalized transport cost. In the range of railway express freight transportation price reasonable, through the change of cargo transport price can adjust the cargo traffic distribution structure between A and B. So that the railway express transportation can be effectively adopt to the changes of the freight market. It can also enhance their market competitiveness and ensure a certain profit.

References

Gao Z. Y., SI B. F. (2001). The model and algorithm of railway passenger ticket price formulation under the market competition condition. *Traffic and Transportations Systems Engineering and Information Technology.*

Hui S. Q. (2014). Railway freight automatic pricing method research based on fuzzy AHP. *Automation and Instrumentation.*

Li, Y. Q. (2009). Research of China Railway Express Freight Transport Pricing Strategy. *Price Theory and Practice.*

Ma S., Chen L. J. (2011). The passenger dedicated railway freight optimization model on the multiple types of passenger travel choice. *Journal of Southwest Jiao Tong University.*

Tian B. F., GAO Z. Y. (2001) The optimization model and algorithm about reasonable formulation of railway passenger ticket price. *Journal of Management Science.*

Tang B. (2014). A study of railway express freight transportation based on modern logistics system. *Southwest Jiao Tong University.*

Yang H. (2000). Present situation of the development of Chinese railway express freight transport *Journal of Northern Jiao Tong University.*

Yang L. (2013). To discuss about carrying out the fast freight transportation on high speed railway in China. *China Railway.*

Characteristics of Resident Trips and Countermeasures of Transport Development in Nanchang, China

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Abstract: Based on the analysis about the indexes of trip time, trip distance and trip times, trips mode, trip purpose with the survey data of Nanchang city and other cities in China, the patterns and characteristics and causes of resident travels are summarized in this paper. The transport development policies are also suggested based on the resident travel characteristics such as development trend.
Keywords: City residents; Trip characteristics; Analysis and comparison; Transportation development policies; Nanchang city.

1 Introduction

With the acceleration of urbanization, the urban residents expand their trip areas; extend the trip time, and also the trip activities getting more and more diversified and complicated. In recent years, the rapid socio-economic development in Nanchang city and building with each passing day, the urban population increasing, all above resulting in urban traffic contradiction is sharpened. As of 2010, the resident population of Nanchang is 5.043 million, the quantity of automobile achieved 0.57million.

2 Analysis on the resident trip characteristics

2.1 Number of trips

The number of trips is residents' daily travel times, which reflects the residents who participate in the activities for the demand for travel in their daily life. The per capita number of travel is the ratio of total trips throughout the day and the total number of residents surveyed, it is an important indicator used to measure the status of urban trips. Per capita travel times data of Nanchang city and part of other domestic cities as shown in table 1.

Generally speaking, the bigger the scale of city, the lower of the average trip times. Nanchang residents average trip times in line with the stage of development characteristics, along with the rapid economic and social development in recent years of Nanchang, residents' trip demand shows a significant growth (Luo, P. C., 2002).

Tab.1 Per capita trip times of partial cities' residents

Name of city	Per capita trip	Survey year
Nanchang	2.61	2012
	2.59	2010
Beijing	2.64	—
Shanghai	1.79	1986
Guangzhou	2.55	2003
Jinan	1.68	1988
Wuhan	1.80	—
Qingdao	1.97	1993
Chengdu	2.16	1987
	2.43	2000
Changsha	2.33	—
Shenzhen	2.41	2003
Hefei	2.75	2007
Nanjing	2.75	2010

2.2 Trip purpose

Resident trip purpose structure usually represents the distribution of the trip purpose The time and mode of travel to different purposes tend to be specific. Therefore, the purpose of the trip can be used to infer the distribution of urban trip demand patterns and behavior patterns. Structure diagram of each trip purpose of different scale city is shown in figure 1.

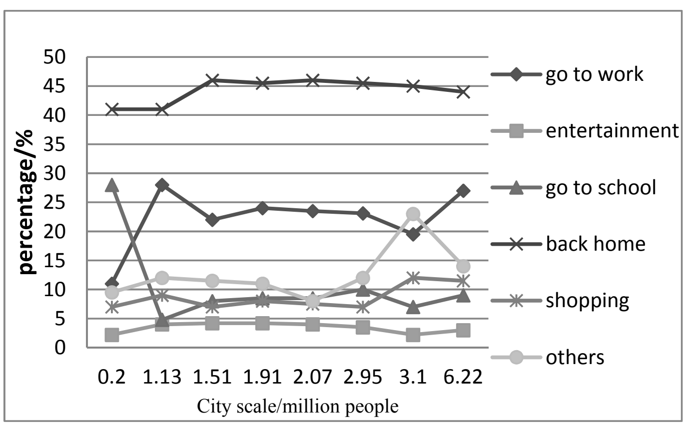

Fig.1 Structure diagram of each trip purpose of different scale city

Investigation data shows that, work, school and other commuter travel is still the main trip activities of residents in Nanchang, whose proportion is about 34.4%. In addition, for the purpose of life shopping trip accounts for 8.08% of the total number, agriculture as the main purpose of travel proportion about 1.41%. Different trip purposes structure map as shown in figure 2.

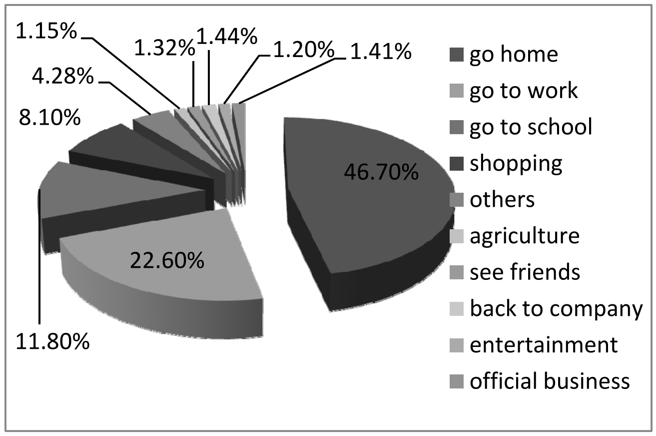

Fig.2 Structure diagram of trip purpose of Nanchang in 2012(total methods)

2.3 Trip time distribution

By the end of 2012, Nanchang civilian vehicle ownership was 0.57 million, 43400 more than last year (excluding scrap vehicles), the annual rate of 8.24%. Resident trip quantity distribution in different time period objectively reflects the pace of life in urban areas and the distribution of traffic demand in time, it is an important reference to analyze and solve the problem of peak hour traffic (Ou, Z., 2012).

Survey data show that residents travel show "twin peaks" (Pendyala, R. M., 2004) in the day time distribution, the morning rush hour ratio is 14.9% higher than 14.65% in 2002. Resident trip at noon also has two small peaks, time from 11:00 to 12:00 and 13:00 to 14:00 respectively and corresponding proportion is 7.47% and 6.81%. Figure 3 below is the residents travel time distribution map of Nanchang (Statistic Bureau of Jiangxi, 2008).

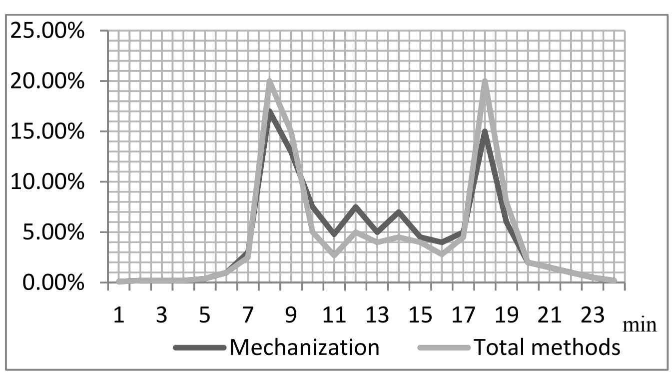

Fig.3. Resident travel time distribution map

2.4 Trip time cost

Urban resident one-way journey time from the starting point to the destination point is resident trip time, the average trip time is an important indicator of measuring a city the overall layout and travel range of rationality and efficiency of traffic (Yang,T., 2008). Traffic mode of its own characteristics, such as direct, flexibility, speed and path, directly determines the size of trip time. It can be seen from the statistical data that, the larger the city, the different purposes of resident trip time consuming smaller. As shown in Figure 4 and Figure 5.

Nanchang resident average trip time is about 25.3 minutes /time, compared with other city, average trip time less than Changsha, Wuhan, Hefei，higher than Shenzhen, as show in figure6(Zhou, Z. Y.,2008). Trip time of Nanchang city residents mainly focus on the short distance trip which usually takes 6-15 minutes or 16-30 minutes.

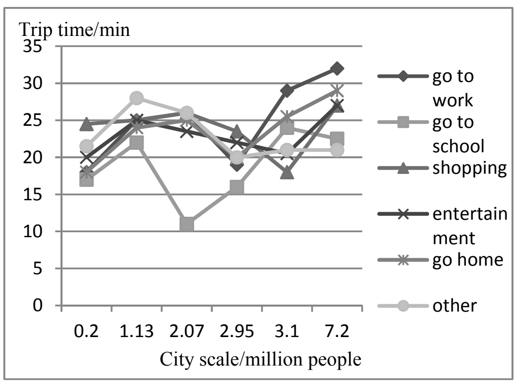

Fig.4 Residents travel time-consuming analysis diagram of different travel destinations

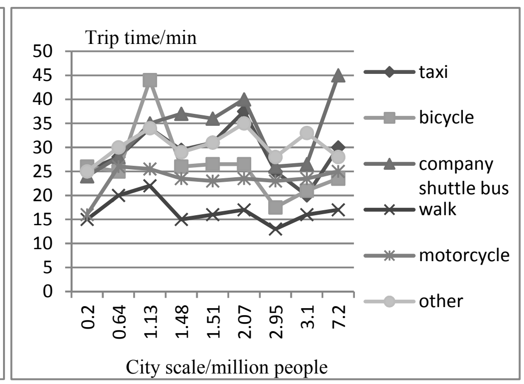

Fig.5 Residents travel time-consuming analysis diagram of different way to travel

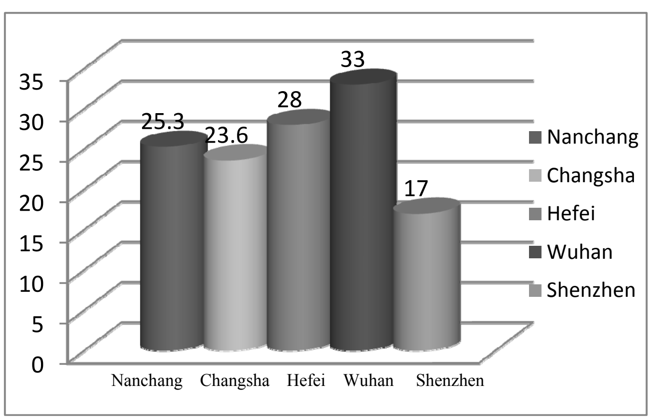

Fig.6 Nanchang city compared with the average travel time of other cities

2.5 Trip Mode Structure

Trip mode structure，generally refers to a collection of proportion used in a variety of means of transport which urban residents use, is an important symbol to reflect the development level of urban traffic(Deng, M. Y.,2000). Resident trip mode in general can be divided into public transport, bicycle, walking, motorcycles, taxis, cars and other units.

Nanchang resident trip motorization degree was 30.19%, which accounted for 7.5% of the motorcycle travel, car travel accounted for 6.26%, buses accounted for 13.8%; non motorized travel accounted for 57.44%, walking and bicycle accounted for 45.9% and 11.54%. Figure 7 below is the various transport modes sharing ratio diagram of Nanchang city residents.

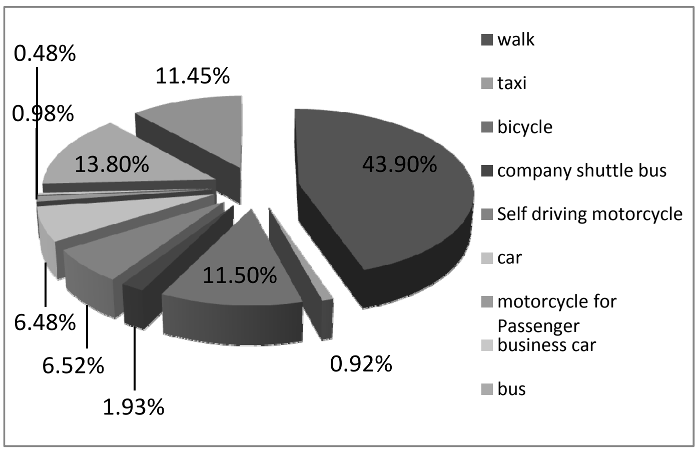

Fig.7 Structure diagram of residents travel mode

3 Analysis of the Main Reasons for the Changes of Resident Trip

(1) City infrastructure construction accelerated and people's trip environment improved. Traffic construction, focusing on the backbone road, transport infrastructure investment continues to a higher level. City infrastructure investment reached 26.94 billion yuan, the total road length up to 1581.57 km, a year-on-year increase of 192.76 km, city road, highway, transportation and other infrastructure scale has been effectively extended, the level of traffic supply further improved. Road construction focuses on the backbone road such as Chaoyang Bridge, Luoyang road tunnel, Jiuzhou elevated, Nanchang bridge overpass etc, at the same time, accelerate the construction of Nanchang West Railway Station, Longtou Gang port and city slow traffic project.

(2) The rapid development of public transport industry creates a good space for citizens to trip. 2012 year the relevant departments comprehensive launched a rail transit network update, urban transportation system planning, Gangkou Avenue project planning, traffic improvement and planning of surrounding Hongcheng big

market etc.

(3) The development of motor vehicle. Especially individual passenger car develop fast, traffic demand growth remains strong. 2012 Nanchang motor vehicle ownership continues to maintain rapid growth, by the end of 2012 motor vehicle ownership reached 0.526 million units, 43400 higher than the previous year, the average growth volume of car is 130 /day. Unceasing enhancement of Urbanization and motorization level, and the rapid development of economy, objectively stimulated the growth of traffic demand.

4 Traffic Development Countermeasure and Suggestion

Through analysis of the present situation of the trip characteristics of residents of Nanchang city and the future development trend, the next few years to improve the urban residents of traffic environment, guide and promote the formation of scientific and rational resident trip mode, the following three main countermeasures and measures need to taken, they are planning, infrastructure construction and management. Details are blow.

(1) To further implement the "Nanchang overall urban planning" (2001 - 2020), strictly control the total increment of center of urban construction, speed up the constructions of metro.

(2) Promoting the construction of urban road network in particular center city road microcirculation system construction, improve the density of roads network. To optimize the existing mode of transit network, continue to add new bus lines in the main passenger corridor and make the bus lines connected

(3)According to the domestic and foreign transportation demand management experience, combined with the traffic characteristics of Nanchang City, applying short-term and long-term combination principle to implement and improve traffic limit line measures. Giver the disordered condition of residents, non motor vehicles, electric vehicles and other slow traffic crossing the intersection, it is necessary to carry out long-term special work

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References

Deng M. Y. and Xie L. (2000). “Analysis on characteristic of the inhabitant trip and countermeasures of urban transportation development in Guangzhou city.” *City planning*, 24, 11, 45-49.

Luo P. C. (2002). "Analysis on characteristic of the inhabitant trip and countermeasures of urban transportation development in Fuzhou city." *Journal of Fujian Teachers University (Natural Science)*, 18, 2, 100-103.

John P. and John L. R. (2002). "Socioeconomics of Urban Travel Evidence from the 2001 NTHS." *Transportation Quarterly,* 57, 3, 12.

Ou Z. (2012). "Research on city residents trip behavior and characteristics." *Ms D Thesis. Changsha: Changsha University of Science & Technology.*

Pendyala R. M. and Bhat C. R. (2004). "An exploration of the relationship between timing and duration of maintenance activities." *Transportation*, 31, 4, 429-45.

Statistic Bureau of Jiangxi (2008). "Jiangxi Statistical Yearbook 2013." <http://www.jxstj.gov.cn/resource/nj/2013CD/indexch.htm>

Yang T. (2008). "Public transit user satisfaction: variability and policy implications". *Transport Policy*. 4, 7-208.

Zhou Z. Y. and Jiang Z. H. (2008). "Analysis on resident trip characteristics in part of Chinese cities." *Journal of Wuhan University of Technology*, 32, 3, 554-557.

Synergetic Analysis of the Public Transit System and Urban Form for Small- and Medium-Sized Cities

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Abstract: Based on the characteristics of small and medium-sized cities, this paper establishes a coordination degree evaluation index system of the public transit system and the urban form. The coordination degree is obtained with the values of the sequential variables from the principal component analysis, by using the coordination degree calculation model. Sample data was obtained from different years of Danyang, Suzhou and Tongling. By comparing the analysis of the coordination degrees of different years in different cities, the number of bus routes, coverage percentage of the public transport station, downtown area and population as well as the road mileage was found as the main influencing factors of the coordination degree of the public transit system and the urban form of small and medium-sized cities.

Keywords: Small and medium-sized cities; Public transit system; Urban form; The evaluation index system; Coordination degree.

1 Introduction

The suitable public transportation mode for different forms of urban development is also different. With the accelerating process of urbanization process in china, the synergetic analysis of public transit system and urban form for small and medium-sized cities is very necessary. This paper takes public transportation development and urban form of the small and medium-sized cities as researching object, selects representative indicators to build the evaluation index system, analysis the mutual relationship of the two systems, estimates their coordination degrees. Some recommendations are given according to the results to guide the coordinated development of public transport and urban form.

2 Coordination degree evaluation index system

The evaluation index system should be able to measure changes in different periods of development level of a city, and can evaluate differences in the levels of different cities during the same period.

2.1 The evaluation index system of urban form

Unlike the multi-centered character of most metropolitan, small and medium-sized cities are mostly monocentric, and the land-use characteristics identifies to be determinants of transit demand were the size of downtown. With the continuous development of our country and the acceleration of urbanization and economy, the rapid development of industrial needs more labor and the countryside surplus labor force gradually flocked to the cities, the urban population has been increasing, leading to the expand of the scale of urban land and the development of urban roads and more traffic demand. According to all this characteristics, the evaluation indexes are chosen and shown in the following table.

Table 1.The evaluation index system of urban form

Objective	Index	
Urban form development level index	c_1-city area(km^2)	c_2-downtown area(km^2)
	c_3-center population(Million)	c_4-city population(Million)
	c_5-GDP(billion)	c_6-the proportion of the second industry GDP
	c_7-road mileage(km)	

2.2 The evaluation index system of public transport system

Compared with some metropolitan, the development of public transit system in small and medium-sized city is relatively slow, and has its own characteristics. (1) The public transit network layout is unreasonable, bus lines tend to focus on a few main streets of the city center, and the non-linear rate coefficient is higher due to the development status of small and medium-sized cities. (2) The service of public transit is circumscribed and inconvenient compared with electric bicycles. (3) The input number of bus and per capita is less. (4) Lacking of bus terminals, and basically priority is given to roadside parking. (5) Public transit trip contribution rate is low, and the trip time consume is longer. According to all this characteristics, the evaluation indexes are chosen and shown in the following table.

Table 2. The evaluation index system of public transport system

Objective	Index	
The public transport system development level index	x_1-urban bus lines	x_2- urban and rural bus lines
	x_3- bus lines total mileage(km)	x_4-public transit network density (km/km^2）
	x_5-repetition coefficient of transit network	x_6-coverage percentage of the public transport station(300m)
	x_7-coverage percentage of the public transport station(500m)	x_8-million people have bus number
	x_9-parking area per bus(m^2)	x_{10}-day bus passenger flow volume
	x_{11}-public transit trip contribution rate (%)	x_{12}- bus trip time consume(min)

3 Coordination degree evaluation model

Referencing the capacity coupling coefficient model in physics, the coupling degree model of urban form and transit system is as follows:

$$U = \sqrt{\frac{F(x)G(y)}{\left[F(x)+G(y)\right]^2}} \tag{1}$$

With $\mathrm{F}(\mathrm{x}) = \sum_{i=1}^{n} a_i x_i^{'}$, $\mathrm{G}(\mathrm{y}) = \sum_{j=1}^{m} b_j y_j^{'}$

$F(x)$ is the evaluation function of public transit system, $G(y)$ is the evaluation function of urban form system. The coefficient a_i and b_j are the values of the sequential variables obtained from the principal component analysis using the sample data. The scope of the coupling degree U is $[0,1]$. Coordination degree model based on the coupling degree model can better evaluation the interaction of two systems, its formula is:

$$\Phi = \sqrt{U * T} \tag{2}$$

With $T = \alpha F(x) + \beta G(y)$, α and β are the undetermined coefficient.

Through the above steps, the coordination degree of small and medium-sized city public transportation and urban form can be obtained. Then contrasting table 3, comprehensive evaluation is reached.

Table 3. Hierarchy of coordination degree

Coordination degree	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5
evaluation	Extreme imbalance	serious imbalance	Severe imbalance	Mild imbalance	Closed to imbalance
Coordination degree	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1
evaluation	Reluctant coordination	Primary coordination	Intermediate coordination	Good coordination	Quality coordination

4 sample data analysis

Danyang, Suzhou, Tongling, which are Chinese typical small and medium-sized cities, are currently in the accelerating period of urbanization. This article selects the relevant data of Danyang in 2006, 2010, 2014, Suzhou in 2006, 2013, and Tongling in 2011, 2012 as sample data, the coordination degree between the urban form and public transit system are computed and analyzed by the coordination degree model constructed before. The sample data as shown in table 4:

Table 4. The sample data

index	Danyang 2006	Danyang 2010	Danyang 2014	Suzhou 2006	Suzhou 2013	Tongling 2011	Tongling 2012
x_1	3	6	17	18	15	23	27
x_2	20	20	16	44	64	26	26
x_3	26.4	64.5	216.1	169.6	236.67	365	412.1
x_4	0.88	3.18	5.40	3.46	2.74	2.81	3.41
x_5	1.31	1.69	2.2	1.93	1.74	1.95	3.07
x_6	29.34	44.67	57.2	54.9	47.6	46.85	44.06
x_7	51.23	70.00	88.3	79.6	73.9	86.35	75.83
x_8	2.8	3.3	3.9	4.71	4.87	10.3	14.83
x_9	52.6	49	68	137.98	136.2	96.02	80.242
x_{10}	60300	67888	69877	96539	114657	109585	128767
x_{11}	3.37	2.5	4	13.2	8.6	10.75	18.7
x_{12}	22.7	22.7	28	30.39	24.1	32.1	24
c_1	1047.44	1047.44	1047.44	9077	9787	1113	1187
c_2	28.3	35.8	40	36.7	68.2	48.9	50.32

c_3	25.6	24.5	30.3	41.7	57.5	43.2	44.76
c_4	80.7	80.9	81.3	600	649.2	73.99	74.21
c_5	430.2	607.67	925.15	359.01	802.4	466.6	621.3
c_6	60.0	56.8	52.3	27	40.6	72.8	73.4
c_7	1989	2084	2140	10789	12612	1109	1258

4.1 Calculation steps and calibration of model parameters

(1) In order to eliminate the influence of different dimensions, the sample data is standardized into [0-1].

(2) Using SPSS software to do the principal components analysis. Taking public transit system as an example, the result is as following table:

Table 5. Eigenvalues of public transit system

component	Initial Eigenvalues			Extraction of sum of squares loaded		
	eigenvalue	variance	cumulative	eigenvalue	variance	cumulative
1	6.38730	53.2275	53.22751	6.38730	53.2275	53.22751
2	2.76350	23.0292	76.25674	2.76350	23.0292	76.25674
3	1.75361	14.6134	90.87016	1.75361	14.6132	90.87016
4	0.81905	6.82543	97.69559			
5	0.23314	1.94287	99.63846			
6	0.04338	0.36153	100			

Table 5 is the eigenvalues of public transit system output of the SPSS software. As can be seen from the table: the variance contribution of the first principal component ratio is 53.23%, the accumulative variance contribution rate of the first three principal components reached 90.87%, so the three main components are appropriate.

(3) Then according to the sample eigenvector table of correlation matrix output of the SPSS, the first principal component of public transit system is obtained:

$$F_1(\mathrm{x}) = 0.989x_1 + 0.306x_2 + 0.925x_3 + 0.518x_4 + 0.790x_5 + 0.615x_6 + 0.775x_7 + 0.762x_8 + 0.573x_9 + 0.862x_{10} + 0.834x_{11} + 0.550x_{12}$$

The second principal component is:

$$F_2(\mathrm{x}) = -0.086x_1 - 0.173x_2 - 0.201x_3 + 0.731x_4 - 0.151x_5 + 0.748x_6 + 0.598x_7 - 0.501x_8 - 0.021x_9 - 0.445x_{10} - 0.444x_{11} + 0.480x_{12}$$

The third principal component is:

$$F_3(\mathrm{x}) = 0.019x_1 + 0.892x_2 - 0.193x_3 - 0.283x_4 - 0.498x_5 + 0.132x_6 - 0.0739x_7 - 0.384x_8 + 0.811x_9 + 0.191x_{10} + 0.020x_{11} + 0.157x_{12}$$

According to the variance contribution of each principal component, the evaluation function of public transportation development level of small and medium-sized city is:

$$\mathrm{F}(\mathrm{x}) = 0.511x_1 + 0.282x_2 + 0.424x_3 + 0.379x_4 + 0.309x_5 + 0.505x_6 + 0.526x_7 + 0.242x_8 + 0.451x_9 + 0.406x_{10} + 0.362x_{11} + 0.420x_{12} \quad (3)$$

Similarly, the evaluation function can be obtained for the urban form:

$$\mathrm{G}(\mathrm{c}) = 0.585c_1 + 0.575c_2 + 0.607c_3 + 0.582c_4 + 0.218c_5 - 0.364c_6 + 0.584c_7 \quad (4)$$

(4) Taking the standardized data into the evaluation function just got above of both systems (formula 3, 4), the quantitative evaluation results would be calculated, as following table:

Table 6. Quantitative evaluation results

years / index	DY 2006	DY 2010	DY 2014	SZ 2006	SZ 2013	TL 2011	TL 2012
Public transit system	0.061	0.989	2.520	3.121	2.659	3.235	3.359
Urban form	0.160	0.227	0.355	1.999	2.998	0.315	0.445
DY represents Danyang, SZ represents Suzhou, TL represents Tongling							

(5) To use the coordination degree model, the value of α and β should be determined firstly. In practical application, keeping the values range of T $[0,1]$ to ensure the coordination degree is between $[0,1]$. With this qualification, the inequalities are as followed:

$$\begin{cases} 0 < 0.061*\alpha + 0.160*\beta < 1 \\ 0 < 0.989*\alpha + 0.027*\beta < 1 \\ 0 < 2.520*\alpha + 0.355*\beta < 1 \\ 0 < 3.121*\alpha + 1.999*\beta < 1 \\ 0 < 2.659*\alpha + 2.998*\beta < 1 \\ 0 < 3.235*\alpha + 0.315*\beta < 1 \\ 0 < 3.359*\alpha + 0.445*\beta < 1 \end{cases} \quad (5)$$

To obtain the optimal solution, namely the $\Phi = \sqrt{U * T}$ has the maximum value, write a program using MATLAB software, and the result was reached- $\alpha = 0.2918$, $\beta = 0.0447$, $T = 0.2918F(x) + 0.0447G(y)$.

(6) Lastly, coordination degrees were calculated according to the formula (2), compared to table 3, the evaluation of coordination degrees were obtained, as in the following table:

Table 7. Coordination degrees

	DY2006	DY2010	DY2014
Φ	0.11	0.34	0.50
evaluation	Extreme imbalance	Mild imbalance	Reluctant coordination
SZ2006	SZ2013	TL2011	TL2012
0.70	0.67	0.52	0.57
Primary coordination	Primary coordination	Reluctant coordination	Reluctant coordination

4.2 results analysis

By the calculated results and the contradistinctive analysis between different years and different cities, it is found that:

The largest weight influences index accounted for Small and medium-sized city public transportation system is urban bus lines, the second is coverage percentage of the public transport station. Urban bus lines index is the most straightforward indicator for public transit system, and the coverage percentage of the public transport station index is the most direct indicator for the public transport system and city form. In figure 1, the two indexes and the quantitative evaluation results of both two systems and the coordination degree have similar trends. It can be inferred that reasonable increase of bus lines and the reasonable layout of bus stops to increase site coverage can effectively improve the coordination degree of two systems in small and medium-sized cites.

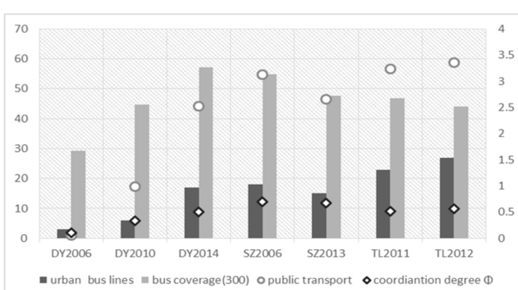

Figure 1. Results contrast

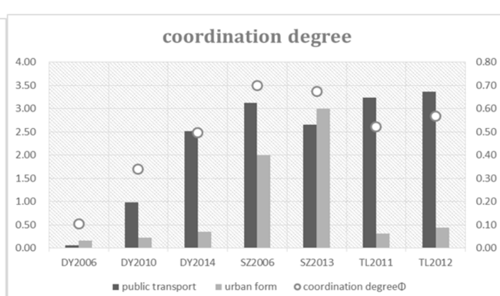

Figure 2. Coordination degree contrast

From table 7 and figure 2, it is found that, on the whole, small and medium-sized cities in our country, as well as the public transport system is constantly moving forward, however the two development is not in coordination. In this situation, consummating public transit system and setting up the integration of urban and rural public transportation system are recommended to guide city development from single-center to multi-center development model.

5 Conclusions

This paper establishes a calculating method and model of coordination degree between urban form and public transit system. The sample data analysis proves the model is effective for small and medium-sized cities. The number of bus routes, coverage percentage of the public transport station, downtown area and population as well as the road mileage was found as the main influencing factors of the coordination degree of the public transit system and the urban form of small and medium-sized cities. From these aspects, improvement strategies can be given.

6 Recommendations for Future Research

The coordinating development of public transit and urban form is important, the synergetic analysis of public transit system and urban form for small and medium-sized cities means a lot. However, due to the limited sample data, this paper has its limitations on representativeness. In future research, more indexes and more sample data may be chosen.

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References

Dadhich, P.; Hanaoka, S. (2012). Spatial investigation of the temporal urban form to assess impact on transit services and public transportation access. Geo-spatial Information Science.

Daniel A.; Eric J. (2000). Transportation-land-use interaction: empirical findings in North America, and their implications for modeling. Transportation Research Part D.

Frank, L.D.; Pivo, G. (1994). Impacts of mixed use and density on utilization of three modes of travel: single-occupant vehicle, transit, and walking. Transportation Research Record.

HUANG S.; MENG J.Y.; WANG X.Y. (2011). Evaluation system for public traffic in the small and medium-sized cities. Journal of Transport Information and

Safety.
Kano, M.; Hasebe, S.; Hashimoto, I.; Ohno, H. (2001). A new multivariate statistical process monitoring method using principal component analysis. Computers and Chemical Engineering.
Smith, W. (1984). Mass transit for high-rise, high-density living. Journal of Transportation Engineering.

Revelation of America's VMT Charging Mode to Chinese Highway Financing

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Abstract: Charging the road users basing on vehicle miles of travel (VMT) is seen by many analysts and policy makers as a potentially viable way to generate revenues while maintaining the idea that users should pay for the system. In 2009，American issued the National Cooperative Highway Research Program (NCHRP), aiming at exploring proposals that might be implemented more quickly, possibly enabling nationwide adoption of direct usage-based charges by 2015. After finishing the oil taxes reform in 2009, China also entered the Era of Fuel Tax. With technological progress and the reform accelerating, China will inevitably encounter many problems in the fuel taxes, which are used in highway financing. This paper primarily introduces China financing model, and expects we can learn from American experiences to improve China's highway financing model.
Keywords: VMT fee; Fuel taxes; Highway financing.

1 Introduction

Chinese oil taxes reform was implemented beginning on January 1, 2009, it raised unit tax amount of refined oil consumption tax. This reform can have a dramatic effect on the structure of highway financing in China. Since then, China has already entered the Era of Fuel Tax. Meanwhile, according to the requirements of the American Association of State Highway and Transportation Officials (AASHTO), also as part of the National Cooperative Highway Research Program (NCHRP) Project 20-24(69),the government planned to charge the road users directly based on vehicle miles of travel (VMT) --the United States is beginning the Era of VMT Charging.

At present, China is in the early stages of the Era of Fuel Tax, there will be a long way to enter the Era of VMT Charging. America's advanced technologies and the development concepts, in the process of implementation of fuel tax, wiill have significance for China. China may learn from its experience and avoid the same difficulties and bottlenecks in its development. More importantly, the relevant research associated with VMT can constantly improving and refining china's highway financing means.

2 VMT charging mode in the United States

In the past century, Vehicle fuel consumption tax had been the main mechanism of generating revenue in the United States federal and state. Although it had many remarkable advantages, but utility they play was limited by the structural and political factors over the coming decades. This led to an idea arising through highway service system instead of the fuel tax. The idea implements through modern traffic electronic toll collection technology, and bases on vehicle mils of travel (VMT). VMT charge can overcome challenge about income from fuel charge, but also provides a solution to implement other policy goals.

2.1 The decline in fuel tax

In the United States federal and many state, vehicle fuel taxes are levied on a per gallon. The unit tax should be raise on a regular basis so as to reduce the impact of inflation and burn up lower. Furthermore, as an anti-tax thought spread in public, U.S. officials have become more cautious on the work, which is unwelcome in politics. At the same time, the frequency and magnitude of the recent raising price has been not enough to maintain comparable purchasing power according to the real income per mile.

2.2 Attraction of VMT charges

VMT charge is based on miles of travel rather than fuel consumption quantity or type, such a system will eliminate the concerns of the fuel consumption lower or the new energy vehicles widely used. In addition, if the system can determine where the vehicle has travelled, the revenue stream from it will be able to accurately split into multiple administrative jurisdictions. Other potential benefits may include reducing traffic congestion, mitigating the adverse effects of pollutants on the health, and reducing the potential threat from climate change. For example, improving mileage charge price on the busy route can inhibit the traffic congestion, the same measurement for the larger polluting vehicles can effectively protect the environment.

2.3 fuel tax vs. VMT charges

Table 1 shows the trend of the growth percentage of VMT and fuel consumption since 1997. As reflected in the table, fuel consumption growth tends to decline gradually, and VMT is falling shortly, but there has been a rising trend. If the trend continues, as many people had expected, the effectiveness of the fuel tax to meet transportation financing will continue to decline in the coming days. It also suggests it is necessary to implement the VMT charge.

3 Cases Of VMT fees In the United States

According to the requirements of the American Association of State Highway and Transportation Officials(AASHTO), American introduced an implementation strategy report in 2009 that sources of funding for transport can be direct usage-based charges, the government plans to charge the road users directly based on vehicle miles of travel (VMT).

3.1 Type of VMT

(1) Press mileage charges. This kind of VMT charging model mainly involves light vehicles (such as car), it can also apply to the truck.

(2) Heavy long-distance truck toll. Similar to the first type in concept, the major

difference is that it only applies to charging for heavy goods vehicle and it takes different charging standards according to the different degree of road wear caused by different weight of the vehicles.

(3) Pay premiums and rental fees by mileage. Vehicle insurance and rental costs tend to be fixed during a fixed period (such as $ 1000 a year on premiums). The charge principle of paying premiums and rental fee by mileage is to calculate the cost on the basis of mileage, that is, less driving, less pay.

With regard to three types of VMT fees, that is, universal fees based-on mileage, heavy long-distance freight fees and paying insurance expenses and rental fees based-on mileage, lots of areas have successfully implemented and obtained good results in American.

Table 1. Growth percentage of VMT and fuel consumption

Years	VMT	Fuel consumption
1997	--	--
1998	3.0%	2.9%
1999	5.4%	6.5%
2000	7.6%	7.5%
2001	9.5%	7.2%
2002	11.9%	11.9%
2003	13.3%	13.4%
2004	16.1%	16.1%
2005	17.2%	16.5%
2006	18.1%	13.9%
2007	18.7%	14.6%
2008	16.5%	11.2%
2009	15.9%	9.4%
2010	16.2%	--

Source: American Highway Statistics 1997-2010

3.2 Universal Charging Based-on Mileage: Oregon Transportation Department pilot project

According to the state legislature's instructions, Oregon department of transportation planed and implemented mileage charge and a wide range of congestion charge study. During the period of 12 months, from 2006 to 2007, the pilot project involves 285 cars, 299 drivers, and two gas stations. The OBU is connected to the GPS receiver to detect whether the vehicles drive in these two areas, and odometer is used for the measuring of distance. Then mileage data is transmitted to the two gas stations by radio, thus, the gap between fuel tax the mileage fee is calculated. After the conventional fuel taxes has been paid, vehicle drivers are divided into two parts to test different pricing concept.

In a certain area, Some drivers need to pay the fixed costs 1.2 cents per mile. While the other drivers need to pay 10 cents per mile in the "traffic congestion areas" in rush hours, yet in other driving time it reduces to 0.43 cents per mile. The owners of vehicles don't need to pay the new fees at gas stations, but they will receive payment account document at the end of the research. In this study, both of the two groups will reduce their total VMT, and the technical effect is remarkable.

3.3 Heavy Long-distance Freight Fees: Austria administration project

Austria administration has implemented the freight charge project successfully in January, 2014, which is managed by Europpass company (subsidiary of the Italian highway). This project applies the mileage charge to the vehicles whose permitted loaded mass is more than 3.5 tons, charge grades depend on the varied weight class and the axle number. In order to participate in this project and avoid the inconvenience of artificial paid, each vehicle need to install the particular DSRC (dedicated short-range communication) vehicle-loaded device, which transmit data through different elevated stations set in the highway system. When the vehicle passes through one of the 420 benches distributed across the network, mileage charge is motivated. If the bench did not perceive a vehicle- loaded receiver, the vehicle will be marked with suspected fee evasion.

3.4 Paying Insurance Expenses Based-on Mileage: Massachusetts project

In April 2008, Massachusetts has introduced the vehicle insurance, with characteristics of bidding. Before that the rate of insurance fees was set by state itself. The insurance company provides discount for the owners of vehicle who drive few miles. For annual mileage between 0 and 5000 miles, there is a discount of 10 percent. However, if annual mileage is between 5000 and 7000 miles, the discount reduces to 5 percent. Their Mileage will be verified by the department of motor vehicle registration in Massachusetts.

4 Highway Financing in China

4.1 Highway Financing In China before 2009

Before the fuel tax reform, China implemented a kind of highway financing mode, which is loans to build and tolls to pay. Although this approach plays an important role in easing the lacking funds for construction and maintenance of china's highway, it also exists many problems.

Table 2 is the related data of china highway financing from 2004 to 2008. The national budget funds rose in 2008, other years are in decline, and each year at about 2%, this shows that the Chinese government in the highway financing support needs to be improved.

Domestic lending has always been an important means of financing, such high bank loans will lead to higher risk of financing, which is not a long-term solution to solve the problem of financing.

Utilization of foreign capital accounts for only around 1%, which shows it is unable to mostly rely on foreign investment in highway construction and maintenance.

Table 2. China's highway financing structure

Year	budgetary funds	Vehicle purchase tax	Domestic loans	foreign capital	Self-raised funds	Last year balance
2004	3.1%	11.0%	40.5%	1.3%	39.3%	4.8%
2005	2.4%	10.3%	38.2%	1.3%	43.1%	4.7%
2006	1.5%	9.0%	40.7%	0.9%	42.5%	5.4%
2007	1.4%	12.1%	38.0%	0.8%	43.8%	3.9%
2008	2.5%	11.8%	36.4%	1.0%	43.7%	4.6%

Source：2004-2008 Statistical bulletin on road and waterway industry transportation development

4.2 Highway Financing In China after 2009

After finishing the oil taxes reform, the traditional "loan to build roads, charge to repay loan" is in the role of decreasing in the ordinary highway financing system. The positive phenomenon brought by the fuel tax reform will be also gradually revealed.

Fuel taxes will be as the main source of funds of ordinary highway construction and maintenance, the reform leads to greatly reduce dependent on domestic lending and state investment, and gradually realize the virtuous cycle of investment and financing environment.

5 Revelation of VMT charging mode

China is at the beginning of the "era of fuel tax", there is still a long way to go to the "VMT charge era". According to the existing situation in china, when to implement VMT fee is still unknown. But along with the rapid development of economy and technology, it is possible to develop the fuel tax.

United States has the problems in the process of implementation of fuel tax, such as due to the effects of inflation, it is still suffering from the threat of loss of purchasing power with fuel tax rate gradually increase. Saving fuel cars and new energy vehicles make people use less fuel, china could also meet the same problems.

Therefore, China should draw lessons about development technology and the development idea in the process of implementation of fuel tax from United States. Meanwhile, it is necessary to prepare VMT records of relevant data and implement plan research in advance.

(1)Building research institute, which increasing devotion of manpower and material resources of VMT research to find out feasible solutions.

(2)Introducing foreign advanced technology and ideas, making some experiment for the foreign VMT measurement method with the domestic situation, recording the domestic vehicle VMT data.

(3)Making the vehicle-mounted device research effort. According to the region classification, planning and registering the existing vehicles.

(4)Increasing public awareness and education, which make the public aware of the meaning of VMT measurement in the long term.

Acknowledgement

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References

Bertini, R. L., K. Sullivan, K. Karavanic, H. Hagerdorn, and D. Deeter. (2002). "Data Transmission Options for VMT Data and Fee Collection Systems". *Oregon Department of Transportation*.

Donath, M., A. Gorjestani, C. Shankwitz, R. Hoglund, E.Arpin, P.M. Cheng, A. Menon, and B. Newstrom. (2009)."Technology Enabling Near-Term Nationwide Implementation of Distance Based Road User Fees". CTS09-20, Intelligent Transportation Systems Institute, University of Minnesota, June.

Forkenbrock, D. J. (2006). "A Mileage-Based Road User Charge – Overview and Discussion of Key Concepts". Public Policy Center, The University of Iowa.

Kuhl, J.G. (2007). "Project Overview: National Evaluation of a Mileage-Based Road User Charge".Public Policy Center, University of Iowa.

National Statistical Yearbook(2000-2009), www.stats.gov.cn.

NSTIFC(2009). "Paying Our Way: A New Framework for Transportation Finance.Report of the National Surface Transportation Infrastructure Financing". Commission. Feb, 26.

Sorensen, P. and B.D. Taylor(2005). "Review and Synthesis of Road-Use Metering and Charging Systems, submitted to the Committee for the Study of the Long-Term Viability of Fuel Taxes for Transportation Finance". Transportation Research Board, Washington, D.C.

Urban construction theory research(2011). "twelfth five-year" highway construction investment and financing analysis.

Whitty, J.M.(2008). "Innovative Alternatives to the Fuel Tax as a Primary Road Funding Source: Oregon's Point-of-Purchase Mileage Charge Collection Pilot Programme". *Journal of Public Works & Infrastructure*. 1(1), 7-19.

Analysis for Deciding Intercity Rail Fares

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Abstract: With the deepening of concept of urban agglomerations and the gradual development of the China's urbanization, China's urban intercity railway is also planning to enter the big construction phase. And with the development of inter-city railway the contradictory between immature pricing theory and rapid formation of intercity railway network has also increasingly been prominent. Ticket revenue is the main source of income for intercity railway and the income is mainly determined by the price and number of passengers. What we want is the best price so the price is the only variable quantity in this paper. The number of passengers is determined by the share rate. Therefore, this paper introduce random utility theory to solve the intercity rail passenger share rate. Share rate is affected by these five factors: price, speed, convenience, comfort and safety. This paper will use AHP to solve weights in random utility. At last the intercity railway benefits will be represented by a function where the intercity rail fare rate is only variable quantity. When this function takes the maximum value we can obtain the best price.
Keywords: Intercity rail; Ticket; Pricing; Random utility theory; Maximum benefit.

1 Introduction

With the gradual development of urbanization in China and the concept of urban agglomeration will be accepted by more people especially from 2008.With four trillion RMB invested into infrastructure, the planning and construction of intercity rail is going to a new high level. Today, almost provinces have developed a large-scale inter-city rail network planning. Meanwhile almost every province has already started construction of intercity rail even completed. For example the intercity rail between Wuhan and Xianning and is completed and the intercity rail between Changsha, Zhuzhou and Xiangtan will be completed. For such an emerging model of transport which has huge investment in intercity rail and costs a lot in the latter. If the operator can not make their own sound competition policy to fight for promoting their share of the transport market, the intercity rail may not be able to succeed in competition with other modes of transport. Intercity rail is generally short-distance transport in urban agglomerations but the main transport in urban agglomerations is short-distance intercity bus in previously time. So Intercity bus will be set as the main competitor intercity railway in this article, thus analyzing how to develop intercity rail fares.

1.1 Literature survey

Chang Myong-Hun proposed a tariff computing model which is based on utility theory.However the specific function expression and parameters are different from practical so this model is rarely used in the real life. Leon and Harold analyze the impact of high-speed rail to other transport modes and change other factors into time scale.Then they analyze transportation choice mode in passenger corridor.Ye Pei used system dynamics optimization model for studying high-speed rail fares.Based on the principles of effectiveness in economic Wei Anqing used efficiency guideline of transport fare to analyze the baes fare in Chengdu-Chongqing high-speed rail.

Through literature analysis we can find out models are difficult and we should collect a lot of data.The innovation of thsi paper is not to obtain the maximun benefit but through the derivation of intercity bus benefit model to obtain the best fare.

2 Establish intercity rail efficiency model

Intercity rail benefits are mainly from turnover and turnover is determined by the number of people aboard and fares so we can establish intercity rail revenue model.

The main function:

$$Z_s = F^{AB} \times P_s \times (\overline{u_s} - \overline{C}_s) \times d_s{}^{AB} \qquad (1)$$

It is the objective function to be solved.Because in this function the only variable quantity is $\overline{u}_s$ so we can obtain the maximun value of $\overline{u}_s$ which is the best fare of the intercity rail through the derivation of formula (1).

Constraints:

$$Z_s \geq o \qquad (2)$$

Transportation revenue must not be negative.Because the transportation company does not lose money intentionally.

$$F^{AB} \times P_s \leq G_s \qquad (3)$$

The actual traffic does not exceed the maximum transport capacity.If the actual traffic exceed the maximum the transport company will be overload.It is dangerous for passengers.

$$\sum_{s=1}^{y} p_s = 1 \tag{4}$$

Each passenger is bound to select a given way to travel.In this paper there are only two ways which are bus and intercity rail.

z_s :The benefit of transporter s;

F^{AB} :The population of district A who want to go district B;

p_s :Share rate of transport s;

$\overline{u_s}$:Average fare rate of transport s which is the only unknown quantity;

$\overline{C_s}$:Cost per kilometer of transport s ;

d_s^{AB} :Distance of transport s;

G_s :Maximum transport capacity of the transports.

2.1 How to calculate p_s

In this article we use random utility to calculate p_s .

According to Logit model, we propose the concept of generalized income-' δ_s '.generalized income does not refer to a specific income but it is comprehensive benefits.In the generalized income function,we selected economy,fast,comfort, secure and convenience of these five factors to determine the p_s .The expression of δ_s is:

$$\delta_s = \frac{\theta_1 \times U_s + z_{fxs} \times \theta_2 + z_{fos} \times \theta_3 + z_{fls} \times \theta_4}{\varphi_f \times \theta_5} + \psi \tag{5}$$

ψ :Undetermined coefficients;

θ_i :Weight factors.

Then using utility theory immediately(Jiang Jinliang,2012)We can get the relationship between p_s and δ_s .

$$p_s = \frac{\exp(-0.01\delta_s)}{\sum_{f=1} \exp(-0.01\delta_s)} \tag{6}$$

Next we will quantify these five factors

(1)Economy.Generally speaking the lower fare the more likely passengers will chose this way to travel.

$$U_s = \overline{u_s} \times d_s \tag{7}$$

U_s :The price of transport s.

(2)Fast.People will chose the way to travel that costs less time.

$$z_{fxs} = \frac{d_s}{X_s} \times \overline{T_f} \tag{8}$$

z_{fxs} :Earnings of quickness of passenger;

X_s :Average speed of transport s;

$\overline{T_f}$:Value of unit time.

$$\overline{T_f} = \frac{GDP}{N_p \times N_t} \tag{9}$$

N_p :The total population of the country;

N_t :Working hours a year.

(3)Comfort.Comfort is a major factor that people should consider especially the higher income people.

$$z_{fos} = O_s(t) \times \overline{T_f} \tag{10}$$

$$O_s(t) = E / \left[1 + \alpha_s \times e^{\left(-\beta_s \times \frac{d_s}{X_s}\right)} \right] \tag{11}$$

z_{fos} :Earnings of comfort of passenger;

$O_s(t)$:Fatigue recovery time of passenger in travel;

E :Limit time required for recovery;

α_s , β_s :Undetermined coefficients.

According to existing research,E=15, α_s =59, β_s =0.29(YI Fujun,2009).

(4)Secure

From existing research about passenger transport safety, most scholars have tended to use ‘safe credibility’ to measure a transportation security.And the ‘safe credibility’ φ_f of intercity rail is 1(Pietro Zitoa, Giuseppe Salvoa, Luigi La Francaa,2011).

(5)Convenience.Ease of access to services is increasingly becoming an important factor when people consider how to travel.When there is no transfer between the transportation and the subway the transportation will attract many people.

$$z_{fls} = L_s \times \overline{T}_f \quad (12)$$

z_{fls} :Earings of convenience of passenger;

L_s :Time from the residential area to the station.

2.2 Factors weight analysis

Accoeding to the classification of passenger the factors affect passenger share rate of intercity may be simplified following factors:Fare, speed, comfort, safety and convenience.The research will focus on five factors.

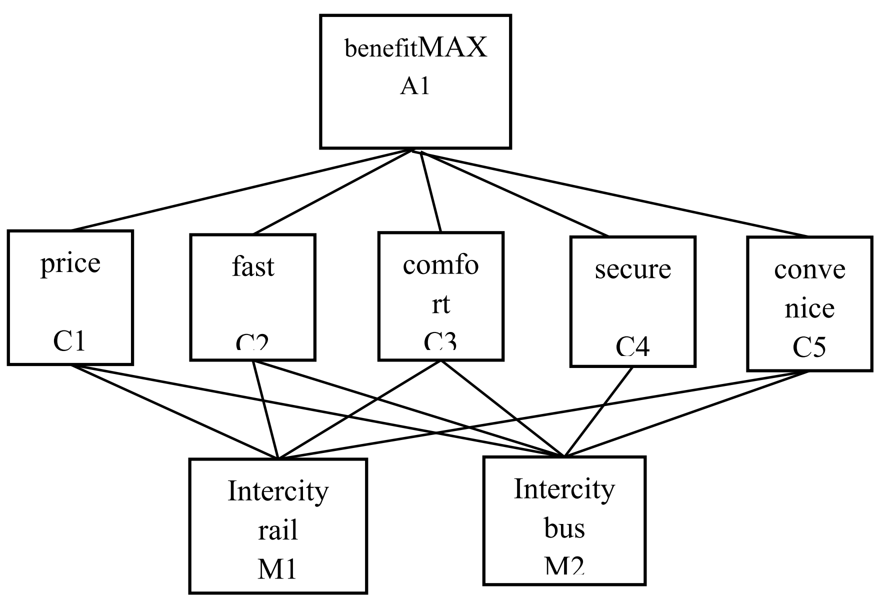

Figure 1.Analytical Hierarchy Figure

According to this multilayer structure,We can more clearly aware of the competition between the operators and passengers and relatonship between the factors and decisions.Based on this model many scholars have proposed the corresponding calculation approach to solute weight(Guo Chunjiang,2010)This article will use the AHP so that we can easily obtain accurate weights.

Table 1.The importance of the meaning of the scale(Nicole Adler,2001)

Significant scale	Meaning
1	Two factors are the same important
3	Former is slightly important than latter
5	Former is significantly important than latter
7	Former is strongly important than latter
9	Former is extremly important than latter
2,4,6,8	Indicating that the intermediate value of these judgments

According to the hierarchy chart,comparing these two factors based on the importance of scaling standard.As follows:

Table2.A-C judgment matrix

A	C1	C2	C3	C4	C5
C1	1	3	5	1/2	4
C2	1/3	1	3	1/3	5
C3	1/5	1/3	1	1/4	1/3
C4	2	3	4	1	5
C5	1/4	1/5	3	1/5	1

Table3.C1-M judgment matrix

C1	M1	M2
M1	1	2
M2	1/2	1

Table4.C2-M judgment matrix

C1	M1	M2
M1	1	1/4
M2	4	1

Table5.C3-M judgment matrix

C1	M1	M2
M1	1	5
M2	1/5	1

Table5.C4-M judgment matrix

C1	M1	M2
M1	1	2
M2	1/2	1

Table6.C5-M judgment matrix

C1	M1	M2
M1	1	1/3
M2	3	1

Using mediation method to Calculate Weight Vectors.Specific formula is:

$$w_i = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ij}}{\sum_{k=1}^{n}a_{kl}} \tag{13}$$

$W_{A-C} = (0.2910, 0.1761, 0.0582, 0.3882, 0.0886)$;

$W_{C1-M} = (0.6667, 0.3333)$;

$W_{C2-M} = (0.2000, 0.8000)$;

$W_{C3-M} = (0.8333, 0.1667)$;

$W_{C4-M} = (0.6667, 0.3333)$;

$W_{C5-M} = (0.2500, 0.7500)$.

3 Examples

In this paper we use intercity rail between Chang,Zhuzhou,Xiangtan as the example to verificate our model.

3.1 Background

The rapid development of ChangSha,ZhunZhou,XiangTan transportation are incompatible with development of economic.Transport infrastructure still has some weak links.Cities are mainly connected with highway and the national road.The structure of intercity transportation is single and this single is not conducive to passenger to travel.So the three cities need the intercity rail.

3.2 Model Solution

Through reviewing the relevant literature we can determine the relevant parameters.

Table7.Parameter calibration

θ_i	d_s^{AB}	X_S	$\overline{T_f}$	L_s	E	α_s	β_s	ψ	$\overline{c_s}$
0.2910, 0.1761, 0.0582, 0.3882, 0.0886.	96km	160km/h	17.379yuan/h	0.5h	15h	59	0.29	1035.14	0.33

Derivating the main function(1)and we can see from the simplified expression the function has a maximun.Ordering derivative value to zero we can obtain $\overline{u_s} = 0.52$ .That is the best rail fare rate and we can obtain the best rail fare.

4 Conclusions

This paper describes the causes and the importance of optimizing intercity rail fares.The analysis shows that the share of passenger intercity rail rate is mainly affected by the fare, travel speed, transfer convenience,comfort and safety.So we introduce Logit mode and random utility theory and analytic hierarchy process to seek contribution rate.And using this model to build a revenue model for intercity railway.The innovation of thsi paper is not to obtain the maximun benefit but through the derivation of intercity bus benefit model to obtain the best fare.The first disadvantage of this article is that we only compare intercity rail and intercity buses.A second drawback of this paper is that when we use random utility model to obtain contribution rate we calculate the weight factor analytic hierarchy process.So the results will not be objective enough.

References

Chun-Hsiung Liao.(2010).Competition between high-speed and conventional rail systems.*Experts Systems Applications.*

GUO Chunjiang.(2010).Game Model of high-speed railway and civil aviation passenger traffic share.Beijing Jiaotong University.

JIANG Jinliang.(2012).Based on non-cooperative game speed railway fares optimization.Beijing Jiaotong University.

Nicole Adler.(2001).Competition in a deregulated air transportation market. European Journal of Operational Research.

Pietro Zitoa, Giuseppe Salvoa, Luigi La Francaa.(2011).Modelling Airlines Competition on Fares and Frequencies ofService by Bi-level Optimization. European Journal of Operational Research.

YI Fujun.(2009)Based on Nested-Logit model in economic circle transportation.Transportation Systems Engineering and Information Technology.

Trip Activity Chain Pattern Recognition and Travel Trajectory Data Mining

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Abstract: This study focuses on recognizing the travel modes and activity types in personal travel trajectory. Firstly the paper proposes a concept of trip-activity chain pattern to describe the general form of travel trajectory, and analyzes the structure and features of this pattern and its sub-patterns: trip sub-pattern and activity sub-pattern. Then normalized Euclidean distance measurement method is adopted to decompose the travel trajectory into trip and activity parts. Finally we apply RBFNN to solve the pattern recognition problem, which obtains an accuracy of 88.5% of travel mode recognition and 74.4% of activity type recognition.
Keywords: Travel trajectory; Trip activity chain; Travel analysis; Pattern recognition.

1 Introduction

Activity chain and trip chain are effective tools to research the resident's travel behavior and demands. The information of trip-activity chain can be acquired by face to face interview and GPS trajectory survey. For GPS track investigation, how to automatically identify and extract the travel path information, and match with the trip-activity chain, is the key problem to be solved.

Research on urban travel information recognition automatically started in recent decades. Wolf proposed a new theory on using GPS data to replace travel diaries in data collection (Wolf 2000). Stopher et al. developed and deployed a new kind of wearable GPS device for transport applications which offered new thinking on passive personal transportation data collection (Stopher et al. 2005). An integrated GPS-GIS system had be developed to extract person travel survey data by Tsui and Shalaby, which also designed an interactive analysis interface (Tsui and Shalaby 2006). Herrera et al. demonstrated that the cell-phone device is an alternative traffic sensing infrastructure (Herrera et al. 2010). Stenneth declared that cell-phones with GPS sensors can acquire transportation modes (Stenneth et al. 2011). Travel mode recognition can be found in the article of Widhalm(Widhalm et al. 2012), and Liao attempted to solve the recognition of activities(Liao 2006). Our former researches focused on travel mode recognition by adopting Neural Networks(Wang and Zuo 2014) and Support Vector Machines(Wang et al. 2014), and attained comparatively good accuracy.

The purpose of this study is to propose an approach to recognize the travel mode and activity type within one's travel by analyzing the travel trajectory collected by smart-phone devices (as shown in Figure 1). We summarized a concept of trip-activity chain pattern to describe the structure of the trip-activity chain, decomposed the pattern into trip sub-pattern and activity sub-pattern, used Euclidean distance to detect the activity parts and trip parts in trajectory data, and applied the method of Pattern Recognition to achieve the target of identifying travel modes and activity types.

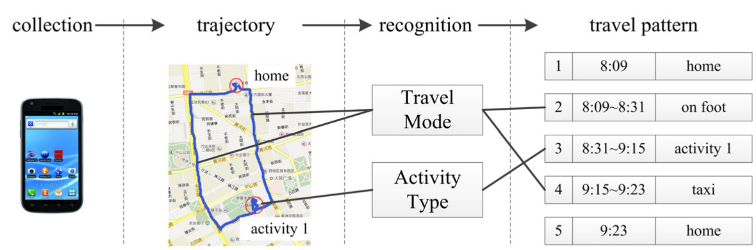


Figure 1. Target of this research

2 Trip-Activity Chain Pattern

Trip-activity chain is a chain structure which is constructed by trip and activity those link each other, which contains enormous travel information. Trip-activity chain pattern is the characteristic of the elements, structure and feature that can specify the trip-activity chain, in order to adopt the Pattern Recognition approach to recognize the information within this pattern automatically.

2.1 Elements of Trip-Activity Chain Pattern

(1) Trip. Trip is the process that traveler move from one place to another.

(2) Stop. Stop is defined as the parts of a whole travel that displacement almost not happens within a certain space and time range. We divide Stop into three categories: a) Activity, b) transfer and c) origin / destination point.

2.2 Structure of Trip-Activity Chain Pattern

(1) Spatial structure

The spatial structure of trip-activity chain is similar to digraph, in which a trip is represented by directed link and an activity is expressed as a node. The activities are connected by trips like the nodes are connected by links, as shown in Figure 2.

(2) Time structure

The time structure of trip-activity chain can be shown as two aspects. The displacement of the traveler is time-varying which is shown in Figure 3, and the parameters those are recorded by the sensors are also changing with time as shown in Figure 4.

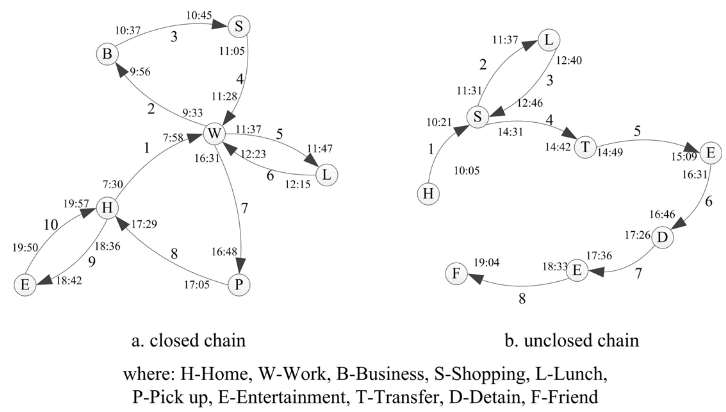


Figure 2. Spatial structure of Trip-Activity Chain

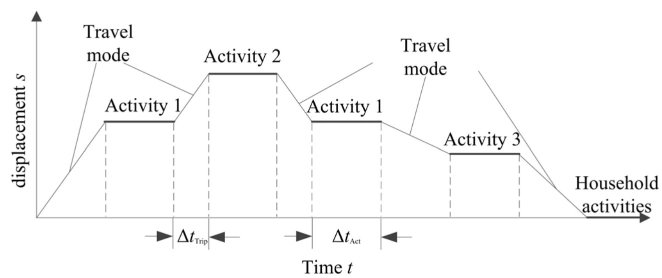


Figure 3. Time structure of Trip-Activity Chain

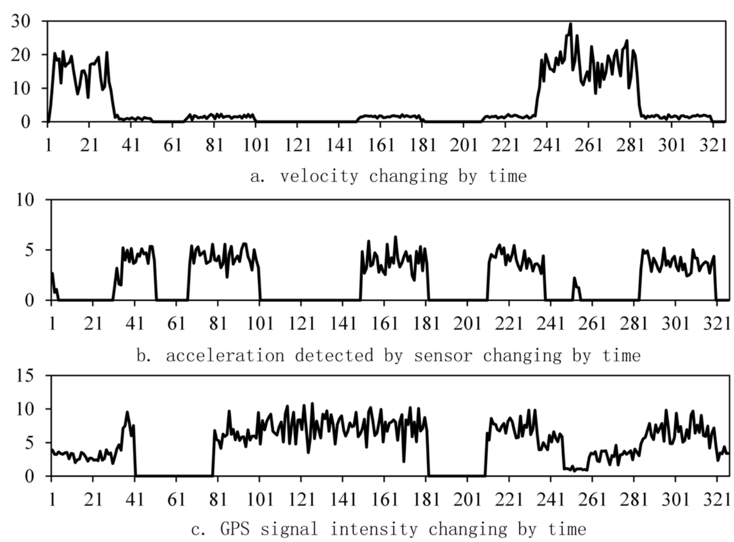


Figure 4. Time feature of parameter

2.3 Features of Trip-Activity Chain Pattern

Though trip-activity chain is relatively complicated with the scope of time-spatial structure, we can decompose the pattern into two sub-patterns:

(1) Trip sub-pattern

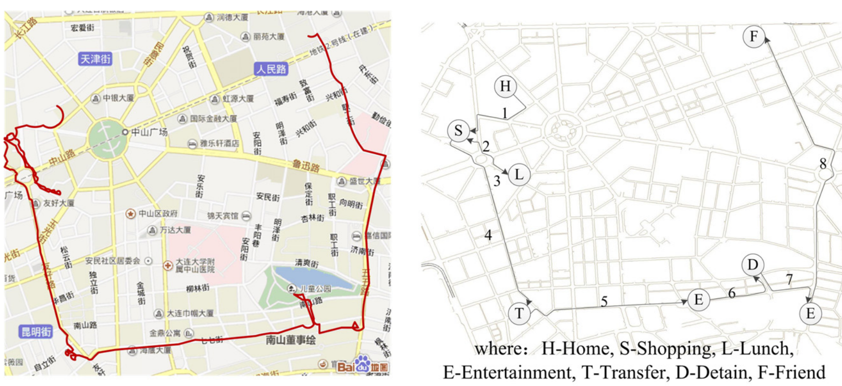
The key point to recognize trip sub-pattern is to identify the travel mode. Travel mode divisibility can be reflected by the following characteristics: a) Velocity. b) Acceleration detected by sensor. c) Moving distance. d) Radius of displacement. e) GPS signal intensity. f) Ratio of missing time. g) Pre-stop-time. h) Origin-destination out of the rode. i) Line compatibility with public transit. j) Traveler’s personal property.

(2) Activity sub-pattern

There are following features of activity sub-pattern: a) Activity location. b) Activity duration. c) Range of activity. d) Trip distance. e) Radius of trip. f) Period in one day. g) Workdays or weekends. h) Visit frequency. i) Time difference and range difference from the former activity / to the later activity. j) Travel mode to arrive and leave. k) Values of sensor during activities. l) Traveler’s personal property.

3 Travel Trajectory Collections

Travel trajectory is a set of time-serial data records that compiles parameters such as position, velocity, and acceleration as a row. A travel trajectory is an instance of the trip-activity chain pattern, while the pattern is the abstract of the trajectory. We can read the trip and activity information from the trajectory data by matching the features of the pattern (see Figure 5.). By applying a smart-phone application, we collected 339 trajectories from16 volunteers (see detail in Table 1.).



a. travel trajectory b. trip-activity chain pattern

Figure 5. Travel trajectory and trip-activity chain pattern

Table 1. Information of trajectory samples

	volunteers	trajectories	frequency	duration
training & validation	16	138	12 per min	1 week
test	16	201	12 per min	1 week

4 Sub-pattern Preparations

Since the trip-activity chain pattern can be divided into two sub-patterns in order to recognize the travel mode and activity type separately, at this step, we need to convert the travel trajectory data into the input vector format to be processed during the travel sub-pattern and activity sub-pattern recognition step.

Travel mode samples and activity samples are decomposed from trajectory samples by normalized Euclidean distance measurement. See formula (1) and (2).

$$b_{ij} = (a_{ij} - \min_j a_{ij}) / (\max_j a_{ij} - \min_j a_{ij}) \quad (1)$$

Formula (1) is the normalization of the feature variables a_i, where a_{ij} is one record of original a_i and b_{ij} is the normalized record of a_{ij}.

$$S_k = \{\{b_{1\cdot j},...,b_{I\cdot j}\} \mid \sqrt{\sum_{i=1}^{I}(b_{ij} - b_{i\cdot j-1})^2} < \varepsilon, I = 1,...,I, j = 1,...,J\} \quad (2)$$

Where, S_k is the data records set of stop k, $\{b_{1\cdot j},...,b_{I\cdot j}\}$ is record j, ε is the threshold of judging stop point, I is the number of feature variables, J is the number of records. Other parts of the trajectory are regarded as the trip records sets. In this research, the maximum Euclidean distance of stop points is below 0.0024 and the minimum of moving poits is above 0.0040, which indicates that stop points and moving points are absolutely separable.

However, points during trip period might stop for a while for signal control or passenger getting on or off. A toleration window τ should be involved to avoid the disturbance of accidental stop points, which means if the continuing τ points are all below ε then they are all stop points otherwise they are trip points.

Figure 6 gives a illustration of dividing trajectories into trip parts and stop parts by the variation of Euclidean distance.

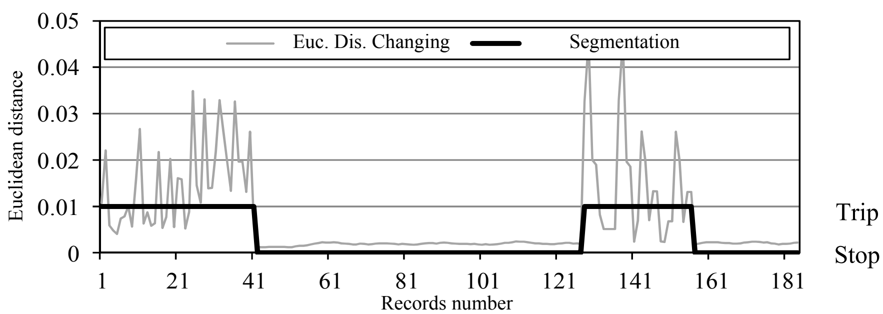


Figure 6. Trajectory segmentation illustration

Results of dividing trajectories are shown in Table 2, and the observation data summary of travel mode and stop type (including activity type, other stop types may be regarded as type other) is shown in Table 3 and Table 4.

Table 2. Travel mode and activities extracted from trajectory samples

	trajectories	travel mode	activities
training & validation	138	498	367
test	201	672	497

Table 3. Sample groups of different travel mode (real data)

	Training	Validation	Test	Total
on foot	144	62	291	497
taxi	31	13	51	95
priv. car	22	10	49	81
bus	110	47	190	347
LRT	41	18	91	150

Table 4. Sample groups of different activity type (real data)

	Training	Validation	Test	Total
work	51	21	96	168
shopping	45	20	87	152
leisure	39	15	78	132
school	28	12	53	93
dinner	46	17	83	146
other	53	20	100	173

5 Trip-Activity Chain Recognition

Since the trajectories are segmented into trips and stops, the trip-activity chain recognition can be conducted separately as trip sub-pattern recognition and activity sub-pattern recognition. Pattern Recognition approaches are the appropriate methods to solve these problems. For travel mode recognition and activity type recognition, we adopted the Radial Basis Function Neural Networks (RBFNN) as the classification method(Wang and Zuo 2014). More about RBFNN see literature(Park and Sandberg 1991).

Giving the feature vector of trip sub-pattern as $CT=(\xi_1,\xi_2,...,\xi_{11})$, and activity sub-pattern as $CA=(\zeta_1,\zeta_2,...,\zeta_{13})$, one real *CT* matches one real trip mode *RT* and one real *CA* matches one real activity type *RA*, which construct mapping of <*CT*, *RT*> and <*CA*, *RA*>. The mapping can be applied to train the RBFNNs where *CT*s match the input neurons and *RT*s match the output neurons of the learning samples, the same as *CA*s and *RA*s. See detail explanation of the variables of *CT* and *CA* in Table 5 and Table 6.

Table 5. Travel mode feature variables

num	variables	symbol
1	average velocity	ξ_1
2	maximum velocity	ξ_2
3	average acceleration detected by sensors	ξ_3
4	maximum acceleration detected by sensors	ξ_4
5	moving distance	ξ_5
6	moving radius	ξ_6
7	location detecting accuracy	ξ_7
8	ratio of missing time	ξ_8
9	time period of the stop before this trip	ξ_9
10	whether the origin-destination out of the rode	ξ_{10}
11	line compatibility with public transit	ξ_{11}

Table 6. Activity type feature variables

num	variables	symbol
1	activity duration	ζ_1
2	activity radius	ζ_2
3	distance from home	ζ_3
4	radius from home	ζ_4
5	time position in a whole day	ζ_5
6	workday or weekend	ζ_6
7	time lag from the former activity	ζ_7
8	time lag to the later activity	ζ_8
9	distance from the former activity	ζ_9
10	distance to the later activity	ζ_{10}
11	arriving travel mode	ζ_{11}
12	departing travel mode	ζ_{12}
13	average acceleration detected by sensors	ζ_{13}

The well-trained RBFNNs can be applied to recognize the trip and activity sub-patterns using the recognition data sets.

Table 7 summarizes the result of travel mode recognition, which indicates the method has an excellent performance predicting the method on foot and a fine ability dividing LRT which achieve accuracy above 90%. The method can tell taxi, priv. car and bus apart, while the vague feature properties still confuse the machine.

Table 8 shows the result summary of activity type recognition, where the method reached a total accuracy of 74.4%, within which the classification effect of leisure and other are below 70% and school and dinner are above 80%.

Table 7. Result summary of travel mode recognition (recognition data)

real	recognition					accuracy
	on foot	taxi	car	bus	LRT	
on foot	279	0	1	9	2	95.9%
taxi	1	31	7	10	2	60.8%
car	0	3	38	5	3	77.6%
bus	3	8	9	164	6	86.3%
LRT	4	0	1	3	83	91.2%
total						88.5%

Table 8. Result summary of activity type recognition (recognition data)

real	recognition						accuracy
	work	shopping	leisure	school	dinner	other	
work	73	9	2	5	0	7	76.0%
shopping	4	65	6	0	5	7	74.7%
leisure	0	4	53	6	11	4	67.9%
school	2	4	0	44	0	3	83.0%
dinner	0	2	4	0	71	6	85.5%
other	9	6	13	7	1	64	64.0%
total							74.4%

6 Conclusions

This paper put forward a research on trip-activity chain pattern recognition by travel trajectory decomposition and classification, which can be applied to improve the efficiency and reduce costs of the study on residents travel behavior and travel demand. In this paper, we define a concept of trip-activity chain to abstract the travel trajectory collected and formatted by smart-phone location services and motion sensors. Then the normalized Euclidean distance measurement implements the segmentation of the trajectory into activity and trip sub-pattern of trip-activity chain pattern, and RBFNN method is applied to solve the classification problem of travel modes and activity types.

This study accomplished an accuracy of 88.5% on identifying the travel modes, but attained a relatively lower accuracy of 74.4% on activity type recognition. The results of our work are fine but not good enough as what other researches have done, which shows a quite broad development space and indicates predictable advancement that can be made.

Acknowledgement

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References

Herrera, J. C., Daniel, B. W., Herring, R., gang, B. x., Jacobson, Q., and Alexandre, M. B. (2010). "Evaluation of traffic data obtained via GPS-enabled mobile phones: The Mobile Century field experiment." *Transportation Research Part C*, 18(4), 568 - 583.

Liao, L. (2006). "Location-based activity recognition." University of Washington.

Park, J., and Sandberg, I. W. (1991). "Universal approximation using radial-basis-function networks." *Neural computation*, 3(2), 246-257.

Stenneth, L., Wolfson, O., Yu, P. S., and Xu, B. (2011). "Transportation mode detection using mobile phones and GIS information." *GIS '11 Proceedings of the 19th ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems*, ACM, 54--63.

Stopher, P. R., Greaves, S. P., and FitzGerald, C. "Developing and deploying a new wearable GPS device for transport applications." *Proc., 28thAustralian Transport Research Forum, sep 28th–sep30th*.

Tsui, A. S. Y., and Shalaby, A. S. (2006). "Enhanced System for Link and Mode Identification for Personal Travel Surveys Based on Global Positioning Systems." *Transportation Research Record: Journal of the Transportation Research Board*, 1972(1), 38-45.

Wang, L., Zuo, Z.-y., and Fu, J.-h. (2014). "Travel mode character analysis and recognition based on SVM." *Journal of Transportation Systems Engineering and Information Technology*, 14(3), 70-75.

Wang, L., and Zuo, Z. "Travel Mode Recognition Using RBF Neural Network." *Proc., CICTP 2014: Safe, Smart, and Sustainable Multimodal Transportation Systems*, ASCE, 711-721.

Widhalm, P., Nitsche, P., and Brandie, N. (2012). "Transport mode detection with realistic Smartphone sensor data." *Pattern Recognition (ICPR), 2012 21st Internationa*, 573 - 576.

Wolf, J. (2000). "Using GPS data loggers to replace travel diaries in the collection of travel data." Citeseer.

Analysis of Dynamic Passenger Flow in Urban Rail Transit Based on Data Mining

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Abstract: According to the more qualitative methods for urban rail analysis, long cycle of diagramming train schedule chart and large passenger flow, getting the real-time statistics of the passengers' IC card information in AFC system, according to the retention time in each station, a scatterplot of the passengers' density can be drawn, intuitively reflecting the distribution of the passengers' density in every station. To gain the data of the passenger flow in each station and on each route, a more accurate full-time traffic planning can be made by using the reliable traffic data. Due to the multi-routes for passengers, Based on the optimization of Dijkstra, the route in a net can be chosen, then mapping the train schedule chart. At the same time, use the data mining technology in large data era to process the history data and the dynamic information of passenger flow to provide accurate and intuitive reference for the update of the train schedule chart.
Keywords: Current; Train plan; Optimize; Data mining.

Due to the quickness and accuracy of modern computer technology, the use of software programming technology for validation is applied. The WPF technology in Visual Studio is applied, connecting to the MySQL database through ADO.NET, an intuitive, friendly software being completed to realize the simulation of the above content. The train schedule chart usually being updated in a long cycle, according to the real-time dynamic traffic statistics, a traffic planning and schedule chart can be generated in a high frequency and set the reasonable threshold to optimize the existing traffic planning and schedule chart in order to achieve the goal of the analysis dynamic passenger flow.

1 Background

With the city subway network gradually formed, during the holidays or influenced by a certain policy, activities, it will bring big impacts on passenger flow to the subway. Modern metro mostly adopt the method of the long-term prediction, while less actual dynamic analysis after operation, which often caused crowded, trample and low efficiency. Optimization of train operation plan and setting passenger flow analysis solution to reduce the accident rate and efficiency is necessary. (liming Song, 2011)

2 Design principle

2.1 Vulnerability analysis

Subway security model analysis:

The main idea of the famous safety management model called "Reason cheese" model: When multiple layers of tissues defect in a precipitating factor in the accident or initially defect at the same time. The events lose multi-level security and happened. As shown in figure 1,the existing prediction methods, hardware upgrade basis and operating unit management's hidden dangers are potential failure factors.Innovation of the passenger flow analysis method by dynamic analysis of passenger flow optimization, improving the train operation plan and the preparation of train diagrams improve the efficiency and security. （James Reason，1990）

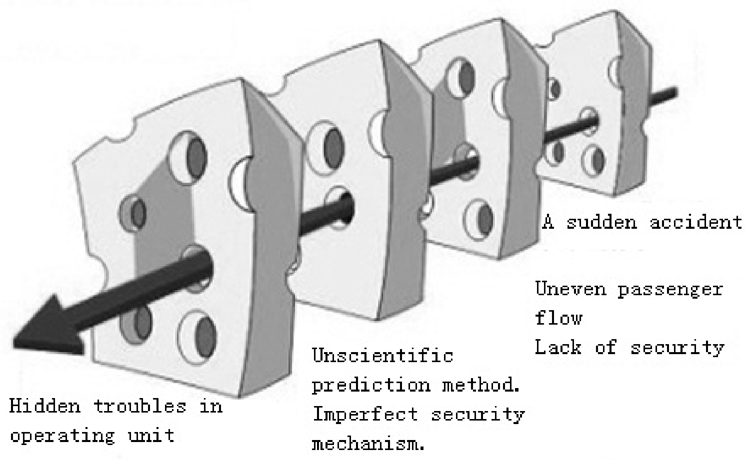

Figure 1. Reason cheese model

2.2 Design ideas

Passenger flow analysis with experimental data and the use of the passenger flow data are more reliable and relatively accurate.At the same time ,using mathematical modeling for the further optimization,then map the train running. The operation of the station passenger density distribution is analyzed, to provide the reference of hardware upgrades and dynamic security arrangements for each station.

2.3 Core architecture

System work process is shown in figure 2：

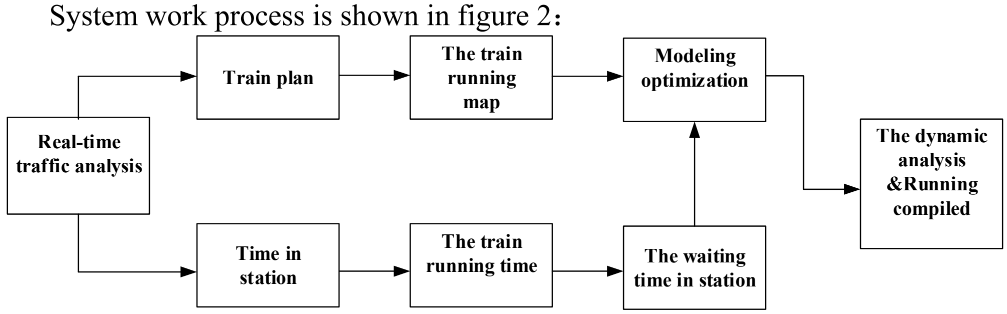

Figure 2. The system work flow chart

2.3.1 To obtain OD Matrix

Defination:OD matrix is the abbreviation of original point - the destination matrix. The matrix of the data is from area A to area B traffic flow.

As larger error exists when use questionnaire to obtain the OD matrix, and the collection is a trouble, so using a computer iteration to obtain the OD matrix iteration must be more accurate.

The principle of the balance of supply and demand is used, which can analyze the inherent law of traffic distribution. And according to the principle of supply and demand balance, a general sense of the traffic distribution can be performed. At this point, The OD matrix system balance model is chosen for passenger flow distribution.

General function of the trip distribution models are as follows（xiangyun Wu canqi Liu，2004）:

$$X_{ij} = T_i \frac{U_j}{f(t_{ij}) + T_i}$$

X_{ij} ——Trip distribution amount intraffic area i to j.

T_i ——The discharge of traffic area i.

U_j ——The charge of traffic area i.

$f(t_{ij})$——The impedance of traffic area i to the traffic area j. t_{ij} represent the the time distance effect parameters from traffic area i to j.

Through related literature query, the $f(t_{ij})$ of subway is often represented as:

$$f(t_{ij}) = t_{ij}^{a_i}$$

Traffic impedance is determined by the walking time of each section, the impedance referred in this article refers to the the time impedance for passengers in the rail transit network from the origin to the destination. (note: due to the difference between different individual's stops the outbound, so in order to study the general impedance, it is determined by the impedance)

The actual survey time data can be obtained by using passengers balance.

Because there are several routes in nanjing subway now ,because of very large amount of calculation and considering some platform traffic traffic was far less than the main station, and by comparing the number of trip distribution models require overlay, together with the influence on the speed of calculation. Some of the big platformare captured.

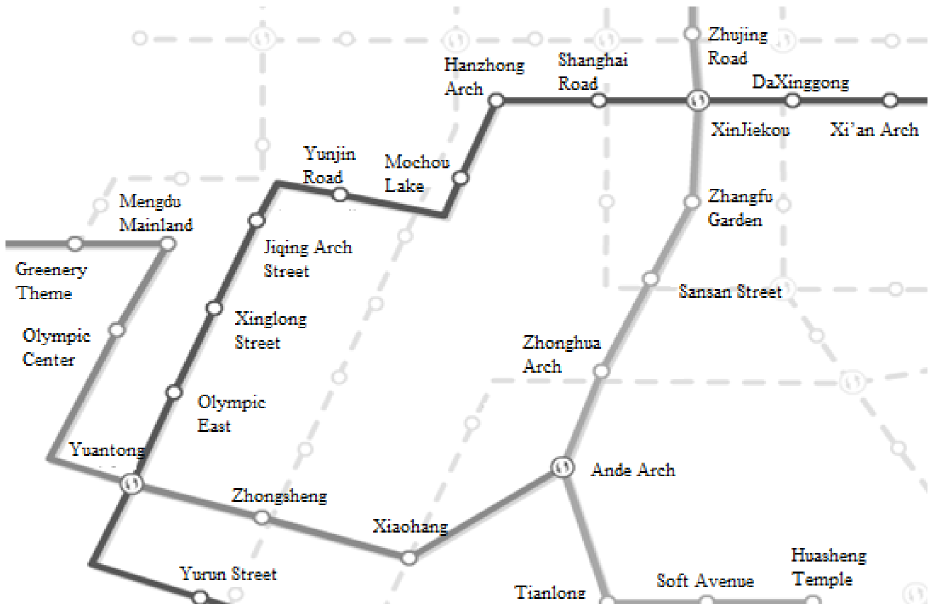

Figure 3. Map of NanJing subway

The survey data shown in the table below:

Table 1.Random traffic statistics

Nunber	Platform	Current/10000	Rate/%
01	Greenery Theme	1.79	0.003815818
02	Mengdu Mainland	1.93	0.004114261
03	Olympic Center	4.89	0.010424217
04	Yuantong	11.58	0.024685568
05	Olympic East	14.27	0.030419953
06	Xinglong Street	10.07	0.021466638
07	Jiqing Arch Street	9.77	0.020827116
08	Yunjin Road	9.81	0.020912385
09	Mochou Lake	10.88	0.023193349
10	Hanzhong Arch	28.29	0.060306971
11	Shanghai Road	49.74	0.106032829

12	XinJiekou	106.5	0.227030484
13	DaXinggong	20	0.042634833
14	Xi'an Arch	15.4	0.032828821
15	Zhujing Road	86.42	0.184225112
16	Zhangfu Garden	14.05	0.02995097
17	Sansan Street	11.64	0.024813473
18	Zhonghua Arch	10.52	0.022425922
19	Ande Arch	9.75	0.020784481
20	Tianlong Temple	7.08	0.015092731
21	Soft Avenue	6.18	0.013174163
22	Huasheng Temple	6.99	0.014900874
23	Xiaohang	7.98	0.017011298
24	Zhongsheng	10.79	0.023001492
25	Yurun Street	2.79	0.005947559

Through the above survey time data t_{ij} and the system supply and demand balance principle, there are the following relations（xuhong Li wei Wang xuewu Chen，2008）:

$$\sum_j X_{ij} = T_i$$

Then tidy the formula:

$$\sum_j \frac{U_j}{t_{ij}^{a_i} + T_i} = 1$$

Get a_i and b_j by using the matlab to iterate for times.

Table 2.The value of a_i and b_j

Nunber	Platform	a_i	b_j
01	Greenery Theme	0.9928	0.9927
02	Mengdu Mainland	0.9944	0.9942
03	Olympic Center	0.9951	0.9962
04	Yuantong	0.9995	1.0008
05	Olympic East	0.9977	0.9969
06	Xinglong Street	0.9968	0.9971
07	Jiqing Arch Street	0.9968	0.9965
08	Yunjin Road	0.9978	0.9979
09	Mochou Lake	0.9964	0.9958
10	Hanzhong Arch	1.0028	1.0035
11	Shanghai Road	1.0036	1.0040
12	XinJiekou	1.0132	1.0093
13	DaXinggong	1.0001	0.9997
14	Xi’an Arch	0.9974	0.9981
15	Zhujing Road	1.0042	1.0050
16	Zhangfu Garden	1.0027	1.0032
17	Sansan Street	0.9987	0.9991
18	Zhonghua Arch	0.9988	0.9990
19	Ande Arch	0.9967	0.9971
20	Tianlong Temple	0.9987	0.9978
21	Soft Avenue	0.9969	0.9977
22	Huasheng Temple	0.9973	0.9975
23	Xiaohang	0.9978	0.9979
24	Zhongsheng	0.9982	0.9984
25	Yurun Street	0.9933	0.9935

2.3.2 Full-time traffic plan

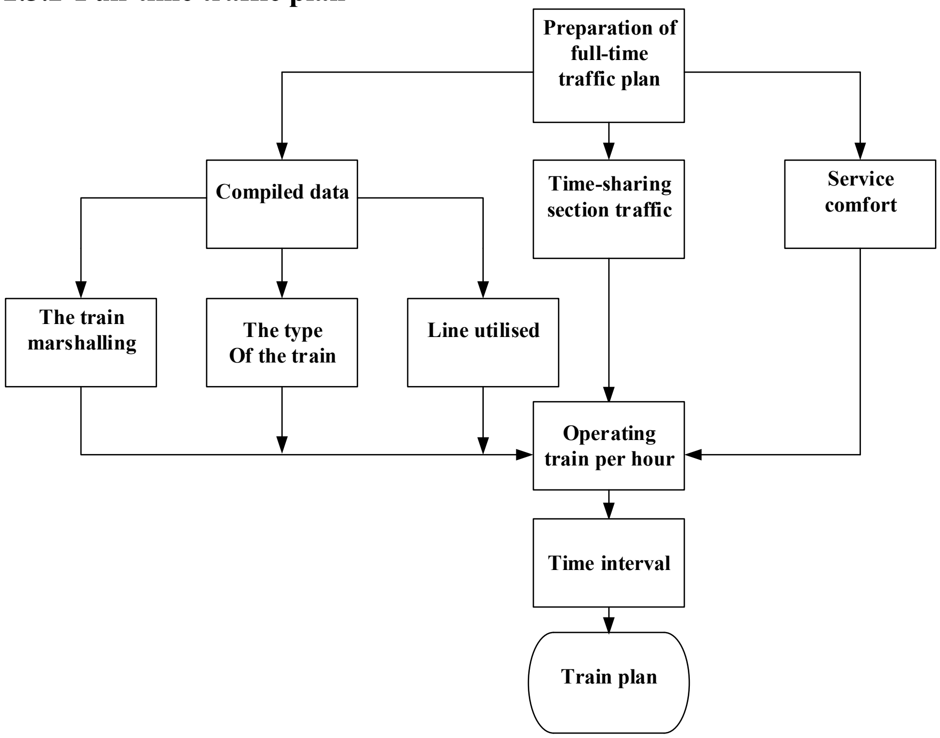

Figure 4. The flow chart of full-time traffic planning

3 Software implementation

Software are designed to prove the theory using the C# to realize all the functions. As shown as follows:

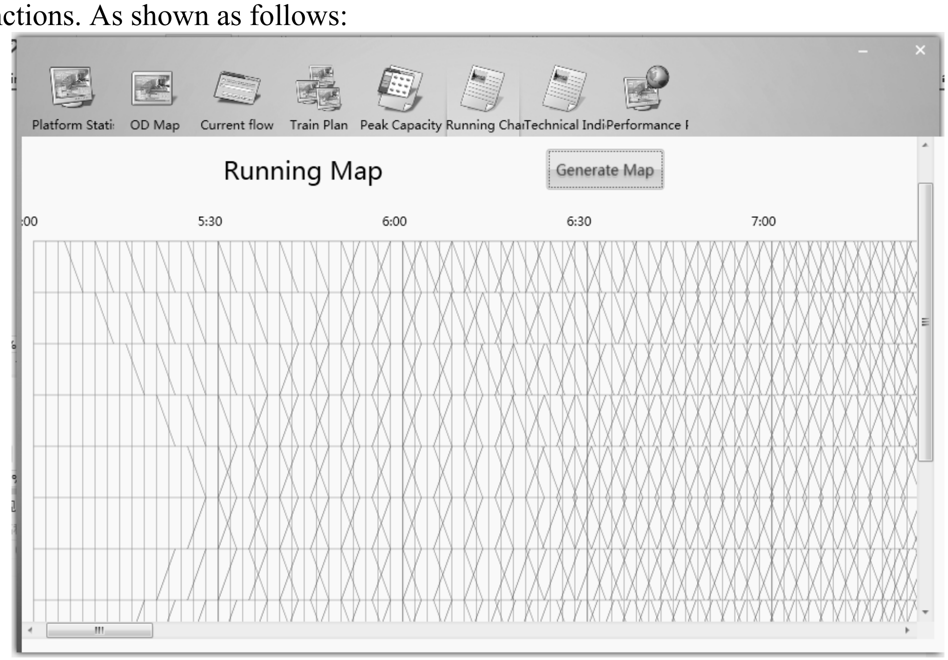

Figure 5. Running Map

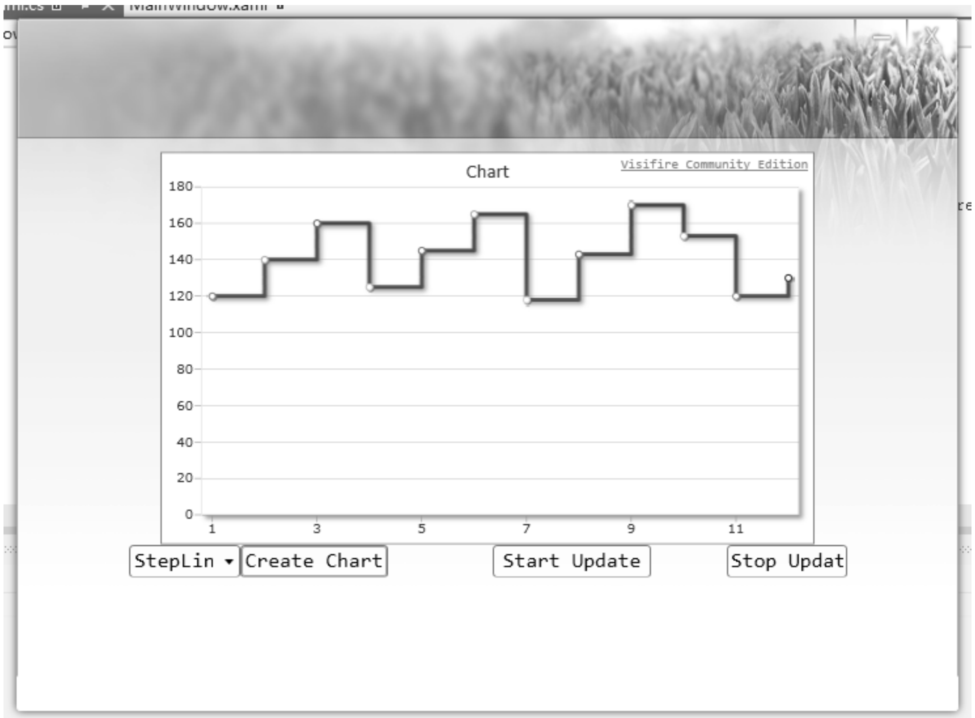

Figure 6. Chart

4 Conclusion

This article is based on the passenger flow data collected by the AFC system an d part of the network of Nanjing subway as an example, using the method of matrix i teration by computers to obtain more accurate OD and passenger trip distribution at s tations. Combine computer programming to generate the traffic plan and draw the tra in running, so as to improve the operational efficiency of the subway,the effective ref erences for metro operation in the rational allocation of transport is provided.

Reference

Liming Song. Response to passenger flow in Metro line 2011.(8):49-64.
James Reason. Human Error[M] Cambridge University Press 1990.
Xiangyun Wu;Canqi Liu.Rail transit traffic equilibrium model and algorithm 2004.09
Honxu Li;Wei Wang;Xuewu Chen .Road traffic planning 2008

Abnormal Vessel Trajectories Detection in a Port Area Based on AIS Data

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Abstract: Vessel trajectories anomaly detection in port areas is concerned with finding deviations from normalcy and it is an increasingly important topic when providing decision support for maritime safety administrations. This study proposes an idea that anomalously behaving vessels can be automatically identified from a large Automatic Identification System (AIS) history data by trajectory anomaly detection algorithm. Firstly, the availability of AIS data with a focus on vessel trajectory detection is analyzed in this study. Second, the framework based data mining for vessel trajectory anomaly detection is proposed. Finally, the trajectory anomaly detection algorithm is adopted in order to find the anomalously behaving vessels. Computer programs for decoding, visualization and detection of AIS data have been developed. Experimental results demonstrate that trajectory anomaly detection algorithm in this paper is able to correctly and effectively detect abnormal trajectories from real vessel trajectory data. Research achievements can be applied to intelligent maritime supervision.

Keywords: Automatic identification system (AIS); Vessel trajectory; Data mining; Anomaly detection.

1 Introduction

In recent years, the design of systems that guarantee a high level of security in highly-crowded and critical areas such as harbors, airports, busy streets, etc., have become an important research subject for both academia and industry. Generally speaking, marine traffic accidents make a very bad impression (safety of life, ocean pollution, etc.). So, dangerous situations and accidents in port areas are increasingly perceived as intolerable. Nowadays, many kinds of sensors such as radar, video and infrared cameras and Automatic Identification System (AIS) are widely deployed for monitoring maritime environments. Especially, AIS was primarily developed to exchange vessel-related data among vessels or AIS base stations by using very-high frequency (VHF) technology to increase safety at sea. The AIS data that are exchanged are divided into three different types (IMO, 2003):

- Static information (e.g., IMO and Maritime Mobile Service Identity (MMSI) number, vessel name, call sign, the dimensions of the vessel, type of vessel)
- Dynamic information (e.g., vessel position, time in UTC (coordinated universal time), course over ground, speed over ground)

- Voyage-related information (e.g., current draught, type of cargo).

AIS dynamic data contains vessel trajectory information. Vessel trajectories anomaly detection is concerned with finding deviations from normalcy. One option to perform these tasks of discovering vessel abnormal trajectories is to design algorithms for them by hand. This is time consuming and difficult. However, we can also use automatic techniques from the fields of data-mining that work with available historical trajectory data directly. This is the approach that we take in this study.

This paper is structured as follows. Section 2 discusses the availability of AIS data with a focus on vessel trajectory detection. The framework based data mining for vessel trajectory anomaly detection is proposed in section 3. A vessel abnormal trajectory data mining method is presented in section 4. Using real vessel trajectory data, we explore the capabilities of our method in section 5. Finally, we give the conclusion in section 6.

2 Analysis of AIS Data

The main goal of this study is to find out vessel abnormal trajectory. So, we only consider dynamic data fields that contain measurements automatically updated by appropriate sensors directly connected to the AIS system. Table 1 shows the data fields of the position reports within this study.

According to the technical characteristics, the reporting interval changes depending on SOG, ROT (rate of turn), and the current state of a vessel (ITU, 2014). Therefore, position reports should be output periodically by mobile stations. Table 2 gives an overview of the reporting intervals for position reports according to these technical characteristics.

Table1. Some position report data fields

Data fields	*Description*
Longitude	*Longitude in 1/10 000 min (±180°, East = positive, West = negative)*
Latitude	*Latitude in 1/10 000 min (±90°, North = positive , South = negative t)*
SOG	*Speed over ground in 1/10 knot steps (0-102.2 knots)*
COG	*Course over ground in 1/10 = (0-3599).*
True heading	*Degrees (0-359) (511 indicates not available = default)*

Table2. Reporting intervals of Class A position reports

Ship's dynamic conditions	*Nominal reporting interval*
Ship at anchor or moored and not moving faster than 3 knots	*3 min*
Ship at anchor or moored and moving faster than 3 knots	*10 s*
Ship 0-14 knots	*10 s*
Ship 0-14 knots and changing	*3 1/3 s*
Ship 14-23 knots	*6 s*
Ship 14-23 knots and changing	*2 s*
Ship 23 knots	*2 s*
Ship 23 knots and changing	*2 s*

From Table 1 and Table 2, we know that position report data is appropriate for vessel trajectory analysis. A large number of AIS data are used as the data source for vessel trajectory analysis in this paper. In next section, we will propose the framework of vessel trajectory anomaly detection based on data mining.

3 Framework of Vessel Trajectory Anomaly Detection Based on Data Mining

Data mining is a technique to discover hidden, previously unknown and useful knowledge from a large database. In particular, our study targets to detect vessel abnormal trajectory possessed by AIS, and combines database management systems, data warehousing and mining algorithm to process and analyze data. The proposed research architecture and processes in Fig.1.

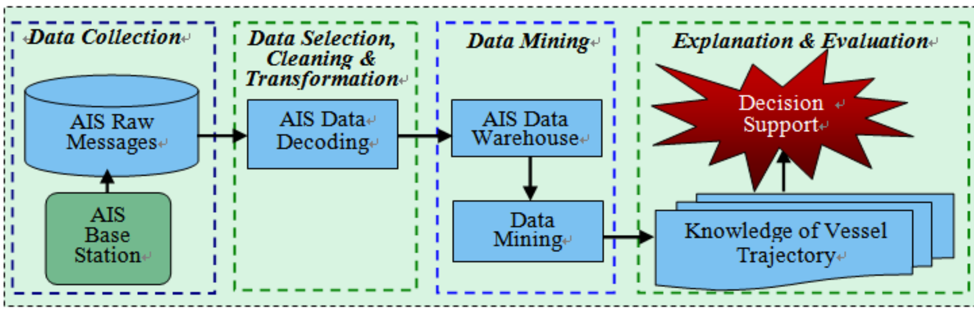

Fig.1 Framework of vessel trajectory anomaly detection

3.1 Data Collection

This study makes use of an AIS base station on the DMU (Dalian Maritime University) campus, about 10km from Dalian port. We use computer programs developed with Visual Studio 2005 C++ to receive AIS original messages and transfer them through the RJ-45 interface to the connected PC's SQL Server 2008 database server (acting as the data storage platform). The total quantity of static and dynamic messages reached 1.0 Gb.

3.2 Data Selection, Cleaning and Transformation

In the AIS technical specification, there are 27 different types of messages (ITU, 2014). In this study, we decode only types 1, 2 and 3 (target vessel position report) and type 5 (dynamic information and voyage related information) messages. Through the use of MMSI as a relational key, each ship's static and dynamic message can be joined together to compose each ship's complete trajectory.

After homogenizing the data and removing redundant information, the data may be deemed "clean". In order that the data mining model can read the information smoothly and perform analysis, we transform the pre-processed data into SQL Server's data warehouse. In this study, several layers of processing and conversion are required from the handling of initial received AIS messages until the end, when the data-mining model can be provided for use.

3.3 Data Mining

This step is based on the research goal of selecting appropriate data mining methods to perform trajectory analysis. In this study, we further describe this step in section 4.

4 Vessel Abnormal Trajectory Data Mining

A number of methods have been proposed where learning is based on estimation of a statistical model for the feature values of individual data points from vessel trajectories. A two-step learning algorithm where feature values of individual data points are first clustered using Self-Organization Map (SOM) and then modelled using Gaussian Mixture Model (GMM) (Kraiman, 2002). A two-level approach based on a combination of GMM and Hidden Markov Model (HMM) for learning and anomaly detection in trajectory data is also proposed (Urban, 2010). However, no details regarding the learning and anomaly detection algorithm are given.

Generally speaking, without considering collision avoidance or other hazardous conditions, vessel will keep course and speed, and make linear motion. The anomaly and danger are more likely to appear, when the vessel is changing speed or course. The abnormal segment may be a portion of the whole vessel trajectory. If we detect the vessel trajectory as a whole, outlying portions of the trajectory may not be able to find out.

Example: TR_3 is not detected as an outlier since its overall behavior is similar to those of neighboring trajectories, shown as in Fig.2. Thus, we miss this possibly important information.

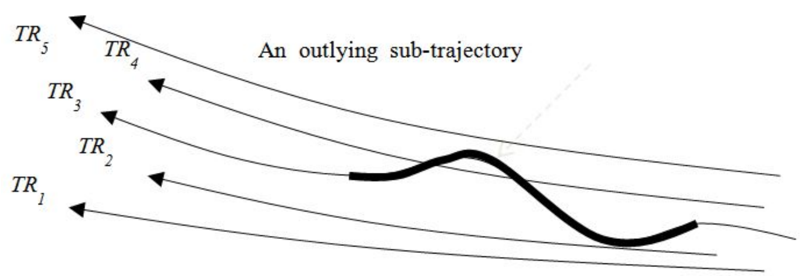

Fig.2 An example of an anomaly sub-trajectory

Therefore, the algorithm for vessel trajectory anomaly detection should be able to detect outlying portions of the trajectories. A trajectory outlier detection algorithm (TRAOD) which was based on partition-and-detect framework was proposed (Lee, 2008). A two-step anomaly detection algorithm is proposed, which first partitions each trajectory into a number of line segments. Next, anomalous trajectory partitions, i.e., line segments, are detected according to a combination of distance-based and density-based analysis.

The TRAOD is based on the partition-and-detect framework. In TROAD, a trajectory is a sequence of multi-dimensional points, which is denoted as $TR_i = p_1p_2p_3 \dots p_j \dots p_{leni}$; a trajectory partition (t-partition for short) is a line segment p_ip_j ($i < j$), where p_i and p_j are the points chosen from the same trajectory.

A t-partition is abnormal if it does not possess a sufficient number of similar neighbors. A trajectory is an outlier if it contains a non-negligible amount of outlying t-partitions. So, there are three parameters in TROAD algorithm: D corresponds to similar, p to sufficient, and F to non-negligible. In this study, we adopt TROAD to detect abnormal trajectory with real vessel trajectory data.

5 Experiment and Result Analysis

In order to detect vessel anomaly trajectories near Dalian port water area, we select a real and original vessel trajectory data set(coverage Dalian Port area: latitude: 38.8ºN~39.0ºN, longitude:121.6ºE~121.8ºE). The data set is extracted from AIS data warehouse as described in section 3. The original vessel trajectory data set is compressed by Douglas-Peucker algorithm (Zhu,2014 and Douglas,1973). We extract the vessel's latitude, longitude from compressed data set. The data set has 465 trajectories and 6293 points.

We conduct all experiments on an i5-2450M CPU @ 2.5 GHz Laptop with 2 G Bytes of main memory, running on Windows 7. We implement our algorithm using Microsoft Visual Studio C++ 2005.

Fig.3 shows the result of the experiment data set. The parameters are set as follows: D = 200, p = 0.95 and F = 0.2. Here, thick yellow lines represent outlying t-partitions, thin yellow lines trajectory outliers with outlying partitions, and thin gray lines normal trajectories. We note that twenty-four trajectory outliers are detected. We can easily see that outlying t-partitions appear if their directions are significantly different from those of neighboring trajectories (such as crossing fairway) in the left-top region and middle region or if they have very few neighboring trajectories. In Fig.3, the outlying t-partitions in the left-bottom region are moving to totally different directions, and the ones in the left region have almost no neighboring trajectory.

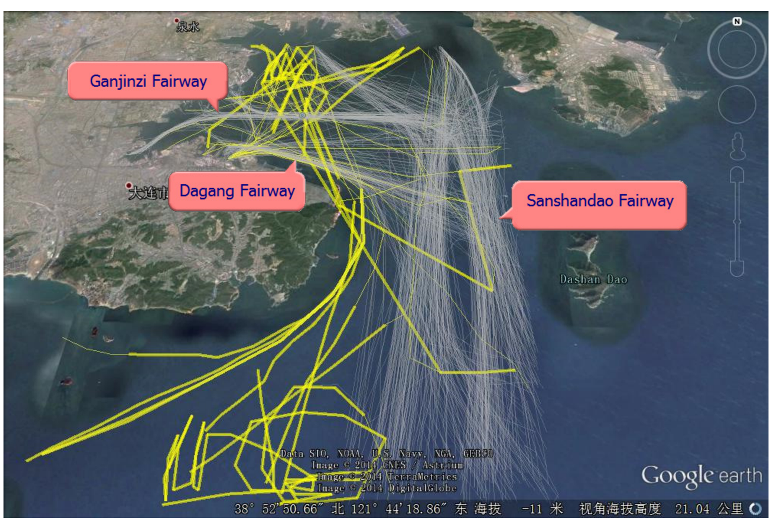

Fig.3 Trajectory outliers for experiment data set

6 Conclusion

Detecting abnormal vessel trajectories from the huge amount of AIS data to improve maritime safety is important for maritime safety administrations. In this paper, we have proposed a framework based on data mining for vessel trajectory anomaly detection. Based on this framework, we have developed trajectory anomaly detection algorithm. The results of experiment show that TRAOD is able to effectively detect trajectory outliers with outlying t-partitions.

This work is just the first step, and there are many challenging issues. First, we consider here only the vessel spatial information. In applications, temporal information and speed information are often associated with spatial information. TRAOD may be not suitable for exploiting multi-dimensional information. Therefore, we should design a new algorithm to vessel trajectory anomaly detection. Second, in order to detect abnormal trajectory real time, it is worthwhile to improve and optimize the related algorithm for AIS big data online analysis.

Acknowledgements

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Reference

D. Douglas(1973). "Algorithms for the reduction of the number of points required to represent a digitized line or its caricature." *The Canadian Cartographer*, 10(2),112–122.

IMO(2003). "Guidelines for the Installation of a Shipborne Automatic Identification System(AIS)." http://www.imo.org/ourwork/safety/navigation/documents/227.pdf. Accessed 26th March 2015.

ITU(2014). "Technical characteristics for an automatic identification system using time division multiple access in the VHF maritime mobile frequency band." *http://www.itu.int/rec/R-REC-M.1371-5-201402-I/en*. Accessed 26th March 2015.

J. Lee, J. Han, and X. Li(2008). "Trajectory outlier detection: A partition-and-detect framework". *Proceedings of the 24th IEEE International Conference on Data Engineering (ICDE)*, 140–149.

J. Kraiman, S. Arouh, and M. Webb (2002). "Automated anomaly detection processor." *proceedings of SPIE: Enabling Technologies for Simulation Science VI*, vol.4716, 128–137.

S. Urban, M. Jakob, and M. Pechoucek (2010). "Probabilistic modeling of mobile agents' trajectories." *Proceedings of the International Workshop on Agents and Data Mining Interaction (ADMI)*.

Zhu Fei Xiang, Miao Limin and Liu Wen (2014). "Research on Vessel Trajectory Multi-Dimensional Compression Algorithm Based on Douglas-Peucker Theory." *Applied Mechanics and Materials*, vol.694, 59-62.

Study of EMU Process Data and Message Data Communication Technology in UIC Gateway and Simulation

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Abstract: UIC556 standard formulates the mechanism and mode of inauguration, process data and message data communication in the UIC gateway of EMU detailed. As the main EMU communication data stream, process data and message data must be effectively processed and converted with the help of the node monitoring database configuration, then can be transferred to the WTB (MVB) bus correctly. In this paper, comprehensive and detailed analysis of communication theory and software architecture of process data and message data were given in the UIC gateway of EMU. Two important media of process data and message data within the gateway are process data marshalling and UIC mapping server. Process data marshalling mainly achieve filtering and calculation of data between WTB and MVB, marshalling type, operating procedures and marshalling framework were deeply researched. UIC mapping server and TCN protocol stack provide the best path and a variety of services. The transmission mechanism of message data in the gateway and the composition and function of each part of UIC mapping server were detailed analyzed. By semi-physical simulation platform, the theory above is simulated and verified.

Keywords: Process data; Message data; UIC; TCN; UMS; PDM.

1 Introduction

In order to improve operational efficiency and meet the demand of inter-regional and cross-country running, EMU often need to dynamically grouping or decoding. Because our country EMU adopts a number of different manufacturers TCN network equipment, different EMU reconnection grouped together (or decompilation) will inevitably lead to the train network topology changes, change the original static and dynamic properties of many vehicles at the same time, lead to communication barriers after reconnection. Here, TCN bus standard IEC – 61375 which defined the basic data communication mechanism cannot satisfy the interoperability demand of different manufacturer's vehicle (Schaefers, 2000). Equivalent of application layer of TCN standard protocol, UIC556 regards vehicles as the basic unit, defines process and message data frame content, inauguration, process data marshalling (PDM) and a series of related problems (Leaflet,2004). As long as the TCN network equipment of different manufacturers communicate with each other according to the UIC556 standard, use hardware interface consistent with UIC556 communication, or converse interface protocol with UIC gateway simply, then can achieve normal communication of different equipment manufacturers vehicles after interconnection (FEMANDEZ,2007) (JIANG,2011).

At home and abroad in recent years, a more comprehensive study was done in view of MVB and WTB (JIMENEZ,2007), but the principle and design report on UIC communication and gateway was less. Based on the status of EMU operations in our country，it is an urgent task to master the core technology of interconnection, intercommunication and interoperability of EMU.

In this paper, the communication mechanism of process and message data after inauguration in the UIC gateway was researched. First, analyzed the UIC gateway internal software architecture. Then for process data marshalling and UIC mapping server which are two communication medium of process and message data, their structure function and communication mechanism were studied. Finally, the above analysis was simulated and verified on the semi-physical simulation platform.

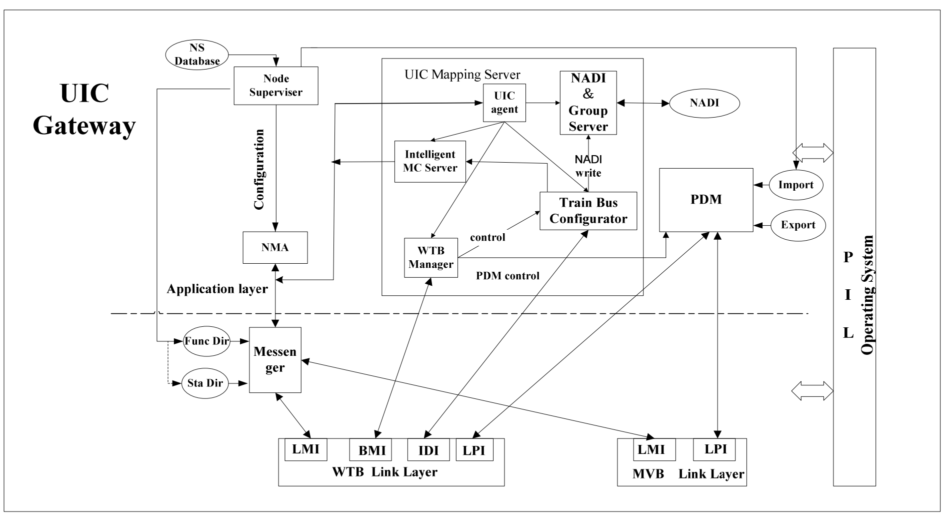


Figure 1. UIC gateway software architecture

UIC gateway and TCN gateway coexist in an entity which, indivisible, with a certain similarity in composition. Application, UIC gateway can fix every process and message data as a frame content which has certain meaning, achieve inauguration and configuration function. The software system architecture is shown in Figure 1. Its software includes TCN protocol stack, UIC mapping server (UMS), process data marshalling (PDM), node monitoring database (NSDB) and real-time operating system (PIL). Among them, LMI is link layer message interface, BMI is bus management interface, IDI is inauguration data interface, and LPI is link layer process data interface.

TCN protocol stack is composed of WTB and MVB link layer, messenger and network management (NMA), can complete TCN inauguration, transfer of process and message data, and have network management functions. UMS mainly accomplishes WTB configuration and control, establish NADI and group serve etc. PDM in charge of marshalling data which between MVB and WTB. In addition to simple data copies, PDM also support the function of process data processing, including and, or, not, maximum, minimum, and so on. NSDB contains all of the vehicles' configuration data, such as PDM, UMS, messenger, WTB configuration, MVB bus management, WTB and MVB communication register. PIL provides a series of system service that is independent of the hardware, and all UMS software components use PIL.

2. Process data transfer mechanism and PDM

2.1 Process data transfer mechanism

As shown in figure 1, if the process data transfer from MVB to WTB, known as exit package. Firstly, move from the MVB physical layer to MVB link layer LPI interface of the UIC and TCN gateway. Then shift up to PDM to filtering and processing, after that the processed data is sent to the LPI interface of WTB link layer and finally reach to the WTB bus physical layer and complete a R frame format conversion. Vice is called entry package.

2.2 PDM

PDM marshalling type is divided into three categories. The marshalling which transmits data from MVB traffic store to the source port of WTB traffic store is called output marshalling. The marshalling which transmits data from WTB traffic store to the configured MVB traffic store is called input marshalling. The marshalling which transmission data is between LVR, MVB or LIO port, is belong to vehicle internal transmission and not through WTB bus, so is called internal marshalling. PDM is composed of many data processing modules, used to implement the data acquisition and preprocessing, functional operation and operation result control etc., and the operation result will eventually copy to the target traffic store. As shown in figure 2.

When R telegram entry package arrives, WTB traffic store first read all variables to PDM memory, and then determine whether is input marshalling. When confirm as input marshalling, check if data's frame type field (FTF) is consistent with NADI's. In the case of FFT correct, execute the marshalling to acquire Pv_Result, otherwise remove the current all WTB data set in PDM memory and all variables becomes invalid. Finally, write the obtained variables from PDM memory to corresponding port of MVB traffic store, shown in Figure 3.

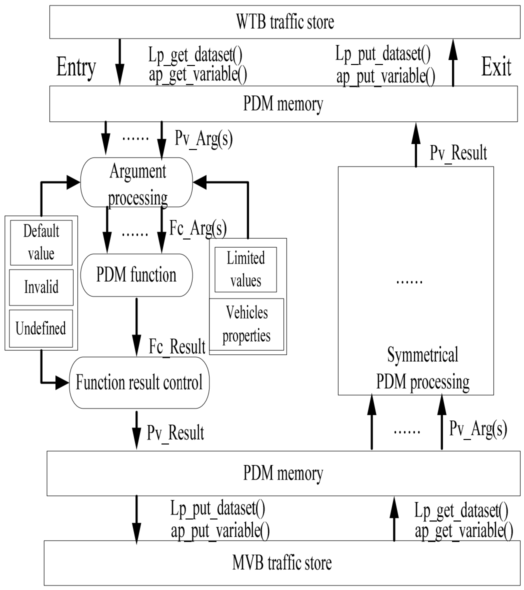


Figure 2. PDM operating procedures

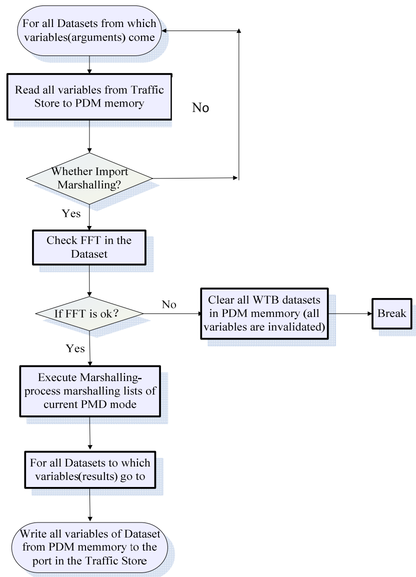


Figure 3. PDM main steps

3 Message data transfer mechanism and UMS

If the message data is transferred from WTB bus to MVB bus and via the TCN ＆UIC gateway, named entry package. The message data from WTB bus will transmit through RTP Real, and afterward get to NMA and UMS for processing, finally reach to MVB bus. NMA module achieves network management through message data. UMS module receives and analyzes E through UAGT modules, and based on the analysis of E telegrams command, determine which sub-module corresponding interface functions should be called to perform operations. Some messages are not transmitted to application and transmitted directly from WTB to MVB bus via messenger. As shown in Figure 4.

UMS is responsible for sending and receiving E telegrams and provide external applications serves, E telegrams from RTP contain remote application service requests submitted. E telegrams are received and analyzed by UAGT sub-module in UMS, then according to different application service requests, functions named UNGS, UWTM, UTBC and UIMCS four sub-modules are called. Among them, UAGT processes result and send reply messages back. UWTM can control inauguration, read the network topology, read node status and other services. UNGS provides NADI and Group database, which stores detailed information about the train, including the inauguration frame version number, R packet data version number, topology, UIC address, train direction, vehicle attributes, additional vehicle information, NADI status, etc. GROUP database holds the information about the vehicle group (LI, 2013). UTBC can deal with leading vehicle request, generate new NADI data and provide redundancy status information and other services. UIMCS is used for changing and grouping information which should be distributed to the corresponding vehicles. Through UIMCS module, distribute above serves as multicast form by TCN protocol.

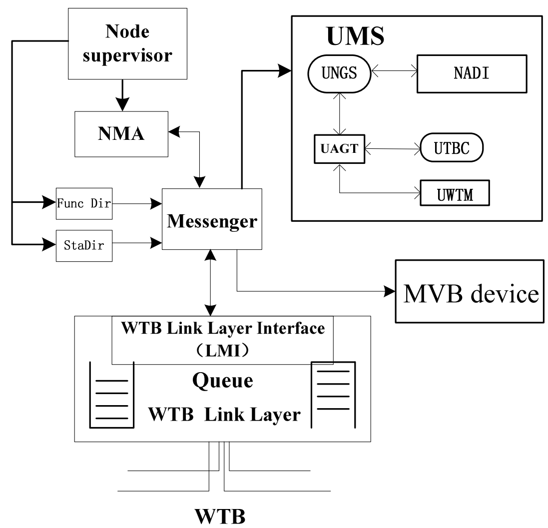


Figure 4. Message data transmission process in the UIC gateway

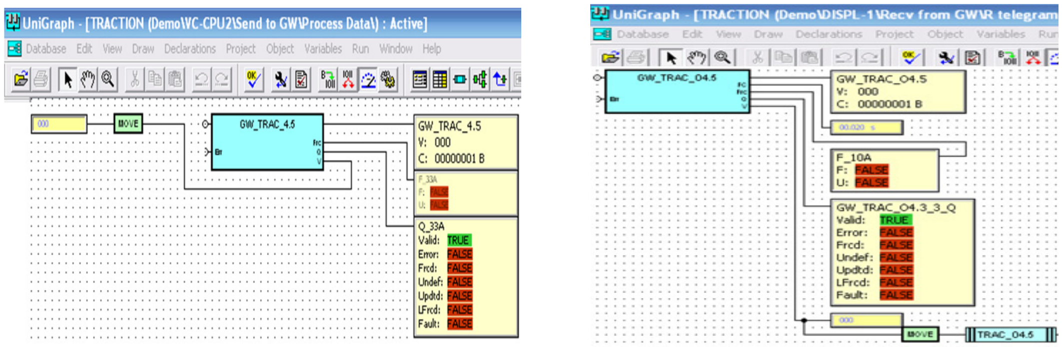
4 Simulation analysis

Semi-physical simulation platform adopted foreign company's TCN＆UIC gateways four set which type was TCN-GW01 / H, 110V power supply, redundant, no I / O interface, for remote shutdown. Additional, equipped with four central processing unit (CCU) and display (HMI) to simulate the corresponding sub-functional units. Used Configuration and Service Station (CSS) software to configure the gateway. Used UIC Train Diagnosis Station (UDS) software to monitor gateway. Each gateway configured one vehicle, and the platform simulated process and message data communication respectively on the train.

4.1 Process data communication simulation

The four sub-function device simulation unit can simulate traction, braking and other equipment of EMU, produce process data and transfer it from MVB bus to UIC gateway. After PDM operation, the data was packaged into R telegram and was sent to other marshalling unit or train. At the same time, UIC gateway received information from other vehicles, and distributed to on-board equipments via MVB bus.

As shown in figure 5, the transmission simulation for train traction of R1 telegram 4.5 (choice of pantograph). First, within the CSS, configured host ports 101 and 104, source ports 201 and 204. Then defined send and receive variables, made variables and defined port match, defined byte offset and checking variables according to the UIC556 standard. Hereafter set up PDM transfer process of process data in gateway, input or output marshalling. Finally, programming with Unicap modular software.



4.2 Message data communication simulation

Select the message telegram 8.2 and 8.2A. If you press the failure Enter key on the display, HMI would send message data request to the leading vehicle simulation unit. After received telegram 8.2, leading vehicle sent 8.2A to HMI. Select index type was function index, code 102 and 103. As shown in Figure 6.

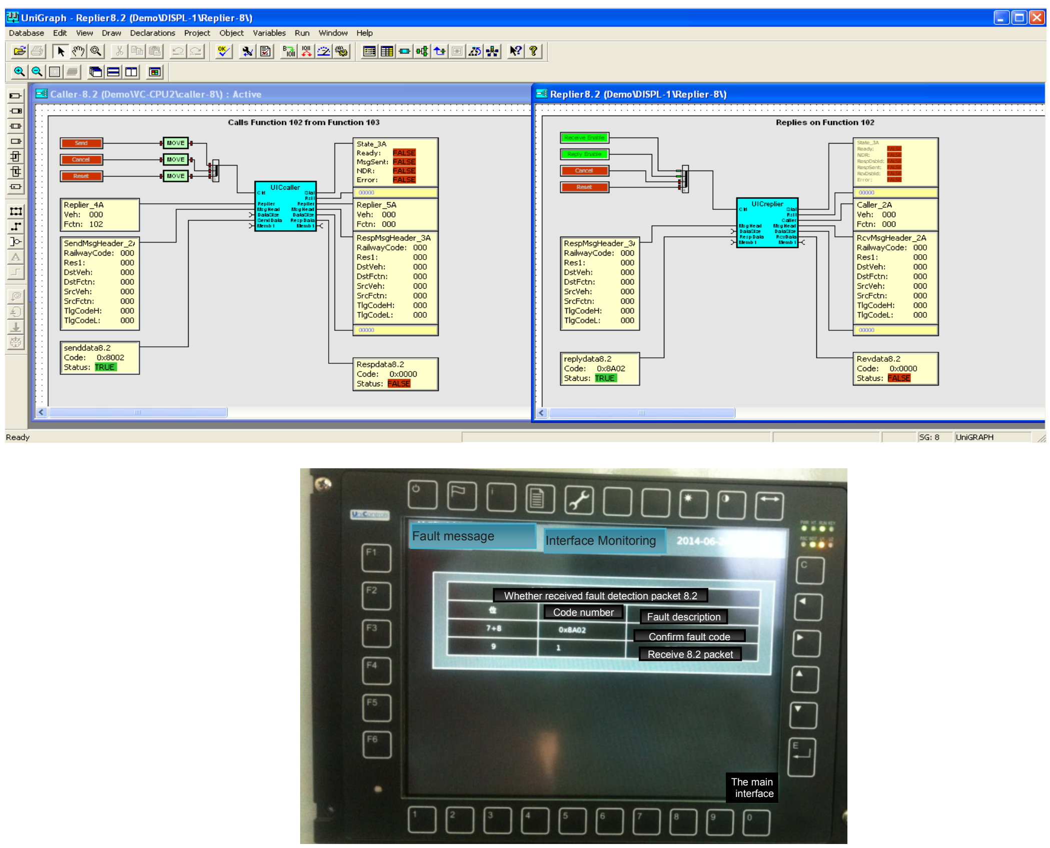


Figure 6. 8.2 and 8.2A telegram transmission simulation

5 Conclusions

UIC gateway is the key equipment to realize interconnection, intercommunication and interoperability between different models of EMU. UIC and TCN protocol stack software is responsible for it.

This paper focused on the transmission mechanism of process and message data and the software composition of PDM and UMS in UIC gateway. This study was conducive to more fully grasp the UIC gateway software technology, and laid the foundation for independent research and development related products. Meanwhile, provided a solution for the interconnection, interoperability and interoperability related technology problems of china EMU.

Acknowledgement

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References

Schaefers, C, Hans, G(2000). “IEC 61375-1 and UIC 556 - international standards for train communication”. *Vehicular Technology Conference Proceedings*. Volume 2,1581-1585.

UIC556 Leaflet(2004).” Information Transmission in the train (Train-bus), 3. Edition”.

FEMANDEZ D, JIMENZ J, ANDREU J, et al(2007). “A TCN Gateway Emulator” .*Proceedings of IEEE International Symposium on Industrial Electronics*, Bilbao: ISIE, 2911-2916.

JIMENEZ J, MARTIN J L, BIDARTE U, et al(2007). “Design of a Master Device for the Multifunction Vehicle Bus”. *IEEE Transactions on vehicular Technology*, 56 (6), 3695-3708.

JIANG Guotao(2011). “Design of WTB Controller Based on FPGA”. *Railway* Locomotive *& Car,* 31 (2), 88-91.

LI Changxian, LIU Yang, ZHANG Tong(2013). “Research on UIC Gateway for Interconnection, Intercommunication and interoperability between EMUS”. *China Railway Science*, 34 (6), 110-116.

Lateral Distribution Regularity of Ships' Sailing Positions within a Channel Based on AIS Data

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Abstract: In order to offer the general view and regularity of choosing right transverse position and reduce the uncertainty of choosing lateral position to the ship officers when navigating within the two-way fairway, with the theory of marine traffic engineering and data mining technology, the regularity of transverse distribution of ship' sailing position within the two-way fairway is mined and counted using the shipborne AIS data. The regularity reveals positive effect quantitatively on the safe navigation of different ships caused by the <Regulations for Preventing Collisions at Sea, 1974> and extent of different length of ship complying with rules. The result can be used for choosing the safe and suitable transverse sailing position when the ship goes through two-way fairway and also for marine traffic organization, layout and planning of fairway conducted by the authorities.
Keywords: Two-way fairway; Lateral sailing position; Marine traffic; Regularity of distribution; AIS data.

1 Introduction

Considering the issue of vessel security, arriving and leaving vessel of harbor water must keep suitable lateral position in the limited two-way harbor channel. With the increasing amount of ship, the channel become more busy, thus how to choose the appropriate lateral position when navigating within the channel is big challenge for the navigator and officer.

In the No.9 provision of <International regulations for preventing collisions at sea,1972>,a vessel proceeding along the course of narrow channel or fairway shall keep as near to the outer limit of the channel or fairway which lies on her starboard side as is safe and practicable. This provision means that no matter what kind of condition the ship is in, when navigating along the channel and fairway, the ship should keep navigating along the starboard side of channel and fairway, as the saying of keeping the ship starboard side of channel is deeply in the brain of navigator.

Actually what is the extent and percent of keeping starboard side and how to decide the lateral position are confused, especially how to balance the limited channel and safe navigating is a very important issue. The method of obtaining the lateral distribution of ship sailing position within the channel is seldom covered in the marine related literature.

The AIS(Automatic Identification System) data transmitted by ship can reflect ship' navigational status and marine traffic condition, it also provide reliable data for extraction rule of lateral position of ship when navigating within the channel. With the big amount of AIS data ,this paper use the marine traffic theory and data mining technology to design the algorithm of extracting the lateral position, revealing the lateral position distribution pattern of different type and length of ship. It can offer guide for navigator when choosing the lateral position according to their characteristic and marine traffic organization and management.

2 AIS data Preparation

The AIS data used below is gathered by Vessel information service system based on ECDIS and AIS, according the need of research, the following information is the key research data.

(1)Ship' name and MMSI are used to identify and distinguish ship.

(2)Ship' length and breadth are used to indicate the ship' size.

(3)Longitude, latitude and time express ship' lateral positon within the channel.

(4)COG、SOG determine ship' sailing direction and speed.

2 Algorithm of extracting the lateral ship position distribution within the channel

2.1 Preprocess of AIS

Some AIS data are missing and inaccuracy during the process of transmit and decoding. So it is necessary to do preprocess of AIS data, the main measures are below procedure:

(1)Delete the data which MMSI is 0 .

(2)Delete the data which longitude and latitude exceed reasonable range.

2.2 Design of algorithm

In order to obtain the ship lateral position within channel, this paper set a line of observation which is perpendicular with the direction of main traffic flow. Thus the research issue is obtaining the ship' position distribution on the line.

2.2.1 Search the AIS data around the observation line

The AIS data in database covers all the area around the observation line, but we want to search the ship' position on the observation line. The dynamic AIS data are discrete and updated depending on the ship' speed, the interval is between 2s and 12s. So not all the dynamic position are accurate on the observation line, one way to solve it is searching the data which is nearest to the line, then calculate the intersection point of ship trajectory and observation line.

2.2.2 Calculating the accurate ship position on the observation line

(1) Calculate ship position' distance to the two end of observation line, obtaining the nearest position to the observation line if the sum of two distances is

minimum.

(2) Calculate the vertical distance between nearest position and line.

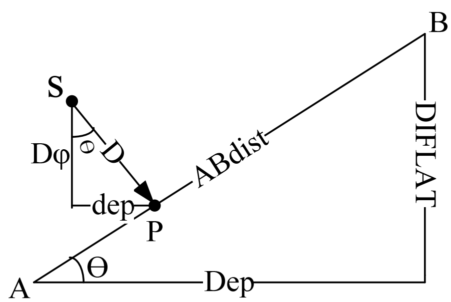

Figure 1. The ship goes across the observation line

As shown in fig 1, A and B is the end of observation line, S is the nearest position of same ship, D is the distance between S and observation line, P is the position when ship passing the observation line, it is also the point we are going to calculate.

(3) Calculate the distance (ABdist), longitude and latitude difference(DIFLONG, DIFLAT) between A and B, and departure(Dep) of A and B. The longitude and latitude difference between P (LatofArrival，LongofArrival) and S(LATITUDE，LONGUTIDE)are Dλ and Dφ. Θ is the angle between line AB and horizontal, Φ_n is the midlatitude of A and B.

(4) The process of calculating the position of P（LatofArrival，LongofArrival):

① Latitude of A and B are $LATITUDE_A$ and $LATITUDE_B$

$\Phi_n=(LATITUDE_A+LATITUDE_B)/2$； （1）

$Dep=DIFLONG*Cos(\Phi_n)$； （2）

② Calculate the sine and cosine of θ：

$Cos(\theta)=Dep/ABdist$； （3）

$Sin(\theta)=DIFLAT/ABdist$； （4）

③ Calculate latitude of P:

$D\varphi=D*Cos(\theta)$ ； （5）

LatofArrival=LATITUDE ± Dφ(+ or – depend on ship position is upward and downward the line) （6）

④ Φ_m is midlatitude of S and P, longitude of P can be calculated:

$\Phi_m=(LATITUDE + LatofArrival)/2$； （7）

$D\lambda=dep*Sec(\Phi_m)=D*Sin(\theta)*Sec(\Phi_m)$； （8）

LongofArrival=LONGUTIDE ± Dλ(+ or – depends on ship position is upward and downward the line) （9）

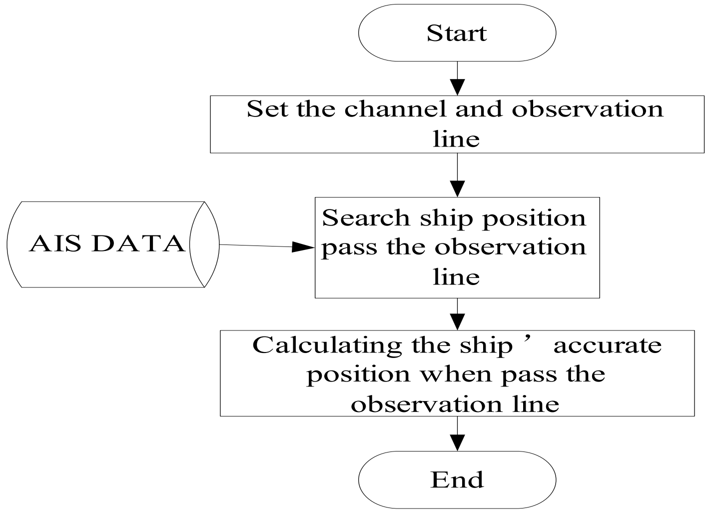

Figure 2. Process of obtaining the position of ship through the observation line

Above algorithm is programed as storage procedure in SQL database, it is very convenient to cope with big data. After the algorithm was carried out, we divide the observation line into small interval, then count the number of ship within each interval which can reflect how to choose the lateral position according to ship' characteristic.

3 Ship lateral position distribution statistics within Xiamen main channel

According to the characteristics of Xiamen channel, choose the channel southeast of gulangyu as our research area. The traffic flow is depicted below, point A and B are selected as the end of observation line.

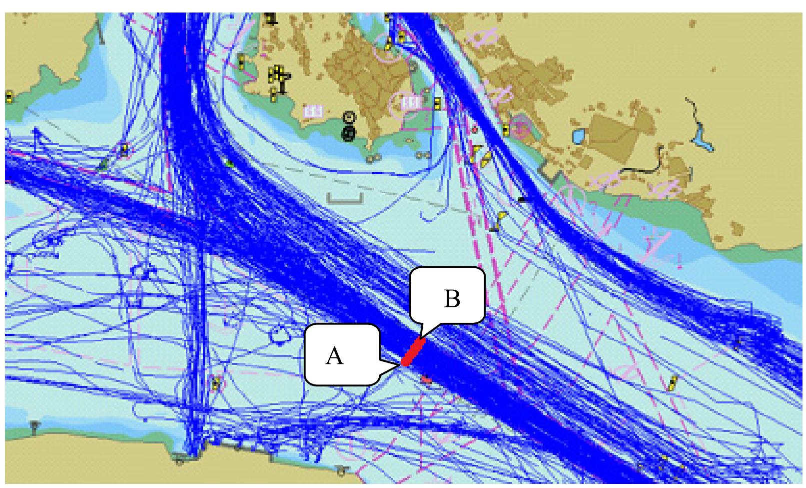

Figure 3. The traffic flow distribution of Xiamen port channel

3.1 Analysis of observation line

As shown in Figure 3, A(24°25.213′N, 118°4.182′E)、B（24°25.35′N，118°04.273′E），we select the AIS data between 2014-7-1 and 2014-7-31.After preprocessing, there are 2703 ship go through the observation line among which 1333 ship going out of port and 1370 ship going into of the port.

3.2 Division of sailing interval

In order to characterize the lateral position ,this paper partition the observation line into 9 intervals according to the distance of observation line end A and B ,as shown below.

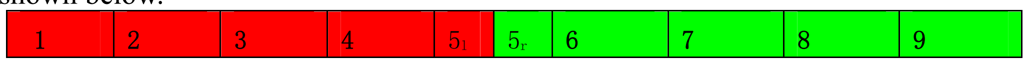

Figure 4. Partition of fairway interval

Even though there is no traffic separation schemes set within the Xiamen channel, ship can go through the channel arbitrarily when going in and out of port, actually the ship is affected by the N0.9 scheme of <rules>,the ship is go along the starboard side when going in and out of channel. As shown above left red side is going-out area(interval No.1-5_l) and right green side is going-in area(interval No.5_r-9).

3.3 Statistic of ship lateral position within sailing interval

Ship lateral position distribution and channel space use ratio is characterized by counting the number of ship navigating within the no.1 to no.9 sailing interval using the statistics theory.

3.3.1 Statistic of going-in area

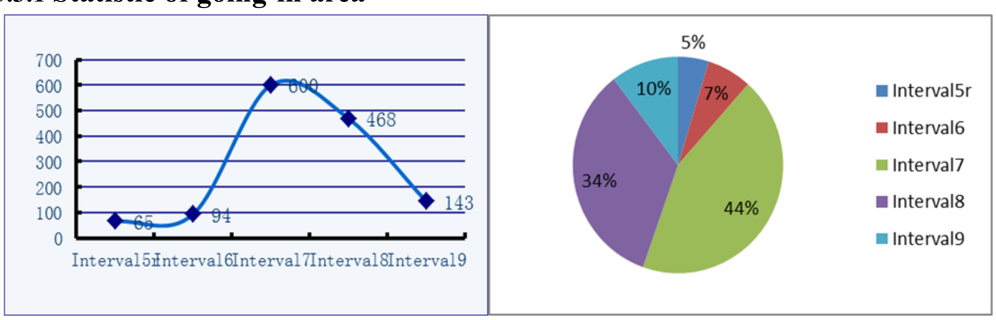

Figure 5. The distribution of arriving ship' sailing position

As shown in Figure5, there are a few percent of ship navigating within the no.5_r and no.6, during which there is 5% ship within the no.5_r and 7% ship within the no.6 sailing interval, these vessels' length is more than 200m, vessel' breadth is more than 30m, these ship choose to navigate almost near the middle of channel for its deep draught need deep water. There are big 44% and 37% within the no.7 and no.8 interval, these ship' length is between 100 and 200, ship' breadth is less than 30m.This means 82% of ship choose to navigate as starboard side of channel, but these ship can’t exceed the bolder of no .8 interval for the outside water’ shallow depth. Within the no.9 interval there 9% ship choose to navigate, these ship’ length is less than 80m and breadth less than 15m for their small tonnage and shallow drought, near outer side of channel can meet their need and safety.

3.3.2 Statistic of going-out area

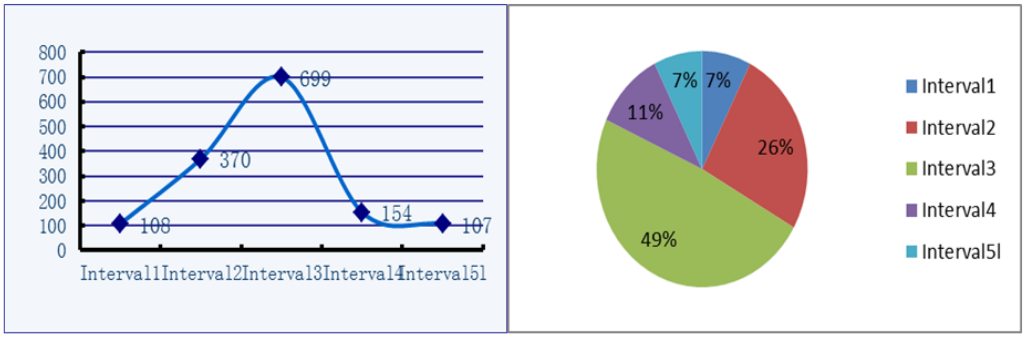

Figure 6. The distribution of leaving ship’ sailing position

As shown in Figure 6, there are a few percent of ship navigating within the no.5_l and no.4, during which there is 6% ship within the no.5_l and 11% ship within the no.6 sailing interval, these vessels’ length is more than 200m, vessels‘ breadth is more than 30m,these ship choose to navigate almost near the middle of channel for its deep draught need deep water. There are big 49% and 26% within the no.2 and no.3 interval, these ship ‘ length is between 100 and 200,ship’ breadth is less than 30m.This means 82% of ship choose to navigate as starboard side of channel, but these ship can’t exceed the bolder of no .2 interval for the outside water ’ shallow depth. Within the no.1 interval there 8% ship choose to navigate , these ship’ length is less than 80m and breadth less than 15m for their small tonnage and shallow drought, near outer side of channel can meet their need and safety.

3.4.3 Statistic of whole channel

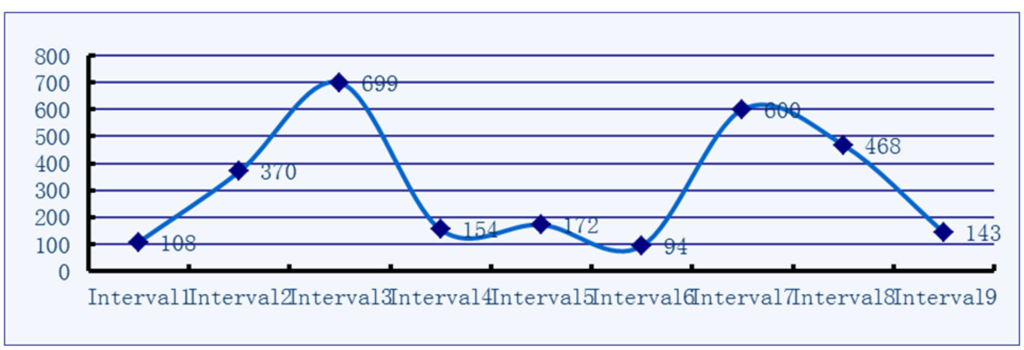

Figure 7. Lateral distribution of ship’ sailing position within the whole fairway

Above shows the ship lateral position distribution within the Xiamen channel, as we see, the amount of ship is increasing from the outer side of channel and reach the top at a quarter width of channel, but there are a few ship at the center of channel. Ship' lateral position is affected by two main reasons, firstly it is affected by the notion of keep the ship as starboard side as possible, this is the reason that there is a few ship choose to sail in the central of channel. On the other hand, navigator must consider ship manoeuvre characteristic and the information of channel, such as the depth of channel and navigational aids. Thus the ship can't navigate too near the starboard side of channel, a quarter width of channel is best choice of mainly middle size ship. Small tonnage ship choose to navigate the outer side of channel, because the shallow water can meet their safe sailing need.

4 Conclusion Analysis

With the theory of marine traffic engineering and data mining technology, the regularity of lateral distribution of ship' sailing position within the Xiamen two-way channel is mined and counted using the shipborne AIS data. This paper characterize the lateral position use ratio of channel, revealing the extent and percent of ship navigating within the two-way channel affect by the <rules>. It proved the navigator' complying attitude toward <rules> and <rules>' good affection on improving the safe navigation within the channel. The result can offer guide to ship operator when choose the lateral based on their ship' characteristic and marine traffic management.

References

JI Xianbiao，SHAO Zheping，PAN Jiacai.(2009)A New AIS-based Way to Conduct OLAP of Maritime Traffic Flow//ASCE. Proceeding of ICTE 2009,America: ASCE.

Karl Gunnar Aarsæther, Torgeir Moan.(2009) Estimating Navigation Patterns from AIS.The Journal of Navigation, (62)： 587-607.

LIN Yixun. (2011) Application of Data Mining Technology in Analysis of Marine Traffic Characteristics, Xiamen, Jimei University.

PAN Jiacai, SHAO Zheping, JIANG Qingshan(2010). Study on Characteristics of Marine Traffic by Data Mining Theory(In Chinese). Navigation of China. 33(4): 57-60

SHAO Zheping,PAN Jiacai,TANG Cunbao (2009).Study on Analysis of Characteristics of Marine Traffic Based on AIS.Proceedings of Asia Navigation Conference,46-52

SHAO Zheping, SUN Tengda, PAN Jiacai. (2007)Development of the Integrated Vessel Information Service System Based On ECDIS and AIS.Navigation of China, (2):30-33.

SHAO Z P，SUN T D，PAN J C，et al．(2007) Vessel information service system based on ECDIS and AIS．Proceedings of ICTE，ASCE, 1678－1683．

TANG Cunbao, SHAO Zheping, PAN Jiacai, etal.(2012) Vessel Track Distribution Algorithm Based on AIS,(2):110-111.

SUN Wenli, SUN Wenqiang. (2004)Shipborne Automatic Identification System. Dalian Maritime University Press.

WU Zhaolin, ZHU Jun. (2004) Marine Traffic Engineering. Dalian Maritime University Press.

IOT Big Data Process Based on Context Temporal-Spatial Characteristics in Petroleum Products Distribution

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Abstract: For solving problem of heterogeneity data process and low data processing capability in IOT, data in IOT is abstracted as "Context"; taking "Context" as the unified object in IOT big data process, a model of big data process based on Hadoop framework (HDC) is designed. Finally, apply the proposed model to solve problem of vehicle scheduling in petroleum products distribution, capacity of data process is validated by MapReduce distributed parallel computing experiments. Results of the experiments show that HDC has obvious excellence in big data process compared with ordinary computing system.
Keywords: Big data; Hadoop; Internet of things.

1 Introduction

In modern society, distribution is the core business of the whole logistics activities. For oil products logistics, distribution is the procedure of transportation from oil depots to gas stations or to other end-users, which is the last and most important link between oil depots and end users. It plays a key role for business efficiency improvement of oil enterprises [1][2].

In recent years, IOT is applied in more and more fields. In petroleum products distribution, IOT is used in products storage, transportation, and also in clients' inventory and the managing level is improved rapidly. Big data management generated from IOT of petroleum products distribution is a key factor which has restricted the improvement of this filed.

Therefore, there are too many different types of data collecting ends in IOT, data collected from these ends is not only of characteristics of traditional big data, for example, large in volume, high in real time; and also has the unique feature of IOT information, for example, obvious heterogeneity, complex relation, fast data growth and high frequency of data switching and querying [1]. Thus, technical support requirements in IOT data process are much higher in recent years.

Currently, there are already a lot of successful solutions for big data in IOT environment, among which Hadoop distributed system architecture is the most successful solution popularly applied. Hadoop is a distributed software framework which can process large amounts of data through a distributed system and has high reliability and good scalability. Hadoop distributed file system HDFS, distributed computing model MapReduce and distributed database HBase are its three core technologies.

From the existing researches, in (Xue yuan su,2012) ,(Cui Jie,2012) and (Abhishek Verma,2012) architectures of information processing system for massive sensor data in IOT environment are proposed. These models have a high data process capacity, but can't solve problems of heterogeneous data process in IOT. Heterogeneity is one of the main characteristics in the IOT data, so that establishing a unified data model for IOT big data process is in strong demand. In (Abhishek Verma,2012), limitation in query with complex structure is solved in some extent, but data process capacity is still low and needs to be improved.

Since the limitation of existing researches in heterogeneity data process and low data process capacity in IOT environment, a Hadoop big data processing model (HDC) is proposed. In HDC, big data and client requirements are abstracted as “Context” which is the unified object to be processed.

Finally, apply HDC to solve problem of big data process in petroleum products distribution. Results show that the HDC is of high efficiency in data process capacity, response capacity, and data execution capacity.

2 Data Model in IOT

In the IOT, entities include the dominant entity "person", computing entity "machine" and end entities with a sense of ability to identify and control the "objects".Data heterogeneity is obvious in data transferring among different entities. In order to process heterogeneous data uniformly and shield heterogeneity to upper applications, a unified abstraction model for heterogeneous data in IOT is in great demands. In HDC, client service requirements and the collected data are uniformly modeled as "Context".

Data in the IOT environment mainly includes: status, security, transaction processing, etc. In order to encapsulate these information in a unified model, this paper presents a data model for IOT object named as "Context" and is the uniform data and client requests format to be processed in HDC which is defined in Definition 1.

Definition 1: "Context" is composed of five attributes: *Context* = (*id*, *t*, *pos/region*, *mode*, *data*). Meanings of the attributes are:

- *id*: object id. It is the unique object identifier.
- *t:* data collected time.
- *pos*/*region: pos* is the data collected location, and this attribute is for object

monitored by point; *region* is the data collected area, and this attribute is for object monitored by region.

- *mode:* data acquisition manner. For example, perception, input, reasoning, checking, feedback and etc.
- *data:* main information. It is data information to be transferred and processed.

3 Big Data Process System Model

Utilizing "Context" as the unified data object, a Hadoop big data processing model named as HDC is proposed to satisfy distributed processing requirements. HDC is focus on improving data processing capacity of traditional Hadoop framework.

3.1 HDC "CONTEXT" PROCESSING MODEL

HDC mainly includes modules of data collection, data adaption, context generation, context preprocess, context pool, context perceiving, context execution and etc. With sensors as the end devices, context processing model and its data processing procedure are expressed in detail in the Figure 1.

As shown in the Figure 1, data collected from sensors of IOT ends will be encapsulated as the "Context" through "Context Adaptor"; the collected data are often electrical signal, digital signal or a string without specific meaning. Procedure of data mapped from original collected information to "Context" is called as context adaptation (Adaption), which can be expressed as adaptation: S->C. The input S for data adaption is data collected from IOT ends and output C is the "Context Collection" which can be identified by system and will be added into context nodes. The "Context" in context nodes will be handled by preprocess modules, so that valid "Context" will be added to "Context Pool" otherwise to be separated. The "Context Analyzer" fetches the "Context" periodically according to rate of heartbeat, and the advanced "Context" will be generated after analyzing and clustering; advanced "Context" assembles all necessary components for execution and then corresponding operation will be executed; finally, "Context" in execution results needed for feedback will be put back to context nodes for future process.

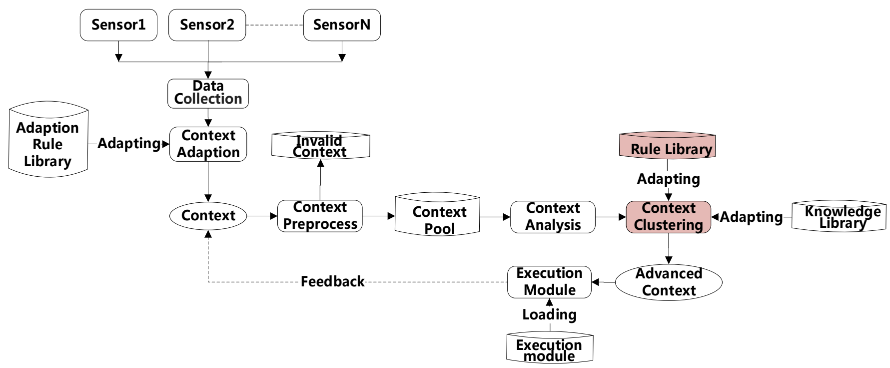

Figure 1. Model of "Context" processing

3.2 DISTRIBUTED PARALLEL PROCESSING MODEL BASED ON CONTEXT QUEUE

The data processing flow shown in the Figure 1 is only a single data processing point in the IOT. In fact, data collection nodes in the IOT are often of characteristics of complex structure, wide distribution and massive quantity, so that single point data processing model can't meet requirements in the IOT environment. Thus, a distributed parallel processing model is required to enhance its practicability.

Based on the single point data processing model, HDC uses Hadoop as basic framework and mainly includes four layers which are computing layer, persistence layer, storage layer and processing layer. In detail, persistence layer manages "Context" access; storage layer stores information of historical "Context" and rules in rule library; computing layer is in charge of data processing and the generated "Context"; process layer listens "Context" in context queue through "Context Listeners" and dispatch them to external interfaces for further process. Considering the limitation of low real-time data processing capacity of Hadoop, the "Context Queue (CQ)" is proposed to be added to HDC as an assistant storage and the improved model structure is shown in the Figure 2.

As shown in the Figure 2, the storage layer is composed of HDFS and HBase. Mass sensor data collected can be stored directly to HDFS or be transformed to "Context" by "Context Adaptor" and then added to the CQ. MapReduce listens "Context" in the CQ and write periodically to HDFS and HBase. As the distributed storage medium for massive sensor information, HDFS and HBase are the base for distributed parallel data processing. MapReduce algorithm in computing layer processes "Context" from context cache pool in parallel, calls the external interfaces for execution and stores results generated to HDFS. "Context Listener", "Context Queue" and external interfaces together formed the "Context Queue Processing Model" (CQPM), which can not only satisfy system distributed and parallel requirements, but also achieve demands of higher system.

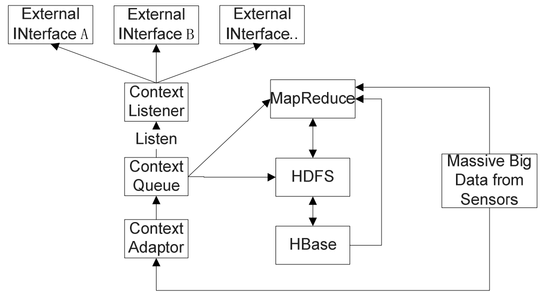

Figure 2. Distributed parallel process model

4 Model Validation and Analysis

Traditional single data process system (SDS) utilizes conventional techniques and consumes expensive computing resources. Simultaneously, SDS uses single server to process data so that data computing capacity is relative. In this section, taking vehicle scheduling in petroleum products distribution as the test case, data process capacity between HDC and SDS is compared and data query ability is also tested.

4.1 TEST CASE

Using the in-transit petroleum products status data collected during distribution procedure as the experiment sample data, which can be defined as vector V_t.

$$V_t = \begin{bmatrix} V_{11t} & \cdots & V_{1nt} \\ \vdots & \ddots & \vdots \\ V_{m1t} & \cdots & V_{mnt} \end{bmatrix} \tag{1}$$

In the vector V_t, row vector V_{it} ($V_{it} = [V_{i1t}, V_{i2t}, V_{i3t}, \ldots, V_{int}]$) is the "Context" information transmitted from some entity at time t. In V_t, m is the number of entities and n is the number of attributes in the one "Context".

The sample data of vehicle information is consisted of two parts: vehicle basic information and vehicle in-transit information. Vehicle sample is defined as vector U_t.

$$U_t = \begin{bmatrix} U_{11t} & \cdots & U_{1nt} \\ \vdots & \ddots & \vdots \\ U_{h1t} & \cdots & U_{hnt} \end{bmatrix} \tag{2}$$

In the vector U_t, U_{jt} ($U_{jt} = [U_{j1t}, U_{j2t}, \ldots, U_{jnt}]$) is the combination of vehicle basic information and current state. The elements in U_{jt} are attributes such as vehicle type, unit transport charge, current state and etc.

Define the best scheduling scheme as one which can not only meet distribution requirements but also achieve a minimum cost. The objective function is defined in formula (8).

$$Min(cost) = d_i(s(V.U)).u_i(s(V.U)) \quad (3)$$

In the formula(3), s(V.U) is the vehicle collection satisfying requirements for distribution. d_i(V.U) is the total distribution distance and u_i(s(V.U)) is the unit price for transportation.

The experiment sample includes distribution status data collected from 10000 (m = 10000) time points and vehicle information data from 100 (h = 100) time points. In map phase, satisfying vehicle collection is got by matching sample data of petroleum product status and vehicle information to meet the distribution requirements; in reduce phase, by analyzing and calculating collections from map phase so that the best scheduling scheme with minimum cost can be obtained.

Hardware configurations of the experiments are shown in the Table1, in which, C_1 is the master server which has relatively better hardware condition. $C_2 \ldots C_{15}$ are the identical slave servers, which are of lower hardware configuration with respect to C_1.

Table 1. Hardware configuration of servers

Name	Configuration	Role
C_1: DELL (Master Server)	Intel(R) i5 CPU 4G Memory 64 Bit Redhat Linux	Datanode, Tasktracker, Jobtracker
C_2 to C_{15}: DELL (Slave Servers)	Intel(R) i3 CPU 2G Memory 32 Bit Redhat Linux	Namenode, Datanode, Secondarynode

We use number after model name to indicate number of servers in experiment environment. For example: experiment environment including five servers in cluster is respectively expressed as "HDC-5" and "SDS-5".

4.2 DATA PROCESSING CAPACITY COMPARISON TEST

As conditions shown in the Table 1, a simulation model is established by MatLab and the objective function value can be calculated by formula (8). Through continuous integrating server resources to experiment environment, nine distributed parallel computing experiments respectively with 1,2,4,6,7,8,10,12,15 servers were carried on. An average data processing capacity (processing capacity is the reciprocal of data processing time) of SDS and HDC are shown in the Figure 3 and data processing time in the Table 2. In the Figure 3, abscissa represents number servers in the cluster.

It can be seen from the Figure 3 and Table 2, in the cluster with 1, 2, 4 servers, SDS has a better performance than HDC (because map and reduce tasks themselves will consume some system resources); with continuous integration of servers, computing capacity of HDC has been rapidly increased. When the number of servers integrated reaches 6, data processing performance of HDC begins to show some advantages than SDS. In the experiment environment with 10 servers, data processing capability of HDC-10 is more than 200 times of SDS-10.

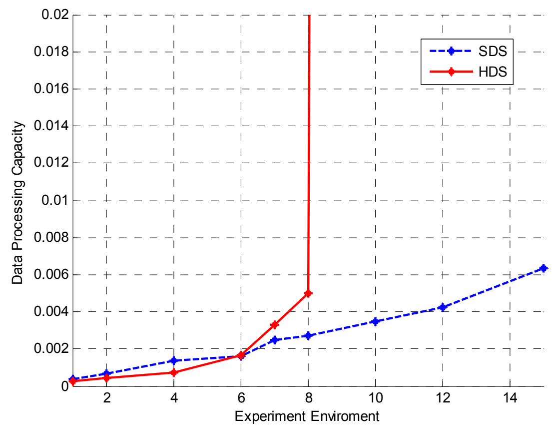

Figure 3. Average process capacity contrast of HDC and SDS

Table 2. Average sample process time contrast of HDC and SDS

Name	Time(ms)	Name	Time (ms)
SDS-1	2568	HDC-1	3469
SDS-2	1484	HDC-2	2377
SDS-4	742	HDC-4	1350
SDS-6	632	HDC-6	598
SDS-7	402	HDC-7	305
SDS-8	371	HDC-8	200.2
SDS-10	287	HDC-10	1.2
SDS-12	235	HDC-12	0.8
SDS-15	157	HDC-15	0.4

4.3 DATA PROCESSING RESPONSE CAPACITY VALIDATION

In this section, still using the case in section 4.1, validation of data processing response capacity is tested.

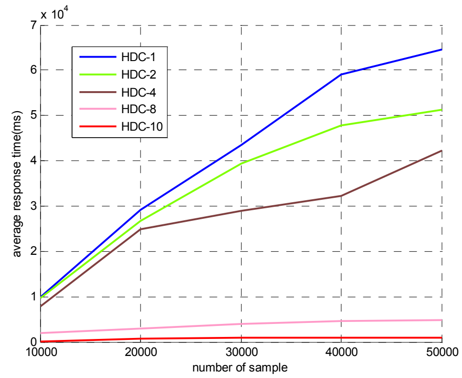

Figure 4. HDC Average response time test

Table 3. HDC average response time (ms) test

Number / Name	10000	20000	30000	40000	50000
HDC-1	10017	29090	43587	58988	64577
HDC-2	9797	26778	39434	47877	51245
HDC-4	7875	24797	28988	32211	42334
HDC-8	2012.5	3012	4013.8	4508.5	4734
HDC-10	417	793	887	921	934

The five distributed parallel computing experiments are processed which respectively includes 10000,20000,30000,40000 and 50000 petroleum sample data and in all experiments, the number of vehicle sample data are all 100. Using the MatLab as the simulation tool, the simulation model was established, and the system response time are shown in the Figure 4 and the Table 3.

It can be seen that data processing performance of HDC is not directly proportional to number of servers in cluster. Especially with relatively more servers integrated to the cluster, the calculation capacity can be greatly enhanced. For example, compared with HDC-8, the HDC-10 is only with two more servers added and the capacity of data processing has been increased by nearly 5 times.

Through the data in above experiments, we can see that in cluster environments with 6 and more servers, HDC has greater advantages in data processing capacity than SDS; at the same time, to improve data process capacity of HDC, it only needs to integrate more servers seamless to the cluster. Especially in a multiple server environment, data processing capacity can be improved rapidly if more servers were added.

5 Conclusion

By analysis of IOT data characteristics, a Hadoop big data processing model (HDC) is proposed. In HDC, big data and client requirements are abstracted as

"Context" which is the unified object to be processed. Based on temporal and spatial characteristics of "Context", definition of CNS is proposed. Uniform Data query operations are also defined upon ideas of CNS. Besides, context & rule matching algorithm and task reorganization algorithm in the CNS is illustrated in detail. Compared with existing researches, HDC is not only able to solve heterogeneous data storage, query, analysis and application in IOT environment but also a good way to improve data processing, data query capability and also data execution effectiveness.

Acknowledgement

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References

Abhishek Verma, udmila Cherkasova, Roy H. Campbell. Two Sides of a Coin: Optimizing the Schedule of MapReduce Jobs to Minimize Their Makespan and Improve Cluster Performance, Modeling, Analysis and Simulation of Computer and Telecommunication Systems.2012, Washington DC, United states,MASCOTS, Proceedings of the 2012 IEEE 20th International Symposium, 12-18.

Cui Jie, Li Taoshen, Lan Hongxing. Design and Development of the Mass Data Storage Platform Based on Hadoop. 2012 Journal of Computer Research and Development 49(Suppl.), 12-18.

Ding Zhiming, Gao Xu. A Database Cluster System Framework for Managing Massive Sensor Sampling Data in the Internet of Things.2012 Chinese Journal of Computers 35(6),1175-1191.

Huang Zhexue,CAO Fuyuan,LI Junjie.Developing Sea Cloud Data System Key Technologies for Large Data Analysis for Large Data Analysis and Mining. 2012 Journal of Network New Media 1(6), 20-26.

Jeffrey Dean,Sanjay Ghemawat.MapReduce: Simplified Data Processing on Large Clusters. 2008 COMMUNICATIONS OF THE ACM 51(1), 107-113.

Jin Ming Shih, Chih-Shan Liao, Ruay-Shiung Chang. Simplifying MapReduce Data Processing. 2011, National Dong Hwa University, Hualien, Taiwan Utility and Cloud Computing, 2011 4th IEEE International Conference: IEEE, 366-370.

Li Chenghua,Zhang Xinfang,etc.MapReduce:a New Programming Model for Distributed Parallel Computing. 2011 Computer Engineering & Science 33(3), 129-135.

Martin Koehler, Yuriy Kaniovskyi, Siegfried Benkner .An adaptive framework for the execution of data-intensive MapReduce applications in the Cloud. 2011, Parallel and Distributed Processing Workshops and Phd Forum(IPDPSW 2011),1122-1131.

Qi Mingyao,Ding Guoxiang. Vehicle Routing Problem with Time Windows Based on Spatiotemporal Distance. 2011 Journal of Transportation Systems Engineering and Information Technology 11(2), 85-89.

Su Wei,LI Jingwen. Design Method of GIS Spatio-Temporal Data Model Based on MapReduce. 2013 Geomatics & Spatial Information Technology 36(7), 41-44.

Wang Xiao dan, Christopher Olston. CoScan: Cooperative Scan Sharing in the Cloud.2011, Cloud Computing, SOCC, Proceedings of the 2nd ACM Symposium.

Wang Xiaojun,Sun Hui.Research of Optimizing Multiway Joins Based on MapReduce. 2013 Computer Technology and Development 23 (06), 59-66.

Xie Gui Lan,Luo SHENG Xian. Study on application of MapReduce model based on Hadoop. 2012 Microcomputer & Its Application 33(8), 4-7.

Xue yuan su, Garret Swart.Oracle In-Database Hadoop:When MapReduce Meets RDBMS. 2012, SIGMOD*, Management of Data, Proceedings of the ACM SIGMOD International Conference*, 779-789.

Yue Hong B.Bi-Hadoop: Extending Hadoop to improve support for binary-input applications, Cluster, Cloud,and Grid Computing, CCGrid, Proceedings 2013- 13th ACM International Symposium,245-252.

Yang Y, Long X. Impacts of virtualization technologies on Hadoop. 2013, Hong Kong,China ,Intelligent System Design and Engineering Applications, ISDEA, Proceedings of the 2013 3rd International Conference ,846-849.

Zheng Di, Wang Jun, Ben Kerong. Research on Component Adaptation Model Supporting Context-aware. 2012 Computer Engineering 38(02), 39-41.

Zhang Yougen,Wu Lingda. Combing Temporal and Spatial Context for Sketched Graphical/Textual Stroke Classification. 2013 Journal of Electronics & Information Technology 35(1), 113-118.

Railway Freight Demand Analysis Based on Multidimensional Association Rules Mining

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Abstract: Railway freight demand are predicted and analyzed by using multidimensional association rule based on Apriori algorithm. At the same time, Three correlation models—goods-weight-transport distance, goods-weight-arrival railroad, goods-weight-arrival province are established by using data mining software Clementine to analysis some railway freight invoice of a railway bureau. Finally, some association rules which are helpful for railway freight demand analysis are obtained. It proved that using multidimensional association rules to analyze the railway freight demand is rational and feasible.
Keywords: Railway freight demand; Data mining; Multidimensional association rule.

1 Introduction

Carrying on an in-depth analysis of the railway freight demand is important for railway department to organize transportation production, to develop the transportation market and to make marketing strategies. Previous researches on the freight demand mostly are concentrated in the mechanism of freight demand, the determination of the influence factors of freight demand and the prediction of freight volume and so on. It couldn't have comprehensive knowledge of freight demand.

This paper use a commonly used data mining technology: the association rule, and establish a multidimensional association rule to analyze a large number of invoice data in practice, in order to find out the relationship between the category of goods, goods weight, transportation distance and other information, and to have a comprehensive knowledge of freight demand, providing the basis and reference for railway enterprises to make decisions.

2 Relevance in the Freight Invoice

Association rule is an important data analysis method in Data mining technology, the purpose is to find out the relationship between different sets of data items in the specified database. Its basis is that if the value of two or more data items in the database repeat and it reaches a certain probability, there is a correlation between them (Ye Xiaoming,2007).

Association rule is put forward by Agrawal et al(Agrawal,1993), which initial application is the analysis of shopping basket in supermarket. After an analysis of store sales record in history, it found that most customers buying milk also will choose to buy bread at a same time, so there is a correlation between milk and bread. Thus the operator may consider bundling the two goods, in order to improve sales.

Freight invoice is the shippers' proof of freight business, which directly reflects the shippers' demands of railway transportation from the category of goods, the weight of goods, transport distance, freight origin destination and so on. Exploring some association rule that cannot be found only by the statistical method through the correlation analysis on the different dimensions of the freight invoice is feasible.

3 Multidimensional Association Rule

According to the selection of data dimension in data mining, association rule can be divided into single dimensional association rule and multidimensional association rule. Single dimensional association rule involves only one dimensional of data. For example, a rule as "grain ⇒ agricultural and sideline products" is obtained by mining the freight invoice. It only involves the attribute dimension of goods category, which indicated that the shippers who send grain mostly also send agricultural and sideline products. If considering multiple dimensions of data, then the mined rules are multidimensional association rule. As the rule "grain∧ Zhengzhou North Station ⇒ Changsha East Station", which involves the attribute dimension of goods category, departure stations, destination station, this shows that the grain is one of the main goods from Zhengzhou North Station to Changsha East station. It can be seen that mining and analyzing freight invoice data with considering only a dimension is difficult to have comprehensive understanding of railway freight demand, so finding the association rule between multidimensional attributes through the multidimensional association mining model, then to analyze railway freight demand is meaningful.

4 Freight Invoice Data Mining Process Based on Multidimensional Association rule

4.1 Association rule mining algorithm

At present, the Apriori algorithm is a commonly used method in mining association rules of data items. The algorithm searches the database successively by using the ideas of iteration, finds all frequent item sets by connecting and pruning, and finally generates association rules from frequent item sets. According to the given minimum support: min_sup, it first find the frequent 1-item set satisfied min_sup, denoted by L_1. Through L_1 connecting to itself, candidate 2–item set is generated, denoted by C_2. By deleting the non-frequent item with pruning in C_2, frequent 2-item set is generated, denoted by L_2. Then L_3 is produced by L_2, so circulates, until L_k is not a frequent k-item set. Finally, the association rules that meet the given minimum confidence: min_conf, are found in all frequent item sets.

4.2 Data preparation

4.2.1 The data source

Some freight invoice data for a station of a railway bureau in January 2015 (export to Excel file, a total of 571 shipping records) are taken as mining object. The data set should be pretreated, converted and discretized and so forth, in order to meet the needs of mining association rules.

4.2.2 Data preprocessing

(1) Data filtering: The redundant field has no significance and reduces the execution efficiency of the algorithm. Therefore, according to research needs, other extra fields are deleted, retaining only the goods category, the name of destination, transport distance and weight for mining analysis.

(2) Data cleaning: When inputting data, wrong operation and other reasons will lead to some of the data or field miss information and format errors, etc. For these cases, the parties need to complete or fix the problem data. An entire record should be deleted if it cannot achieve the prescribed cleaning requirements, lest it has impact on the final mining results.

After the pretreatment, 568 complete records are retained for mining analysis.

4.2.3 Data conversion

(1) The goods category field: Because the goods category is numerous, so the delivery record belong to a category of goods is not much, which will lead to this record's support is not enough, and not conducive to the mining of the association knowledge. Therefore, according to the regulations of *Table of the classification and code of Names of Railway Goods*, All goods category information was merged into 26 categories. Thus the number of cargo records of a certain categories was increased.

(2)The origin-destination field: Similarly, merging the origin-destination information according to the categories also contribute to the discovery of association rules. We can convert the origin-destination information to the two new fields. One is the province that the origins or destinations belong to, so we can know that supply and demand of the goods in different parts. Another is the railway bureaus that the origins or destinations belong to, so that we can know the goods circulation between each railway bureau. Obviously, the meaning of rules according to two fields is different.

4.2.4 Data discretization

In the process of transport of goods, some attribute values are continuous, such as the goods weight, transport distance etc. But Apriori algorithm can only deal with discrete attributes. Therefore, discretization of continuous attributes is necessary.

(1) Discretization of transport distance value: This paper uses the predefined concept hierarchy to discretize transport distance attribute. The discretization of numerical attributes with interval values can be processed like goods category (each distance interval as a class). It is generally believed that 0-500km is the road transport market, while railway transport market is 500-1500km (Lei Dingyou,2003), but as Railway Bureaus operated bulk cargo trains and high-speed railway express trains, transport distance also began to involve 500km inside and 1500km outside. Therefore this paper divides distance information into four classes: I (0-500km), II (500-1000km), III (1000-1500km) and IV (more than 1500km).

(2) Discretization of cargo weight: Local discretization methods are commonly used with equal width interval method, frequency interval method (Zhang Wenyu, 2002). As the goods weight information is dispersive, the above method is not applicable for this research. So this paper uses K-means clustering method to cluster all the weight information into three classes: I (0~0.5 tons), II (0.5~1.5 tons), III (1.5~3 tons). Some clustering results as shown in Table 1.

Table 1. Cargo weight information clustering results

Sequence Number	Weight (tons)	Classes	Sequence Number	Weight (tons)	Classes
1	3.000	III	5	0.410	I
2	2.115	III	6	0.340	I
3	2.250	III	7	1.850	II
4	1.200	II	8	0.580	I

Finally, after processing, the format of freight invoice data table used in the data mining as shown in Table 2.

Table 2. Freight invoice data after preprocessing

Sequence Number	Cargo Category	Cargo Weight	Transport Distance	Arrival-railroad	Arrival-province
1,2, …,	26 classes	I, II, III	I, II, III, IV	18 railroads	34 provincial administrative region

4.3 The establishment of multi-dimensional association rules mining model

Subsequently, those preprocessing freight invoice data are the data source, and three Apriori correlation model are established by software Clementine12.0.

(1) The goods-weight-transport distance correlation model: through the data filtering, the categories and weight of goods are the input, the transport distance are the output, the minimum support and minimum confidence are set to 5%, 25%;

(2) The goods-weight-arrival railroad correlation model: through the data filtering, the categories and weight of goods are the input, the arrival-railroad are the output, the minimum support and minimum confidence are set to 3%, 25%;

(3) The goods-weight-arrival province correlation model: through the data filtering, the categories and weight of goods are the input, the arrival-province are the output, the minimum support and minimum confidence are set to 3%, 25%.

The whole process of data mining is shown in Figure 1.

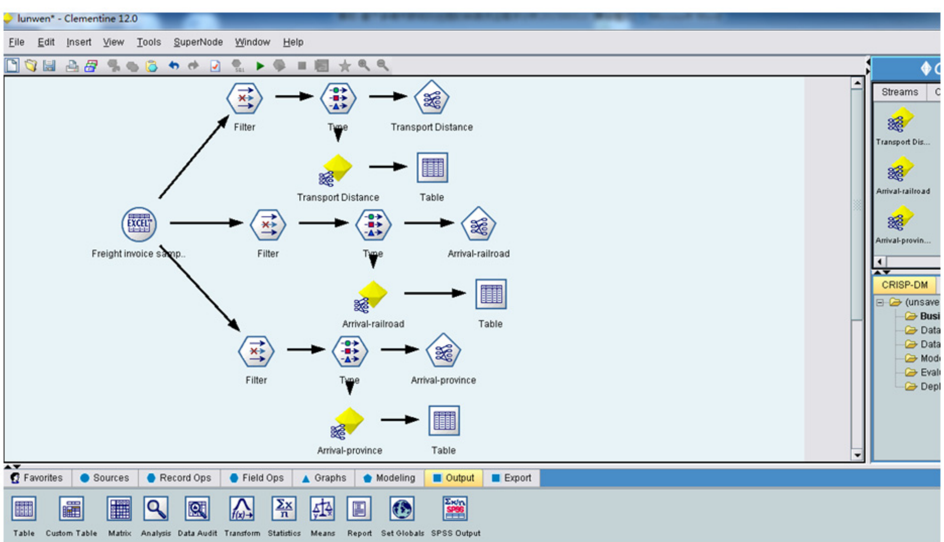

Figure 1.The process of data mining

4.4 The test results

Obtained by data mining, some significant association rules between different attribute fields, which are shown in Table 3, Table 4, and Table 5.

Table 3. Association results of goods-weight-transport distance correlation model

Sequence Number	Association rules	Support %	Confidence%
1	Industrial machinery $\wedge$ Class I weight $\Rightarrow$ Class IV transport distance	5.254	70
2	Pharmaceuticals $\wedge$ Class I weight $\Rightarrow$ Class IV transport distance	5.079	68.966
3	Grain $\wedge$ Class I weight $\Rightarrow$ Class IV transport distance	38.704	59.729
4	Food and tobacco products $\wedge$ Class I weight $\Rightarrow$ Class IV transport distance	6.48	56.757
5	Other goods $\wedge$ Class I weight $\Rightarrow$ Class IV transport distance	6.83	43.59
6	Electronic, electrical machinery $\wedge$ Class I weight $\Rightarrow$ Class II transport distance	5.429	41.935
7	Textiles. Leather, fur and products $\wedge$ Class I weight $\Rightarrow$ Class IV transport distance	5.779	36.364
8	Electronic, electrical machinery $\wedge$ Class I weight $\Rightarrow$ Class IV transport distance	5.429	32.258
9	Textiles. Leather, fur and products $\wedge$ Class I weight $\Rightarrow$ Class III transport distance	5.779	30.303
10	Grain $\wedge$ Class I weight $\Rightarrow$ Class III transport distance	38.704	25.792

Table 4. Association results of goods-weight-arrival railroad correlation model

Sequence Number	Association rules	Support %	Confidence%
1	Electronic, electrical machinery $\wedge$ Class I weight $\Rightarrow$ Inner Mongolia	5.429	41.935
2	Textiles. Leather, fur and products $\wedge$ Class I weight $\Rightarrow$ Liaoning Province	5.779	33.333
3	Other goods $\wedge$ Class I weight $\Rightarrow$ Liaoning Province	6.83	28.205

Table 5. Association results of goods-weight-arrival province correlation model

Sequence Number	Association rules	Support %	Confidence %
1	Electronic, electrical machinery $\wedge$ Class I weight $\Rightarrow$ Harbin railway bureau	5.429	48.387
2	Textiles. Leather, fur and products $\wedge$ Class I weight $\Rightarrow$ Shenyang railway bureau	5.779	33.333
3	Industrial machinery $\wedge$ Class I weight $\Rightarrow$ Shanghai railway bureau	5.254	30.0
4	Food and tobacco products $\wedge$ Class I weight $\Rightarrow$ Shanghai railway bureau	6.48	29.73
5	Other goods $\wedge$ Class I weight $\Rightarrow$ Shenyang railway bureau	6.83	28.205
6	Agricultural and sideline products $\wedge$ Class I weight $\Rightarrow$ Shanghai railway bureau	4.904	25.00

In Table 3, rule 1 indicates that the main demand of distances for industrial machinery is concentrated in 1500 km outside. Rule 3 and 10 show that the demand of distances for many small batch grain in 1000km outside. And through the entire table 3, it can be seen the demand of distances for many kinds of goods are existed in 1500km outside. In the transport market above 1500km, compared with the air transport, railway transport has many advantages, such as great capacity, low cost, safety and not being affected by weather and so on. To further cement and expand transportation market above 1500 km, the railway bureau can consider operating high-speed express for long distance transport

From Table 4, it can be seen that, in the goods sent by this bureau, the main destination of electronics, electrical machinery is Inner Mongolia. Many Textiles. Leather, fur and products, other goods are flowed to Liaoning province. So the bureau should launch marketing work actively in the local, and carry out in-depth cooperation with production enterprises, to understand the enterprise production cycle, which can guarantee enough supply of goods and arrange reasonable transportation production plan.

In Table 5, we can see goods circulation through these rules, which is convenient for the railway bureau to master goods transport demand. And we can get the usage of different types of trucks, which is helpful for operator to arrange for trucks, to improve efficiency, and to reduce the cost of transportation.

5 Conclusions

This paper uses multidimensional association mining technology to analyze freight invoice data, and obtain some illuminating association rules. Compared with statistical and traditional data analysis, it has a more comprehensive understanding of the railway freight demand. But the data value lies in the circulation, if an enterprise only focuses on their own data, it cannot has a great development in the era of big data. Thus, how to exchange data with production enterprises, planting, and even other transportation companies, in order to achieve a win-win situation, is an important problem to study for the railway enterprises in the future.

Acknowledgement

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References

Lei Dingyou, Chen Zhiya (2003). "Data mining of railway freight invoice information", *China Railway Science,* 04:46-49.

R. Agrawal, T. Imiclinski, and A. Swami (1993). "Mining Association Rules between Sets of Items in Large Databases", *Proceedings of the 1993 ACM SIGMOD Conference*, Washington DC, USA, 160-172.

Ye Xiaoming, Liu Bingxiang (2007). "Strategy of retail cross-selling based on association rule mining", *Statistics & Decision,* 07:156-157.

Zhang Wenyu, Jia Rong, Xue Huifeng et al (2002). "Research on Discretization of Successive Attributes in Knowledge Discovery", *Journal of Xi'an University of Technology,* 03:249-253.

Discussion about Rail Freight Market Reclassification Based on Freight Production Data

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Abstract: Nowadays, the information technology has been basically realized during the process of the rail freight production with a large number of freight production data has been accumulated. If these data can be reasonable used, it will provide effective assistance for railway freight marketing. Based on this, the article uses three production indexes (freight turnover growth rate, relative market share rate and the internal freight share rate) to build a model. Combining with the Excel software, we reclassify the existing goods category. Put forward the corresponding marketing strategies about the reclassification category according to actual condition.
Keywords: Production indexes; Goods category; Railway freight market.

1 Introduction

So far, many experts think that market segmentation is an important part of marketing, effective market segmentation helps companies quickly and efficiently identify target markets, develop targeted marketing strategies. Market segmentation is in accordance with the buyer's needs and desires, attitudes purchase, buying practices of different variables, the market is divided into a number of different behaviors buyers groups.

The traditional classification of rail freight is mainly based on single variable for simple classifying, according to the classification of goods stipulated by the government, the goods which rail can transport can be divided into oil, coal, cotton, salt, containers , etc. 28 classes. The reclassification is based on the company's data, using data processing tools to build model. Then find the rule of freight market from the data. So, in this paper, based on marketing theory, there will be a repartition of the existing classification.

2 The Market Reclassification Based on Production Data

2.1 The establishment of the model

During the reclassification, for one kind of goods, the growth rate of turnover volume will be compared with the growth rate of GDP. And it is acceptable to set the average relative market share as 50%. The railway has 25 kinds of goods category. So it is reasonable to set the average interior freight resource occupancy rate as 4%. Based on the present goods classification, this article use the growth rate of turnover volume (L), the relative market share rate (X), and the interior freight resource occupancy rate (N) as three new indexes for reclassification. The model is as following:

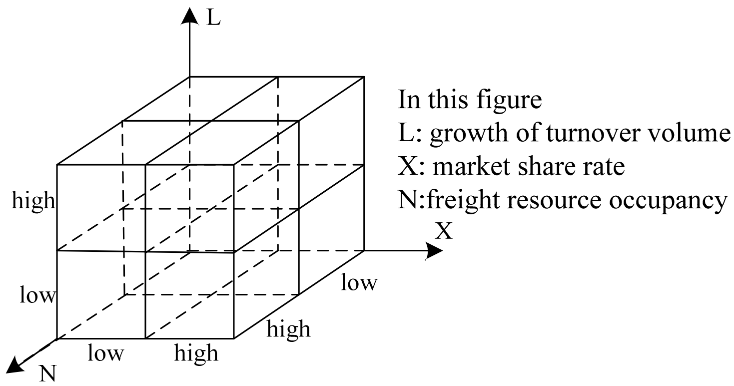

Figure 1 the model of the railway goods reclassification

The three indexes are calculated as following:
The growth rate of turnover volume for i:

$$L_i = \frac{Z_i - Z_i^{'}}{Z_i^{'}} \times 100\% \tag{1}$$

$Z_i, Z_i^{'} \rightarrow i's$ freight turnover volume in this year and last year

The relative market share rate for i:

$$X_i = \frac{q_i}{C_i} \tag{2}$$

$q_i, C_i \rightarrow i's$ volume of freight traffic and $i's$ yearly output in this year

The interior freight resource occupancy rate:

$$N_i = \frac{Z_i}{\sum Z_i} \times 100\% \tag{3}$$

$\sum Z_i \rightarrow$ all kinds of goods's freight turnover volume in this year

2.2 The repartition of the market

According to the three indexes, we can reclassify the market as following:

Table 1. The advance classification of the railway freight market

Market category	Turnover volume's growth	Market share rate	Resource occupancy rate	Market characteristics
I	high	high	high	Good prospect, high market share, more freight resource
II	low	high	high	Bad prospect, high market share, more freight resource
III	high	low	high	Good prospect, low market share, more freight resource
IV	low	low	high	Bad prospect, low market share, more freight resource
V	high	high	low	Good prospect, high market share, less freight resource
VI	high	low	low	Good prospect, low market share, less freight resource
VII	low	high	low	Bad prospect, high market share, less freight resource
VIII	low	low	low	Bad prospect, low market share, less freight resource

3 Processing Data

3.1 Data compilation

From China Statistical Yearbook, we get the recent ten years' data as following:

Table 2. The year 2003—2013 production data of five main kinds of goods

	Year	Coal	Coke	Oil	Steel	Fertilizers	Aggregate
Turnover volume (Million ton kilometers)	2003	505540	63789	102934	165545	72312	1632341
	2004	571298	66151	109964	178964	83276	1810994
	2005	637383	73831	118495	198931	100246	1934612
	2006	672849	82234	118015	216023	102052	2032162
	2007	741632	86550	115831	232889	111233	2185613
	2008	836028	86009	116236	237386	114795	2336032
	2009	847819	83952	119234	237412	117247	2335450
	2010	1001551	93953	120986	245146	119353	2562619
	2011	1124668	102006	112788	248284	131288	2729649
	2012	1087436	99947	108213	246565	145464	2692553
	2013	1086168	103321	108287	238943	141454	2670285
Yearly output	2003	167000	13800	16960	22234	7750.63	227744.6

(ten thousand tons)	2004	196000	17748.5	17587	28291	9491.41	269117.9
	2005	219000	23281.72	18135	35310	10307.82	306034.5
	2006	238000	28054.15	18477	42266	10620.51	337417.7
	2007	253000	32894.33	18632	48966	11573.87	365066.2
	2008	262000	32359.26	19043	50049	12015.96	375467.2
	2009	291000	34501.69	18949	56784	12677.73	413912.4
	2010	324000	38757.1	20241	62665	12552.96	458216.1
	2011	352000	42800	20362	68326	12299.06	495787.1
	2012	365000	44323.14	20748	71654	13552.97	515278.1
	2013	368000	47600	21000	77904	13915.81	528419.8
Volume of freight traffic (ten thousand tons)	2003	88132	7124	10765	15280	5660	126961
	2004	99210	7189	11944	16083	6392	140818
	2005	107082	7918	12667	17536	7163	152366
	2006	112034	8831	12743	20059	7417	161084
	2007	122081	9327	12702	21594	8152	173856
	2008	134325	8775	12671	20716	7811	184298
	2009	132720	8549	12531	21527	8029	183356
	2010	156020	9494	12847	22428	8179	208968
	2011	172126	9895	12564	22779	8308	225672
	2012	168515	9338	12652	21932	8925	221362
	2013	167946	9997	12732	21570	8340	220585

3.2 Processing data

We use nonlinear regression analysis to get predictions of the three indexes. The bigger R is, the higher correlation degree is. Based on calculation of regressive analysis, using the trend line fitting function of Excel software, we get the regression curve of the three indexes as follows:

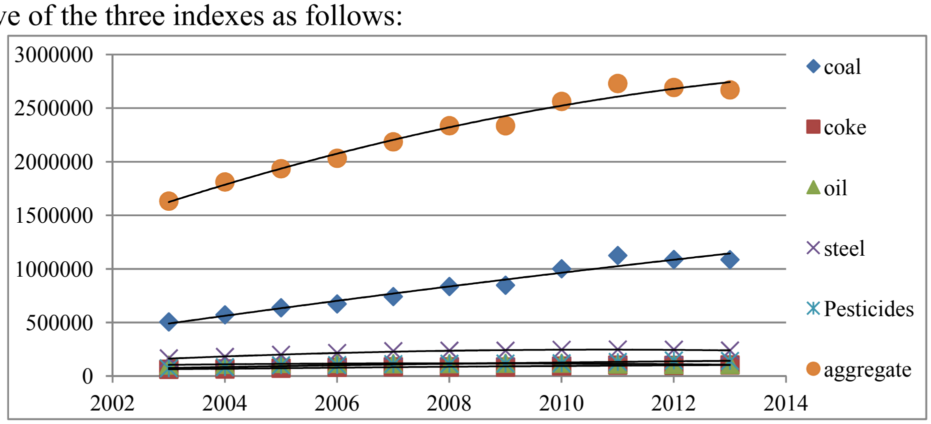

Figure 2.Regression analysis prediction of the turnover volume of the goods

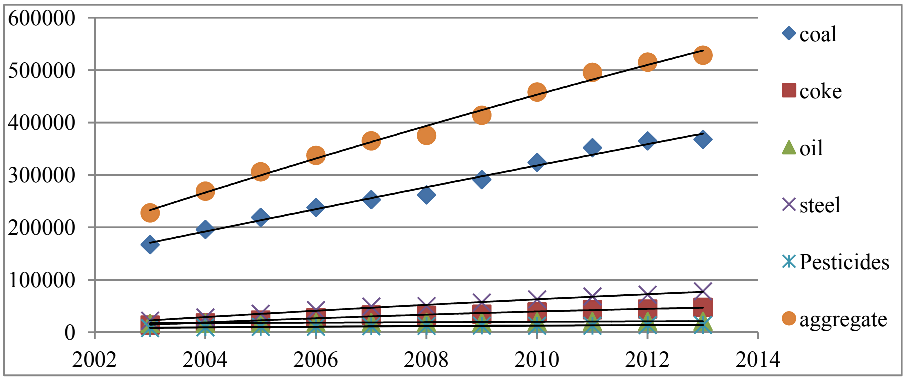

Figure 3.Regression analysis prediction of the yearly output of five goods

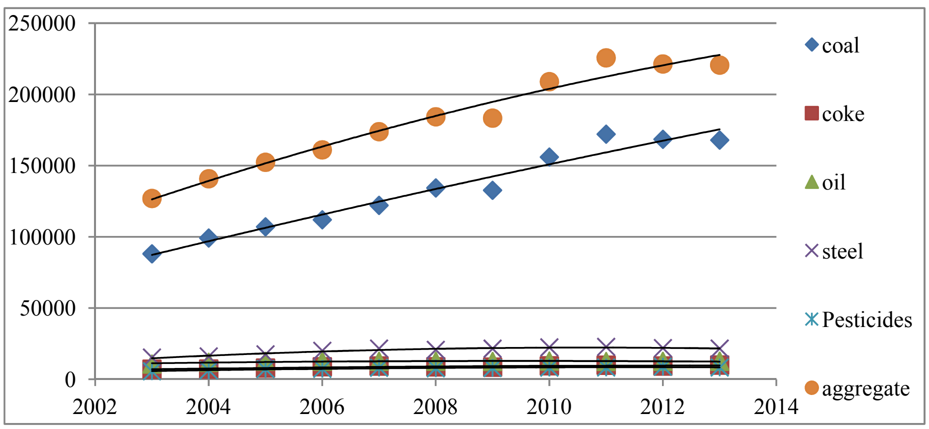

Figure 4.Regression analysis prediction of the freight volume of the five goods

3.3 The consequence

Combining the quadratic regression curve equation, get the table as following:

Table 3.The prediction of the five main kinds of goods in 2014

Category of goods	Coal	Coke	Oil	Steel	Pesticides and fertilizers	Aggregate
Turnover volume (tons kilometer)	1212914	111675	117003	247272	148367	2808359
yearly output (tons)	400000	51840	20900	84012	13654.5	570406
volume of freight traffic (tons)	184583	9346	11870	21292	8319	235410

4 The Market Classification and Marketing Strategy

Using equation (1) (2) (3) to calculate the three indexes in 2014 is as following:

Table 4.Five main goods' three indexes and market reclassification

Goods	Growth rate of turnover volume L_i (%)	relative market share rate X_i (%)	interior freight resource occupancy rate N_i (%)	Market category
Coal	11.67	66.1	43.19	I
Coke	8.04	18	3.98	VI
Oil	8.04	56.79	4.17	I
Steel	3.486	25.3	8.8	IV
Fertilizers	4.89	60.9	5.28	II

Combining with the actual situation, the marketing strategy is as following:

Oil, coal is I market. These two goods have good prospects. Demand of energy is growing with the development of China, so the marketing department should seize this opportunity to seize the energy transport market. Coke is Class VI, this kind of goods has good prospect. Coke is easy to wear and tear, so transit should be reduced during the transport. Steel is Class IV with poor prospects, rail is not its main mode of transport but take more resources. In recent years, domestic infrastructure is slowing down. So for steel, railways should find other sources as soon as possible. Pesticides and fertilizers are Class II with low transport rate. China's production of pesticides and chemical is too high in recent years. In view of this situation, the railway should make proper preparations, actively seeking new sources of supply, do not sit still.

5 Conclusions

Coal, coke, oil steel, pesticides and fertilizers these five very important freight category are important materials for national economic development, to analysis them can provide a reference for freight companies. So, this paper analyzes these five categories of goods freight production data over the past decade. In this process, we use the nonlinear regression method and Excel software to get the reclassification and appropriate marketing strategies. This paper discusses the rail market reclassification based on freight production data. In order to push the pace of rail freight transport data marketing in the actual freight market, we need more data with a more scientific approach.

Acknowledgement

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References

Zhang Ya. (2014). “Application of Data Mining technology for Freight Marketing.” Southwest Jiaotong university master degree thesis.

Zhou Lin. (2013). “Research on precise marketing strategy based on Data Mining.” Henan University of Science and Technology master degree thesis.

Guo Yuhua. (2011). “China Railway Freight Transportation Marketing Theory & Development.” Central South University master degree thesis.

Gao Quan. (2011). “Research on Data Mining of Data for Railway Freight Transportation.” Central South University master degree thesis.

Analysis of a Freight Pallet Pooling System Based on Spatial Data Mining in GIS

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Abstract: In order to establish and optimize pallet pooling information system, it is the key issue to analyze and mine the related data on the existing pallet pooling system. Here, firstly, the crucial techniques of pallet pooling system and spatial data mining method based on GIS are presented. Then, the functional structure of the pallet pooling system is proposed. Finally by erecting an actual model of spatial data mining system, with the utilization of relevant mining algorithms, a case is studied to dig out the implicit knowledge of spatial database and visualize the output of the spatial data mining result. This system model can not only display the knowledge (the amount of each pallet service station pallet, current on-hand quantity), but can also be found hidden in the pallet pooling system information platform implicit knowledge (in which areas suitable for establishing pallet service station, and where the pallet to more intense). A conclusion is also given to provide auxiliary decision-making to managers.

Keywords: Freight pallet pooling system; GIS; Spatial data mining.

1 Introduction

Pallet pooling system is responsible for pallet leasing, recycling, maintenance and update of social service system (WU 2003).With the increasing scale of pallet pooling system, pallet service stations, pallet rental customer and the increasing number of pallets, data and information derived from the pallet pooling system is increasingly enormous and complex. And spatial data mining based on GIS is to make full use of GIS and computer-related technology, networks, and other resources to manage the pallet pooling system (including hardware and software resources) efficiently in various aspects, such as pallet location, breakage rate, maintenance rate, the number of pallets and other complex information network management of service station. With constant expansion of business, the existing pallet service station cannot meet the demand of customers. Therefore, it is imperative to build the updated pallet service stations to satisfy the growing business needs. According to the result of the data mining analysis, the area where pallet circulation is more concentrated can be analyzed, and the decision to invest a lot of resources can be made accurately. It is the utilization of a series of treatment technologies based on GIS spatial data mining process that can turn the precipitation data into useful knowledge, which can also provide auxiliary decision function.

2 Pallet pooling system functional structure

Pallet pooling system is made up of online public information platform and multiple offline service stations under the reasonable layout. Public information platform is to complete the business flow, information flow, cash flow and electronic commerce related to the pallet pooling business. And pallet service station fulfills the pallet information real-time acquisition and empty pallet of transport, storage, maintenance, and others logistics function (LIU 2012).

In order to integrate the business flow, cash flow, logistics, realize seamless link between pallet rental customer and pallet rental business, promote consistently transportation pallet, such information platform as based on business model and process requirements should be built. By means of information technology, computer technology and network technology, such efficient services can be provided as real-time acquisition, online transactions for rentals business in portal and rental customer support, and the pallet of pallet service recovery, transportation and other business management, as well as other value-added platform services.

3 The method of spatial data mining

There are so many spatial data mining method. According to the found object can be divided into relational database, object-oriented database, spatial database and tense database and text database, multimedia database, heterogeneous database, etc. According to found methods can be divided into machine learning methods(inductive leaning, decision trees, rule induction, based on sample learning, genetic algorithm), the statistical method(regression analysis, discriminant analysis, clustering analysis, the agent simply analysis), neural network(BP algorithm, self-organizing neural network winding), database approach; According to found the task can be divided into the classification, clustering, discovering association rules, time series prediction, evolution, etc. In this paper, it’s will be uses the space clustering algorithm to demonstrate the instance case.

4 Case study

As far as the pallet pooling system in Chengdu is concerned, after a long time of study, it is identified that 200 pallet rental customer business needs of Chengdu, mainly involving the pallet rental customer location coordinates, the number of leasing pallet and the main pallet flow. The k-means clustering algorithm is used to classify the pallet rental customers to determine in which areas some new pallet service stations need to be built.

4.1 Statistical pallet number of pallet service station

Pallet rental customers only need click the "pallet service station" button I that will open a map of Chengdu city, and click what to view in the region pallet service station, the pallet service usage is presented. All pallet service stations, pallet rental customers, such as pallet flow information in the geographical location of Chengdu city, exchange of pallet information and data are stored in pallet pooling system. By means of the statistical analysis of these data, such pallet service information as annual pallet utilization rate, repair rate can be got. Moverover, system management personnel can adopt corresponding decision method to improve service ability.

4.2 Spatial data clustering analysis

As a research branch of clustering, spatial clustering is a process to find the optimal partition. According to the clustering termination conditions, the division is constantly optimized so as to get the optimal solution.

Here, in view of Chengdu 200 pallet rental customers, clustering analysis is presented with the consideration of such data of three dimensions as pallet rental customer location, the number of leasing pallet and pallet data mining on the main flow direction Decisions should be made to determine in which area to erect Chengdu pallet service station and in which key line to support vigorously.

Similar to the traffic OD (Origination to Destination) line, it can be analyzed how much the pallet to lease and where to load goods for a pallet rental customer. Firstly, 200 pallet rental customers from each of the five logistics park of Chengdu are selected. These five areas are Longquan, Shuangliu, Qingbaijiang, bonded logistics center and Xindu respectively. These 200 pallet rental customers are corresponding to the latitude and longitude rental distribution in above five areas. With the operation of the goods, the pallets commute among the five regions. With relevant analysis, it can dig out where communication is more closely, and in which area pallet demand is bigger.

(1) Data source. To be seleced from the transaction data of pallet pooling system, including the number of pallet which pallet rental customers lease, and pallet real-time positioning and flow data.

(2) Data preprocessing. To get the data cleaning and analysis from three dimension: pallet location, the number of pallet leasing and flow direction of the pallet.

(3) Algorithm selection. Using K-means clustering algorithm for mining. K-means algorithm is a typical target algorithm based on the prototype, which is a data point to the prototype of a certain distance as the objective function of optimization, by using the extreme of function as iterative operation adjustment rules. Based on Euclidean distance as the similarity measure, k-means algorithm is a initial

clustering center vector for the number of the optimal classification, makes evaluation index minimum (WU 2011).

Given a certain n of d dimension data set X= {x1,x2,…,xi,…,xn} among them $x^i \in R^d$,as well as to the number of generated data subset k, k-means clustering algorithm to the data object organization for k, C= { c^k， i=1, 2…K} . Each segment stands for a class c^k, each category center is u^i. The similarity and distance judgment criteria are chosen as Euclidean distance calculation at various points within the class to the clustering center distance sum of squares.

$$\mathrm{J}\left(c_k\right) = \sum_{x_{i\in c_k}} \left\|x_i - u_k\right\|^2 \tag{1}$$

The goal of clustering is to make all kinds of total distance sum of square $\mathrm{J}\left(c\right)=\sum_{k=1}^{k} J\left(c_k\right)$is minimal.

$$\mathrm{J}\left(\mathrm{c}\right) = \sum_{k=1}^{k} J\left(c_k\right) = \sum_{k=1}^{k} \sum_{x_{i\in c_k}} \left\|x_i - u_k\right\|^2 = \sum_{k=1}^{k} \sum_{i=1}^{n} d_{ki} \left\|x_i - u_k\right\|^2 \tag{2}$$

Among them, $d_{ki} = \begin{cases} 1, \ x_i \in c_i \\ 0, \ x_i \in / c_i \end{cases}$

From an initial k-means clustering algorithm classification, the data points are assigned to the various categories to minimize the total distance sum of square. As the total distance sum of squares of k-means clustering algorithm increase with the number of category k to reduce (when k=n, J(c) =0), the total distance sum of squares can only under a certain category number k, to obtain the minimum value.

In order to find out whether or not to increase the pallet service station to meet the growing needs of the business. There are five pallet service stations in the original five logistics park. Clustering number is set to 6 that is more effective. So, it should be in the place of clustering 6 to construct a pallet service station, so as to improve the service demand.

Here, R language is used to achieve k-means cluster analysis. Specific operation is as follows.

Firstly, the external data source is collected and saved to excel in the table, then saved as .csv format. In the R language input the following code.

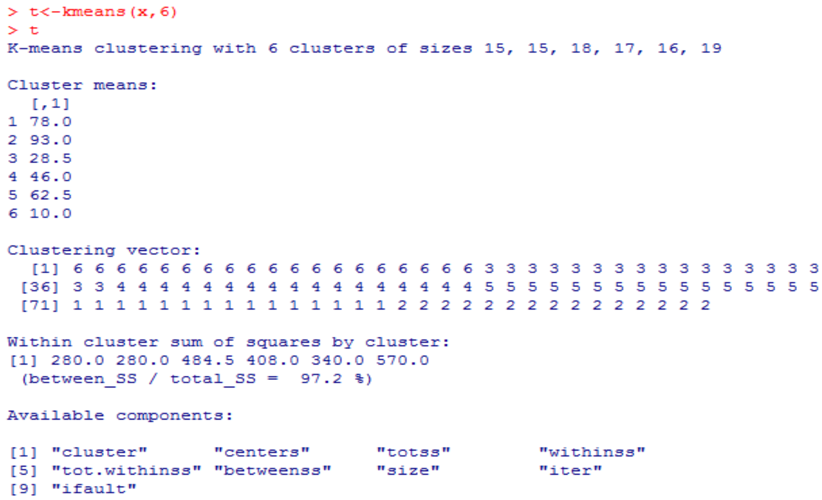
>Read.csv(file= “D:\\work\\data1\\.csv”)

Secondly, the clustering operation is shown as below.

>t<-kmeans(x,6)

>t

The output is as below.



```
> t<-kmeans(x,6)
> t
K-means clustering with 6 clusters of sizes 15, 15, 18, 17, 16, 19

Cluster means:
  [,1]
1 78.0
2 93.0
3 28.5
4 46.0
5 62.5
6 10.0

Clustering vector:
  [1] 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
 [36] 3 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
 [71] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2

Within cluster sum of squares by cluster:
[1] 280.0 280.0 484.5 408.0 340.0 570.0
 (between_SS / total_SS =  97.2 %)

Available components:

[1] "cluster"      "centers"      "totss"        "withinss"
[5] "tot.withinss" "betweenss"    "size"         "iter"
[9] "ifault"
```

Figure 1. k-means clustering output

(1) Clustering vector. Each record belongs to clustering (6 on behalf of the sixth clustering, 2 for the second clustering...).

(2)（between ss/total_ss=97.2%）. Set the distance between the sums of squares accounts for 97.2% of the overall distance sum of squares, that is to say, the distance between each cluster achieve to the most.

Then, data are visualized.

>plot cluster(x, t$cluster)

Using word to display the results of data visualization, which is shown in figure 2 as below.

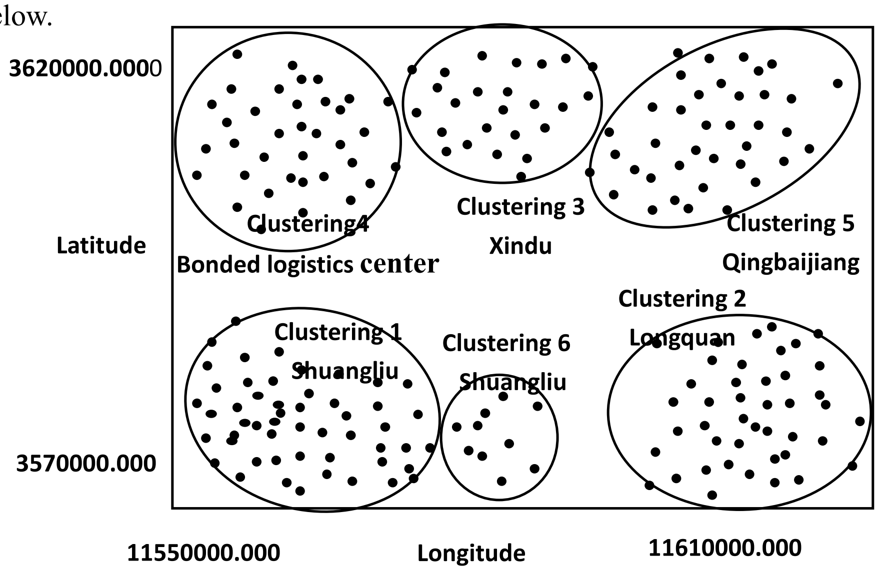


Figure 2. k-means clustering visualization

Finally, the result is analyzed. From above process it clearly seen that 200 pallet rental customers distributed in five area of Chengdu, which gather in these six clustering. The number of clustering 1 and clustering 2 are in majority, which means that the pallet demand in Shuangliu and Longquan is in major, and closely with each other .As the key area of pallet application and circulation, more resources should be put to the side. Clustering 1 and 6 are original in Shuangliu region, and now divided into two clustering, which shows that the gap between these two clustering is relatively large based on space. So, it should be considered whether to build a new pallet service station in order to meet the needs of the grow customers in Shuangliu area, so as to provide better services to pallet rental customers, which will be helpful for the transfer and use of the whole pallet system as well as improvement of customer satisfaction.

5 Conclusion

With the integration of Pallet pooling system and GIS spatial data mining system, a mode of spatial data mining system is proposed, which can not only dig out the explicit knowledge (the number of service stations, each pallet breakage rate, repair rate), but also find implicit knowledge (whether to increase the pallet stations), and the data mining results visualization output in the pallet pooling system (LV 2010). At present, Chengdu will be one of the second batch of pilot cities. In view of the urban joint distribution logistics standard, the pallet standardization can drive forklift, shelves, and all chain standardization. By use of the pallet pooling system and the application of GIS spatial data mining, the efficiency of the pallet on the social circulation, as well as the modern logistics level of Chengdu can be greatly improved, and which will be of important significance to save the cost of logistics.

Acknowledgement

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References

WU qingyi. (2003). “The establishment of china pallet pooling system”.*Logistics technology and application.*

LIU ye. (2012). “Research on the solution of Pallet Pooling System Information Platform”. *value engineering.*

WU suhui, CHENG ying. (2011). “Survey on K-means Algorithm”. *Knowledge organization and management.*

LV caofang. (2010). “Mining Research Based on GIS Spatial Data”. *West anhui university journal.*

Analysis of a Commercial Mode for the Pallet Pooling System

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Abstract: Nowadays, with the rapid development of logistics, the pallet plays a crucial role as a basic carrier for containized unitization. Here, a new commercial mode of the Pallet Pooling System is put forward. There are three aspects to be analyzed such as market analysis, business model, cost structure and revenue model. Firstly, the value provided by the Pallet Pooling system is presented as well as the target market and the marketing tools. Then, there is a discussion about the participants and business processing. Finally, the cost structure, revenue sources of the pallet exchanging platform and the pallet pricing are studied.
Keywords: Containerization; Pallet pooling system; Business mode.

1 Introduction

It is well-known that the application level of pallets is becoming one of the most important symbols of logistics modernization. Combined with forklifts pallets can integrate the scattered cargoes， which forms an effective handling system to greatly enhance the efficiency of loading and unloading. Nevertheless, the statistics of pallet Professional Committee shows that most of pallets are used within the factory rather than recycling in the whole society, which increases the handling work and the cost of logistics.

Pallet Pooling System integrates the pallet resource to recycle in the whole society, so that cargoes need not leave the pallets when transferred among different companies, what have to be changed is only the renter of the pallets. This mode will greatly improve logistics efficiency and reduce the waste of social resources.

Therefore, a new commercial mode of Pallet Pooling System based on the pallet sharing union is put forward, and more details are studied in three aspects including market analysis, business model and revenue model.

2 Market Analysis

Market analysis is the initial step to establish the Pallet Pooling System, which analyzes the market and how to open up the market. This section involves three aspects such as value proposition, target market and marketing strategies.

2.1 Value Proposition

Value proposition is the value which the operator provides to consumers via its products and service. The value that the Pallet Pooling System provides to customers can be described in three aspects.

The first aspect is the realization of the pallet sharing. The Pallet Pooling System integrates the pallet resources to make the pallets shared in the whole supply chain, thereby contributing to the implementation of pallet consistent application. The second one is to provide different rental models which are adaptable to different demands of customers, make the pallets sharing more flexible and wider range of applications. The last one is the participants in the Pallet Pooling System can get certain benefits, including economic benefits and social benefits.

2.2 Target Market

Target market is the company targeted consumer groups. These groups have some commonalities that enable the company to create value for these commonalities. The characteristics of the target market are described in four aspects such as the geographical factors, the object of factors, consumer behavior factors and consumer psychological factors.

Table 1.The target Market of the Pallet Pooling System

factors	Target market		Feature
Geographical factors	Developed cities and moderately developed city		traffic and economic situation more developed
Object factors	Industry	Manufacturing enterprises	The origin of the supply chain which has large demand for pallets
	Company scale	Large or Medium-sized enterprises	Doing a large scale of business which means a large demand of pallets
	Technical level	High technical level	Equipped with more technical facilities
consumer psychological factors	The purpose	Improving efficiency Getting value-added services	Hoping to improve the handling efficiency, and get value-added service
consumer behavior factors	Time point to get into market	Early experience person and Public users	Having advanced ideas and adapting to pallet sharing mode
	Loyalty	Brand loyalists	Willing to give most or even all of their orders to the platform

2.3 Marketing

The pallet exchanging platform provides a kind of service whose main contents are to help the owners of pallet to rent and be responsible for holding delivering and recycling after renting. There are two ways to market for the pallet providers. One is direct marketing, which is to find the potential rental to marketing services. Another is indirect marketing, which is marketing throng the service stations that are distributed in different areas. Therefore, according to different ways of marketing and the feature of the pallet pooling system, four marketing plans are put forward. .

(1)Pre-business promotion on the basis of the early research on the pallet manufacturer.

(2)During the study period of the platform, academic achievements can be published in professional journals and conferences, forming an extremely professional way to promote the platform.

(3)Promoting through the pallet-related associations such as the National Federation of Logistics and Purchasing and some local government departments or business organizations.

(4)Promoting in the industry related professional website.

3 Business model of the pallet pooling system

Business model is a problem which should be solved in the mid-term of Pallet Pooling System development, which includes the Pallet Pooling System, its related business activities and business processing.

3.1 Participants in the pallet pooling system

There are four participants in the pallet pooling system, including the pallet exchanging platform, pallet providers, pallet lessee and service station. Among them, the platform is the core part, and the three other parts join the pallet pooling system to form the confederation.

(1)Pallet exchanging platform consists of network information platform and operating company. Network information platform is responsible for online information publishing and receiving orders. And the operating company is responsible for order scheduling and the capital settlement management.

(2)The pallet providers are the companies which own the certain amount of empty pallets that can be rented. They can register as members of the platform and publish the relevant information of pallets. They can make profits by renting pallets without caring the process of distribution, recycling and transition.

(3)The pallet lessees are the companies which look for the pallets that can meet their needs to rent and pay a certain amount of rent.

(4)The service station cooperates with the platform and provides pallet service such as holding, distributing, recycling and maintenance so as to earn a certain amount of logistics cost.

3.2 Business activities of pallet pooling system

There are four stages in the business process including information dissemination stage, order processing stage, pallets transferring stage and funding segmentation stage. More details are analyzed in the business process to form these four stages. A transaction flow diagram is also given in figure 1 as below.

(1)Information dissemination stage. After registering as a member of the platform, the pallet provider can publish the pallet information in the platform.

(2)Order processing stage. Pallet provider submits orders to the pallet exchanging platform in accordance with the needs of the pallet type, quantity, location, and etc. After receiving the orders, the platform will assign them to the appropriate service station based on the order information. Service station will finish the off-line business.

(3)The pallet transferring stage. After receiving the order, the service station will pick up pallets and delivery them to the right place in the right time according to the order. The pallets will turnover between the different companies with cargoes that loads until the cargoes are off the pallet, and then they will be returned to the local service station by the last lesser.

(4)Funding segmentation stage. After the pallets finish a transferring process, the pallet lesser should pay rent to the platform. And then, the platform will divide the profit to the pallet providers, service station and the platform itself according to a certain rate.

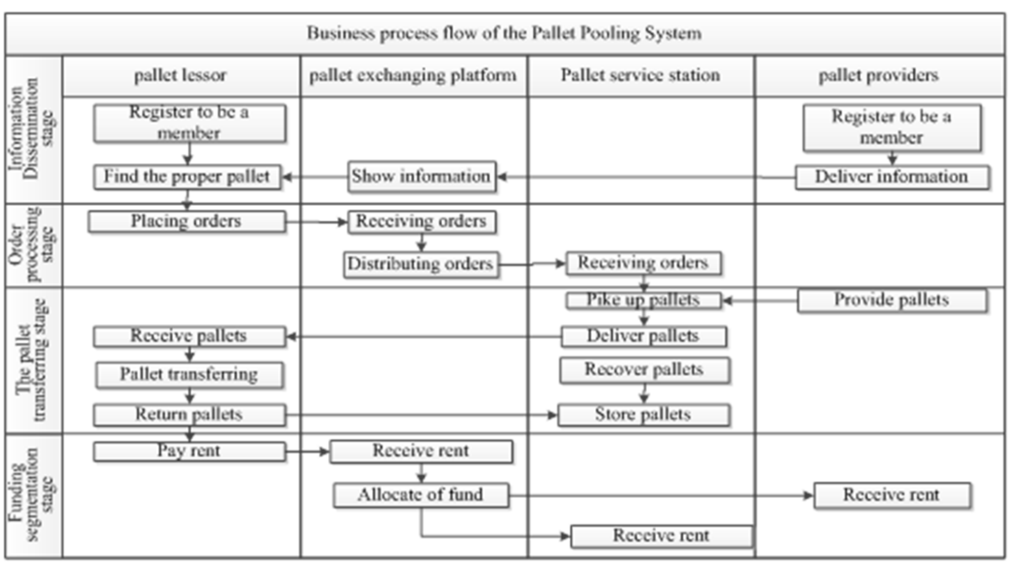

Figure 1. Business process flow of the Pallet Pooling System

The business processing of the Pallet Pooling System shows the complete value chain, which includes all the value-added business in the operation process. Such business processing can lay the foundation of the establishment of the revenue model of pallet pooling system.

4 Cost structure and revenue model of pallet pooling system

The Pallet Pooling System is a for-profit organization whose ultimate goal is to obtain a profit. So it is important to analyze cost structure and profit model of the Pallet Pooling System.

4.1 Cost structure

The cost of pallet pooling system is divided into four parts such as construction costs, marketing costs, daily cost and after-sales cost.

(1)The construction costs include the human cost and infrastructure cost for the software development

(2)Marketing cost includes advertising costs, publicity department staff salaries, travel allowance of business promotion, etc.

(3)The daily cost is incurred in usually operations, which includes a lot of aspects, such as water bills, electric bills, staff salaries, online banking service, and etc.. These expenses are necessary to maintain the normal operation of the platform.

(4)In the provision of services, there will always be some customers who have some doubts incomplete service, which causes the after-sale cost of the pallet exchanging platform. After-sale costs include customer service costs; pallets damaged costs and bad debts.

4.2 Revenue model

The revenue model is a key component of the business model. It is a framework for generating revenues and identifies what revenue source to pursue, and how to price the value.

4.2.1 The source of revenue

There are five sources for the platform to get revenue which are trading commissions, interest of shop margin, technical service revenue, advertising promotion revenue and value-added service revenue.

(1)Trading commissions. The platform will set aside a certain percentage of their commission to pay for their labor in leasing process, which is the main income of the platform.

(2)Interest of shop margin. Use the interest which is got from the shop margin to do financing or venture capital to make profits.

(3)Technical Service Annual Fee. Pallet platform provider can provide rental shop with some technical services, such as shop decoration, periodic notifications of the pallet status, rent settlement notice and etc. to make profit.

(4)Advertising promotion revenue. The platform can set some advertising sectors in the home page for renting to make profit.

(5)When the platform development maturity, it can launch a series of value-added services, such as item tracking and data mining and etc. to make profit.

4.2.2 Price the pallet

Pallet rental price is composed of the platform commission revenues, costs and pallet market share decision, which is calculated as follows.

$$\text{Price} = \frac{\text{annual commission revenue} - \text{annual cost}}{\text{annual circulation volume of pallet}}$$

(1)Annual commission revenue. If the platform wants to recover the initial investment of establishment during the payback period, it should obtain certain annual revenue to ensure. So the annual net revenue should be the ratio of the construction cost to the investment, with the consideration of the VAT (17%) and sales tax (5%). The commission revenue is to take a certain percentage of the whole revenue. Therefore, commission revenue is calculated as the platform.

$$\text{annual commission revenue} = \frac{construction\ investment}{payback\ period \times (1-17\%) \times (1-5\%)} \times a\ certain\ rate$$

(2)Annual cost. It refers to the variable costs of daily operations of platform, including the marketing costs, daily cost and after sales cost.

(3)Annual circulation volume of pallet. The product of quantity of pallet in whole society, market share of the platform and the annual average circulation times of pallet

5 Conclusion

The business mode of the pallet pooling system is studied with certain theoretical and practical significance under the circumstances of contemporary logistics of China. The details of the three stages during the establishment of the Pallet Pooling System are presented, which proposed solutions in aspects of marketing, operation and profiting, and offered the guarantee and theoretical evidence for opening market, operating smoothly, and getting profit.

Acknowledgement

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Engineering Laboratory of Comprehensive Traffic Transportation 2014), Southwest Jiaotong University， the People's Republic of China.

References

Charles D. Ray, Judd H. Michael, Bruce N. Scholnick. (2006)"Supply-chain System Costs of Alternative Grocery Industry Pallet Systems". *Forest Products Journal.*

Don McKerrow. (1996)"What Makes Reusable Packaging Systems Work". *Logistics Information Management.*

LI taiping. (2006). "The Issues and Countermeasures of Establishing the Pallet Pooling System". *East China Economic Management*

WU qingyi. (2003). "The Study On the Establishment of The Pallet Pooling System in China". *Logistics Technology and Application*

ZHANG xueyan, REN jianwei. (2009). "The Study on The Conceptual Model of The Pallet Pooling System". *Chinese Market*

The Trend of Urban Freight Regulatory Path under the Cloud

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Abstract: The vigorous development of cloud computing and mobile internet provides a new opportunity for the collection, storage, development and utilization of traffic data. By literature investigation, considering the transformation trend of the functions of government agencies in China, this paper reviewed to effectively identify the traffic state of urban road based on the cloud due to Internet of Things (IoT), put forward employing the cloud cooperation applications to dynamic optimization urban freight activities such as consolidation and parking, finally summarized that the cloud logistics mode has promoted as a new logistics service mode. This study improves understanding of how this technology may diffuse within the supply chain.
Keywords: Cloud computing; Urban freight; Logistics service.

1 Introduction

Urban freight, as part of supply chains, is characterized by multiple firms providing their resources and processes to meet customer demand in an efficient manner. It has been acknowledged that the autonomy of the supply chain participants-and their business objectives-as well as the contractual relations between participants have to be maintained when designing an inherent coordination mechanism. Often, new mechanisms are triggered by innovation in the Information and Communication Technology (ICT) industry.

As a key competitive factor, logistics companies depend on tremendous advanced ICT solutions for information processing and sharing. Cloud computing is a great candidate for complementing weaknesses of logistics information systems(heterogeneous processes, geographically scattered and seamed connectivity, etc.) and for supporting innovative activities of logistics(Jung and Kim 2014) Moreover, not only the largest companies can afford advanced systems but also small and medium logistics companies have IT-competence promoting cooperation between them, which in turn reduce transaction costs. For instance, Zagarskikh et al. (2014) focused on the use of shared cloud-computing technologies for data processing and resource-intensive modeling, GIS-technologies for visualization of incoming data and computational results, and tools for the creation of a control with graphical user interface and human-computer interaction. Meanwhile, the number of social network users has recently grown at a rapid pace, which is all the more remarkable. Chen et al. (2012) exploited the use of a cloud services platform for information exchange in combination with the contemporary popular community sites, while developing the site architecture based on the socio-technical system's theory as an indicator.

This paper organized as following structure: (1)government traffic and transport departments has been launched ITS for many years and accumulated vast historical data, and with widely distributed Internet of Things(IoT), advanced cloud computing and universally accessible smart devices, all of these contribute to the optimization of the travel decision of urban freight participators; (2) logistics enterprises especially middle and small ones employing cloud computing will not only cut their operation cost but also benefit from business process or activities up-to-date.

2 IoT and ITS in Urban Area for Carpooling and Parking

Thanks to advances in IoT and smart mobile devices, urban systems collect the abundance of geospatial data. The surveillance of urban traffic systems depends on the effective handling of near real-time traffic observation data. Figure 1 identify traffic state methods based on cloud computing with extracting the traffic information on-line real-time and historical database to deliver decision support for traffic management. (Wei-ning Liu et al. 2010)

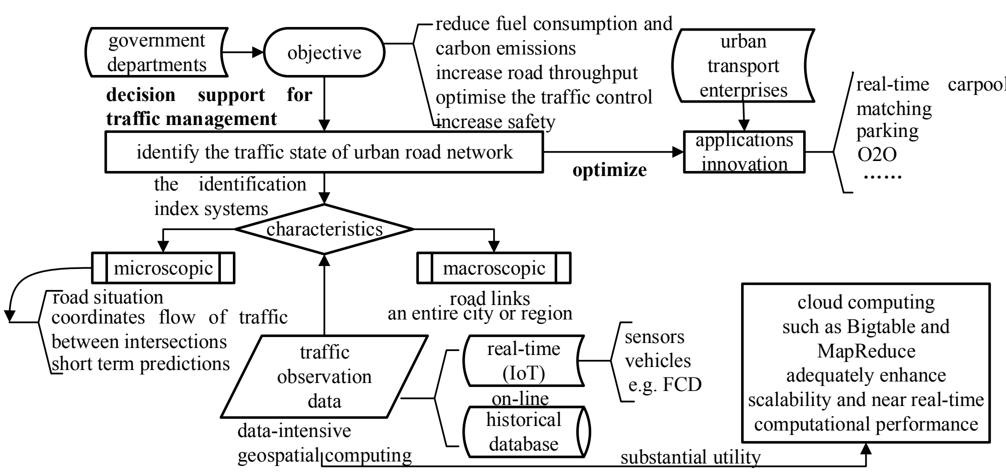

Figure 1. The relationship of urban freight decision support and traffic states in cloud

Firstly, government traffic and transport departments facilitate identify the traffic state of municipal road network in cloud computing environments. The system's optimisation objective is performed on several planning planes simultaneously. One side is the microscopic characteristics of urban road network traffic flow. For instance, the intersection Control Service responsible for coordinating flow of traffic between intersections. Jaworski et al. (2011) treated the vehicles are as cloud services and geographical multicast addressing are used to target all vehicles in the specified areas. On the other side are macroscopic characteristics of urban road network traffic flow, which greatly contributes to monthly or weekly pattern recognize and guide the proper travel decision made. Massive floating car data (FCD) is prevailing methods, Li et al. (2011) investigated the processing of the FCD query, FCD map matching, and speed computation for road links for traffic surveillance with cloud-computing technologies such as Bigtable and MapReduce.

If properly publish and tap those identified pattern, urban transport enterprises could develop all kinds of business innovation applications with the trend of smart mobile devices. For example, Chih-Hsiang Lin et al. (2012) proposed an intelligent real-time carpool system called BlueNet as Figure 2.

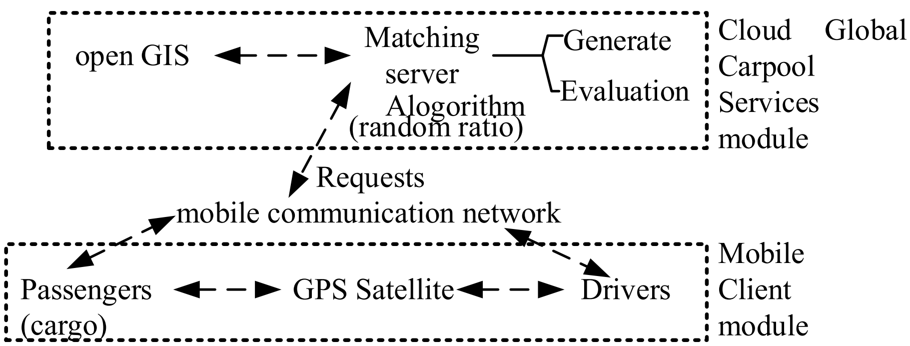

Figure 2. Carpooling and matching

Users can use their smart phones or other devices to find carpool matches by utilizing the Cloud Global Carpool Services(CGCS) module via the mobile communication network. The CGCS module is used to deal with carpool requests and generate suitable carpool match results through the proposed real-time carpool-matching algorithm, which integrated the open GIS system with abundant global geographical information. This also fits cargo consolidation in an urban area. For example, Grzybowska et al. (2013) detailed the use of mobile solutions in the supply chain, and presents the electronic freight and warehouse exchanges as a type of hybrid cloud supply chains. He et al. (2014) presented a multilayered vehicular data cloud platform, namely, an intelligent parking cloud service and a vehicular data mining cloud service, for vehicle warranty analysis in the IoT environment, along with a Naive Bayes model and a Logistic Regression model for the vehicular data mining cloud service.

3 Urban Freight Applications Innovations under Cloud

3.1Cloud especially for SMLSPs

Cloud computing is changing the ways software developed and managed in enterprises, which is changing the way of doing business in that dynamically scalable and virtualized resources are regarded as services over the Internet. Traditional manufacturing systems are typically developed case by case. In cloud-computing-based systems, distributed resources are encapsulated into cloud services and centrally managed. The integration between physical resources and cloud services can be enhanced by combining IoT technology and Software-as-a-Service (SaaS) technology.

In nature, the demand has become increasingly clear in the optimization of the modern supply chain management for the virtual structure of the supply chain business contact. (Zhang 2014) As an enabler of electronic supply chain management systems, to build logistics service platform the decision to adopt cloud computing is based upon complex circumstances as Figure 3(Sun et al. 2012), which affected by information processing requirements and information processing capability proved by Cegielski (2012) with organizational information processing theory. Drawing on the innovation diffusion theory, Subramanian et al. (2014) noted that Chinese small and medium-sized logistics service providers(SMLSPs) are attracted by cloud computing.

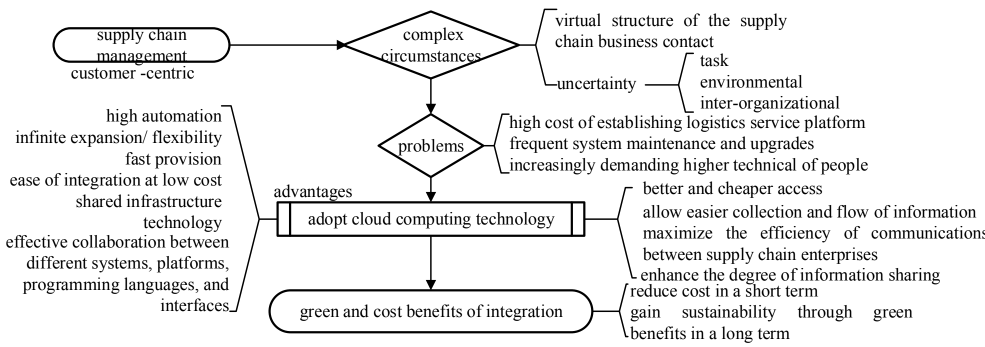

Figure 3. Why is cloud in supply chain management

3.2Logistics companies under cloud

With cloud computing, Kawa (2012) proposed an idea of the SMART model based on agent technology, Kawa and Ratajczak-Mrozek (2013) described the creation of the multi-modal platform designed for cooperating logistics service providers and their customers. In Europe, LOGICAL(http://www.project-logical.eu)'s objective is to enhance the interoperability of logistics businesses of different sizes, to improve the competitiveness of Central European logistics hubs through a decrease of transaction costs, and to promote collective (sustainable) modes of transport.

3.3Develop supply chains management systems under cloud

Chen et al. (2014) proposed an approach for improving cloud-based manufacturing systems based on a four-layer SaaS model. Leukel et al. (2011) proposed representing supply chains as a set of service offerings and customer demand as service requests; coordination is then a problem of determining optimal service compositions. Li et al. (2013) studied the resource virtualization and service encapsulation of a logistics center. After the resources of a logistics center are encapsulated in web services, consider service selection as an optimization problem and create a Particle Swarm Optimization-based web service selection model with quality of service constraints. Sun et al. (2012) described the basic framework of logistics service platform built on cloud computing. And proposed a security framework by research on the security of the framework.

4 Conclusions and Discussion

As an emerging technology, cloud computing is changing the form and function of information technology infrastructures. With the ever-increasing popularity of cloud computing and IoT, the cloud logistics mode has promoted as a modern logistics service mode. This provides a feasibly cost-effective design framework to meet the logistic economy, which will improve the competitiveness of enterprises. This study improves understanding of how this technology may diffuse within the supply chain.

Cloud backup scheme adopting the necessary redundancy strategy may provide relevant data security in one way. Spares and repairmen as two decision parameters in the system are considered to maintain regulated service quality for the cloud users. Jiang et al. (2012) developed for evaluating the profit patterns using the finite-source queuing theory.

And the ICT innovations are always on the way. For instance, Zhao et al. (2012) proposed a method for locating the objects of interest, e. g. traffic signs or road lamps, by computing object-based saliency given a cloud of 3D laser points of an urban scene. Much more convenient mobile customized services for related groups of urban freight transportation benefit are coming. All these facilitate freight service enterprises to provide safer, greener, more efficient transportation service for municipal units and residents.

Acknowledgement

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References

Cegielski, C. G. (2012). "Adoption of cloud computing technologies in supply chains: An organizational information processing theory approach." *The International Journal of Logistics Management,* 23, 184–211.

Chen, C.-Y., Chang, C.-J., and Lin, C.-H. (2012). "On dynamic access control in web 2.0 and cloud interactive information hub: trends and theories." *Journal of Vibration and Control*, 20, 548–560.

Chen, S.-L., Chen, Y.-Y., and Hsu, C. (2014). "A new approach to integrate Internet-of-things and software-as-a-service model for logistic systems: a case study." *Sensors (Basel, Switzerland)*, Multidisciplinary Digital Publishing Institute, 14(4), 6144–64.

Chih-Hsiang Lin, Ming-Kai Jiau, and Shih-Chia Huang. (2012). "A cloud computing framework for real-time carpooling services." *Information Science and Service Science and Data Mining (ISSDM),* 266–271.

Grzybowska, K., Kovács, G., and Lénárt, B. (2013). "The Supply Chain in Cloud Computing-the Natural Future." *KES-AMSTA*, 284–292.

He, W., Yan, G., and Xu, L. Da. (2014). "Developing vehicular data cloud services in the IoT environment." *IEEE Transactions on Industrial Informatics*, 10(2), 1587–1595.

Jaworski, P., Edwards, T., Moore, J., and Burnham, K. (2011). "Cloud computing concept for Intelligent Transportation Systems." *2011 14th International IEEE Conference on Intelligent Transportation Systems (ITSC)*, IEEE, 391–936.

Jiang, F.-C., Yang, C.-T., Hsu, C.-H., and Chiang, Y.-J. (2012). "Optimization technique on logistic economy for cloud computing using finite-source queuing systems." *4th IEEE International Conference on Cloud Computing Technology and Science Proceedings*, IEEE, 827–832.

Jung, J. U., and Kim, H. S. (2014). "Deployment of Cloud Computing in Logistics Industry." *Journal of Digital Convergence*, 12(2), 163–171.

Kawa, A. (2012). "SMART logistics chain." *Intelligent Information and Database Systems*, Springer, 432–438.

Kawa, A., and Ratajczak-Mrozek, M. (2013). "Cooperation between logistics service providers based on cloud computing." *Intelligent Information and Database Systems*, Springer, 458–467.

Leukel, J., Kirn, S., and Schlegel, T. (2011). "Supply Chain as a Service: A Cloud Perspective on Supply Chain Systems." *IEEE Systems Journal*, 5(1), 16–27.

Li, Q., Zhang, T., and Yu, Y. (2011). "Using cloud computing to process intensive floating car data for urban traffic surveillance." *International Journal of Geographical Information Science*, Taylor & Francis, 25(8), 1303–1322.

Li, W., Zhong, Y., Wang, X., and Cao, Y. (2013). "Resource virtualization and service selection in cloud logistics." *Journal of Network and Computer Applications*, 36(6), 1696–1704.

Subramanian, N., Abdulrahman, M. D., and Zhou, X. (2014). "Integration of logistics and cloud computing service providers: Cost and green benefits in the Chinese context." *Transportation Research Part E: Logistics and Transportation Review*, 70, 86–98.

Sun, F., Liu, C., Cheng, X., and Zhang, D. (2012). "Security Research on Cloud-Based Logistics Service Platform." *Internet of Things*, Springer, 394–400.

Wei-ning Liu, Qing-Lu Ma, Di-hua Sun, and Yu-Fang Dan. (2010). "Traffic state identification methods based on cloud computing model." *2010 8th World Congress on Intelligent Control and Automation*, IEEE, 4671–4676.

Zagarskikh, A., Karsakov, A., and Tchurov, T. (2014). "The Framework for Problem Solving Environments in Urban Science." *Procedia Computer Science*, 29, 2483–2495.

Zhang, H. (2014). "Research on Role of Cloud Computing in Optimization of Supply Chain Management." *International Conference on Economic Management and Trade Cooperation (EMTC 2014)*, 130–135.

Zhao, Y., He, M., Zhao, H., Davoine, F., and Zha, H. (2012). "Computing object-based saliency in urban scenes using laser sensing." *2012 IEEE International Conference on Robotics and Automation*, IEEE, 4436–4443.

Application of Data Mining Technology in an Integrative Intelligent Transportation System

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Abstract: The study of traffic flow data mining technology is meaningful to traffic flow induction, dynamic traffic allocation, traffic management and control. In this paper, we applied the combined model algorithm, traffic flow jam mining algorithm and traffic flow distribution pattern mining algorithm to an integrative Intelligent Transportation System based on data mining technique and also provide an efficient tool for the traffic management.
Keywords: Road traffic; Data mining technology; Intelligent transportation system.

1 Introduction

At present, ITS has accumulated a large number of basic data and become an important application in our country and people's livelihood (CAI, 2003). Therefore, it is very urgent and necessary to research on data mining technology in ITS. The system is committed to achieving traffic data cleaning、traffic accident correlation analysis、traffic flow congestion incident mining、intersection short-time traffic flow forecasting demand and so on, providing an effective tool for auxiliary traffic management and rational allocation of traffic resources(WANG, 2013). The system working process is shown in figure 1.

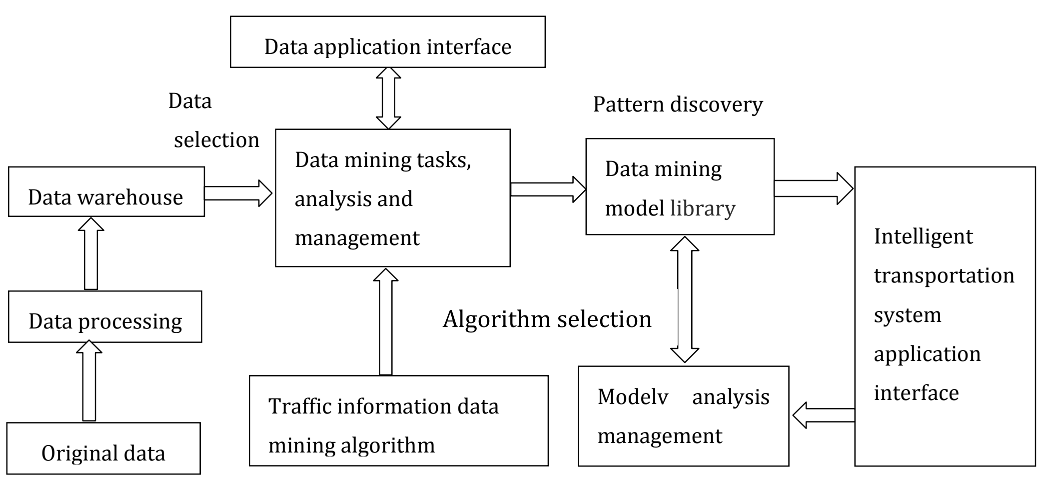

Figure.1. System working flow chart

2 System's Architectural Framework

Integrative ITS based on data mining technology adopts four-layer architectural framework of intelligent transportation mining application platform (LI, 2008). This application platform is convenient for the establishment of data mining algorithm analysis function, data mining system development and configuration. Therefore, users can adopt data mining technology according to their actual demands. Integrative intelligent transportation system is divided into four layers: traffic data layer, data mining layer, analysis logic layer and application system layer.

The system architectural framework is based on data mining algorithm tool, increases analysis logic layer between data mining layer and application system layer, extracts specific analysis model on analysis logic layer, maps to the appropriate data mining algorithm and analysis process, makes the data mining technology and concrete applications combined closely.

(1)Traffic data layer

After the access to external data, external data becomes internal data through format conversion, data cleaning and other processes, providing support for data mining analysis (ZHANG, 2014). Traffic data sources widely and contains large amounts of traffic information, so it's necessary to convert traffic data into appropriate formats before data analysis. The data warehouse provides a unified storage and analysis platform for different data frameworks. Building up traffic data warehouse is the core of traffic data layer, through three parts of data collection and ETL, data warehouse management system and metadata management system. In the process of modeling, considering the wide range in ITS field, therefore the traffic data warehouse is required to have a strong scalability: not only integrate traffic information collected by each application system, but also establish on the basis of its working database for a specific application system.

(2)Data mining layer

Data mining layer contains data mining algorithm tool, visualization method and other auxiliary tools, focusing on data mining algorithm and related tools, such as statistical methods and auxiliary tools. In the algorithm design, we need to give users more choices so as to allow users to set and adjust parameters. In data mining layer, there should be auxiliary tools related to data mining algorithm. For example, similarity measure is the core issue of cluster quality in clustering algorithm. Different similarity measures are for different data, and these similarity measures are also a part of data mining layer.

In present data mining set, we need to achieve basic data mining algorithms, such as: K-means clustering algorithm, hierarchical clustering algorithm, decision tree classification algorithm and so on (ZHANG, 2013).

(3)Analysis logic layer

Analysis model is an independent entity. Application system layer can be realized according to the actual needs corresponding to analysis logical layer. During of intelligent transportation system's data mining, analysis function of extraction and corresponding data mining algorithm need to combine integrated traffic system domain knowledge and data mining technology closely. Analysis model contained in the analysis logical layer is extracted from the actual demand analysis, being able to accomplish a certain number of independent analysis functions. The building up of data mining model in ITS is shown in figure 2.

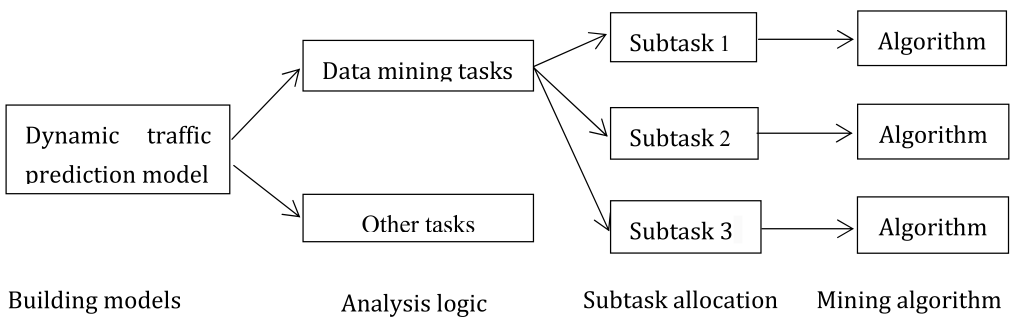

Figure.2. Data mining task analysis logic

(4)Application system layer

Application system layer is set up by users and is the corresponding entry of analysis logic layer by adopting a flexible manner, such as B/S and C/S. Use multilayer structure to meet different demands and finally be applied in the network environment according to the characteristics of ITS.

3 Data Integration and Fusion

There are many different kinds of intelligent traffic data, and the data are distributed among various traffic application systems. Data warehouse provides effective data processing platform for data mining. As a result, intelligent transportation system needs all kinds of traffic data extracted from database operation. After data cleaning and a series of process, traffic data is integrated into the transportation information data warehouse. Due to the urban traffic management decision data regards existing traffic management computer system as data source, traffic information data warehouse shall meet the following requirements:

(1) Get data from traffic management system and application system according to business demands, so the original data can be collected and updated automatically;

(2) Provide flexible and convenient extraction method, new data will be put into the system through friendly user interface;

(3) Provide flexible on-line analytical ability and a multi-angle, deep analysis on original data;

(4) Meet the requirements of future development, scalability and expansibility, ensure technical sophistication;

(5)Serve decision support system effectively, making the decision support system achieve better effect. Decision support system can use many tools to access converted, clean and professional data;

Due to an integrative intelligent transportation system includes many different types of traffic information collection systems, and the data collected by different traffic information collection technologies includes different contents and structures. At the same time, there are errors, omissions and imprecise problems in data more or less. Therefore, we need to do fusion calculation for different sources of data; meanwhile, merge different judgment results on the same traffic event, forming a consistent traffic state.

4 System's Linkage

Linkage is the implementation process of event or state, its trigger condition is the appearance of one or more events' combination in the monitored objects. Linkage system is function modules in comprehensive monitoring system platform handling dangerous information (SUN, 2013). When emergency incident happens, linkage system collects each subsystem's danger information uniformly, then manages and records. At the same time, linkage system completes the related equipment control. When there is a linkage, system platform operates automatically or prompts managers to perform an action based on event situation combining the design plan in advance system. Finally, make rapid and efficient emergency respond to realize the unity of the various application resources (as shown in figure 3).

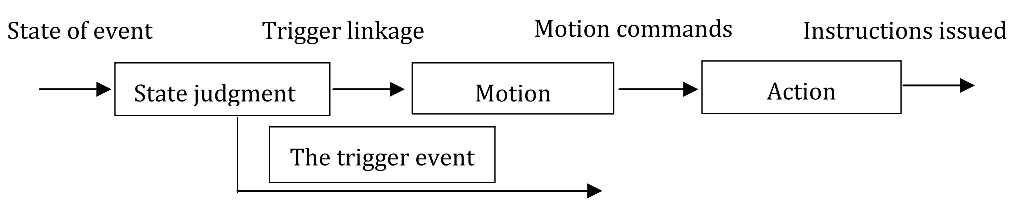

Figure3. System linkage execution graph

Trigger source is the combination of some trigger conditions. When its trigger condition is true, one event is produced and published to linkage system. When it becomes false from true, the trigger condition is restored and another event is published. Trigger condition is generally classified into two types: trigger source based on time and trigger source based on alarm condition according to different trigger conditions.

5 System Functions

Integrative intelligent transportation system based on data mining technology displays a role of traffic mining business functions by application platform. For other functions in intelligent transportation system, such as traffic signal control, traffic data collection, the model can realize these functions through the application of platform. Among them, functions related with traffic flow data mining technology are as follows:

(1)Real-time traffic state judgment

Judge road traffic condition with the evaluation of classification: smooth, mild crowded, crowded, congestion and severe congestion according to the judgment of traffic flow data collected by devices. Get real-time traffic state of road, showing relevant sections with green, light green, yellow, orange, red on the map. After establishing traffic flow pattern warehouse, system calls the mining algorithm to deal with each traffic flow data, give the current state of traffic flow, and display traffic status on the map, so as to show the road traffic state information intuitively.

When system detects that the traffic state is changing, system will generate new traffic state diagram via system linkage function and send new information to the intersection traffic induction device, so as to lead traffic flow and ease traffic congestion.

(2)Regional correlation mining

In view of serial case, mine collected traffic monitoring data, analysis vehicle's information in the near, do regional correlation mining according to the present frequency of suspected car, screen related information of suspected car, and predict possible area of the vehicle.

(3)Vehicle relevance mining

In criminal cases, most of the suspects use vehicle to escape, especially in the vehicle rob case. Therefore, after determining the suspected specific vehicle, analyze its activity rule in this case, find associated vehicles through the way of data mining.

(4)Deck vehicles mining

Regard the thicker traffic flow collection device sections as the center, divide the whole monitoring area into multiple mining areas, do data mining analysis in these areas of traffic flow. If suspected deck car appears, user may inform the intersection officers to intercept suspected deck car.

(5)Abnormal vehicle mining

Moving vehicles in a certain area pass through different traffic information site, the information site will keep track of the vehicle's location, state, pass time, etc. After a period of time, vehicles in the area will leave related activity records in system database basically. Through mining algorithm, all the vehicle's active records are analyzed for a certain period of time combining car registration, calculate the normal vehicle and abnormal vehicle operation.

6 Conclusions

This paper designs an integrative intelligent transportation system based on data mining technology. Describe the system levels, system framework, traffic data mining function module. The system uses road traffic data algorithm with rich analysis functions, do data mining in intelligent transportation system, build up traffic task of data mining model warehouse, providing an effective tool for road traffic management.

References

CAI Wenqin(2003). "A Strategic Consideration on Chinese ITS Development." *Journal of Transportation Systems Engineering and Information Technology*, 3(1), 17-22.

JIANG Jinyong, YANG Xiaoguang(1999).“The national intelligent transport system structure overview.” *Journal of Highway and Transportation Research and Development*, (6), 49-52.

LI Qingquan, XIONG Wei, LI Yuguang(2008). “System Architecture and Enabling Technologies of Intelligent Road System.” *Journal of Transportation Systems Engineering and Information Technology*, 8(1), 40-47.

SUN Dihua, LI Yongfu, LIU Weining, ZHAO Min, LIAO Xiaoyong(2013). “Research Summary on Transportation Cyber Physical Systems and the Challenging Technologies.”*China Journal of Highway and Transport*, 26(1), 144-153.

WANG Guofeng, SONG Pengfei, ZHANG Yunning(2013). “Development and Prospect of Intelligent Transportation System.”*Highway*, (5), 217-222.

ZHANG Jing. CAI Bogeng. WU Jianping(2003). “Research on mobile detection technology.” *Journal of Northern Jiaotong University*, 27(3), 80-83.

ZHANG Shaoyang, GE Lijuan, AN Yisheng, CAO Jinshan(2014). “Research status and development of transportation data standards.”*Journal of Traffic and Transportation Engineering*, 14(2), 112-125.

ZHANG Shaoyang, GAO Hang, GUAN Shengchao, CAO Jinshan(2013). “Hierarchical modal of basic data element of transportation information and its application.”*Journal of Chang'an University(Natural Science Edition)*, 33(6), 79-83.

A Method of Data Cleaning Based on IC Card and GPS Data in Chengdu

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Abstract: It is feasible to infer passengers' boarding and alighting station by using IC card data and GPS data. However, in most cases, the data collected has some problems, such as replicated data and missing data because of the drawbacks of transit system and the influence coming from the external environment. Furthermore, data users cannot explain the data reasonably because they do not know how data is collected. This paper, taking Chengdu transit system as an example, focus on the data cleaning method in data preparation phase. It presents some methods of data cleaning about the data quality problems in IC card and GPS data, and then discusses the triggering distance of buses in Chengdu.
Keywords: Data cleaning; GPS; IC card.

1 Introduction

Data cleaning is the process of detecting and correcting (or removing) corrupt or inaccurate records from a record set. Using the IC card data and GPS data for what decides what kind of method should be used to conduct data cleaning. This paper study on the data cleaning methods that contribute to using the IC card and GPS data to infer passengers' boarding and alighting station, and the fields needed in the two data set of Chengdu transit system are as Figure1 and Figure2 shows: the field CONSUMEDATE in IC card record means the boarding time of a passenger; the field ACTDATETIME in GPS record means the arrival or departure time of a bus on a station; the field STATIONNUM is an unique id of a station.

(1)IC card data

LINENO	BUSNO	CARDNO	CONSUMEDATE	CONSUMETYPE	BALANCE
20	011060	000103293340	2014-11-09 07:38:33	2	(null)
20	011060	000103885324	2014-11-09 07:38:41	2	(null)
20	011060	000115274017	2014-11-09 11:00:59	11	(null)

Figure 1. Sample of IC card data

(2)GPS data

LINENO	BUSNO	ACTDATETIME	GPSSPEED	STATIONNUM
1	046006	2014-11-03 06:52:14	8.53	30463
1	046006	2014-11-03 06:53:33	5.09	30461
1	046006	2014-11-03 06:56:06	5.71	20308

Figure 2. Sample of GPS data

It is necessary to give a brief introduction about the basic rules of inferring boarding station. If a passenger's CONSUMEDATE is between a stop's arrival ACTDATETIME and departure ACTDATETIME, the current STATIONNUM in GPS record is regarded as the boarding station. If a passenger's CONSUMEDATE occurs before the first stop's arrival ACTDATETIME, the first station is choose. If a passenger's CONSUMEDATE occurs after the final stop's departure ACTDATETIME, the passenger's boarding station is unknown (Marie-Pier Pelletier, 2011; Jason B. Gordon, 2012).

This paper describes the data quality problems in Chengdu transit system and proposes a solution for each of them. The rest of paper is organized as follows: in section 2, literature review focuses on the data cleaning of IC card and GPS data; in section 3, the replicated data in both two data set and the abnormal data in IC card data set is discussed and some methods of data cleaning are proposed; section 4 is an analysis about the value of triggering distance in Chengdu transit system; the last section contains the conclusions of this paper.

2 Literature review

Many researches about inferring passengers' boarding and alighting station using IC card and GPS data were made, but little attention was paid to data cleaning in the data preparation phase. Jason B.Gordon proposed a solution for the problem that the timestamp of swiping card was truncated to the minute in London transit system (Jason B.Gordon, 2012). N.B.Hounsell discussed the data consistency in AVL data, and the selection of timing point of a measurement of GPS data (N.B.Hounsell, 2012). Some data quality problems, such as missing data, wrong data and the consistency problem, were presented and a methodology was also used to process these dad data, but more details about the methodology was not available (ZHANG Yu, 2010).

Different from those aforementioned researches, a paper of Guo Shuxia, taking the IC card and GPS data in BeiJing as an example, discussed the problems of data quality in IC card and GPS data set, and designed a methodology to clean the both data set. Steve Robinson found out the data quality problems coming from software, hardware, data and user four aspects, and then developed relevant methodology to process bad data, but that paper didn't refer to the data cleaning of GPS (Steve Robinson, 2014). In fact, it is also very crucial to understand the mechanism of GPS data collecting for us to conducting data cleaning and further research, but surprisingly very little literature was found which investigates the mechanism of GPS data collection, except N.B.Hounsell, in which a simple introduction was made (N.B.Hounsell, 2012).

3 Replicated data and abnormal IC card data

Many factors may lead to replicated data during the process of data collecting, data transmission and data storage, such as equipment trouble, storage trouble and so on (Cheng Shaohui, 2012), and there are also some abnormal data in IC card data set. Fig 3 is a method to process replicated and abnormal data, and more detail is given in three independent parts. The 3.1 discuss the replicate record in IC card data set and 3.2 discuss the replicate record in GPS data set and 3.3 discuss the abnormal data in IC card data set.

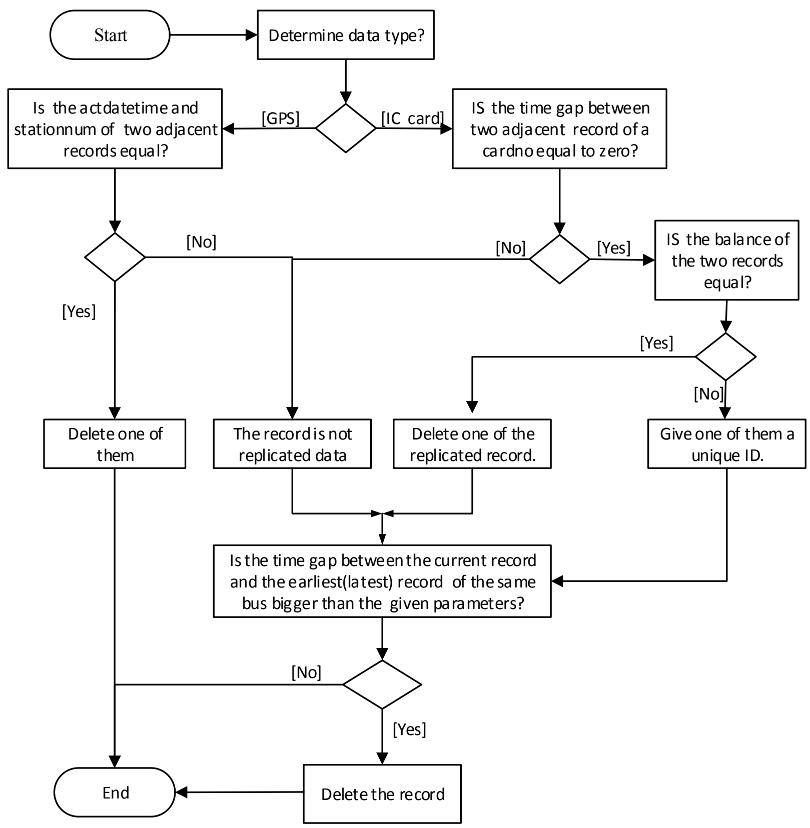


Figure 3. Process of cleaning replicated and abnormal data

3.1 IC card replicated data

In an ideal case, an IC card can has only one record at a specific time, but there exist two kinds of replicated data in the IC card data set: the former is that two records have same CONSUMEDATE, CARDNO, and balance; the latter, just as Figure 4 shows, is that two records have same CARDNO, CONSUMEDATE but different balance, which means that the two records are both valid data. This kind of "replicated data" may result from the fact that people can swipe a card for two times during a boarding event, but the card reader fails to distinguish the difference of ACTDATETIME between them. For the former, the best solution is to delete them from the data set. For the latter, we can give each "replicated data" a different id or simply treat two replicated data as two single record and do nothing with them.

LINENO	BUSNO	CARDNO	CONSUMEDATE	CONSUMETYPE	BALANCE
64	028928	000100001987	2014-11-07 11:12:56	11	(null)
64	028928	000100001987	2014-11-07 11:12:56	1	41.4
309	146009	000100003313	2014-11-05 17:51:50	1	18.35
309	146009	000100003313	2014-11-05 17:51:50	1	16.55
332	119067	000100004136	2014-11-04 16:46:58	1	48.4
332	119067	000100004136	2014-11-04 16:46:58	1	46.6

Figure 4. Sample of replicated IC card data

3.2 GPS replicated data

Just as IC card data, there are also two types of replicated data in the GPS data set: one is that many records have the same ACTDATETIME and PRODUCTID, which may result from the trouble of GPS clock or data management, another is that one arriving (leaving) station event has two or more records, which may result from the swinging of bus during it's running process. As Figure 5 shows, the station #50637 has two records of leaving station event. For the former, it is necessary to delete them from GPS data set directly, and for the latter, it is reasonable to remain the first record of arriving event data and the last one of leaving event data order by ACTDATETIME increasingly, which keeps a longer in-station time of a bus avoiding the phenomenon that many passengers' CONSUMEDATE is not between the arrival time and departure time.

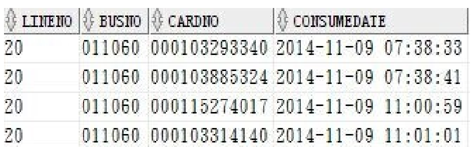
ROUTEID	PRODUCTID	ACTDATETIME	ISARRLFT	LEADIS...	LAGISARRLFT	STATIONNUM
204	011013	2014-11-03 08:12:07	1	1	2	50637
204	011013	2014-11-03 08:12:10	2	1	2	50637
204	011013	2014-11-03 08:12:10	2	2	1	50637
204	011013	2014-11-03 08:13:23	1	2	2	50453

Figure 5. Sample of replicated GPS data

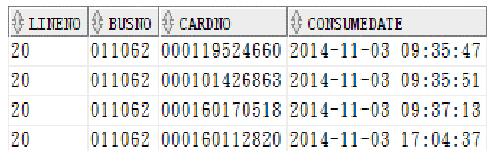
3.3 Abnormal IC card data

In transit system, a bus arrives at a specific station, open the door and then passengers swipe their card one by one, and after these processes, the bus closes its door and leaves for the station. The IC card data in a day should present consistent generally. The abnormal IC card data is these records, whose ACTDATETIME is earlier than the ACTDATETIME of the first record of same bus and same date, or far behind the last record's ACTDATETIME. Just as Figure 6 shows, in (a), there is a large gap between the record at 2014-11-09 07:38:41 and the record at 2014-11-09

11:00:59, and at the same time, the earliest record in GPS data turns up at 2014-11-09 11:00:44, which means that the first two IC card records are invalid; in (b), the latest record in GPS data turns up at 10:18:22, while the latest record in IC card data turns up at 17:04:37,which means that the record at 17:04:37 is invalid. As for the data showed in (a) and (b), it is reasonable to delete these invalid data, but the problem is how to distinguish them from a sea of data. A practicable method is joining IC card and GPS data by time at first, and then add two fields meaning the earliest and latest time of a bus in GPS data for each day, and at last we can distinguish these invalid data by comparing the CONSUMEDATE and the earliest or latest time.



LINENO	BUSNO	CARDNO	CONSUMEDATE
20	011060	000103293340	2014-11-09 07:38:33
20	011060	000103885324	2014-11-09 07:38:41
20	011060	000115274017	2014-11-09 11:00:59
20	011060	000103314140	2014-11-09 11:01:01



LINENO	BUSNO	CARDNO	CONSUMEDATE
20	011062	000119524660	2014-11-03 09:35:47
20	011062	000101426863	2014-11-03 09:35:51
20	011062	000160170518	2014-11-03 09:37:13
20	011062	000160112820	2014-11-03 17:04:37

(a) **(b)**

Figure 6. Sample of abnormal IC card data

5 Triggering distance

The GPS data records the information of arrival and departure. When a bus runs close to a station, an arrival event is triggered and when bus leaves for a station, a departure event is triggered. But we do not know how long the triggering distance is, in other words, how far is between the bus and the station when an arrival event or departure event is triggered? In the process of inferring boarding and alighting station, triggering distance is important for us to decide some parameters' value.

In Chengdu transit system, GPS equipment sends a record per ten seconds, and when arrival or departure event is triggered, a record is sent to the data management center. We can get the triggering distance by calculating the distance between the bus and the station when an arrival or departure event is triggered using the latitude and longitude of the station and the record sent by the bus. Each arrival or departure event has a triggering distance. First, taking the line #146 as an example, we calculate the triggering distance of all buses on November 3, 2014 and then get the statistical frequency of triggering distance using an interval 5 meter, and the result is as Figure 7 shows: the 0 on X axis means triggering distance is between 0 and 5 meters and 1 means that between 5 and 10 meters. It is obvious that an large part of triggering distance are between 35 meters and 50 meters with an average value 40 meters, but there are also some cases which have a very long triggering distance and that will be analyzed in the following section.

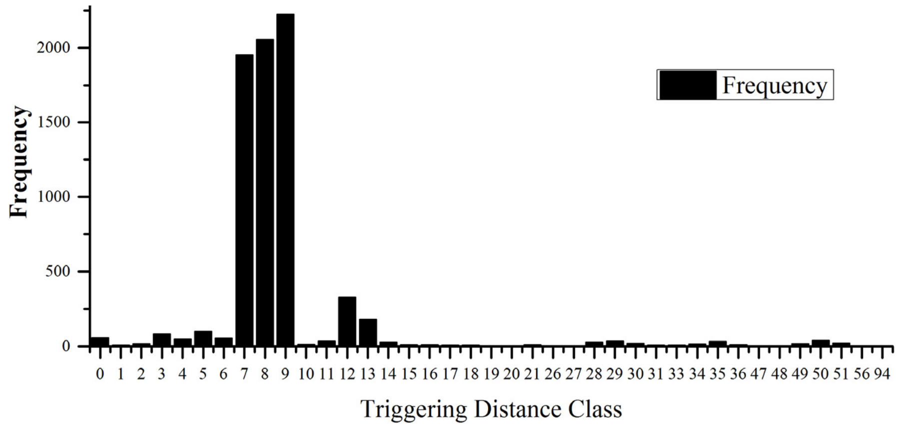


Figure 7. Frequency distribution of triggering distance

Having the aforementioned result, it is necessary to analyze the triggering distance of a specific bus at every station during one turn. Here, we choose one bus on line #146, and then calculate its triggering distance of first turn on November 3, 2014. As Figure 8 shows, the triggering distance of each station during a turn is also between 35 and 50 meters except for the XiangXieLi with a large value of 250 meters.

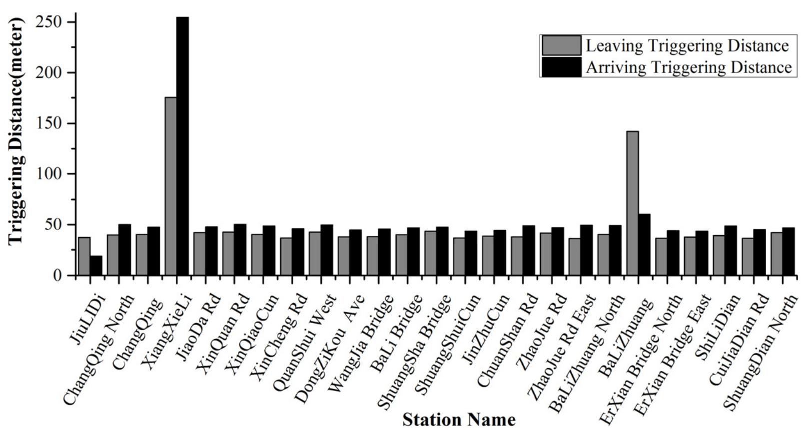


Figure 8. the triggering distance of a single bus during its first turn

As for the XiangXieLi, it is important to find what factors lead its large triggering distance and there are two methods can be taken for that question. First, the average triggering distance grouping by station during a day can tell us whether the latitude and longitude of relevant station leads to its large triggering distance or not. So we calculate the average triggering distance of all buses on line #101 on November 3, 2014 for each direction and station. As Figure 9 shows, being in compliance with the result in Figure 8, the triggering distance in different direction of each station is also between 35 meter and 50 meter largely except for the XiangXieLi, which to a great extent means that the latitude and longitude of XiangXieLi leads to its large triggering distance.

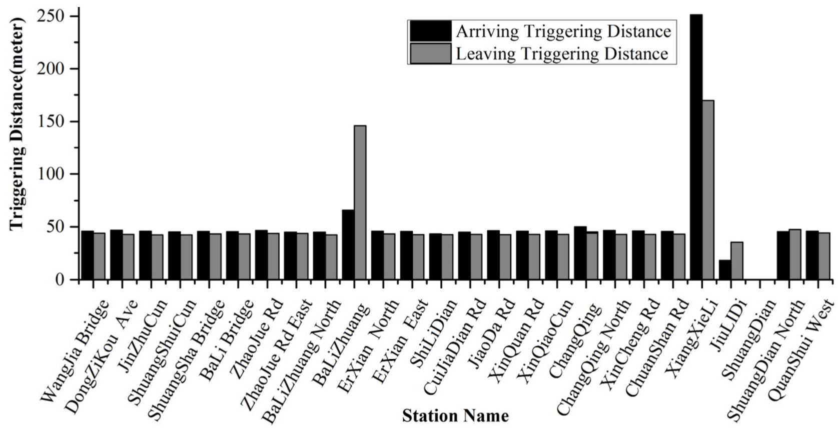


Figure 9. the average triggering distance of each station in the up direction

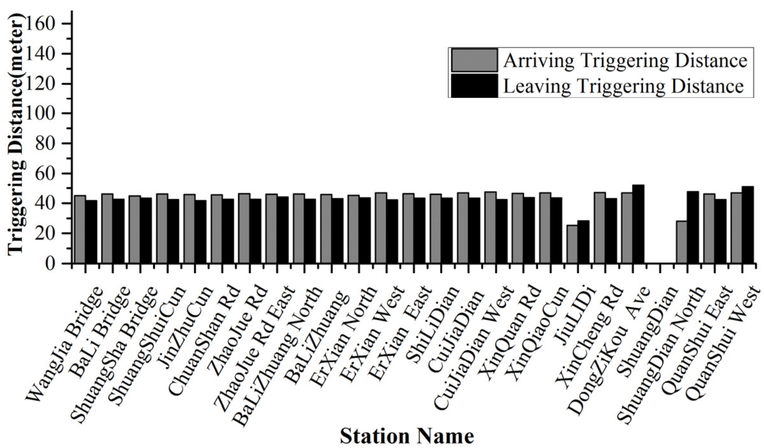


Figure 10. the average triggering distance of each station in the down direction

In order to further validate that conclusion, we consider the relation of time in both two data set: one is the passengers' swiping-card time, namely CONSUMEDATE; the other is the bus's arrival and departure time of each station. In figure 11, the station ChangQing and JiaoDa Rd looks normal, because CONSUMEDATE is between the arrival time and departure time, which is in compliance with the boarding behavior in transit system, while at the XiangXieLi, the CONSUMEDATE falls behind the departure time of the bus, which is not reasonable. Furthermore, we can find that the bus triggers both the arrival and departure events before arriving at the XiangXieLi by putting the latitude and longitude of the XiangXieLi and that sent by the bus when it triggers arrival and departure event at XiangXieLi on map. This phenomenon to a great extent results from the failure in updating the change of the location of the XiangXieLi. Now, it is clear that the triggering distance is largely between 35 and 50 meters in normal sense, but caused by the change of the location of station there are also some stations have large triggering distance.

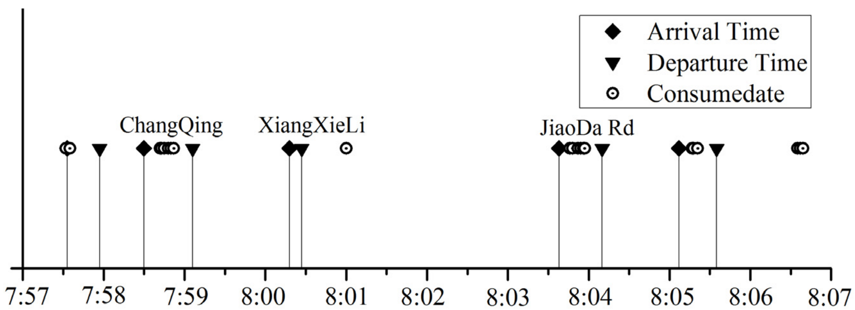


Figure 11. the CONSUMEDATE of IC card and Arrival (Departure) Time of bus

For the latter situation, some measures should be taken to avoid the phenomenon that the passengers boarding at the next or last station, are considered to board at the current station, for example XiangXieLi. One method is to update the latitude and longitude of stations that have changed location, but it proves difficult to get the exact latitude and longitude data if you do not have professional skills and equipment. The other is to change the CONSUMEDATE of records that board at the next and the last station of current one that has changed location information, and make it fall somewhere between the arrival time and departure time. So the first step is inferring boarding station using methods proposed in section *Introduction* and then calculate the difference between the departure(arrival) time of bus and the CONSUMEDATE of passengers'. Let's take XiangXieLi as an example, if a passenger is inferred that he or she boards at a station with large triggering distance and the difference is far less than the given parameter whose value depends on the average difference between the ACTDATETIME in GPS data set and CONSUMEDATE in IC card data, the passenger boards at the station ChangQing, and if more than the given parameters, the passenger boards at the station JiaoDa Rd.

6 Conclusion

Data cleaning is a very important process for further research, during which we should not only exclude the useless data but also find out how data is collected. According to the research above, some methods of data cleaning were proposed about different data quality problems, which make the IC card and GPS data is suitable for inferring the boarding and alighting station. The triggering distance is largely between 35 and 50 meters and there are some stations have a large triggering distance, for which the solution has also been proposed, which helps us to make the rules of inferring boarding and alighting station more reasonably.

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References

Chen Shaohui. (2012). “An Approach on Station ID and Trade Record Match Based on GPS and IC Card Data.” *Journal of Highway and Transportation Research and Development.*

Guo Shuxia. (2010). “Models and Algorithms for Urban Transit Dispatching Coordination Based on Time-Varying Dual Source of Data”. *Beijing Jiaotong University.*

Jason B.Gordon. (2012). “Automated Inference of Full Passenger Journeys Using Fare-Transaction and Vehicle-Location Data”. *Department of Civil and Environment Engineering.*

Marie-Pier Pelletier, Martin Trépanier, Catherine Morency. (2011). “Smart card data use in public transit: A literature review.” *Transportation Research Part C* 19 (2011) 557–568.

N.B. Hounsell, B.P. Shrestha, A.Wong. (2011). “Data management and application in a world-leading bus fleet”. *Transportation Research Part C* 22 (2012) 76-87.

Steve Robinson, Baskaran Narayanan, Nelson Toh, Francisco Pereira. (2014). “Methods for pre-processing smartcard data to improve data quality”. *Transportation Research Part C* 49 (2014) 43–58.

Zhang Yu. (2010). “Dynamic Public Transit Origin-Destination Estimation Based on Data Mining”. *Beijing Jiaotong University.*

IC Card-Based Data Mining Characteristics of Urban Public Bicycles

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Abstract: This article takes three bicycle sharing systems as the research object , the Citi Bike of New York City , the Capital Bike share of Washington and the Divvy of Chicago. Adopting the method of Data mining, the corresponding long-term historic credit card data, bicycle sharing system location data and the land-use properties coming from three bicycle sharing systems are compared and analyzed to get bicycle sharing system in seasonal, spatial and temporal distribution, site symmetry aspects of trip characteristics, which provides support for bicycle sharing system Operational decisions.
Keywords: Public bicycle; Data mining; Travel characteristics.

1 Introduction

Public bikes have become more and more popular in many cities, mainly because they “provide the missing link between existing points of public transportation and desired destinations” (Midgley, 2009).In addition, public bikes offer a mode of transportation that is not only environmental friendly ,but also can be a mode of healthy exercise.

As access to public or shared transport systems becomes increasingly digitised, new data-sets have emerged offering opportunities to research travel behaviour in a continuous large-scale and non-invasive way (Blythe and Bryan 2007).

This paper conducts comparison on three bicycle sharing systems (Citi, Capital Bikeshare, Divvy) vertically to search for similarities and differences on the travel characteristics of public bicycles, and provide effective support for operational decisions.

In here , we mainly concentrate on following points :The first part mainly shows the resource of the rules of data pretreatment; The second part introduces the conditions of three bicycle sharing systems; The third part emphatically analyses the rules of the frequency at weekend and working day trips in time distribution; The fourth part makes a study on the temporal distribution on frequency of pubic bicycle trips. The fifth part studies the features of frequency distribution on public bicycle trip duration. The sixth part analyzes the relationship between the frequency of trip and the ratio of public bicycle borrows and returns. The seventh part explores the influence of the features of seasonal temperature changes on public bicycle trips.

2 The Citi Bike, Capital Bike share and Divvy system

The Citi in New York City is the nation's largest bicycle sharing system, which has 332 bike rental sites and 6,000 public bikes, mainly located in the Manhattan North and Brooklyn South region. In May 2013, officially opened to the public since Citi public bicycle system popularity, by September 2014, the number of systems in use has more than 7 million times, more than 100,000 people have paid a member annual fees.

Capital Bike share was United States first bicycle sharing system, you can choose any of the over 300 stations across Washington, D.C., Arlington and Alexandria, VA and Montgomery County, MD and return it to any station near your destination. In Washington, DC, Capital Bike share has about 24,000 members, annual fee and monthly members.

Chicago Divide was launched a bike sharing system, which is called "Divide & Share" in the summer of 2013. The system includes more than 400 bike access stations (including planning and under construction), a total of 4,000 bikes covering the downtown subway stations, commercial centers and tourist attractions in the surrounding areas.

3 Data

3.1 Data acquisition

This data comes from New York, Washington, Chicago, public bike system Web site, which includes Credit card data and each rental Systems' latitude and longitude. The samples' time interval is from August 2013 to July 2014 in New York, August 2013 to August 2014 in Washington and July 2013 to June 2014 in Chicago. Such as New York Citi bicycle sharing system, its Credit card data contains records of travel time, the terminus name and number, user types (Ordinary or VIP), arrival and departure time, bike number , age and gender. As shown in the following table1.

Table 1. Citi Bike trip data

trip duration	start time	stop time	start station id	start station name	end station id	end station name	bike id	user type	birth year	gender
634	2013/7/1 0:00	2013/7/1 0:10	164	E 47 St & 2 Ave	504	1 Ave & E 15 St	16950	Customer	\N	0
1547	2013/7/1 0:00	2013/7/1 0:25	388	W 26 St & 10 Ave	459	W 20 St & 11 Ave	19816	Customer	\N	0
178	2013/7/1 0:01	2013/7/1 0:04	293	Lafayette St & E 8 St	237	E 11 St & 2 Ave	14548	Subscriber	1980	2
…	…	…	…	…	…	…	…	…	…	…

Table 2. Citi Bike trip data

number	station name	station latitude	station longitude
1	St Marks Pl & 1 Ave	40.72779126	-73.98564945
2	E 11 St & Broadway	40.73261787	-73.99158043
3	Cleveland Pl & Spring St	40.7218158	-73.99720307
4	Leonard St & Church St	40.717571	-74.005549
5	Greenwich St & Warren St	40.71542197	-74.01121978
6	Greenwich St & N Moore St	40.72043411	-74.01020609
…	…	…	…

3.2 Data Preprocessing

When Public bike system records in large travel information, existing part of the error message and data. Before analyzing the entire data sources, we should carry out data cleansing, rectify and delete data failed, specific principles of data cleaning as the following

1. The departure time is later than the arrival of time recorded data will be excluded;

2. Duplication of ID data, and keep only one ;

3. Each record shall be recorded starting station and terminal information, travel records will be excluded if anyone is missing;

4. The data of use of time and arrival time is within 2 minutes will be excluded;

5. Travel time is less than 1 minute and starting station and the Terminal is same site , this kind of data will be excluded;

6. Travel time 10 hours (600 minutes) over as exception data will be excluded.

7. The sample data which travel time is more than 24 hours will be excluded;

8. Management vehicle trip data generated by their exclusion from it. (Patrick Vogela, 2011)

4 Time distribution of trip frequency of public bicycles

We have figured the trip frequency of public bicycles at each period of a day at hourly intervals. As shown in the figure 1, the trips distribution at working days feature has two high peaks, namely 8:00 to 9:00am and 17:00 to 18:00pm, while the high peak occurs at 14:00 to 16:00 at weekends. Besides, public bicycle's card reader times at working days of the 24 hour a day is 2 to 3 times of that at weekends and the using rate is 3 to 4 times of that at high peaks at weekends usually, it is more focused on the outdoor trip at afternoon.

The reason public bicycles show different characteristics at working days and weekends is that they are most frequently used at rush hours at working days with typical commuting feature while bicycles on weekends are usually used for shopping, travailing and leisure,etc.

Public bicycles can not only serve as a convenient vehicle but also a good mean to do city sightseeing. Trip frequency of public bicycles system can be efficiently improved through a special road network linking the sights in the city.

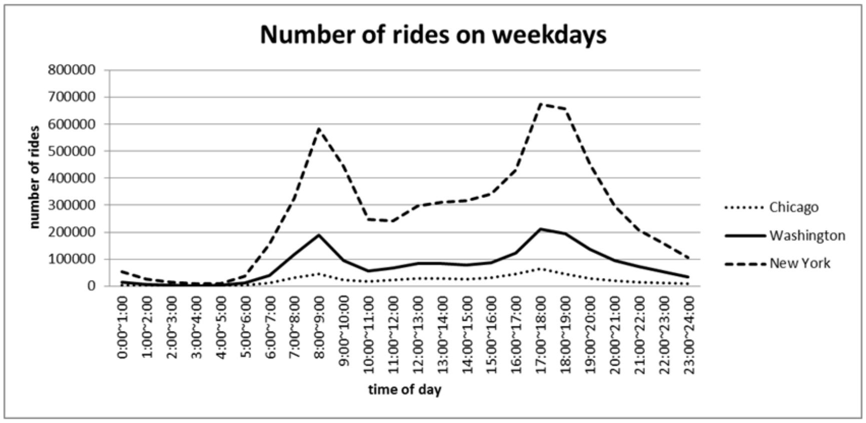

Figure 1. Number of rides per hour on weekdays

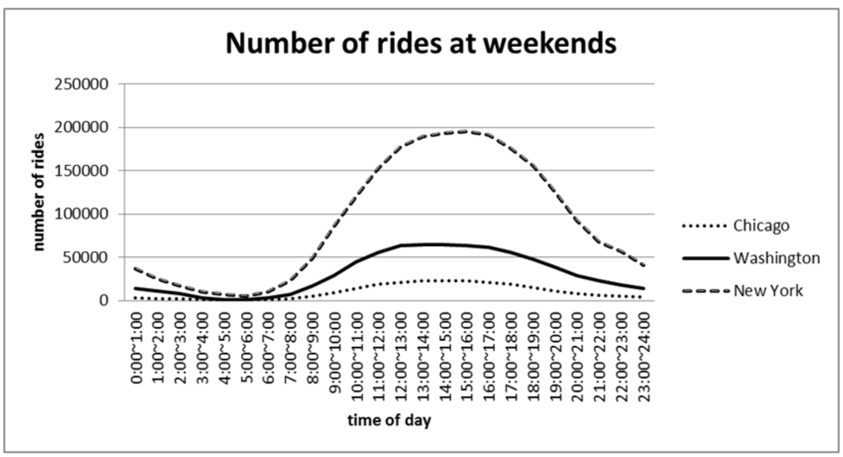

Figure 2. Number of rides per hour at weekends

5 The frequency distribution of travel time

The function of the public bike system is conducting the residents of "last mile" of travel demand and travel time is one of the most important considerations in public bike system. You can see from Figure 5, 90% or more in three different cities travel time are concentrated in less than 30 minutes. In three cities, it is all free when travel time is less than 30 minutes , which is the most important reason for travel are all less than half an hour.

In addition, travel time in maximum frequency values is seen at about 10 minutes in three cities, calculated in accordance with biking in general average speed

15km/h, coupled with road vehicle disturbance and traffic light wait time reduction, more than half of the public bicycle travel radius should be about 2 km.

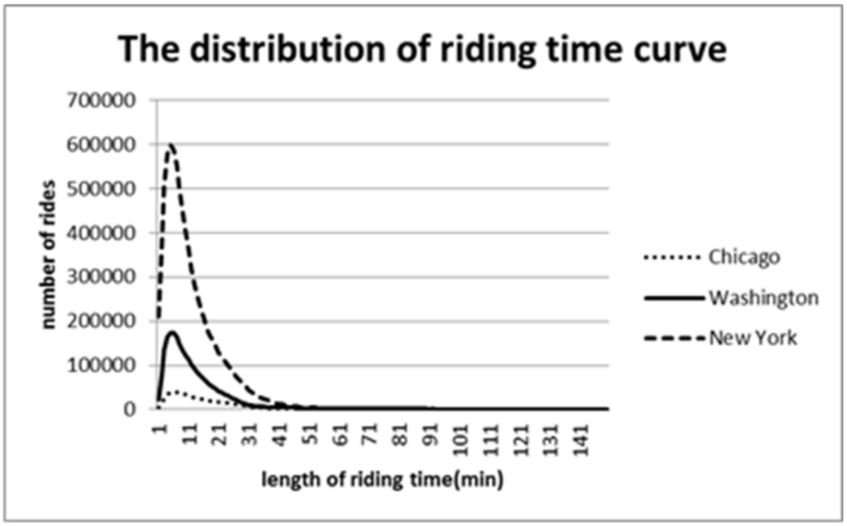

Figure 3. The distribution of travel time curve

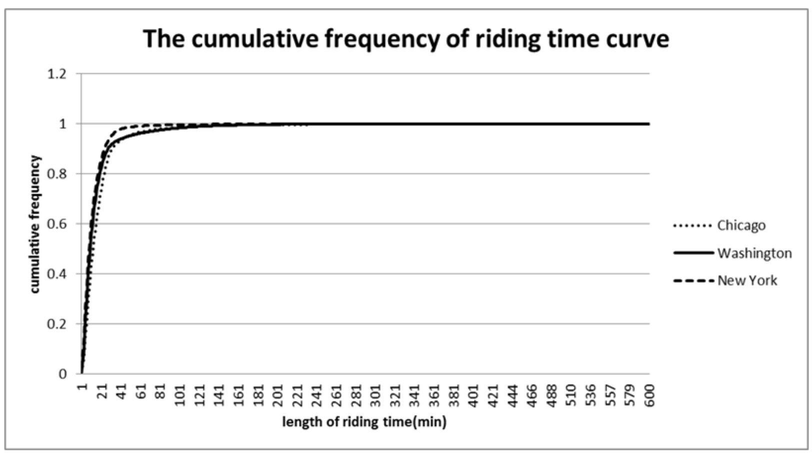

Figure 4. The cumulative frequency of travel time curve

6 The relationship between the frequency of trip and the ratio of public bicycle borrow and return

A public bicycle rental point can be both a starting point and a terminal, only if the number of loaned bike as a starting point and the number of returned bike as the terminus in a certain time period can achieve balance, the site is running properly, otherwise operators should adjust each sites' bike numbers. In Public bicycle operation, due to the differences properties of surrounding land-use of the site, bike borrows and return is imbalance in the same point, In order to ensure the normal operation of the system, we need to schedule a certain amount of vehicles. For operators, vehicle scheduling is one of the highest operational costs, how to achieve the balance of borrow and return for a certain period is significance for optimization of the operating system.

This section focuses on the site lending ratio and frequency of use, as shown in the figure, Longitudinal axis is the ratio of bike loan amount and return amount for the site . Closer to 1 shows better the balance of the site, the horizontal axis for each site's amount of trip swing card in whole year.

Through the comparison on three bicycle sharing system, we can see, each city's law is different. In Washington's public bike system, the frequency of use , the higher the site circulation ratio is closer to 1, while New York and Chicago, there is no obvious relevance. This suggests that circulation associated with the frequency of use is up to which city as your sample .

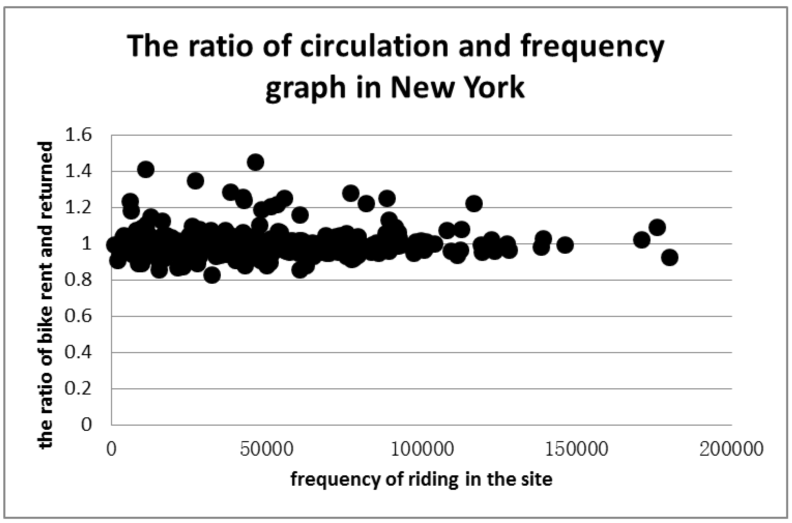

Figure 5. The ratio of circulation and frequency in New York

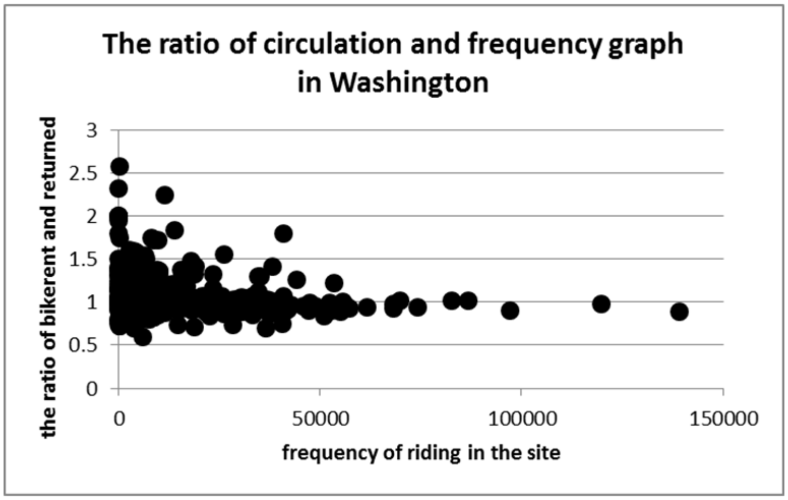

Figure 6. The ratio of circulation and frequency in Washington

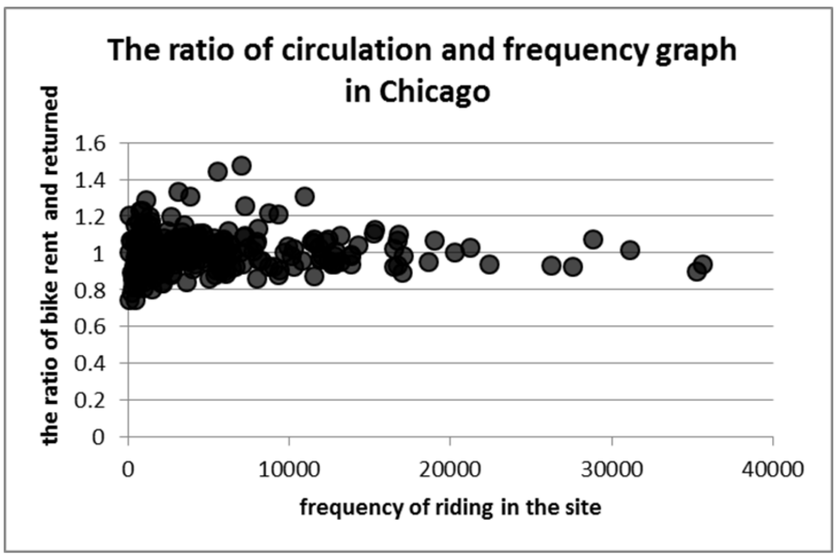

Figure 7. The ratio of circulation and frequency in Chicago

7 The effect of climate on the use frequency of public bicycle

Climate (long-term, seasonal changes) and weather (short-term and daily changes) have a significant impact on cycling and it may be expected that they also influence the level of bike-and-ride (Karel Martens,2004). Cold temperatures, rain, and high humidity levels reduce both the likelihood of using bike share and the duration of trips(Kyle Gebharta,2013).

We could conclude that, from chart 8, climate has a great influence on the use of system of public bicycle. Varied from the big gap on the swing card curve in New York, the change tendency between Chicago and Washington is quite flat. But the common issue is that the lowest usage rate concentrates on January and February of winter, the coldest season of the year. The use of public bicycle in the spring begins to rejuvenate and shows growing tendency but it becomes slow in summer gradually and maintains relatively high level in the end. The summit rate of three curves happens in September and October of Autumn and pleasantly cool weather makes it possible to reach the top for the use of public bicycle.

The use of public bicycle system is remarkably influenced by the change of seasonal temperature. People tend to choose other transportation to go out in cold winter compared to unshelled bicycle. So it is a tough issue for operators to contemplate on how to improve the use frequency of public bicycle on bad weather conditions, such as cold winter.

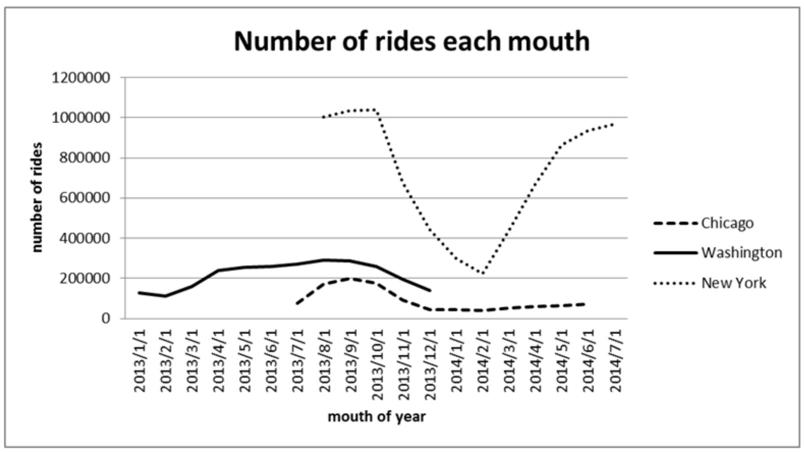

Figure 8. Number of rides in the mouth of year

5 Conclusions

Through data mining methods, we analyze public bicycle system in New York, Washington, Chicago comprehensively and get a lot of findings. . Public bike trips on weekdays is much more than on weekends, each other distributed in time are also completely different, the former showed significant commuter characteristics, which indicates that commuting is one of the most major public bicycle trip purpose. Because of its inherent limitations, Public bike has a significant feature in travel distance and time, the public bike system in three cities are free to use in less than 30 minutes, which led to more than 90% of trips concentrated within this period. The price mechanism for the development of the frequency of use of public bike has an important impact. By comparing the different cities, we also found that the site lending ratio and frequency of use are not necessarily linked. High and low temperatures for the use of public bicycle has an important impact, we found a relatively low winter temperatures will lead to a substantial decline in public bicycle usage.

Acknowledgement

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References

Blythe, P. and H. Bryan. (2007). "Understanding Behaviors through Smartcard Data Analysis." Proceedings of the ICE – Transport 160 (4): 173–177.

Karel Martens.(2004). "The bicycle as a feedering mode: experiences from three European countries. " Transportation Research Part D 9 (2004): 281–294

Kyle Gebharta and Robert B. Noland.(2013). " The Impact of Weather Conditions on Capital Bike share Trips. " For presentation at the 92nd Annual Meeting of the Transportation Research Board

Midgley, P. (2009). "The Role of Smart Bike-sharing Systems." In: Urban Mobility. Journeys. May. 23 – 31.

Patrick Vogela, Torsten Greisera, Dirk Christian Mattfelda(2011). "Understanding Bike-Sharing Systems using Data Mining Exploring Activity Patterns. "Procedia Social and Behavioral Sciences 20 (2011) 514–523

High-Speed Railway Train Diagram Planning Based on Big Data Analysis

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Abstract: Train diagram planning is the fundamental transportation organization planning, whose quality is related directly to passenger's experience of riding and the revenue of railway interests. By analyzing the characteristics of high speed railway train diagram planning in China, and combing the big data analysis technics, this article offers a way to optimize high speed railway train diagram planning in order to provide passengers with more comfortable environment and convenient riding.
Keywords: Train diagram; Planning; Big data; Optimization.

1 Introduction

High speed railway adapts well to urban transportation with high-density and has great impact on stimulating economic growth. High speed railway in China has led national fast passenger transportation to a new dimension. Currently, a Beijing-centric eight-hour transportation circle has basically formed and the passenger train graph executed in 10 Dec. 2014 includes 2673.5 pairs of passenger trains, among which 1556.5 pairs are motor train unit, accounting for 58.2%. From the beginning, passengers generally didn't like choose high speed railway to go out, but now, most of them turn to high speed railway, which accounts for the increasing recognition of it. This high recognition results from the desire of railway interest to meet the multiple demands of passenger, and their efforts to increase their competitive power depending on the scientific and technological progress. Also, it results from their utilization of new concepts and technology in operation management. The object of railway interests is offering a more convenient and comfortable riding experience to passengers. As an enterprise, meanwhile, they also spare no efforts to get more interests.

Currently, various modes of transportation are facing passengers. Each mode of transportation varies in passenger capacity and the volume of passenger transportation. When confronted with increasingly fierce competition, it's important to offer service in high quality and efficiency for the purpose of appealing to passengers. The quality of train diagram planning influence passengers on choosing trip mode. There are two aspects to judge the quality of train diagram planning. One is judging though service satisfaction from passengers, the other is judging from whether the income and expense are reaching to the equilibrium according to the planning (Shi Feng2004, Cha Weixiong 2000).

The object of passenger train service is people, thus, it's a prerequisite to consider thoroughly about multiple travel demand, and to offer satisfactory products to most of people. Based primarily on the first aspect, this article provides train diagram planning with decision basis according to the demand and satisfaction of passengers, and establishes a planning that meets the demand of market in high quality.

2 The method and difficulties of train diagram planning

1.1 The method of train diagram planning

From the macroscopic scheme to microscopic implement, railway passenger transportation plan can be classified worldwide as: railway network, train diagram planning, train working diagram, utilization of steward and rolling stock, real time scheduling of train movement ; In each phase, according to the characters of different transportation plan, optimization theory and method of train diagram planning correspondingly is "strategy level" in the aspects of enactment timing, focus and timeliness of transportation mission. As for the subsequent "operation level", determine the origin-destination of train, train lines passing, station, frequency of service, train class, marshalling, according to feature of passenger flow is the fundament to carrying out plan.

The enactment and modulation of train diagram planning can be divided into 5 steps (Fu Huiling 2009):

Step1: Microscopic analysis of passenger flow. Enact project of railway network, transportation infrastructure and mobile devices configuration according to passenger transportation demand; Predicting the total passenger flow volume of railway by using prediction technique.

Step2: OD generation of railway network passenger flow. Before formulate train diagram planning, transform total passenger flow volume into OD distribution of railway network passenger flow, which can also be viewed as "distribution of railway physical network".

Step3: The generation of alternative set of train diagram planning. "The alternative set of train diagram planning" is a reasonable universe set of all possible trains within planning. When optimizing train diagram planning, some workable train combinations within alternative set will be chosen to be the final plan. The generation of alternative set is based on the OD distribution of the railway net passenger flow, and it will offer origin-destination of train, operation pathway between them, the frequency of service and range of number of marshalling.

Step4: Optimization of train diagram planning. If there is no constraint of transportation capacity and operation cost, the trains within the alternative set can well meet the demands. However, the scarcity of transportation resource require downsizing of the alternative set by optimizing thereby making the objective function feasible within the constraint of passenger flow and transportation capacity.

Step5: The modulation of train diagram planning. Simulate passenger's selecting behavior for train service before applying, and evaluate, as well as modulate the planning so as to meet well the demand and reasonably utilize transportation resource.

1.2 The difficulties of the establishing of train diagram planning

Based on the procedure of train diagram planning summed above, passenger flow of railway network is the basis of enacting train diagram planning. The number of passenger flow decides the quantity of trains about to work. The distribution of OD determines the section of train operation. Meanwhile, the analysis of passenger travel behavior, mainly including: demand for travel time, ticket price, ways of transfer etc. is considered another factor. According to the factors stated above, it can be determined the class, number, marshalling, speed of train, also, starting station, terminal station, operation pathway and stop-schedule plan. Generally speaking, main difficulties are as follows:

(1)The investigation and prediction about passenger flow

The investigation contains the research contents, location, time, designing the survey, selecting and using of the research equipment, method of research as well as collecting and rearranging of the investigation data, calculating the index and analysis of the results, etc.

The frequently-used method are comprehensive passenger flow investigation, sample survey of passenger condition, passenger flow of, holidays and festival passenger flow investigation, investigation of outburst passenger flow. By using these methods, do statistical analysis of number of passenger, passenger flow of section, number of station, average riding distance.

The methods mentioned above have their advantages and disadvantages, Comprehensive passenger flow investigation: long time, high workload, requiring many investigators, but in high accuracy. Sample survey: often by questionnaire, the type and amount of sample influence greatly the accuracy. Investigation of section of passenger flow: conduct sample survey to passenger flow, usually research on maximum section of passenger, and observe directly the number of passengers in train. Holidays and festival passenger flow investigation: mainly conduct a survey about passenger flow in spring festival, national day and other significant holidays and festivals by questionnaire. Investigation of outburst passenger flow: conduct survey at public places like stadium, gym, cinema, etc. Main reasons of the existence of prediction errors are: the deficiencies of the prediction models itself, dynamic changes of the premise conditions, inadequacy of sample data, only retain high prediction data rather than low, etc.

(2) Analysis of passenger travel behavior

In order to study the traits of travel behavior more accurately, we should consider the traits of passenger (like gender, age, career), traits of travel behavior (like travel objection, departure etc.), attraction area of passenger flow of station, degree of acceptance of travel cost (like first-class seats, second-class seats, hard sleeper, hard seat etc.)

Meanwhile, the analysis of passenger's individual consuming behavior is also a must so as to provide personalized service.

(3) Analysis of passenger satisfaction to train diagram planning

Passengers are the direct service objects of the train diagram planning, so, it is important for railway interest to make subsequent optimization according to feedback of passengers. As far as I know, for the new trains, railway interests will establish train diagram planning according to the passenger flow they predict, and then put new trains into operation. After that for a period, adjust the planning again according to revenue of tickets, seat occupation rate and other data, whose main source are ticket system, rather than passenger. Thus, it results in waste of resources.

3 The analysis and prediction of passenger travel based on big data.

Big data is the fundament of the proliferation of complex web science and human dynamics. The excavation technology of big data has been applied widespread to research on transportation field, especially in prediction of demand.(Wang Pu 2013) Owing to the high cost of traditional OD diagnoses in manpower and material resources, a new research direction, analyzing and acquiring OD flow by utilizing various information resources to dig data, has come into being.

The advent of big data technology provides problems stated previously with a good solution. The main contents of the problem that big data technology is able to solve are as follows:

1.3 Collection of big data

Collection of big data generally is split into 2 layers: IntelliSense layer, and basic support layer.

IntelliSense layer: include data sensing system, network communication system, sensing and adapting system, intelligent identification system and accessing system of hardware software resources. It can realize the intelligent identification, locating, tracking, accessing, transmitting, and transferring of signals, monitoring, preliminary processing and management of mass data in structuring, semi-structuring, and non-structuring. It requires the emphasis on the technology, such as the intelligent identification, sensing, adapting, transmission, accessing of big data resources.

Basic support layer: provide big data service platform with basic support environment. For instance: virtual service, database in the form of structuring, semi-structuring, and non-structuring, and resources of Internet of Things.

1.4 Preprocessing of big data

We may not necessarily get what we are concerned about from the data collected by big data collecting technology, due to the error of data, which disturbs the analyzing. Thus, preprocessing of big data is the prerequisite before storing them.

Preprocessing of big data consists of discriminating, extracting, cleaning data. The first is due to the various structures and type of data, extracting process can help us transform these complicated data into single or easy-to-process configuration, in order to analyze and process quickly. The second is filter worthless and erroneous data from those useful ones.

1.5 Storing and managing of big data

It requires the storing of data by reservoir, and the establishing, managing, calling of corresponding database. Also, it mainly solve complex technological problem of structuring, semi-structuring, and non-structuring big data managing and processing, and make big data storable, denotable, disposable, reliable, besides, make possible the effective transmission of it.

Currently, although hardware performance is increasingly enhancing, the speed of reading and writing profile through hardware is discordantly low. In particular, field of modern intelligent transportation asks for high requirement for speed of data-processing and precision, whereas traditional database can hardly meet demand, which brought about a new generation of database: NoSQL. The main representative database systems are MongoDB, HBase etc. Yahoo established a distributed calculating platform Hadoop for managing, storing and analyzing a great volume of data. Hadoop is a batching system with the merits of enormous cargo handling capacity and automatic tolerance of errors, which is applied extensively in mass data processing. However, there are some shortcomings when it is processing real time data, thus, some real time processing platform emerged in succession, like S4, Storm, who have great advantages in processing uninterrupted stream data.

1.6 Analytical processing of big data

The data processing platform of Hadoop is the core of transportation prediction and analysis system. Combined with data storage layer, it adopts Hadoop system computing framework in order to realize the processing of batching data in database.

Processing program is developed to apply in Hadoop processing platform, high-speed data processing, in order to get a more credible traffic demand analysis and forecast results. The design algorithm of the data processing, will directly affect the final demand analysis results. When conducting mining process about data for the first time, it's a prerequisite to verify model sufficiently, in order to ensure the accuracy of the basic data for subsequent. Combined with the classical traffic demand analysis model, aiming at large data characteristics, design practical data analysis algorithm can guarantee the reliability of the results of the analysis of the final demand.

3.5 Analysis of big data about travel & designing of prediction system framework

The architecture designed to analyze and forecast passenger travel are shown as bellow. It falls into four tiers, data collection layer, calculating layer, data storage layer and the interface layer.

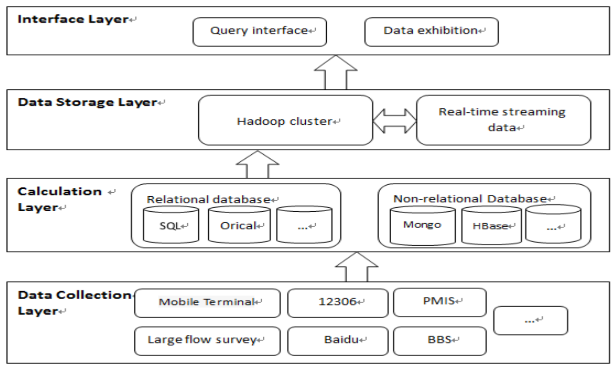

Figure 1. Framework of Data Collecting and Processing System of Big Data

The data collection layer functions as collecting traveler requirement data, which includes:

1) Large flow survey: Collecting data concerning the holiday and school time of colleges and universities, the number of students and their distribution, the cluster of migrant workers, and major events of government, large and medium-sized enterprises and institutions.

2) 12306, PMIS: Recording users' query data on the 12306 website. Each query represents a demand. 12306 has provided favorable conditions, which could record every demand of a user (travel time, change trains, preferable train types) and extract information of sold tickets, both historical and current.

3) Mobile terminal: As the number of cell phones has outweighed that of PCs, applications based on cell phone systems are becoming more diversified. With the help of APPs, data of traveler demands can be easily collected.

4) BBS: Obtaining traveler demand information and feedback through BBS.

5) Other ways: Tourism websites like CTRIP and Qunar, search engine like Baidu could be of important use. By now Baidu has provided big data prediction to forecast passenger flow volume OD.

Calculation layer: Establish corresponding data preprocessing models and algorithm model, input the data from the data collection layer and get the result data including OD, customer behavior, etc.

Data storage layer: For mass data storage, storing and retrieving data should not be restricted to a single database. Considering the trait of the traffic data, multiple database storage containing relational and non-relational databases is employed. In this layer, data sources offered by databases need to be screened in order to provide a reliable and complete access service to the databases. Often, the format of data collected by different system varies. It is necessary to process heterogeneous data in the way that, store them in different sets, design data processing algorithm for them separately and finally, integrate valid data.

Interface layer: Mainly responsible for providing data query and the presentation, providing data support for the compilation of train plan.

4 The compilation of train plan based on big data analysis

Based on the above analysis platform, the compilation process of train plan can be determined as figure 2 based on analysis of large data.

Make compilation of train plan according to the result of big data analysis, figure out several plans in the process of compiling, obtain evaluations after announcement, and adjust the result from the feedback so that we form a closed-loop with feedback. When the evaluation index reaches a set value, it will be determined as the ultimate solution to the train plan.

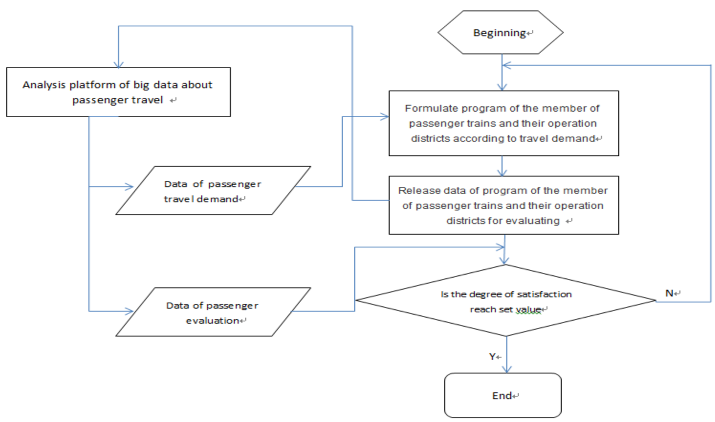

Figure 2. Train Diagram planning flow based the big data analysis

5 Conclusion

This article could not deeply discuss forecast algorithms and models, barely arguing about processing procedure of the big data analysis, roughly designing a system structure based on the technology of big data. In the days to come, how to process transportation requirement analysis according to characteristics of the big data of transportation, and combine classic mathematic models, design reasonable requirement forecasting and analytical algorithms, and make use of advantages the transportation big data is a keynote of the coming research.

Acknowledgements

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References

Cha Weixiong, Fu Zhuo. (2000) Research on the Optimization Method of Through Passenger Train Plan, JOURNAL OF THE CHINA RAILWAY SOCIETY, 22:(5): 1- 5.

Fu Huiling, Nie Lei, Yang Hao, Lu Tong, (2009) Analysis of Formatting Flow Path of High Speed Railway Train Diagram Planning, Railway Transport And Economy, Vol.31, No.10: 4-7

Shi Feng, Deng Lianbo, Li Xinghua, Fang Qi-gen, (2004) Research on Passenger Train Plans for Dedicated Passenger Traffic Lines. JOURNAL OF THE CHINA RAILWAY SOCIETY, 26(2):16-20

Wang Pu, Huang Zhiren, and Gong Hang, (2013) Transportation Engineering in the Big Data Era . Journal of University of Electronic Science and Technology of China, Vol.42 No.6, Nov, 806-815.

Application and Influence of Big Data in the Logistics Industry—Take Cainiao Network as an Example

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Abstract: Since the concept of big data was put forward by McKinsey, it has become a frequently cited phrase across all sectors in recent years. Logistics industry is a major beneficiary in the era of big data. Taking the logistics pattern of Cainiao network as an example, this paper analyses the application of the big data in the logistics industry, and studies the influence of big data in the logistics industry.
Keywords: Big data; Logistics.

1 Introduction

In May 2013, Alibaba Group, Intime Group, a joint Fosun Group, Fuchun Holdings, SF Group, tee one up (Shen Tong, Yuantong, Zhongtong, Yunda), ZJS Express, Huitong, and related financial institutions jointly launched the "China smart logistics backbone "(referred to as CSN) project, and the Cainiao network Technology Co., Ltd. "was established.

Cainiao network uses its own technology and resources, cooperates with industry partners, shares data with each other and creates the first domestic logistics of large data sharing platform. It helps logistics express enterprises strengthen information technology and service capabilities and reduce duplication of information systems industry. The platform enables e market analysis, quality indices service, customer mining, and data prediction function.

With the rapid development of information technology, especially in cloud computing, networking technology matures and facilitates big data applications in the logistics industry.

2 Improve the logistics processes and the efficiency of logistics

The most basic application of big data analysis techniques in logistics industry is to summarize, classify and integrate various data of the logistics chain, and then analyze and refine by technological means, help the logistics chain improvements and upgrading and allow logistics to be more intelligent, to achieve the goal of improving operating efficiencies and reducing cost.

3 Customer-centric, shifts from price competition to value competition

The core competitiveness of logistics enterprises is the quality of service, which has been improved by shifting from price competition to value competition. "Data mining" and other big data technologies which can analyze customer consuming information and grasp the consumer behavior characteristic help logistics enterprises to improve customer relationships and enhance the quality of logistics services. Logistics express enterprises should accelerate the introduction of big data and cloud computing technologies.

4 Promote the formation of "big logistics" system - Cainiao network

The arrival of the era of big data has effectively promoted the formation of the "big logistics" system and brought significant changes to the logistics industry. The so-called "big logistics" refers to the enterprise's own logistics (personnel, fleet, warehouses, etc.) and third-party logistics and distribution companies to share information and resources in order to achieve a greater level of use of various resources and reduce logistics costs. Cainiao network, a new company which established "Chinese intelligent backbone" focuses on creating a network of Chinese smart logistics backbone network that uses advanced networking technology, cloud computing and other Internet technologies, to establish an open, transparent, shared data application platform. This platform provides quality services for logistics companies, e-commerce businesses, warehousing companies, third-party logistics service providers, supply chain service providers and other types of enterprises. Cainiao network helps the logistics industry further develop to high value-added areas.

Applications of big data in Cainiao network mainly lie in the following two aspects. ① Data mining techniques to predict consumer information. For example, the network has mastered the consumer and product information in the "double 11" to guide participation of the business, logistics and express companies, consumers logistics information linkage, Cainiao network based on historical consume data, volume and other information prepared comprehensive data analysis and forecasting, to guide businesses stocking. A data mining team has been put in to analysis consumer information. ② "Logistics Data Radar" service to improve order management. "Logistics Data Radar" can provide detailed forecasting of regional and network, not only to monitor the transfer station, but also to monitor the administrative and service outlets county. These data will help courier companies to make decisions. Through line prediction it will help major courier companies to allocate warehouse explosion, and improve the last mile delivery service quality. Through radar data, businesses can clearly realize the logistics order management. Businesses can also take corresponding measures for different situations, such as care of long-term orders, the after service of orders, active follow-up and coordination of treatment and other users express abnormal situations.

With the development and application of big data technology, logistics industry will undergo enormous changes.

Firstly, big data can improve logistics resource utilization ratio. From the viewpoint of the supply chain, every step of goods distribution requires fast and efficient connection. At the same time, each node generates and needs great amount of information. An open, transparent and shared social logistics information exchange platform created through Big Data technologies can combine large data with warehousing and distribution and other logistics capabilities. Information platform can dig and analyze customer source, allow real-time tracking and analyze customer behavior by taking advantage of Intelligence and massive data analysis and processing capabilities. It allows enterprises in the system to keep abreast of logistics information and customer information. When logistics resources are insufficient, these enterprises can find internal and external idle resources through data analysis. With this technical support, scheduling or logistics can fulfill more logistics services，which will increase supply chain surplus.

Secondly, big data can reduce the cost of the logistics industry. In the traditional logistics industry, information lag, high distribution costs and other problems are prevalent. Big Data break the traditional methods of fixed personnel and fixed-line distribution. It uses minimum allocation resources to meet the largest needs of the distribution and furthest reduce logistics costs. Cainiao's information network platform collects items, personnel, vehicles, traffic and other information and stores in the database. Before delivery, based on available information, the platform fully maximizes the vehicle load, and design distribution plan and distribution lines accordingly. In the course of the flow of goods, companies can know and analyze real-time items, vehicles, traffic and other information to optimize the line in time, thus maximally saving time and costs.

Thirdly, big data changes the service mode in logistics industry. Big data provides professional information processing and value mining for logistics industry and encourages enterprises in the system to change from the behindhand service mode to advanced service mode， focus on data, and increase the level of automation and information. Through the collection, collation and analysis of the logistics industry data, we can unearth the potential customer demand, forecast the quantity and quality of commodity distribution, analyze the market trends and configure the appropriate logistics resources in the special period, in order to meet the needs of market development. In addition, the results of analysis can provide personalized service for every customer. From the enterprise's own management situation, according to the daily operation data, the platform can analyze which business is a high-profit business and recommend enterprises to develop the business by investing resources and energy. Reducing the investment in unnecessary operations and processes or giving up the business part with low profit will increase business income. In addition, enterprises can also adjust the current business structure, transfer the extra resources, and optimize the business structure of the enterprise.

Fourthly, big data can improve the management of the logistics industry. Transparent data and intelligent analysis make information of operating status and business situation of any spot in the corporate network easy to obtain. Also, big data can be used to manage, analyze, and determine the behavior of business operations, so that problems can be identified timely. This technology provides important support and guidance for corporate strategic planning, operations management and daily operations, and continuously improves the management level and services quality.

Today is an era of rapid development. The development of the logistics industry is inseparable from the use of big data, it has become a trend. Rational use of big data technology plays a positive role in management, decision, customer relationship maintenance, and allocation of resources in logistics enterprises. Eventually logistics companies become data-driven enterprises, which is a necessary condition for the enterprise in the era of big data for further development.

References

Liu Yuqi (2014). "E-commerce logistics in Cainiao Age." China logistics and purchasing.

Tu Jiangping (2014) "Big Data boost e-business logistics development." China market.

Wang Huihui (2014) "The impact on the logistics industry and the prospect of the Internet of things era of big data and analysis." E-Business Journal.

Yan Jun (2013). "Impact of Big Data on the development of the courier industry." Logistics technology.

Structure Sensitivity of the CRH3 EMU Based on FEM

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Abstract: The bodywork structure sensitivities can provide modification direction information in structure design and optimization. This research focuses on the CRH3 bodywork, in which the finite element model is established by implementation of Hypermesh software, meanwhile the modals are performed by use of finite element method. The chassis, side wall, top plate, end wall and other part thicknesses are used as the design variables, and consequently the sensitivities of the CRH3 bodywork modal frequencies to the design variables are achieved by use of numerical differential method. Results show that the sensitivities of the modal frequencies to the chassis and the side wall are maximum and to the top plates are lesser. For the end wall and the chassis front end, the sensitivities are negative.

Keywords: High-speed train; Finite element analysis; Sensitivity; Modal frequency.

1 Introduction

The highest running speed of the CRH3 has reached 350Km/h. In order to reduce its structural weight and increase the reliability, the bodywork has been widely manufactured using aluminum profile (Chang, S.M., 2004). Aluminum alloy profile bodywork carry the loads as a whole structure, so chassis, side wall and top plates could all absorb loads. The design goal of the bodywork is to satisfy the requirements of strength and stiffness under the condition of minimum weight (Tong, W.L., 2009). The bodywork stiffness is to meet the demands of the modal frequency, which is regulated by the railway industry standards of "Test methods for dynamic performance of locomotive and rolling stock on testing (TB/T 3115 2005)". The standard requires that the first-order bending modal frequency of servicing bodywork is not less than 10 Hz, and the ratio between this value and the natural frequency of vertical vibration of the framework should be greater than 1.4. During the process of optimization design, if the weight of the aluminum alloy bodywork is reduced, the strength is generally easy to be satisfied, however this sometimes leads to a fact that the modal frequency does not satisfy the requirement (Chen, X.H., 2000).

In the process of structural modifications, the structure sensitivities are needed, sensitivities are the derivative of responses to the structural parameters, the structural modifications direction can be achieved by sensitivities information (Xie, S.M., 2004), and in structure optimization design the structure sensitivities are essential (Tang, M.P., 2003). In this article a finite elements model of CRH3 emu bodywork is established, the sensitivities of modal frequency with respect to structure parameters are calculated using numerical differential method.

2 The Basic Theory of Structural Sensitivity

The sensitivities of the modal frequency to the structural parameters can be obtained directly by the differential of both sides of the modal equations. Undamped structure free vibration equation is expressed as follows

$$([K]-\lambda_i[M])\{\phi_i\}=0 \tag{1}$$

where $[K]$ and $[M]$ are structural stiffness matrix and mass matrix , respectively; λ_i is the i[th] modal frequency of the structure, $\{\phi_i\}$ is the i[th] modal vector. If the j[th] design variable is x_j, then the following equation could be achieved.

$$([K]-\lambda_i[M])\frac{\partial\{\phi_i\}}{\partial x_j}+(\frac{\partial[K]}{\partial x_j}-\lambda_i\frac{\partial[M]}{\partial x_j})\{\phi_i\}=\frac{\partial\lambda_i}{\partial x_j}[M]\{\phi_i\} \tag{2}$$

By the left multiplication $\{\phi_i\}^T$ for Formula (2), we reach the following Formula (3).

$$\{\phi_i\}^T([K]-\lambda_i[M])\frac{\partial\{\phi_i\}}{\partial x_j}=0 \tag{3}$$

Combining Formula (2)&(3), Formula (4) is obtained as follows.

$$\frac{\partial\lambda_i}{\partial x_j}=\frac{\{\phi_i\}^T(\frac{\partial[K]}{\partial x_j}-\lambda_i\frac{\partial[M]}{\partial x_j})\{\phi_i\}}{\{\phi_i\}^T[M]\{\phi_i\}} \tag{4}$$

Where $\frac{\partial[K]}{\partial x_j}$ and $\frac{\partial[M]}{\partial x_j}$ are the derivatives of structural stiffness matrix and mass matrix with respect to design variables, respectively. To accurately solve $\frac{\partial[K]}{\partial x_j}$ and $\frac{\partial[M]}{\partial x_j}$,we need to know the specific form of elements stiffness matrix and mass matrix, which is usually solved by finite difference method.

3 The Modal Analysis

3.1 Finite element model

The theoretical analysis shows that the sensitivity analysis is based on the finite element method, so in the first place we should establish the finite element model. The finite element method has become the basic method of structural analysis and is also the basic for the structural sensitivity as well as the optimization design. The finite element model of CRH3 emu T02 bodywork is shown in Figure 1. The car bodywork uses shell elements, whereas the main transformer, air equipment and other facilities utilize lumped mass to simulate.

Figure 1. Car bodywok finite element model

3.2 Modal analysis

Modal calculation uses the full vehicle model. The first-order bending modal vibration mode is shown in Figure 2. The first six orders modal frequencies are listed in Table 1.

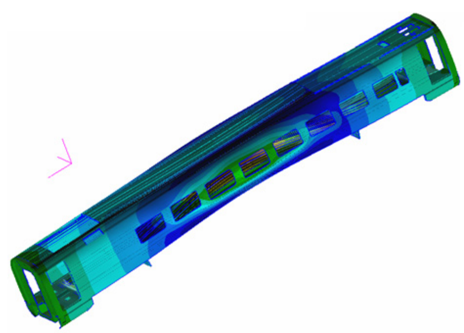

Figure 2. First-order bending modal vibration mode

Table 1. Modal vibration modes and frequencies

Modal orders	Vibration mode	Modal frequency
1	First-order diamond	7.99
2	First-order bending	8.66
3	Second-order bending	10.78
4	First-order torsion	11.51

5	Chassis second-order bending	13.53
6	Third-order bending	14.87

4 Results of The Sensitivity Calculation

4.1 Design variables

In order to research the effects of the chassis, side wall, top plate, end wall and other positions on the modal frequency, the design variables are shown in Table 2. The design variables on the outside of the middle chassis are shown in Figure 3. The only chosen design variable is the shell thickness.

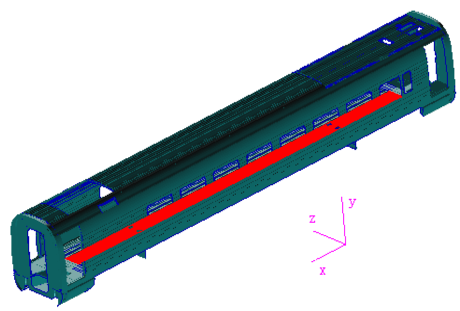

Figure 3. Design variables of the middle chassis

Table 2. Design variables

Serial number	Design variables	Thickness (mm)
1	Top plate S3	3
2	Flat plate S8	8
3	Side wall S3	3
4	Floor S3	8
5	End wall S8	5
6	End wall S5	4
7	End wall S4	6
8	End wall S6	10
9	Door S10	8
10	Front chassis S8	5
11	Chassis carling S5	7
12	Chassis lateral plate S7	32
13	Chassis coupler end grider S32	16
14	Chassis coupler carling S16	6
15	Chassis end cant beam S6	3

4.2 Modal frequency sensitivity

The sensitivities of the first six orders modal frequencies with respect to the design variables are shown in Figure 4. Figure 4 shows that, the sensitivities of each modal frequency to the side wall and to the floor are greater than to others. The maximum is modal 5th sensitivity to design variable 4 (floor), the maximum value is 0.1Hz/mm. On the contrary, for design variable 5(end wall), the sensitivity values are negative, meaning that when the thickness of design variable 5 increases, the modal frequencies will decrease.

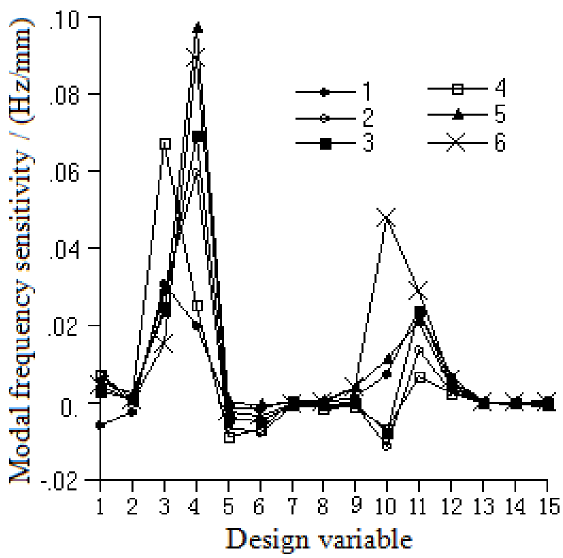

Figure 4. Sensitivities of the modal frequency

This indicates that the increase of those thicknesses have rather small or negligible contributions to the car body strength, but the impact on the bodywork's mass is greater than that on its stiffness. Generally, with the increase of the modal frequencies, its sensitivities will increase too. The rising of the most panel's thickness will lead to the rise of the bodywork's modal frequency.

5 Conclusions

This article established the finite elements model of CRH3 emu bodywork and calculated the bodywork's modal. By implementing the numerical differentiation, we calculated the sensitivities of modal frequencies with respect to each panel thickness of different parts. The results show that with the increase of modal frequencies, the sensitivities increase too. The bodywork's modal frequencies increase with increase of thicknesses of most panels. The bodyworks modal frequencies are most sensitive the chassis and side wall thickness. In general, the contribution of increase of panel thicknesses to the car body stiffness is greater than to the total mass. The research in this paper can quantitatively express rate of change of the modal frequency along with the change of the car body panel thickness, which provided a quantitative means for the bodywork structural modification.

Acknowledgement

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References

Chang, S.M., Ma, J.J. (2004). Aluminum alloy body structural design conception. *Railway Vehicle*, 42(9):9-13.

Chen, X.H. and Xin, C.Y. (2000). Lighenting design in structure and static and dynamic strength calculation for 200km/h high-speed motor car body. *Journal of the Chinese Railway Society*, 22(1):25-30.

Gong, D., Zhou J.S. and Sun, W.J. (2011). Vertical Ride Quality of Flexible Car Body Railway Vehicles with Optimal Control. *Journal of Tong Ji University*, 39(3):416-420.

Tong, W.L. (2009). Optimization strategy of aluminum alloy carbody of high speed train uint. *Chinese Journal of Computational Mechanics,* 26(3):424-427.

Tang, M.P. and Yan, G.P. (2003). Overview of Structural Sensitivity Analysis and Computation Method. *China Railway Science*, 24(1):74-78.

Xie, S.M., Yan, X.D. and Zhao, W.Z. (2004). Research on Weight Lightening of the High-speed Aluminum profile car body Base on Sensitivity Information. *Journal of the Chinese Railway Society*, 26(3):26-30.

Yao, S.G., and Xu, P. (2002). The application of new materials in high speed passenger vhhicle. *Railway locomotive vehicle*, (3):24-26.

Zhao, H.L., Yu, C.L. and Wang, W.B. (2007). Study on optimization Design of Car body Structure of High-speed Maglev Train. *Journal of the Chinese Railway Society*, 29(4):43-47.

Lectotype and Quantity Optimization of Handling Machines for Railway Freight Transport: The Case of Kunming Railway Bureau

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Abstract: The proportion of loading and unload machines in the logistics industry improves constantly, rational selection and handling technology of loading and unloading machine has become an important factor in determining efficient logistics operation method. In terms of domestic railway transportation requirements, the development of mechanization of loading and unloading the is overall slow, the equipment configuration is not suitable for the handling goods category and capacity of freight yards, especially the requirements derived from the regional differences and the diverse needs of customers on the freight transportation cannot be met. Aimed at practical handling operations of freight transportation in Kunming Railway Bureau, this paper puts forward the "three-phase method" for model selection of handling machines, establishes the binomial distribution model for reasonable configuration of handling machines. And the forklift configuration of public freight yards in Kunming East Railway Station is taken as an example for analysis and solution, the results has certain operability.
Keywords: Railway freight transport; Handling machine; Model selection; Quantity configuration; Optimization.

1 Introduction

Railway loading or unloading operation is the first or last working stage of freight transport working procedure, which is throughout the whole process of freight transport. Any kinds of freight transport can't be finished without handling operations. The configuration allocation of handling equipments has direct influence on the efficiency, quality and safety of railway freight transport.

Kunming Railway Bureau (KRB) is particular in the national railway network, in which exist standard gauge tracks and meter tracks at the same time. The operation conditions are unique, many stations have different drawbacks in their freight transport. The phenomena, such as over-term service, poor technical condition and obsolete equipment still in use, exist to varying degrees. In the scope of management, there are various kinds of goods, the conditions for loading and unloading them are different, and the workload varies considerably. For some kind of goods there may be several kinds of machines suitable for handling operation, various configuration schemes of handling machines may be adopted. Thus it would be necessary to compare and select various possible types and quantity schemes of handling machines in conjunction with the freight transport practices of Kunming Railway Bureau, especially with the requirements to promote logistics center construction and the ratio targets of mechanization and equipment integrity, so as to determine the optimal configuration scheme of handling machines for the freight transport of Kunming Railway Bureau.

2 Analysis on the present handling operations of freight transport in KRB

Kunming Railway Bureau administrates the railways distributed in Yunnan, Sichuan and Guizhou provinces. The railways includes three kinds of tracks with standard gauge (1435mm), metre gauge (1000mm) and cun gauge (a Chinese unit of length, 600mm). The cun gauge tracks ceased operations in 1990, so Kunming Railway Bureau becomes the unique one with standard gauge and meter tracks in operation at the same time. The operating station layout of freight transport in Kunming Railway Bureau is as shown in Figure 1.

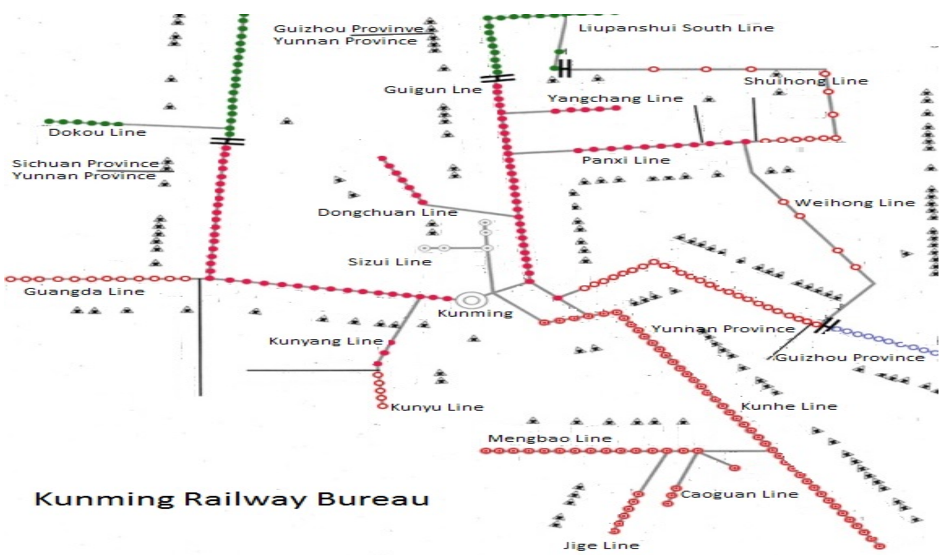

Figure 1. Sketch map of operating stations of freight transport in KRB

With the development of Yunnan Province and its association with surrounding countries, as well as Southeast Asia and South Asia becoming more open, the regional geographic environment and the location of environmental economy of Yunnan are unique and significant. The problem of insufficient for the external obsolete equipment still in use, exist to varying degrees. In the scope of management, there are various kinds of goods, the conditions for loading and unloading them are different, and the workload varies considerably. For some kind of goods there may be several kinds of machines suitable for handling operation, various configuration schemes of handling machines may be adopted. Thus it would be necessary to compare and select various possible types and quantity schemes of handling machines in conjunction with the freight transport practices of Kunming Railway Bureau, especially with the requirements to promote logistics center construction and the ratio targets of mechanization and equipment integrity, so as to determine the optimal configuration scheme of handling machines for the freight transport of Kunming Railway Bureau.

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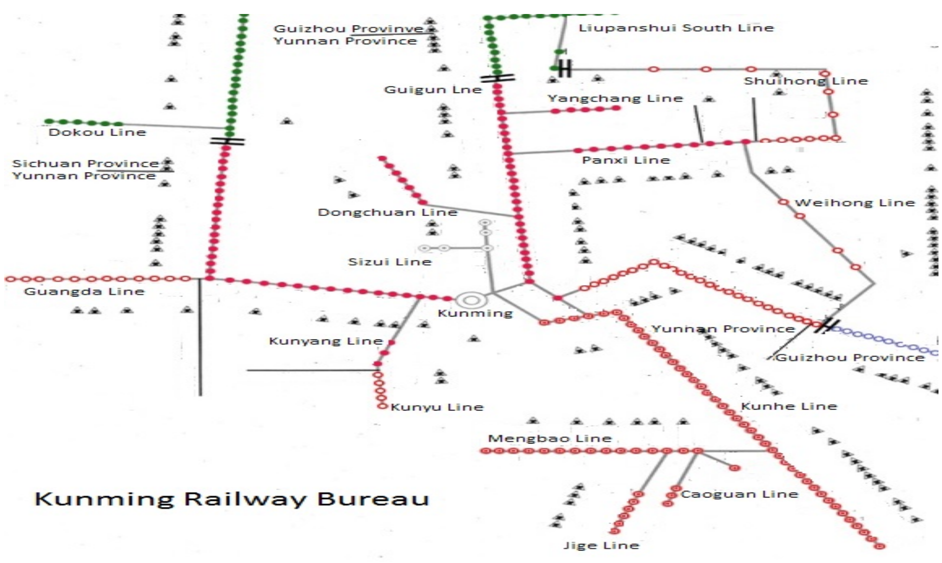

Figure 1. Sketch map of operating stations of freight transport in KRB

With the development of Yunnan Province and its association with surrounding countries, as well as Southeast Asia and South Asia becoming more open, the regional geographic environment and the location of environmental economy of Yunnan are unique and significant. The problem of insufficient for the external passage, especially international railway passage becomes more serious. The transport volume trends of major goods in KRB are represented as Figure 2 (Kunming Railway Bureau and Southwest Jiaotong University, 2014).

At present, there exist some problems in the configuration or allocation of handling machines for the freight transport in KRB as the following:

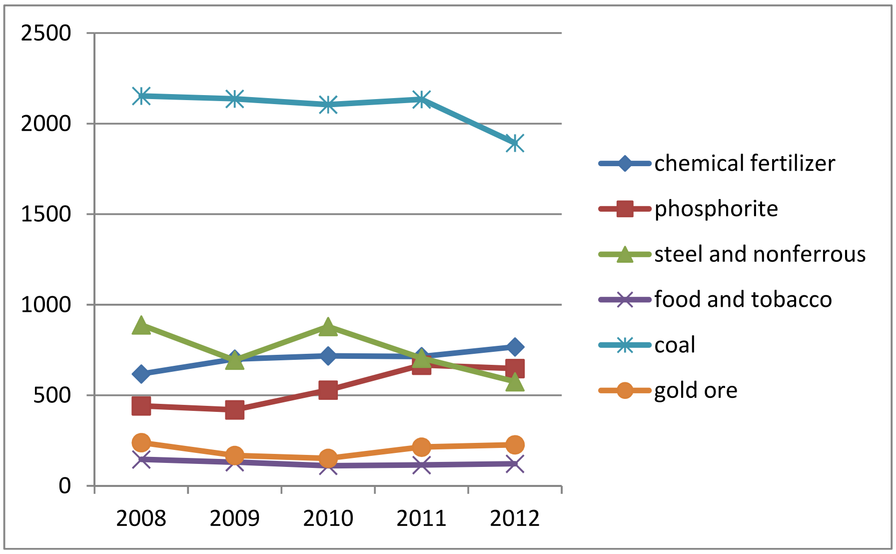

Figure 2. Transport volume trends of major goods in KRB

(1) The equipments are in overtime service, the degree of aging becomes more and more and the performance has been degrading. For example, the 20T gantry in Qujing Station has been in service since 1988.

(2) Because of the repeated installation of handling resources in some areas it is difficult for the scale effect to come true, such as Baita Village station and nearby small stations.

(3) The equipment quantity is insufficient, the loading and unloading are carried out fundamentally by manual labor in some public freight yards, such as Yuanmou station.

(4) Special equipments and universal ones are mixed use, the configuration or allocation of handling machines does not adapted to goods category and yard capacity.

(5) In the model selection there is either blindly novelty seeking, or yield to the temptation of low prices. So scientific criteria are absent and model selection is improper.

3 Model selection method of handling machinery

Aimed at the freight handling practices in KRB, the “Three Phase Method” for the choice of handling machinery types in KRB as the following:

Phase 1——Preliminary Filtering

The basic principles in this stage are：

(1) Based on the characteristics of freight category.

(2) Adapting to the operation property of railway freight yard.

(3) Considering time requirements.

(4) The equipments selected have smooth functioning and work cooperatively.

(5) Various rigging could be adopted to extend the operation scope for a kind of handling machinery.

(6) Standardization, energy conservation and environment protection.

Phase 2——Property Matching

By means of analyzing respective characteristics of handling equipments and tasks (e.g. works of train loading and unloading area, horizontal transport and goods stacking area respectively.), the matching among the handling equipment, goods and conditions can be achieved to determine reasonable handling equipment.

Phase 3——Comprehensive Comparing and Selecting

Through the above two phases the model selection of handling machinery have mainly finished for the great majority of railway freight yards. For some loading and unloading equipments whose operation characteristics are similar and each performance has its own merits, the choice is difficult, so it is necessary to make further comparison and selection in consideration of technical performance, utilization of yard and handling cost so as to make a explicit and scientific decision.

4 Quantity optimization of handling machinery

As the loading and unloading operations in railway yards requires multiple machines working cooperatively, the problem of handling equipment allocation ratio emerges.

4.1 Ratio control

Select 3 kinds of loading and unloading machine commonly used in container center stations as the research object: rail-mounted gantry cranes, front-handling mobile cranes (reach stacker, positive hanging) and container trucks. And suppose the following hypotheses:

(1) The rail-mounted gantry cranes and reach stackers work in uniform motion.

(2) The waiting time cost is ignored.

One-third containers in the trains are transported to auxiliary container yards, so there must be some intervals for the container trucks to reach the handling tracks. The rail-mounted gantry cranes, reach stacker and container trucks work cooperatively to accomplish the handling and transporting tasks of the containers. That is

$$\frac{NT_G}{Z_G} = \frac{N_J T_J}{Z_J} = \frac{N_Z T_Z}{Z_Z} \tag{1}$$

where N, N_J and N_Z is the handling volume of container trains (TEU), transporting volume of trucks (TEU) and handling volume of reach stackers (TEU) respectively, Z_G, Z_J and Z_Z is the quantity of rail-mounted gantry cranes, container trucks and reach stackers respectively, T_G, T_J and T_Z is the average cycle working time of rail-mounted gantry cranes, container trucks and reach stackers respectively.

This model objective is to minimize the waiting and spare time in the process of loading and unloading in which the containers are loaded or unloaded to/from trains and transported from/to the origins/destinations, that is, the quantity ratio among the rail-mounted gantry cranes, container trucks and reach stackers is to be optimized.

4.2 Reasonable amount determination

Relative researches indicate that there is a certain relationship among the handling machinery amount, attendance number and serviceability rate in a railway freight yard. Suppose there is a freight station equipped with *n* handling machines whose serviceability rate is α. When *m* handling machines are required to be on duty, they must be selected from *n* ones, and each choice has two results: in good condition or not. So the number on duty, express as *x*, is binomial distribution (Chen Chuanshi and Li Deyuan, 1988) on *n* and α, which can be written as

$$P\{x = m\} = C_n^m \alpha^m (1-\alpha)^{n-m} \qquad (m = 0,1,2,...,n;\ \ 0 < \alpha < 1) \tag{2}$$

Then let $P_k (0 < k \le n)$ stand for the attendance rate of guarantee that means the probability of *k* machines can be selected at least from *n* ones. Thus there is

$$P_k = \sum_{m=k}^{n} P_n(m) = \sum_{m=k}^{n} C_n^m \alpha^m (1-\alpha)^{n-m} \qquad (k = 0,1,2,...,n) \tag{3}$$

And the mathematical expectation of the rate (A_k) can be obtained by multiplying the number on duty and the attendance rate of guarantee of handling machines, that is,

$$A_k = k \cdot P_k = k \sum_{m=k}^{n} C_n^m \alpha^m (1-\alpha)^{n-m} \tag{4}$$

In response to different *k*, there will be a series of P_k and A_k, the most A_k of which corresponds to the optimum number on duty k^*. In this way there will also be a series of n, α and k^* corresponding each other, which can be transformed into a table. Given α and k^* the reasonable amount of handling machines in possession n can be looked up in the table.

5 Application of Kunming Railway East Station

Kunming Railway East Station (KRES) equips with various types of loading and unloading machines, the problem of reasonable amount determination is discussed in the case of forklifts in the public freight yard of KRES as follows.

There are 40 forklifts distributed in the south, east and west public yards. Their serviceability rate is 95%. According to statistical data, the numbers of forklifts on duty and its frequency in the public yard of Kunming Railway East Station are listed in Table 1 and their cumulative frequency distribution is shown as Figure 3.

Table 1. Numbers of forklifts on duty and its frequency

Number on duty	Occurrence number	Frequency
12	8	0.022
25	16	0.044
28	25	0.069
29	30	0.082
30	38	0.104
32	52	0.142
33	69	0.189
34	78	0.214
35	43	0.118
36	4	0.011
38	2	0.005

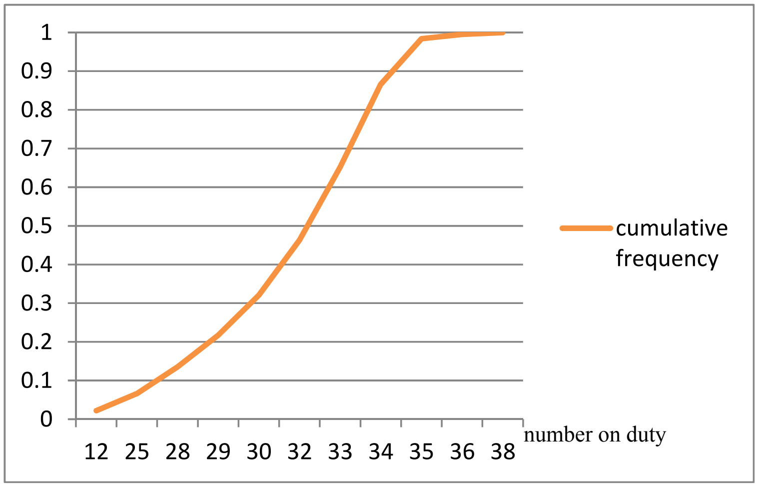

Figure 3. Cumulative frequency distribution of the forklifts on duty

By assigning different values, n and α vary in a certain range. The k^* varying accordingly may be obtained based on the above models with the help of MATLAB compiling and computing. Then a set of n, α and k^* corresponding each other are transformed into the Table 2 as below. The k^* in it stands for practical number of forklifts on duty to ensure normal production, thus n stands for the reasonable number of forklifts in possession.

6 Conclusions

In short, the selection of handling equipment cannot justly distinguish good and bad, but should be combined with practical operational needs, thus the main operation mode and optimal quantity can be determined according to different regions. Finally developing vision problems, along with the changes in the loading and unloading conditions, selected machinery will also change.

Table 2. Query table of reasonable number of forklifts in possession

α / n / k^*	95%	90%	85%	80%
20	17	16	15	14
26	23	21	19	18
30	26	24	23	22
36	32	29	27	25
40	35	33	30	28

46	41	38	35	32
50	44	41	38	35
55	49	45	42	39
60	53	50	46	43

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References

Chen Chuanshi, Li Deyuan. (1988). *Modern equipment management,* China Communication Press, Beijing.

Kunming Railway Bureau (KRB), Southwest Jiaotong University (SWJTU). (2014). *Modern logistics center construction oriented allocation optimization of freight handling machines,* Kunming, Yunnan Province.

Strength Analysis of Mounting Brackets and Connecting Bolts on an EMU Inner End Door

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Abstract: The strength of the key parts and associated coupling bolts on the high-speed car body, which have direct related to the safe operation, is an important content of vehicle design. Nonlinear static strength analysis of mounting bracket on EMU inner end door was calculated on 8 working conditions with ANSYS software and very part was assessed. Then, sliding coefficients of hanging bracket on the most dangerous condition were analyzed. Results show that contact surface sliding coefficients were less than 1, the hanging bracket is safe and is not prone to sliding. Finally the influence of the sliding coefficient and bolt strength based on different preload was studied. With the preload becoming increasingly, the sliding coefficient became smaller and the bolt stress became larger. Taking the both influence into consideration, a proper range of the preload meeting the design requirements was obtained to provide some technology reference on the structural design and selection of bolts for engineers.

Keywords: Bolt; Contact nonlinear; Strength; Sliding coefficient.

1 Introduction

In order to meet the strength requirements, confirm weakness and provide reference for improvement and determine of the connecting parts on high-speed train, detailed strength analysis is needed. The bolt coupling has been widely used among the key components of high-speed train. Compared to other connections, bolts are easily assembled and repaired. This connection type can increase the preload to prevent loosening and cannot cause a phase change of material component. At present, there are two main calculation methods about bolts strength at home and abroad. One is the traditional theoretical calculation which is generally based on the "Mechanical Design Handbook" or few based on "VDI 2230", the other one is FEA. Taking the mounting bracket on EMU inner end door as object, the 3D model and contact relationship were built with ANSYS software to conduct contact nonlinear strength analysis and sliding coefficients calculation. Under different preload conditions, bolt stress regulation and hanger sliding coefficients change were studied to provide a strong technical support for similar structure design in the EMU.

2 Contact nonlinear finite element method

Overall, the solution method of contact problem can be divided into two categories, one is finite element method, the other is mathematical programming method. Contact force and deformation meet boundary condition through the iterations and the introduction of the penalty function and Lagrange multiplier method etc. In this paper, Lagrange multiplier method is used. Taking the smooth contact for example, the satisfied constraint conditions are:

$$\begin{cases} g_n = U_n - U'_n - \delta^0{}_n \ge 0 \\ (U_n - U'_n - \delta^0{}_n)P_n = 0 \\ P_n \le 0 \end{cases} \tag{1}$$

U_n、U'_n、$\delta^0{}_n$ are respectively for the normal displacement, initial spacing at any contact point on the boundary objects Ω and Ω'. P_n is the normal force.

The common finite element formula is below.

$$[K]\{U\} = \{F\} \tag{2}$$

The equation can be obtained by the energy functional variation.

For example, the potential energy functional of a deformable body can be expressed as:

$$\Pi_p = \frac{1}{2}\{U\}^T[K]\{U\} - \{U\}^T\{F\} \tag{3}$$

According to the principle of minimum potential energy, for the displacement of deformable body satisfying the boundary conditions, the potential energy Π_p is minimum and satisfies the stress boundary conditions. That is:

$$\delta\Pi_p = 0 \tag{4}$$

The functional is written as with Lagrange multiplier method:

$$\Pi_L = \Pi_p + \{\lambda\}^T\{g_n\} \tag{5}$$

$\{\lambda\}$ is the introduced multiplier. The formula (4) can be rewritten as:

$$\delta\Pi_L = 0 \tag{6}$$

In which displacement $\{U\}$ and Lagrange multiplier $\{\lambda\}$ are unknowns. Π_p is the quadratic term of displacement $\{U\}$. After formula (6) variation, the elements of main diagonal corresponding $\{U\}$ are not zero and corresponding the multipliers $\{\lambda\}$ are zero in the total stiffness matrix which cannot be solved due to singularity. For this reason, a perturbation Lagrange multiplier method is created. The formula (6) through $\varepsilon > 0$ introduction is written as:

$$\Pi_c = \Pi_p + \{\lambda\}^T \{g_n\} - \frac{1}{2\varepsilon}\{\lambda\}^T \{\lambda\} \tag{7}$$

Compared with Π_L, Π_c has a quadratic term $\{\lambda\}$. The main diagonal elements are no longer zero corresponding to $\{\lambda\}$ and the total stiffness matrix is no longer singular matrix. When $\varepsilon \to \infty$, the formula (7) is reduced to the equation (6).

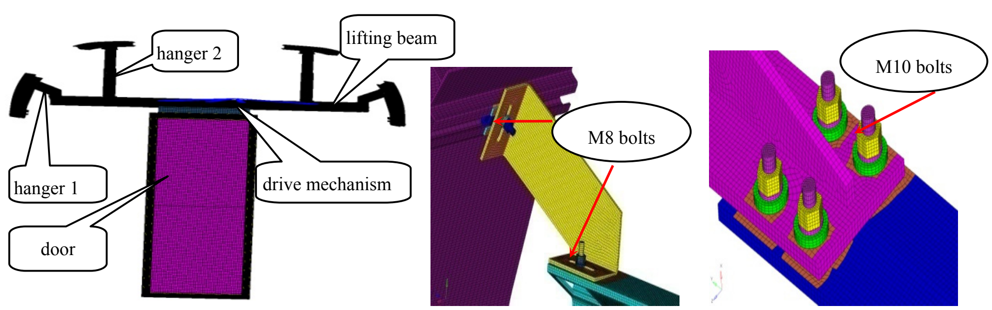
3 The finite element model

3.1 Geometry

The mounting bracket structure was comprised of hanger, lifting beam, bolts, door and drive mechanism etc (as shown in Fig. 1). Hanger 1 was connected with the roof and lifting beam by two M8 bolts respectively. Hanger 2 was connected with itself by eight M10 bolts, with roof by four M10, and with lifting beam by eight M8 bolts. Inner end door weight was about 60 kg and drive mechanism weight was 20 kg.

3.2 Finite Element Model

The finite model was meshed with hexahedral elements (solid 185) and driving mechanism was meshed with mass element (mass 21). According to contact location, the relationships of all parts between bolt, bolt gasket, hanger and lifting beam were defined and there were 104 contact pairs in total. The whole finite element model was 670,664 elements and 922,426 nodes.



(a) overall view (b) local view 1 (c) local view 2

Fig 1. Finite element model

3.3 Calculation Conditions

(1) Preload calculation

There were two types of bolts M10 (tightening torque 36 N•M) and M8 (tightening torque 12 N•M) in the model. The preload was calculated with Eq. 8 in "Mechanical Design Handbook" .

$$F = T/(0.2d) \tag{8}$$

Where d was the bolt diameter, T was tightening torque, F was the preload. According Eq. 8, the preload of M10 bolt was 18000 N and M8 bolt was 7500 N.

(2) The loading cases

According to EN12663-2010 standard, the acceleration values of the device and its components were shown in Table 1.

Table 1. Load case

Case	Longitudinal	Lateral	Vertical	Case	Longitudinal	Lateral	Vertical
1	3*g	1*g	(1 + c) *g	5	3*g	1*g	(1 - c) *g
2	3*g	-1*g	(1 + c) *g	6	3*g	-1*g	(1 - c) *g
3	-3*g	1*g	(1 + c) *g	7	-3*g	1*g	(1 - c) *g
4	-3*g	-1*g	(1 + c) * g	8	-3*g	-1*g	(1 - c) *g

Note: C was 2 depending on the position of the inner end door.

(3) Displacement constraints

Roof and side wall profiles on both sides were full restraints, x = 0, y = 0, z = 0.

4 Nonlinear static strength calculation results

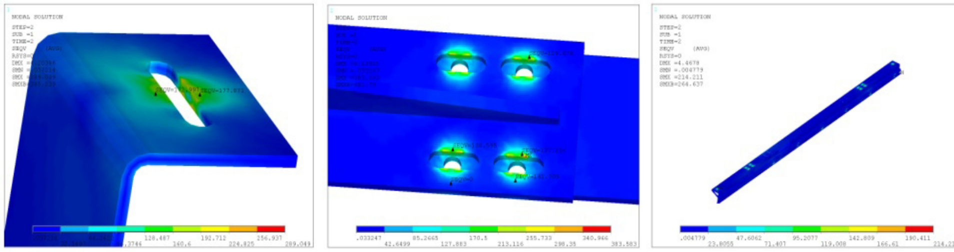
4.1 Component strength calculation

After contact nonlinear finite element analysis, the maximum static strength results of the components under 8 working conditions were shown in Table 2 and stress cloud were shown in Fig. 2.

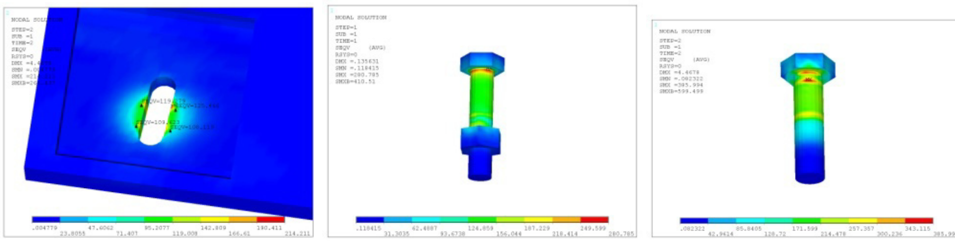
Table 2. Strength results

Unit: MPa

Parts	Case	Maximum stress	Yield stress
Hanger 1	7	178	205
Hanger 2	1	142	215
Lifting Beam	4	126	145
M8 Bolt	preload	281	450
M10 Bolt	3	386	450



(a) local hanger 1 (b) local hanger 2 (c) lifting beam



(a) local lifting beam (b) M8 bolt (c) M10 bolt

Fig 2. Stress results

Table 2 and Fig.2 showed that hangers, lifting beam and bolts were satisfied with the strength requirements.

4.2 Hanger sliding coefficients

(1) Calculation Method

If two objects under the external force only have sliding tendency and no the relative sliding (as shown in Fig. 3), the force between contact surface preventing their relative sliding is called static friction force. There is a maximum value changed with external force. The maximum static friction force is calculated as:

$$f_{\max} = N \times \mu \tag{9}$$

Where μ is the friction coefficient, N is the maximum positive pressure.

If a object relative to another object has relative movement tendency, the static friction force increases with external force, but not infinitely increases and when external force increases to exceed the maximum static friction force, object can move. With the principle mentioned above the sliding contact surfaces are analyzed.

(2) Sliding coefficients analysis process

Reading the ANSYS calculation results;

a) Finding a contact pair;

b) Extracting pressure and friction force between the contact surface on current case;

c) According to the ratio of contact friction force and maximum static friction force(sliding coefficient), judge contact surface sliding conditions. If the ratio is 1, the object may be slid.

(3) The calculation result

Fig. 4 showed the number and location of the contact surface of hanger 2. The sliding coefficients on the most dangerous condition (case 3) were given in Table 3.

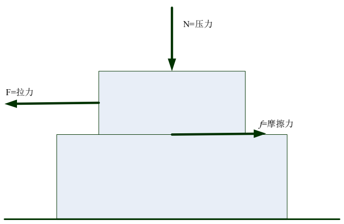


Fig 3. Friction force sketch

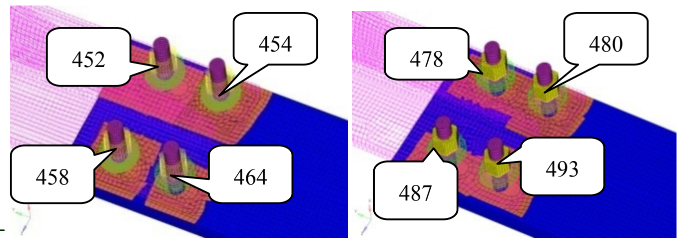


Fig 4. Contact surfaces number sketch

Table 3. Sliding result data

Element number	Pressure N (N)	Maximum static friction force (F_{max} =N*0.15) (N)	Contact friction force f (N)	Sliding coefficient (f/F_{max})
452	15756.0	2363.4	434.5	0.184
454	16552.3	2482.8	324.4	0.131
458	16881.2	2532.2	693.2	0.274
464	18016.7	2702.5	817.4	0.302
478	16451.0	2467.6	314.1	0.127
480	15753.1	2363.0	437.6	0.185
487	16935.3	2540.3	689.8	0.272
493	18303.8	2745.6	959.1	0.349

Note: friction coefficient μ is 0.15.

From Table 3, in the most dangerous condition, the sliding coefficients of the contact surface around the hanger bolt were relatively small, less than 1, indicating that the hanger 2 was not prone to slid.

5. Preload influence on sliding coefficient and bolt strength

5.1 Preload influence on sliding coefficient

With the change of M10 bolt preload, hanger sliding coefficient changed gradually. Taking the contact surface NO493 for example, relationship between the preload and the sliding coefficient was shown in Table 4.

Table 4 . Sliding coefficient variation

Preload F (N)	Sliding coefficient	Preload F (N)	Sliding coefficient
10000	0.705	16000	0.399
11000	0.623	17000	0.361
12000	0.579	18000	0.349
13000	0.539	19000	0.303
14000	0.49	20000	0.282
15000	0.442	21000	0.265

As shown in table 4, with the increase of the preload, the hanger sliding coefficient decreased. When the coefficient was 1, the hanger would be slid. If the sliding coefficient was considered only, preload could be selected in the range of 10000 ~ 21000N.

5.2 Preload influence on bolt strength

With the change of M10 bolt preload, bolt stress changed gradually. The relationship between the bolt preload and bolt stress was shown in Table 5.

Table 5. Bolt stress variation

Preload F (N)	Bolt stress σ_s （Mpa）	Safety factor	Preload F (N)	Bolt stress σ_s（Mpa）	Safety factor
10000	222	2.03	16000	354	1.27
11000	244	1.84	17000	376	1.20
12000	266	1.69	18000	386	1.17
13000	288	1.56	19000	420	1.07
14000	310	1.45	20000	442	1.02
15000	332	1.36	21000	464	0.97

As shown in table 4, with the increase of the preload, bolts stress increased gradually. When preload increased to 20000 N, bolt stress reached to 442 MPa closely to its yield strength 450 MPa. If continue to increase preload, bolt stress could be larger than 450 MPa. Taking bolt safety factor (1.2-1.5) on static load into consideration, bolt preload should be selected in the range of 13167 N~17000 N.

6. Conclusions

1) The analysis showed that the static strength of hangers, lifting beam, bolts and other parts of mounting bracket meet the design requirements in working condition and hanger 2 would not prone to slide;

2) The preload had a critical impact on bolt strength and sliding coefficient. With the preload increased, the sliding coefficient decreased and bolt stress increased. When the preload exceeded 20000 N, bolt stress would exceed its yield strength.

3) If the sliding coefficient was less than 1, considering common bolt safety factor (1.2-1.5) under working conditions, the corresponding bolt preload selection should be in the range 13167 N~17000 N. In this range, bolt safety and reliability could be guaranteed and they provide a good reference for engineers on bolt preload selection.

References

CHEN, Z. (2011). "Strength Analysis of Bolt Joint on Wind Turbine Tower Flange Based on VDI2230." *Modern Manufacturing Engineering,* (5):125-129

CHENG, D.X. (2007). Mechanical Design Handbook Beijing

FU, D. L., and MA, M. L. (2012). "Research on the Analysis Method for Strength of Bolts." *Rolling Stock*, 50(1):19-20

GAO, Y, (2013). "Strength Analysis of Suspended Structure Under Intercity EMUs" *Dalian Jiaotong University*, 34(5):12-15

Glowwinski. R. (1986). "Augmented Lagrange Techniques for Solving Frictionless Contact Problems in Finite Elasticity." *Finite Element Method for Nonlinear Problems Europe-US Symposium, Trondheim*, Norway,:745-757

PENG, H. (2014). "Finite Element Analysis of Bolted Connection of Hydro-generator Shaft." *Mechanical & Electrical Engineering*, 31(2): 170-172

Stein, E. (1986). "Finite Element Post-bucking Analysis of Shells with Nonlinear Contact Constraints." *Finite Element Method for Nonlinear Problems Europe-US Symposium, Trondheim*, Norway,:719-744

WO, X.L. (2011). "FEM Based Strength Verification of High Duty Bolts in MW Class Wind Turbine." *Power & Energy*, 32(3):228-231

Xin, J. (2012). "Strength Research on the Carbody and Fastener of High-speed Test Train." *Beijing Jiaotong University*

XU, Z.Y. (2013). "Analysis on Application of Connecting Bolts in Slewing Bearings." *Bearing*, (5):11-13

Subjective and Objective Evaluation of High-Speed EMU Interior Sound Quality Preference and Correlation Analysis

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Abstract: Taking a high-speed EMU as the research object, the noise samples of vehicle at different speeds are collected, the subjective evaluation experiments of sound quality preference are conducted using paired comparison method. After calculation and analysis of the main psychoacoustic parameters of each sample, it can be found that the sound quality preference in EMU decreases with the increasing of speed. SPSS are used to analysis the multivariate linear relationship of preference and objective parameters in EMU. It can be found that the relationship between preference and objective parameters are linear negatively. The preference has obvious strong linear relationship with loudness and sharpness, which show that sound quality in EMU is closely related to loudness and sharpness. The mathematical fitting model between subjective assessment of preference and objective parameters is established by calculating loudness and sharpness. Then through the comparative analysis of the sound quality preference curve from evaluation model and experiment, the evaluation results of the overall sample has strong consistency with the evaluation results of the traditional method of paired comparison. It can be used to predict and calculate the interior sound quality of EMU.
Keywords: High-speed EMU; Sound quality preference; Subjective and objective evaluation; Correlation.

1 Introduction

Foreign researchers found that the interior sound quality of EMU comes from the evaluator's general auditory properties, which is depended on the relevant features of EMU. The preference reflects the occupants' auditory perception to sound, which could be used to describe the preference degree of occupants to sound. Domestic researchers have done a lot of work on how to select the psychoacoustic parameters that is in line with Chinese people's characteristics (Sahin, 2008), and how to obtain a more accurate subjective sensation of the evaluators. According to analysis of evaluation results, the evaluation model is built to measure sound quality preference objectively, which is important to analyze, control and evaluate the interior noise of EMU.

Subjective evaluation of sound quality involves many fields, such as the experimental preparation before work, experimental method and experimental data processing and analysis of inspection, etc. German HEAD Acoustics noise and vibration measurement and analysis system, including the SQLab II multi channel data acquisition recorder and HMS III binaural information collector and Artemis measurement analysis software is used to collected sound samples in this experiment. Acquisition of the sound samples are play backed in laboratory and objectively analyzed, excluding samples from outside interference or unstable operating conditions of the sample, the original signal sampling to select the length truncation and loudness equalization processing, and 12 effective noise samples is obtained, the length is 5 seconds, the subjective evaluation was performed using the paired comparison method. The words selected to describe sound quality are all preference, and according to calculation of main psychological acoustical objective parameters of the noise sample and analysis of the relationship between the subjective evaluation and objective parameters, the prediction model of the interior sound quality of EMU is proposed based on the theory of regression analysis (Zhao Linfeng, 2012).

2 Subjective evaluation experiments and analysis

2.1 Experimental design of paired comparison

2.1.1 Evaluation body

Reference to foreign experience to form the jury and the actual situation of this study, in this paper, the experimental evaluation of a total of 20 selected officers are college students with normal hearing, aged 21 years to 28 years old, mean age 24 years, of which 10 were boys and girls 10, in good health and no hearing impairment, 18 people ride over EMU (Zhang Xiaojuan, 2013).

2.1.2 Experimental Design and Process

The subjective evaluation was chosen in a semi-anechoic room, shown in Figure 1, the room temperature is about 21°C, humidity between 30% to 45%, well ventilated no smell, hearing guaranteed environment. On the basis of the evaluation does not affect the validity of the experiment, in order to reduce the workload, the single-byte matrix is used, 12 sound samples through permutations and combinations, pairwise comparison, a total of 84 pairs. Each sound sample is about 5 seconds, the interval between two sound samples is 2 seconds, then the evaluation time of each pair is about 12 seconds, the time required to complete the evaluation of a group is about 18 minutes, which can fit the foreign evaluation experience of sound quality.

Figure 1. Subjective evaluation experiment in semi-anechoic room

2.2 Data processing and inspection

According to statistical knowledge, the subjective evaluation data can not be directly used as the final result of the analysis parameters, experimental data error may occur due to the influence of subjective and objective factors. In order to ensure the authenticity and reliability of the statistical results obtained, the error and reliability must be tested, and the invalid data should be eliminated. In this paper, the data inspection method of Professor Mao Dongxing of Tongji University is used to eliminate error and ensure the validity of data (Mao Dongxing, 2005).

In order to determine whether the data are reliable, the paper adopts the method of weighted error rate of the proposed by Kendall to carry out the reliability(Kendall MG,1940). Through calculation, the weighted consistency coefficient of evaluation are calculated as shown in Table 1. From table 1, it can be simply find that except tp01 is 85.50%, tp09 is 87.90%, the weighted consistency coefficient of remaining 18 evaluators are more than 90%, and the average weighted consistency coefficient is 96.1%, which indicates that the entire evaluation of experimental data has a higher reliability.

Table 1. Weighting consistency coefficient

Evaluator	Tp1	Tp2	Tp3	Tp4	Tp5	Tp6	Tp7	Tp8	Tp9	Tp10
weighting consistency coefficient	0.855	0.974	0.978	0.905	0.946	0.968	0.975	0.974	0.879	0.953
Evaluator	Tp11	Tp12	Tp13	Tp14	Tp15	Tp16	Tp17	Tp18	Tp19	Tp20
weighting consistency coefficient	0.995	0.952	0.903	0.917	0.971	0.964	0.989	0.944	0.966	0.967

2.3 Calculation and analysis of the preference value

According to the result of weighted consistency, the evaluation data evaluation personnel of Tp1 and Tp9 should be eliminated for its low reliability. Excluding the two reviewers' misjudged data, the average number of remaining with one voice all the evaluators to sample a sound preference scores that samples are selected evaluators all valid, the value calculated by Matlab is the final preference value, which is shown in Table 2. The greater the preference value, the better the sound sample sounds.

Table 2. preference level and parameters values

	Preference	linear	A Weighting	loudness	sharpness	roughness	fluctuation
S1	4.80	106.6	68.7	26.5	1.38	2.17	0.0828
S2	3.90	108.3	70.6	28.7	1.47	2.19	0.0709
S3	3.10	105.5	69.4	27.9	1.41	2.16	0.0864
S4	3.70	104.7	69.6	27.1	1.42	2.13	0.0546
S5	0.80	109.6	71.9	32.2	1.65	2.51	0.0728
S6	1.40	107.1	73.1	35.8	1.58	2.55	0.0661
S7	7.90	104.5	64.2	17.7	1.17	1.07	0.0796
S8	8.90	104.8	63.1	18.1	1.26	1.16	0.1005
S9	7.80	104.3	64.7	20.3	1.29	1.48	0.0817
S10	8.20	106.2	64.6	20.4	1.28	1.44	0.0842
S11	7.10	106.7	65.3	21.6	1.34	1.69	0.0537
S12	8.20	106.9	66.2	22.8	1.36	1.67	0.0501

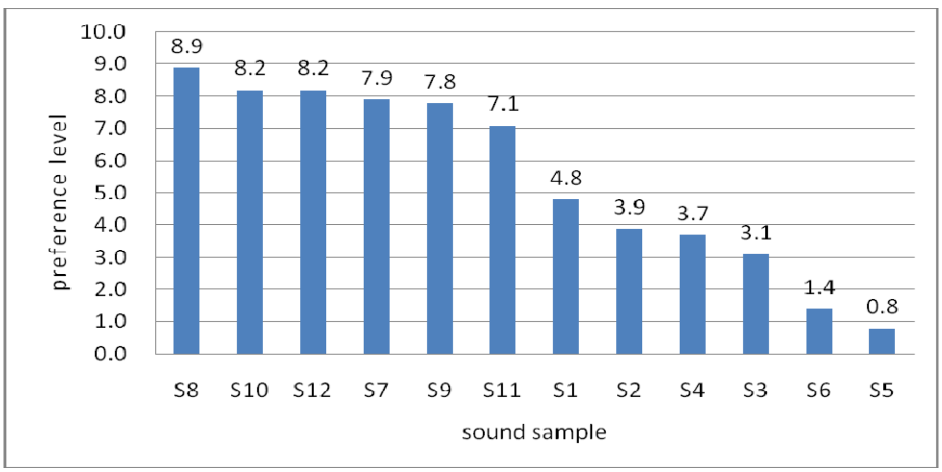

Figure 2. preference level of the sample

It can be seen from Figure 2, the sound preference value of sample 8 is the highest, and it is generally believed that the subjective feeling of sample 8 is the best. In contrast, the sound preference value of sample 5 is the smallest, and its loudness and sharpness are the largest, which shows that the vast majority of evaluators' evaluations to sample 5 are poor.

2.4 The correlation analysis of subjective evaluation and objective of sound

2.4.1 Correlation between subjective and objective

The main purpose of correlation analysis is to research the relationship among these variables. The correlation coefficient r is the main parameter to indicate the relationship among variables, which is in the range [-1,1]. The absolute value of the correlation coefficient r is closer to 1, the relationship among variables is more closely; the absolute value of the correlation coefficient r is closer to 0, the relationship among variables is more estrange (Blauert J, 1997).

Pearson correlation coefficient is used to measure whether the two daters in a line. The formula is:

$$r = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - (\sum x_i)^2}\sqrt{n\sum y_i^2 - (\sum y_i)^2}} \quad (1)$$

Pearson correlation coefficients can be obtained from software SPSS19, as shown in Table. It can be seen from Table 3, the relationship between preference and objective parameters of the sound samples is highly negative, the higher the value of each parameter, the worse the preference value. The correlation relationship between Loudness and A-weighted sound pressure level and preference is high, which is more than 0.96, but the attenuation characteristic of A-weighted sound pressure level is low. So, if loudness is selected as a dependent variable of preference, the correlation coefficient of preference and loudness is 0.964, which is the strongest(Kang Runcheng,2011).

Table 3. Pearson correlation coefficient between preference level and objective parameters

	Preference	A Weighting	linear	loudness	sharpness	roughness	fluctuation
Preference	1	-.961**	-.578	-.964**	-.957**	-.943**	.192
A Weighting	-.961**	1	.606*	.988**	.927**	.955**	-.274
linear	-.578	.606*	1	.658*	.675*	.662*	-.251
loudness	-.964**	.988**	.658*	1	.948**	.976**	-.286
sharpness	-.957**	.927**	.675*	.948**	1	.968**	-.307
roughness	-.943**	.955**	.662*	.976**	.968**	1	-.345
fluctuation	.192	-.274	-.251	-.286	-.307	-.345	1

Note: "**" denotes when confidence coefficient (double side) is 0.01, the correlation is significant. "*" denotes when confidence coefficient (double side) is 0.05, the correlation is significant. "-" denotes negative correlation.

In order to reveal the correlation between subjective evaluation results of preference and psychoacoustic objective parameter obviously, Scatter plot was used to analyze the correlation between subjective and objective evaluation, which can be used to determine the relationship between subjective preference and psychoacoustic parameters , as shown in Figure 3-4.

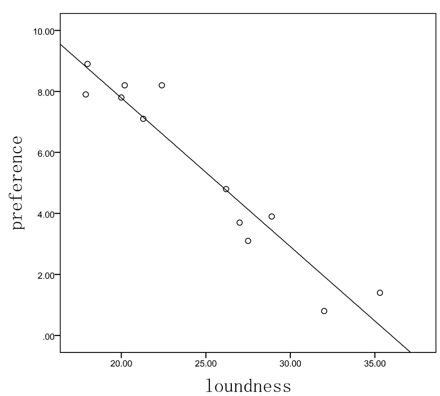

Figure 3.Relationship between preference level and loundness

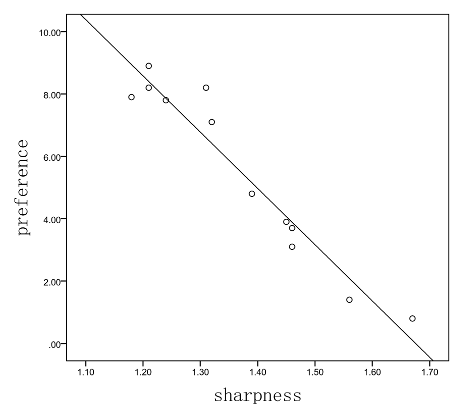

Figure 4. Relationship between preference level and sharpness

From Figure 3-4, it can be found that the relationship between preference and objective parameters are linear negatively, the preference has obvious strong linear relationship with loudness and sharpness, colinearity index is more than 0.91, which shows that sound quality in EMU is closely related to loudness and sharpness.

2.4.2 Multiple linear regression analysis of preference and objective parameters

The statistical analysis software SPSS19 is used for multivariate linear regression analysis (Jiao Fenglei, 2004), the results are shown in Table 4.

Table 4. Multiple linear regression coefficient Table

model	Non standardized coefficient		standardized coefficient	t	Sig.
	B	standard error	Beta		
(constant)	25.523	3.41	-	7.379	0.000
loudness	-0.212	0.119	-0.405	-1.665	0.133
sharpness	-10.700	4.528	-0.586	-2.401	0.042

As can be seen from Table 4, the final variable into the regression equation is loudness and sharpness, and the corresponding regression coefficients are -0.212 and -10.700, from which the mathematical fitting model of sound quality subjective evaluation preference and objective parameters can be obtained as follows:

$$SQ=25.523-0.212L_d-10.7S_p \quad (2)$$

In the formula, SQ is the sound quality preference of EMU, L_d is the loudness and Sp is sharpness (Hempel T, 1990).

Equation (2) shows that the sound quality preference can be described objectively by loudness and sharpness, therefore, in order to improve the sound quality preference in EMU, loudness and sharpness should be controlled seriously. In addition, the absolute values of standardized coefficient of loudness and sharpness are 0.405 and 0.586, which shows that sharpness has slightly larger influence than loudness to sound quality preference in EMU under the conditions of the experiment.

2.4.3 Data **Verification**

A total of 12 sound samples are used, the sound quality preference obtained by subjective evaluation and the sound quality preference obtained by model are compared, the results are shown in table 5:

Table 5. Model calculation value compared with the subjective evaluation value

Sample No.	**1**	**2**	**3**	**4**	**5**	**6**
Subjective evaluation value	4.80	3.90	3.10	3.70	0.80	1.40
Model calculated value	5.01	3.78	3.37	4.06	0.78	1.35
Relative Error	4.3%	3.1%	8.7%	9.7%	2.5%	3.6%
Sample No.	**7**	**8**	**9**	**10**	**11**	**12**
Subjective evaluation value	7.90	8.90	7.80	8.20	7.10	8.20
Model calculated value	8.25	8.66	7.92	8.19	6.82	8.07
Relative Error	4.4%	2.4%	1.5%	0.1%	3.9%	1.6%

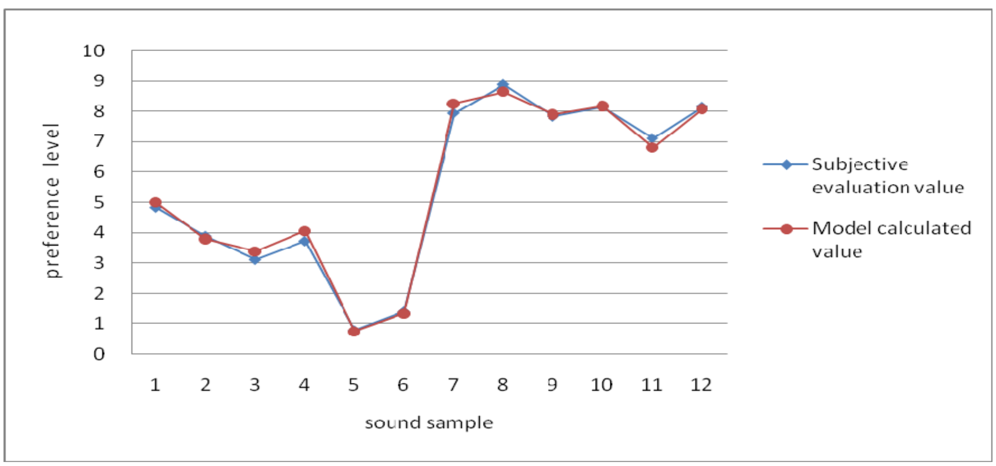

Figure 5. Model calculation value compared with the subjective evaluation value

Compared the two results get from the model and the subjective evaluation, the difference between them is small, the dispersion of error is small, and the error is mainly in the range of 10%. The calculated values and evaluation values are almost the same, such as sample 5, 6, 8 etc, which shows that evaluation model has high accuracy and it can be used to predict sound quality.

3 Conclusions

(1) The paired comparison method is used to conduct subjective evaluation experiments, and it can be obtained that the sound quality preference in EMU has inverse proportion to speed. When the speed is 370 km/h, the preference value in ordinary compartment is of 0.8 (minimum), and when the speed is 330 km/h, the preference value in ordinary compartment is of 8.9 (maximum).

(2) The paired comparison method is used to analyze the correlation of subjective and objective, and it can be concluded that sound quality preference has a high negative correlation with A-weighted sound pressure level and loudness, and its Pearson correlation coefficients are -0.961 and -0.964.

(3) By analyzing the calculated fitting result of the model between sound quality preferences and objective parameters and subjective evaluation value curve analysis,, the curves are basically the same, this shows that the evaluation model has high accuracy and can be used to predict the sound quality, which is important to analyze and control the interior noise of EMU.

References:

Blauert J, Jekosch U. (1997). Sound quality evaluation-a multi-layered problem, Acta Acustica, 83(3): 747-753.

Hempel T, Chouard N. (1990). Evaluation of interior car sound with a new specific semantic differential design. J AcoustSo-cAm,105(2): 1280-1285.

Jiao Fenglei, Liu Ke, Mao Dongxing. (2004). Using a multidimensional scale analysis the quality of noise subjective evaluation. Acoustic Technology, (23): 95-96.

Kang Runcheng, Ye Changjing, Li Qinglin. (2011). Study on the Objective and Subjective Evaluation of Vehicle Sound Quality. Automotive Science and Technology, (5): 57-61.

Kendall MG, Smith B B. (1940). On the method of paires comparisons. Biometrika, 31(3/4): 324-345.

Mao Dongxing, Yu Wumin, Wang Zuomin. (2005). Statistical validation and criterion for paired comparison data in sound quality evaluation. ACTA ACUSTICA, 30(5) 468-472.

Sahin Yildirim, Ikbal Eski. (2008). Sound quality analysis of cars using hybrid neural network. Simulation Modeling Practice and Theory, (16): 410-418.

Yuan Jixuan, Zhou Shiqiong, Song Zhumei. (2012). An Improved Semantic Differential Method and Its Application to Sound Quality Evaluation. Journal of Shenzhen Institute of Information Technology, (3): 84-86.

Zhang Xiaojuan, Liu Yan. (2013).Research on Sound Quality Subjective Evaluation of Certain Domestic Automobile Interior. JOURNAL OF SICHUAN ORDNANCE, (6):140-145.

Zhao Linfeng. (2012). Study and Application of Subjective Evaluation of Vehicle Sound Quality. Tsinghua University.

Analysis for the Harmonics of an Air-Gap Magnetic Field in Asynchronous Magnetic Coupling

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Abstract: Harmonics of Air-gap Magnetic Field has great influence on the working performance of Asynchronous Magnetic Coupling (AMC). Without properly handled, a great deal of vibration and noise problems would happen. Therefore, these harmonics should be analyzed in-depth. Based on the Laplacian/Poissonian equation, the analytical model of Air-gap Magnetic Field was obtained by the boundary condition about permanent magnets and air-gaps. And the harmonics in Air-gap Magnetic Field is analyzed using the result of this model. Furthermore, a method that changing permanent magnetic rotor's pole-arc coefficient is proposed to weaken the influence exerted by harmonics on electromagnetic torque and cogging torque of AMC.
Keywords: Asynchronous Magnetic Coupling (AMC); Air-gap Magnetic field; Harmonics.

1 Introduction

Asynchronous Magnetic Coupling (AMC) has become a research focus for its compact dimension, low weight, environmental-friendly feature, excellent execution efficiency and precise adjustment of both output speed and output torque, etc. (Richard, 2002), (Wallace, 2000).

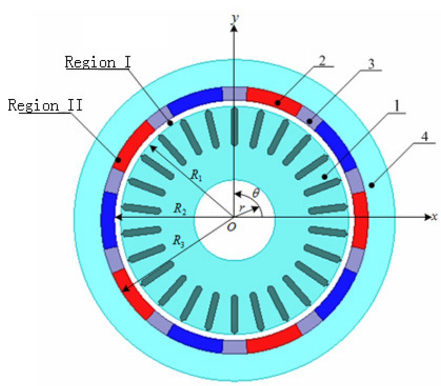
Harmonics in AMC has great influence on the value and ripple of electromagnetic torque, so the main purpose of studying harmonics is to analyze the electromagnetic torque and copping torque in-depth. By taking the derivative of magnetic energy, literature (Noboru, 2012) and (Wang, 2003) gave the mathematical relationship between copping torque and excitation system, which makes parametric analysis on copping torque of permanent magnetic gear and permanent magnet motor respectively. However, the models established in these two papers wasn't relate to air-gap magnetic flux density, so that it can't discover the fundamental cause of influences on the copping torque that are exerted by excitation system parameters.

Taking a scalar magnetic potential as variables, literature (Ge, 2012) used 2D Laplacian/Poissonian equation to derive a analytical model of air-gap magnetic field for a permanent magnet gear, which obtained the analytical result of the field by introducing Neumann boundary condition and was validated by 2D FEM. Taking a vector magnetic potential as variables, literature (Nie, 2012) combined magnetic field with magnetic circuit to put forward a 3-D analytical approach for the calculation of the field and torque of a magnetic gear. Taking into account the slotting effect and the armature reaction magnetic field, literature (Lubin, 2010) establish model based on the resolution of the two-dimensional Laplace's and Poisson's equations in polar coordinates. However, there are some disadvantages in literature (Ge, 2012) and (Nie, 2012). Firstly, the effect of yoke iron on the field is ignored when boundary conditions is set up in these three literatures. Secondly, in literature (Ge, 2012) and (Nie, 2012), pole-arc coefficient was equal to 1 during the analyzing of Permanent Magnet (PM) magnetization, which didn't take into account the effect of PMs' distribution.

In this paper, taking vector magnetic potential as variable, the relative mathematical model of magnetic field in AMC is set up. After solving the model, the analytical solution of harmonics in air-gap magnetic field is decomposed based on its specialty, which can help to analyzed the copping torque of AMC well. Based on these analyzing, changing the pole-arc coefficient, as an effective approach, is proposed to weaken the influence exerted by harmonics on electromagnetic torque of AMC.

2 Calculation of Air-Gap Magnetic Field

Fig. 1 shows the mechanical structure of AMC. The cage rotor and the permanent magnet rotor rotated around the common axis. And their radii are R_1, R_2 and R_3 respectively. θ is circumferential angle, and r is radial vector which starts from point O as shown in Figure 1. Region I is the air-gap between the cage rotor and the permanent magnet rotor. Region II is the annular area of PMs.



1 cage rotor 2 permanent magnet 3 non-magnetizer material 4 yoke iron

Figure 1. Mechanical structure of AMC

All the PMs in this paper are tile-shaped and magnetized radially.

Supposed M is magnetization intensity, M_r is its radial component. As the orientation of M is radial well-distributed, the circumferential component of M is zero, and the M_r can be written as:

$$\mathbf{M}_r(\theta) = \pm M(\theta)\mathbf{r} \qquad (1)$$

In (1), $M(\theta)$ is the constant of PMs, and it can be expressed as $M(\theta) = \frac{B_r}{\mu_0}$,where B_r is remanence and μ_0 is permeability in vacuum.

While the segments of PMs in the permanent magnet rotor are separated by non-magnetizer materials, the relationship between $M(\theta)$ and θ can be illustrated from Fig. 2. In Fig. 2, p is the number of pole pairs of permanent magnet rotor, α_p is pole-arc coefficient and T is the cycle length.

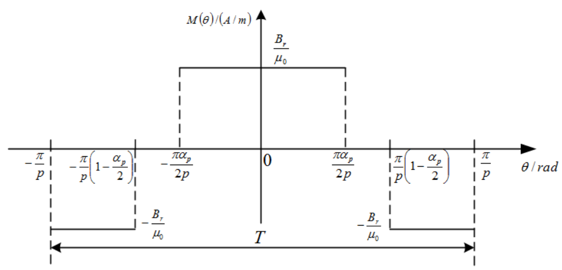


Figure 2. Relationship between $M(\theta)$ and θ

In the light of Fourier expansion method, we get that

$$M(\theta)=\sum_{n=1}^{\infty}\left(\frac{4B_r}{n\pi\mu_0}\sin\left(\frac{\pi n\alpha_p}{2}\right)\cos(np\theta)\right)=\sum_{n=1}^{\infty}M_n\cos(np\theta) \qquad (2)$$

In (2), M_n is the Fourier coefficient, $n=1,2...$

Supposed A_K ($K=1,2$) whose direction are along Z axis is the vector magnetic potential in region I and region II, and its corresponding magnetic flux density is B. B_{Kr}, $B_{K\theta}$ （$K=1,2$）are radial and tangential components of B respectively. Based on the definition of vector magnetic potential and Laplacian/Poissonian equation, B_{Kr} and $B_{K\theta}$ can be calculated as follows

$$B_{Kr}=\frac{1}{r}\frac{\partial A_K}{\partial\theta},\quad B_{K\theta}=-\frac{\partial A_K}{\partial r} \quad (3) \qquad A_1=\sum_{n=1}^{\infty}(A_{n1}r^{np}+B_{n1}r^{-np})\sin(np\theta) \quad (4)$$

$$A_2=\sum_{n=1}^{\infty}(A_{n2}r^{np}+B_{n2}r^{-np})\sin(np\theta)+\sum_{n=1}^{\infty}\frac{np\mu_0M_n}{(np)^2-1}r\sin(np\theta) \qquad (5)$$

where ∇^2 is the Laplace operator, A_{n1}, A_{n2}, B_{n1} and B_{n2} are undetermined coefficients of general solutions in (4) and (5).

Supposed permeability of the yoke in Fig. 1 is infinite. According to the continuous boundary condition in magnetic field and equations (4) to (5),The matrix among A_{n1}, A_{n2}, B_{n1} and B_{n2} can be gained:

$$\begin{bmatrix} R_1^{np-1} & -R_1^{-np-1} & 0 & 0 \\ 0 & 0 & R_3^{np-1} & -R_3^{-np-1} \\ R_2^{np} & R_2^{-np} & -R_2^{np} & -R_2^{-np} \\ \mu_r R_2^{np-1} & -\mu_r R_2^{-np-1} & -R_2^{np-1} & R_2^{-np-1} \end{bmatrix}\begin{bmatrix} A_{n1} \\ B_{n1} \\ A_{n2} \\ B_{n2} \end{bmatrix}=\begin{bmatrix} 0 \\ -\frac{\mu_0 M_n}{(np)^2-1} \\ \frac{np\mu_0 M_n R_2}{(np)^2-1} \\ \frac{\mu_0 M_n}{(np)^2-1} \end{bmatrix} \qquad (6)$$

In (6), μ_r is the relative permeability of PMs. From equation (6), we can get A_{n1} and B_{n1}, A_1 can be obtained by substituting A_{n1}, B_{n1} into (4). Then substituting A_1 into (3), it yields $B_{1r}(r,\theta)$ and $B_{1\theta}(r,\theta)$ respectively as follows:

$$B_{1r}(r,\theta)=\sum_{n=1}^{\infty} np\left(A_{n1}r^{np-1}+B_{n1}r^{-np-1}\right)\cos(np\theta) \quad (7)$$

$$B_{1\theta}(r,\theta)=-\sum_{n=1}^{\infty} np\left(A_{n1}r^{np-1}-B_{n1}r^{-np-1}\right)\sin(np\theta) \quad (8)$$

2 Analyzation for Harmonic of Magnetic Field

In order to analysis the harmonics of air-gap magnetic flux density, Matlab is employed to calculate and draw its distribution.

Fig. 3 and Fig. 4 show radial and tangential component of air-gap magnetic flux density at r respectively when all PMs are magnetized along radial orientation.

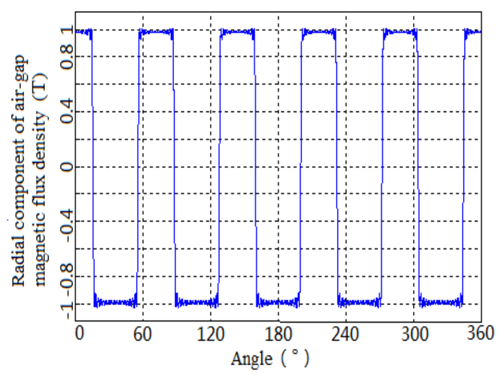


Figure 3. Curve of the radial component magnetic field in Air-gap

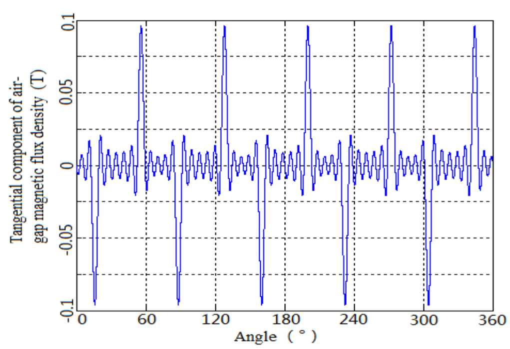


Figure 4. Curve of the tangential of component of magnetic field in Air-gap

As can be seen from fig. 3, the curve of radial component of air-gap magnetic flux density is similar to rectangular wave. It is because that remanence along radial direction are equal everywhere due to the assumption that the magnetizing intensity is evenly distributed. From Fig. 4, tangential component of air-gap magnetic flux density is approximately zero. The reason is that the distribution of air-gap magnetic flux density in the excitation structure shown in Fig. 1 is mainly along the normal direction while the tangential component is insignificant. Overall, the magnetic field in AMC is mainly formed by the radial component, while tangential component can be ignored. So all the following air-gap magnetic field refer to radial-magnetic field.

Equation (7), replacing n with different consecutive integers, can be expressed as curves in figure 5 by employing Matlab.

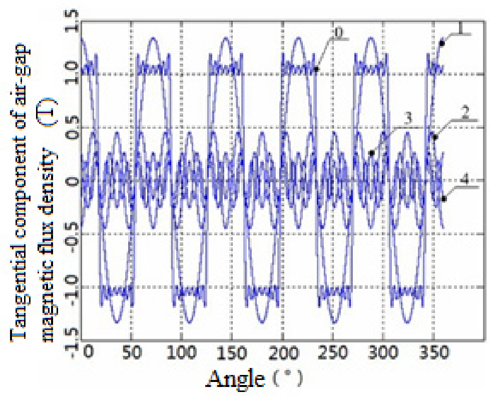
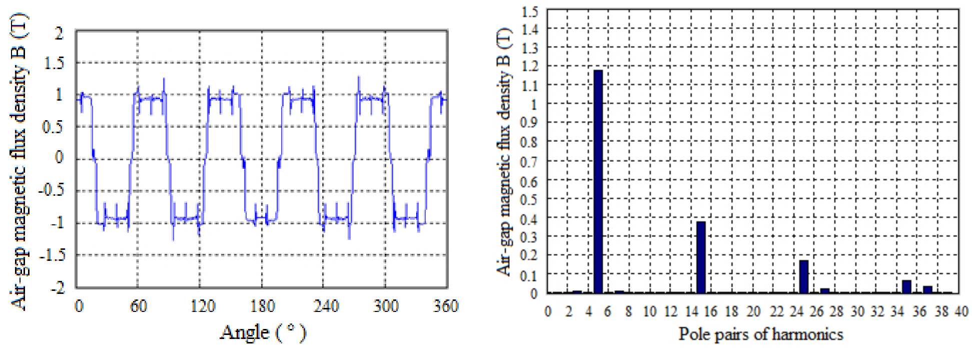


Figure 5. The curve of harmonic distribution of magnetic field in Air-gap

From fig. 5, the waveform of magnetic field in fig. 3 consists of a series of odd sine waves. Among these waves, whose pole pairs and value of amplitude are similar to the ideal sine wave is called fundamental wave, others are harmonics. In fig. 5, number 0 marks actual wave (rectangular wave); number 1 is fundamental wave and its p is 5; while number 2, 3, and 4 mark third, fifth and seventh harmonics and their p are 15, 25 and 35 respectively.

The curves in fig. 6, drawn by FEM software, consist of the main waveform and harmonics of the air-gap magnetic flux density. From fig. 6(a), we find that the air-gap magnetic field density, produced by five PMs in AMC, was constituted by five wave crests and troughs. This curve is in good agreement with that of fig. 3. From fig. 6(b), we find: $p = 5$ refer to fundamental wave, $p = 15$, 25 and 37 refer to third, fifth and seventh harmonics respectively. The curves shown by figure 6 are in good agreement with that of figure 5. Therefore, the analytical model in this paper is correct.



(a) Air-gap magnetic flux density waveform （b） Air-gap magnetic flux harmonic wave

Figure 6. Harmonic analysis of air gap flux density of AMC

3 Magnetic Harmonics Influence on Torque

From fig. 5, we find: the pole pairs p of fundamental wave is 5, while $p=15$, $p=25$ and $p=35$ are corresponding to 3rd, 5th and 7th harmonics respectively. When rotate speed of magnetic field is n_1, the rotate speed of fundamental wave is n_1 due to its pole pair is equal to that of the synthetic magnetic wave. Taking example for 3rd harmonic whose $p=15$ and rotate speed is $\frac{1}{3}n_1$. When the 3rd harmonic rotate more slowly than the inner rotor, the relative inductive current of 3rd harmonic in squirrel-cage bars moves inversely to fundamental wave. As a result, a slight decrease of the electromagnetic torque will happen. Similarly, the electromagnetic torque rise slightly when the rotate speed of 3rd harmonic is faster than that of inner rotor. Both the rise and decrease trends, increasing the copping torque, magnify the ripple of both electromagnetic torque and rotate speed due to the different cycles between fundamental wave and harmonics.

The above phenomenon also applies to other harmonics. Therefore, the magnetic flux density of harmonics should be minimized as far as possible during the design process of excitation system of AMC.

From (7), we find: values of harmonics change with different α_p and δ. Therefore, the effects of α_p and δ should be taken into consideration when design the excitation system.

Curves of harmonics magnetic flux density changing with α_p is shown in fig. 7. In these curves, each one does not experience the linear variation with the increase of α_p. The red curve demonstrates minimum sums of all the harmonics with corresponding α_p.

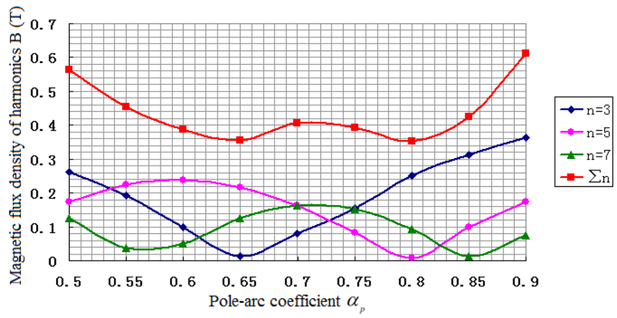


Figure 7. Curves of harmonics magnetic flux density changing with α_p

Literature (Richard Killen, 2002) put forward a method to identify the harmonic that has the most impact on the copping torque.

$$N = \left[\frac{nZ}{2P}\right]_{\min} \tag{9}$$

In (9), n is harmonic order; Z is the number of rotor slots.

In table (1), $p=5$, $Z=32$, the most impact on copping torque is exerted by 5th harmonic. Overall, taking both the value of electromagnetic torque and the degree of torque ripple into account, the pole-arc coefficient should be 0.8.

Fig. 8 shows the ripple of electromagnetic torque when the pole-arc coefficient is 0.8. In fig. 8, the electromagnetic torque ripple remain basically stable (the ripple is 1% approximately).

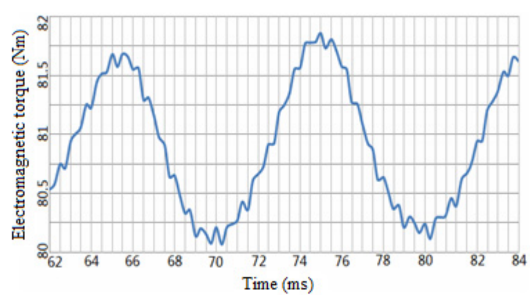


Figure 8.Electromagnetic torque ripple

4 Conclusions

(1) The PMs that are radially magnetized in AMC distributes mainly along the radial direction. The waveform of air-gap magnetic flux density is similar to the rectangular wave, and the radial component of magnetic is made up of fundamental wave and harmonics mainly.

(2) A series of odd harmonics in air-gap magnetic flux density have great influence on the value and ripple of electromagnetic torque in AMC. Different pole-arc coefficients influencing these odd harmonic can be chosen to minimize the electromagnetic torque ripple. Namely, the chosen pole-arc coefficient should not only ensure the sum of all the harmonics to be the minimum but make the value of

nth harmonic as small as possible.

Acknowledgement

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Reference

Ge Y. j., Xin Q., and Nie C. Y. (2012). "Research on the relationship of the field modulated permanent magnetic gear structural parameters and its torque," *Chinese Journal of Mechanical Engineering*, vol. 48, no. 11, Jun. 2012, pp. 153-158.

Ge Y. J., Nie C. Y., Xin Q. (2012). A three dimensional analytical of the air-gap magnetic field and torque of coaxial magnetic gears. *Progress In Electromagnetics Research*. 2012, 131: 391-407.

Lubin T., Mezani S., Rezzoug A. (2010). Improved analytical model for surface-mounted PM motors considering slotting effects and armature reaction. *Progress In Electromagnetics Research B*, 2010, 25: 293-314.

Noboru Niguchi and Katsuhiro Hirata. (2012). Cogging Torque Analysis of Magnetic Gear. *IEEE Trans. On Industrial Electronics*, 2012, 59(5): 2189-2197.

Richard Killen, Maple Valley (2002). Adjustable Magnetic Coupler: *United States*, 0132671 A1. 2002-09-19

Wang X. H.，Yang Y. B.，Fu D. J．(2003). Study of Cogging Torque in Surface-Mounted Permanent Magnet Motors with Energy Method．*Journal of Magnetism and Magnetic Material*，2003，267(11):80-85.

Wallace A.，Jouanne A. V, Ramme A. (2000). A Permanent Magnet Coupling With Rapid Disconnect Capability . *IET Electric Motors and Drives.* 2000, 82(01): 058 -064.

Zhu Z，Howe D．(1993). Instantaneous magnetic field distribution in brushless permanent magnet DC motors, III: Effect of stator slotting．*IEEE Transactions on Magnetics*，1993, 29(1): 143-151．

Fine Modelling and Strength Analysis of Metro Car Body Structures

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Abstract: Fine modelling is realized on the metro car body. The total element number of the car body model is more than 200 million, and the model is highly similar to the prototype of the car body. The loads are applied according to the EN12663, and 15 load cases are applied to this model. Calculation results showed that car strength is satisfied the design demands. Compression and tension cases are the most serious in all load cases. In all load cases, stress major focused on the corners of the doors and windows, and designers should pay more attentions on these places. Some nodal stress data are extracted from test results. The test data are used to verify the simulation results.

Keywords: Fine modeling; Strength analysis; Metro car body; Test verification.

1. Introduction

Metro car possesses many advantages, such as safety, quick speed, environment protection, energy saving, save space and so on. Currently, the world is seeking to develop metro to address the growing problem of traffic, environment and energy issues. In our country, there are more than 20 cities have opened or opening metro transport services.

Rapid development of the metro is based on safety. As the main body of the conveyance, car body's security is the most important consideration. Some papers have discussed the related questions, such as the effects of materials (Cheng, 2006; Kezhong, 2003), research on the simulation methods (Gong, 2011; Xiong, 2006), and the simulations from different car types (Wang, 2001; Feng, 2010) and so on. But mostly previous results are based on a simplified model. It maybe misses some details. In this paper, based on a B-type metro car body, a fine finite element model is built. The fine finite element model is highly similar to the prototype. Metro car body's strength is calculated. The simulation results are verified by experimental results, and the simulation data match the experimental data very well.

2. Fine finite element model of the car body

The main bearing structure of the car body is made of aluminum alloy materials. The length of the metro car body is 19000 mm, the fixed distance is 2600 mm, the body width is 2800 mm, and the body height is 3470 mm. Some other technical parameters are listed in Tab. 1 and Tab. 2

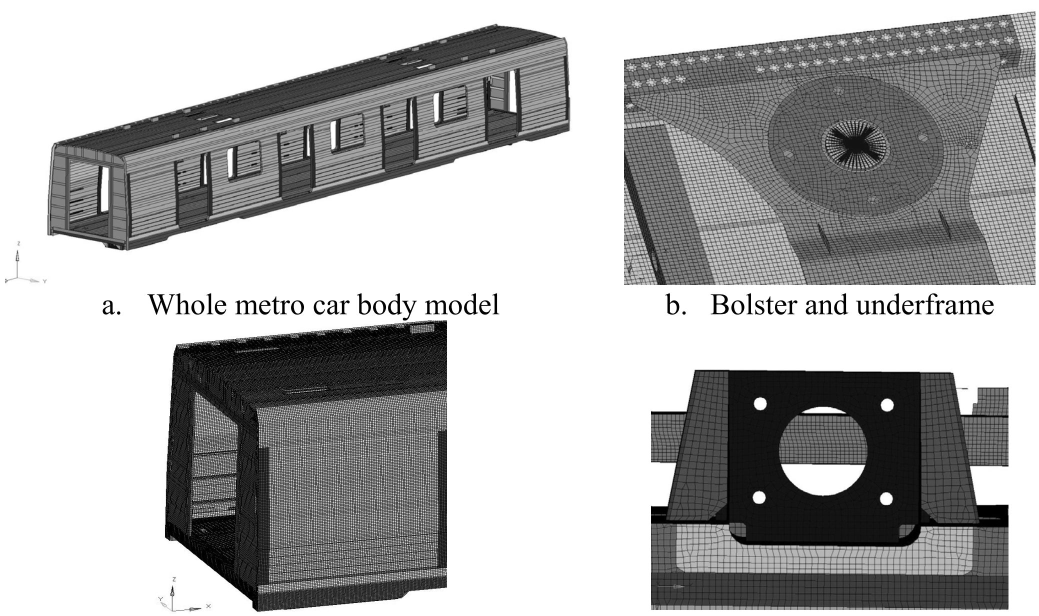
Tab. 1 Car body's mass parameters

No.	Items	Mass (t)
1	Kerb mass (exclude bogies)	21.0
2	One bogie	7.0
3	Bearing structure	7.9
4	Overload	20.6

Tab. 2 Some material properties

Aluminum Material	Thickness (mm)	Young's Modulus (MPa)	Passion Ratio	Density (t/m^3)	Yield limit (MPa)	
					Base	Weld
6005A	t≤5	69	0.33	2.7	225	115
	5<t≤10				215	115
6082	t≤6				260	125
	6<t≤12.5				255	125
Q690D/E	--	206	0.3	7.82	690	627.3

This fine finite element model is built based on the large-scale commercial processing software HyperMesh and finite element analysis software ANSYS. The model is highly approximated to the metro car body. Four-node thin shell element is the mainly element type for the simulation accuracy. Total number of the element is 2344614, and the node number is 1928048. Fig. 1 is the finite element model mesh.



a. Whole metro car body model b. Bolster and underframe

c. End wall d. Coupler-set structure

Fig. 1 Finite element model

According to the EN12663 standard and task documents, 15 load cases, including AW0, AW3, compression and tension on coupler-set, compression and tension on the end wall, support on 3 points etc., are calculated in this fine model.

3. Calculation results

Analyze the results of 15 load cases, the compression and tension on coupler-set are the most serious cases. The loads on these two cases are: vertical load on the car body 408 kN, longitudinal compression force on coupler-set 800 kN, longitudinal tension force on coupler-set 640 kN. Fig. 2 shows constraints and loads of the two serious cases. Fig. 3 shows some stress concentration points of compression and tension cases. The maximum stress is located at coupler-set. Bolster, corners of door and windows are also the dangerous places. Car body strength is satisfied demands in other load cases.

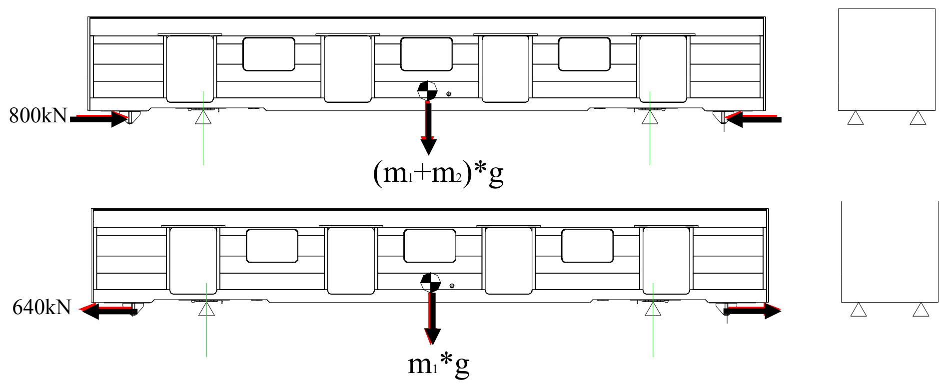
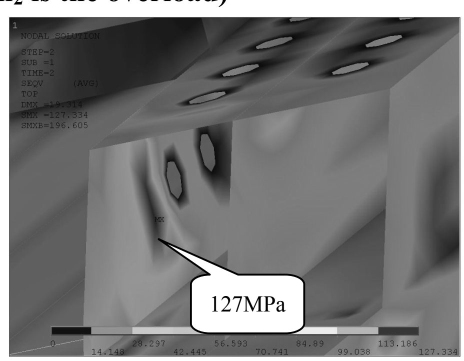
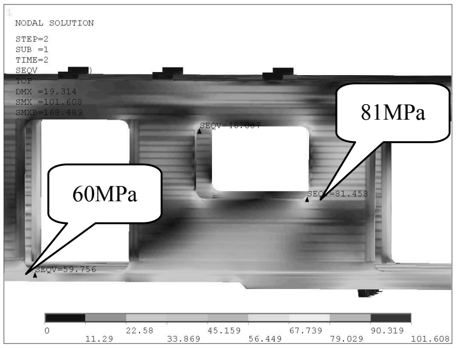


Fig. 2 Compression and tension cases
(m_1 is kerb-mass and m_2 is the overload)

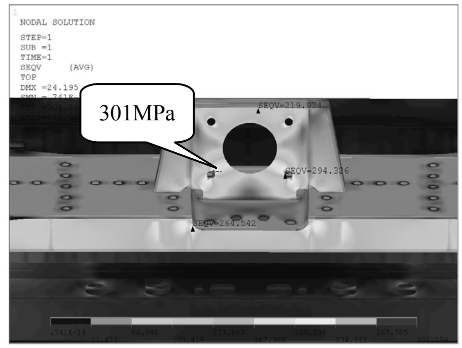
a. Stress on coupler-set (Compression)



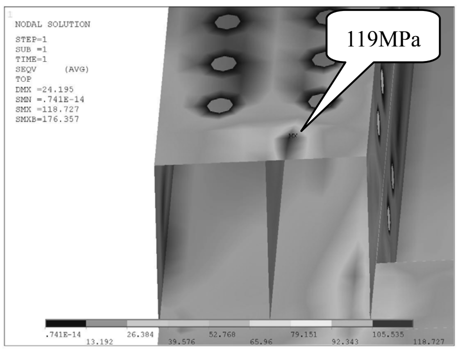
b. Stress on bolster (Compression)



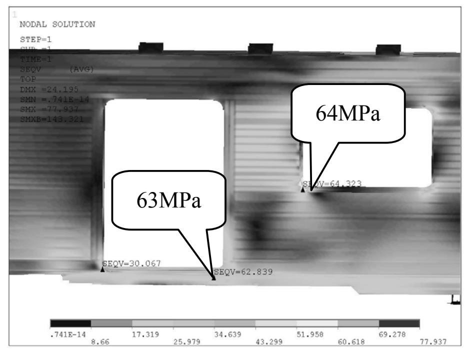
c. Stress on corners (Compression)



d. Stress on coupler-set (Tension)



e. Stress on bolster (Tension)



f. Stresses on corners (Tension)

Fig. 3 Stress cloud picture from some calculation results

4. Test verification

To verify the simulation's accuracy of the fine finite element model, a sample metro car is loaded by the 15 load cases, and some stress data are extracted to be compared with simulation results. Verification results show that the fine finite element model can get a more accurate results. The simulation results are similar to the test data. The error is less than 11%.

Tab. 3 Compression load case verifications (Stress unit: MPa)

No.	Test Stress	Calculation Stress	Error Ratio
D01	-160.0	-156.1	2.44%
D02	231.0	223.7	3.16%
D03	222.4	219.3	1.39%
D04	167.0	149.3	10.60%
D06	-100.1	-100.4	0.30%
D07	215.6	211.6	1.86%

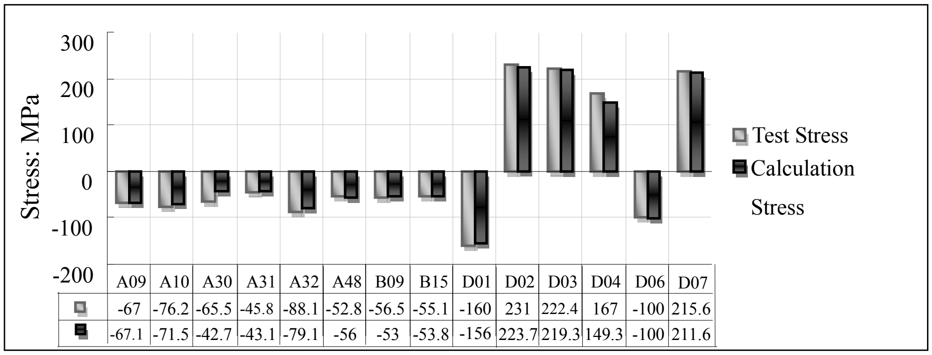


Fig. 4 Compression load case verification figure

Tab. 4 Tension load case verifications (Stress unit: MPa)

No.	Test Stress	Calculation Stress	Error Ratio
D02	187.9	195.2	3.89%
D03	178.7	180.0	0.73%
D05	-118.5	-113.4	4.30%
D06	93.5	90.2	3.53%
D07	170.7	167.8	1.70%
D17	91.4	95.8	4.81%

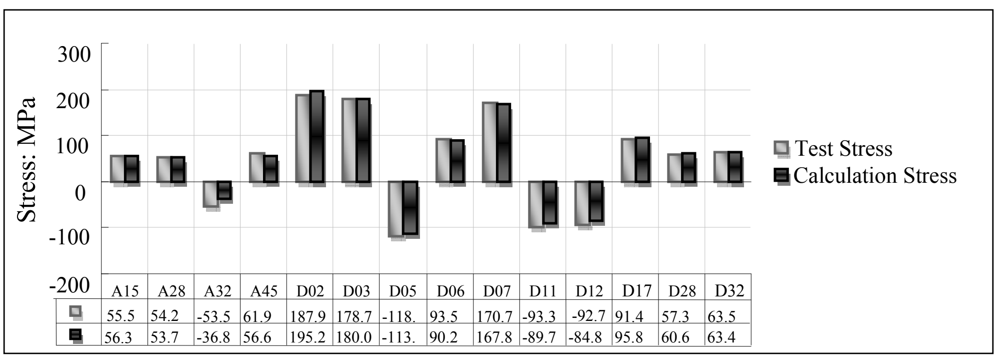


Fig. 5 Tension load case verification figure

5. Conclusions

A fine finite element model is built based on the HyperMesh and ANSYS in this paper. The model includes 15 load cases according the standard EN12663. The simulation results show the compression and tension load cases are the most serious load cases, and the maximum stress is 383MPa lies on coupler-set. Except coupler-set places, door corner, window corner etc. are also the stress concentration places. Compared to the simulation results to the test data, the most nodal stress error is under 11%. The fine modelling and analysis processing are benefit to promote the simulation accuracy. The experience can be used to guide related research work.

6. Acknowledgement

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Reference

Cheng Lei, and Shou ne X. (2006). "Structure Design and Strength Analysis of the Aluminum Alloy Car body for Metro Vehicle". *Electric Drive for Locomotives*, 24(1), 1-15.

Feng G, Yan yan Z, and Jian ning Y. (2010). "Static strength and mode simulation for the A-type aluminum alloy car body structure of metro vehicle", *Advanced Technology of Design and Manufacture (ATDM 2010)*, 181-184.

Gong D, Sun W, and Zhou J. (2011). "Analysis on the Vertical Coupled Vibration between Bogies and Metro Car Body". *Procedia Engineering*, 16(1), 825–831.

Ke zhong X. (2003). "Selection of Car Body Materials for Urban Railway Vehicles". *Urban Mass Transit*, 18(4), 1-4.

Wang D, Li Q. (2001). "Study on Modal Analysis of Steel Structure of High-Speed Passenger Car Body". *Journal of Northern Jiaotong University*, 32(4), 20-23.

Xiong Z, Luo H. (2006). "Preprocessing technology of FEA based on HyperMesh software". *Drainage and Irrigation Machinery*, 24(3), 35-38.

Vibration Characteristic Analysis of Elevated Maglev Transportation

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Abstract: A field measurement of vibration was performed on the Shanghai Maglev Train Line in China. In the paper, according to the data measured, characteristics of vertical vibration attenuation of the elevated maglev transportation are analyzed. Variations of vertical acceleration level of ground vibration in relation with train speed are investigated. And the differences of vibration between elevated maglev transportation and elevated rail transit are compared. The results show that when the maglev vehicle speed is 150-250 km/h the vibration level away from centerline of 30 m attenuates under the limited value of environmental requirement. With the increasing distance from the track centerline, the difference of vertical acceleration level with different train speed is decreasing. Comparing with elevated rail transit, vertical vibration of elevated maglev transportation attenuates with distance more obviously.

Keywords: Elevated maglev line; Vibration characteristic; z-level vibration.

1 Introduction

Maglev trains, a new rapid transport system, have attracted more attention around the world because of their fast speed and low power consumption. However, vibration induced by the maglev train–guideway interaction may cause a serious environmental problem.

Vibration, as a new kind of city pollution, impacts on people's work and life in many aspects. The vibration frequency range in 1-80Hz is sensitive to the human body, and the feeling of different vibration direction is discrepant. In addition, the vibration affect the accuracy of precise instrument, machine tool and household appliances. Besides, vibration makes negative effects on buildings.

With the development of environmental requirement, the vibration along rail transit becomes a major concern. Many scholars have carried out a series of theoretical analysis and actual measurement to investigate the vibration caused by elevated maglev transportation and elevated rail transit. The effective frequency range of the vibration acceleration sensors used in the test is 0.25-80 Hz (Zhai,2015) .

The vertical vibration level reduces with increase in distance, and there is a rebound 15m away from the track centerline (Chen,2011). Ground vibration enhances about 10 dB as the vehicle speed increases from 125 km/h to 430 km/h (Zhao,2010). These studies have achieved many results and obtained a lot of meaningful conclusions. But these studies are lack of researches on the vibration attenuation of the elevated maglev line and the comparison of the vibration of elevated maglev transportation and rail transportation, which the paper focuses on.

The SMT employing Transrapid Maglev System Technology is the world's first high-speed maglev commercial commuting system. The 30 km elevated double-track project with prototype concrete guideway connects Shanghai Pudong International Airport (SPIA) and the Longyang Road Station. The test was conducted at the NO.499 Beam A Rail. Measuring points are arranged at top of the pier, and horizontal distance aground 0m, 5m, 15m, 22.5m, 30m. The accelerometer (DH103) used in the ground vibration test is produced by Donghua Testing Technology Co., LTD in Jiangsu province of China. The vibration signal acquisition instrument adopted is named DH5920.This test records the vertical acceleration signals of maglev train with the speeds of150km/h, 200km/h, 250km/h, and the background vertical acceleration signals. During the skylight time of Shanghai Maglev Transportation System, the test train ran at three different speeds on the A rail without the interference. The measuring points were installed at the steel stents, which were embedded about 30cm in concrete. The location of measuring points are shown in Fig. 1.

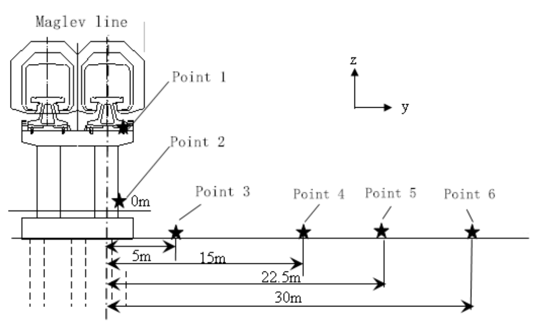

Figure1. Arrangement of measuring points

2 Vibration attenuation with distance

According to "Standard of environmental vibration in urban area"(GB10070-88) and "Measurement method of environmental vibration of urban area"(GB10071-88) we used vertical vibration level as fundamental measure. In addition, the definition of z-level vibration: ISO2631/1-1985 regulates that vibration makes the revision by weighed factor to get vibration level, denoted as VL_Z, in decibels (dB). The standard is applicable to the steady vibration, shock vibration and random vibration. For the occurrence of shock and vibration several times a day, the maximum does not allow to exceed the standard value of 10dB during the day and 3dB at night.

According to GB10070-88 and GB10071-88, from the weak vibration that human just feels (vibration acceleration is about $10^{-3}m/s^2$) to the strong vibration which the body cannot stand (vibration acceleration is about $10^3m/s^2$), vibration acceleration change up to a million times. It makes the measurement, the expression and the operation inconvenient. For the convenience, the national and international standards about vibration use the vibration level instead of vibration acceleration.

Vibration level is defined by the type 1

$$V_a L = 20\lg \frac{a}{a_0} \tag{1}$$

In the formula：

V_aL—vibration level（dB）

a —measured vibration acceleration (m/s^2)

a_o — referential vibration acceleration (m/s^2)

In order to simplify the measurement, we use a single value to represent the effect of vibration on man, which is called the frequency weighed vibration level (VLz). The frequency-weighted ground vibration makes the resonance phenomenon more prominent, because the frequency weighted method considers the perception of human body to ground vibration. According to the weighted method used in ISO2631-1-1997, the higher the center frequency is, the greater decline of the weighted vibration level in the corresponding 1/3 octave band is. Thus, the weighted vibration level depends on the vibration energy in the octave band and the corresponding center frequency. All of the signals at 1-80Hz frequency range are weighted to get the weighted vibration level. VL_Z is defined by the type 2.

$$VL_Z = 10\log \sum (V_a L_i + \alpha_i)/10 \tag{2}$$

In the formula：

VL_Z—weighted vibration level（dB）。

V_aL_i —measured vibration level of each band (m/s^2)

α_i — weighted factor of each band (m/s^2)

It can be seen in Fig.2 that at 250km/h, vibration level of the pier is 103dB, and attenuate to 77dB after transferring to the bottom of the pier. Transferring on the ground along the lateral direction it attenuates with distance: 1dB (5m), 5dB (15m), 9dB (22.5m), 11dB (30m), and at a distance 30m eventually attenuates to 66dB. The vibration produced by of maglev train attenuates very obvious. The vibration of maglev transportation can satisfy vibration requirement on the maglev line at 30m away except in vibration requirement of special residential areas (less than 65dB), which embodies the green character of maglev transportation.

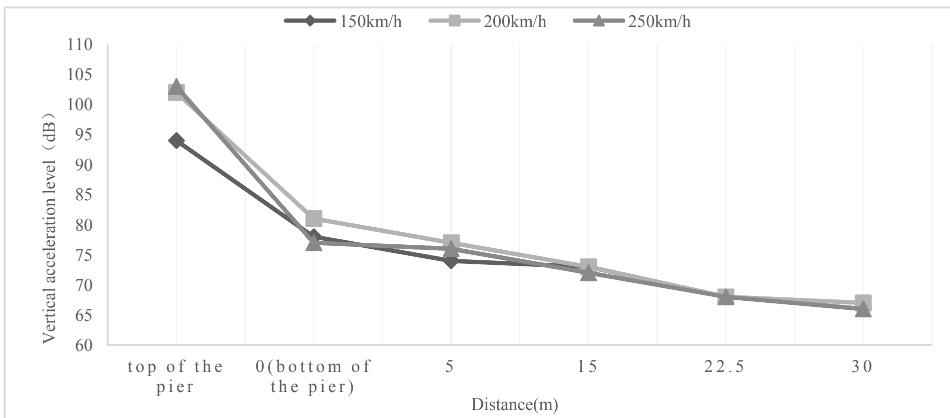

Figure2. The attenuation of z-level vibration 1/3 octave band (0~80Hz) with distance

3 Variation of vibration level with train speed

According to the test results, variation of vibration level with train speed is analyzed. Background vibration level is tested and calculated at the same location when no train passes by. In the Fig.3, when the maglev train passed at 150-250 km/h in the test section, the vibration level at the top of pier (measure point 1) was different obviously from the background vibration level. And away from centerline of 0-30m, when a train passes by, the vibration level is about 10 dB higher than the background vibration level. It shows that the maglev train passing by will have a clear incentive to the vibration of pier.

Difference between measuring point 1 and other measuring points increases with the the distance away from the centerline. By the curve in Fig.3 can be seen, at each measuring point, the variation of maglev train speed influences on the top of pier obviously. And the speed is higher, the attenuation is more obvious. Along with the increase of distance, vibration under different speeds gradually converges. Away from centerline of 15-30m, the vibration level changes little with the velocity.

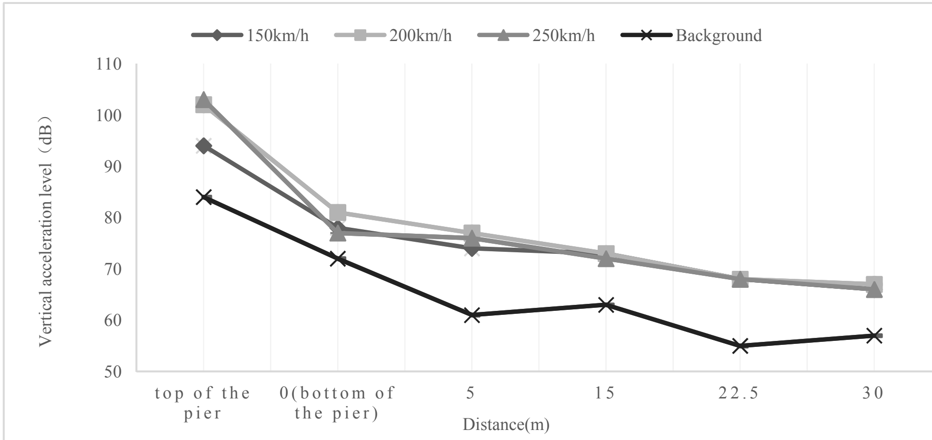

Figure 3. Weighted vertical acceleration level with different speeds

4 Comparison of vibration of maglev transportation and rail transit

This test about elevated rail transit system is at a distance of 80m away from the platform of the Jinsha River Road Station of Shanghai Metro Line 3. The measuring points arrange at the top of the pier, 0m (the bottom of the pier), and 5m, 15m, 22.5m. As can be seen from Fig.4, although the maglev transportation is much faster than the rail transit, the vibration level of maglev transportation and rail transit is not very different. Comparing with the rail transit elevated line, vibration source data of the maglev elevated line is about 6dB higher. But after transmitting from structure to the interface, vibration level of the elevated maglev transportation is about 5~9dB lower than the elevated rail transit on the interface. This suggests that the vibration attenuation of elevated maglev line is more obvious than the vibration attenuation of elevated rail transit.

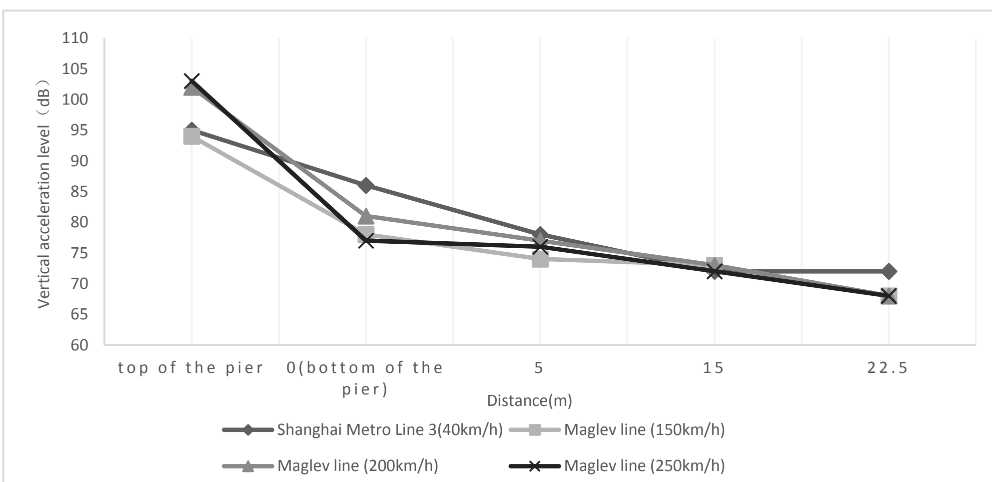

Figure 4. Attenuation of vertical acceleration level for rail transit line and maglev line

5 Conclusion

By measuring and analyzing vibration characteristic of maglev elevated line system, the followings can be concluded:

(1)The vibration of maglev transportation can satisfy vibration requirement (except in vibration requirement of special residential areas) away from centerline of 30 m, which embodies the environmentally friendly characteristic of maglev transportation.

(2)On the track beam, the difference of vibration effect with different speeds is obvious. The farther the measuring point from the track centerline is, the less the influence of the train speed on ground vibration level is. And the variation of the vibration level with different speeds is little 15m away from the track centerline.

(3)The vibration attenuation of elevated maglev line is much faster than the vibration attenuation of elevated rail transit line, and the vibration level of elevated maglev line lower than the vibration level of elevated metro line 15m away from the track centerline.

Acknowledgement

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Reference

Chen, J., Xia, H., Yao, J. (2011). “Test for environment vibration induced by trains on viaduct” Journal of Vibration and Shock, 30(2), 159-163.

Zhai, W., Wei, K., Song, X., Qu, J. (2015). “Experimental investigation into ground vibrations induced by very high speed trains on a non-ballasted track” Soil Dynamics and Earthquake Engineering, 72(2015), 24-36.

Zhao, C., Jia, X., Zhai, W. (2010). “Numerical Analysis of Ground Vibrations of Viaduct Induced by High-Speed Maglev Vehicle” Journal of Southwest Jiaotong University, 45(6), 825-829.

88, GB10070. Standard of Environmental Vibration in Urban Area. Diss. 1988.

88, GB10071. Method of Environmental Vibration in Urban Area. Diss. 1988.

ISO 2631-1-1985.Mechanical vibration and shock-evaluation of human exposure to whole-body vibration-Part Ⅰ:General requirements.

Health Status Evaluation Approach of Critical Equipment in an Urban Rail Transit System

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Abstract: The urban rail transit system in Chinese metropolis is developing into the network operation and structure optimization stage. With the high frequency of Critical equipment failure, equipment intelligent maintenance management needs highlighted. The paper puts forward a method of the evaluation of critical equipment health status in urban rail transit signal system with the needs of overhaul line in Shanghai urban rail transit. The method introduces the equipment service safety concept and defines the health status. Then the paper builds the multi-layer hierarchical structure model of equipment health status combining with considering the multi-dimensional influence factors of signal system equipment such as physical characteristics, economic characteristics and technical characteristics. Finally, the technical process of the fuzzy comprehensive evaluation of equipment health status is put forward. While take the switch which is the critical equipment of urban rail traffic signal system as an example to validate the proposed approach. The results show that the assessment consequence of the proposed method is consistent with the realistic expectations. The method can provide the reference for the diagnosis of hazard factors in service safety while quantitatively analyzing the equipment serving safety level.

Keywords: Urban rail transit; Critical equipment; Health status; Fuzz comprehensive evaluation.

1 Introduction

In nearly 10 years, the rapid development of the urban metro scale in Shanghai has entered the stage of network operation and structure optimization development. Shanghai metro line 10 accident shows that the high load of rail transit system operation leads to the problem of the critical equipment service life. At the same time, the equipment maintenance mode has been developed from after maintenance, planned maintenance to preventive and predictive maintenance, which puts forward new challenges for the management and maintenance of key equipment: how to judge equipment status and evaluate equipment service life scientifically, strengthen the maintenance and management of quick-wear parts, prolong the service life of signal system has become a problem which urgently to be solved.

At home and abroad the research on health monitoring, fault diagnosis and forecasts is mainly focused on mechanical system and electrical system in electrical industry and so on. With reference to the development trajectory of the equipment management study in these industries. By using the system quantitative analysis based on the data of critical equipment in the urban rail transit system instead of single quantitative analysis of equipment life and scientific assessment method instead of single standard, which becomes the inevitable trend of rail transit equipment intelligent management in our country. The evaluation theory and method based on the equipment real-time status detection is the common used equipment management method. But at the most time the equipment real-time status is observed the variation of equipment instantaneous status only from the perspective of performance or functional and unable to track the evolution of equipment performance systematically. It is difficult to describe the system health status and service security accurately by only using the equipment real-time status with comprehensively considering the effect of the physical characteristics, environmental conditions, technical characteristics and many other influence factors in the critical equipment in rail transit system.

In view of the operating unit attaches importance to construction and despises management, the thinkable operating data sample of the critical equipment is limited and cannot support the modeling of fine evaluation method. Relying on the rich expert experience and the part of observable real- time status in operating stage, this paper introduces a concept of equipment health status and puts forward a fuzzy comprehensive evaluation method for critical equipment health status to manage the health status of the critical equipment in the whole life cycle effectively.

2 Division of health status

Health is defined that a person keeps well in the physical, mental and social aspects and can activate normally. The equipment health status is often associated with the equipment service life in the practice of the equipment management. The better the equipment health status is, the longer the remaining service life is and the less possibility of an accident is happened. Following the concept and technique of health status monitoring in the literatures, the definition of the equipment health status in this paper qualitatively describes the ability level of the critical equipment that realized the corresponding technical indexes and functional structure in the specific operation conditions. The paper adopts "health value (HV)" to characterize the equipment health status quantitatively. The classification criteria of the four equipment health status is shown in table 1. It makes the health value as the evaluation index and classifies the equipment state as health, sub-health, sick, serious sick.

Table 1. Division of equipment health status

Status	Value	Feature
Health	$0.75 \leq HV \leq 1$	At the beginning of the equipment life, the health status is perfect.
Sub-health	$0.5 \leq HV < 0.75$	At the middle of the equipment life, there are some risk during the running.
Sickness	$0.25 \leq HV < 0.5$	At the end of the equipment life, there are some serious problems in running.
Serious sickness	$0 \leq HV < 0.25$	The equipment life has been exhausted and cannot run.

The health status of critical equipment in urban rail transit system rail transit system is influenced by multidimensional factors, and the system evaluation has many characteristics, such as multi-objective, multi-criterion and multi-change etc. It is impossible to qualitative analysis the health status of equipment only using logic judgment based on the experience of evaluators. Based on fuzzy mathematics, comprehensive fuzzy evaluation using the principle of fuzzy synthesis to quantitative analysis some factors of fuzzy boundaries, and evaluate the evaluation criterion comprehensively from down to up according to the membership grade of multiple factors to the evaluated things. In the condition of the lacking of current data, comprehensive fuzzy evaluation can effectively simulate human fuzzy language information to process nonlinear and uncertainty system, and describe the engineering experience accumulated by experts, realizing the decision inference. And comprehensive fuzzy evaluation has been widely used in the field of rail traffic safety assessment. This paper uses the comprehensive fuzzy evaluation to conduct a comprehensive assessment of the equipment health status, and draw inspiration from the relative quantitative evaluation can be obtained in two rough comparison, using analytic hierarchy process to determine the comprehensive weight of each index.

3 Modeling for fuzzy comprehensive evaluation

3.1 Hierarchical structure model

Comprehensive evaluation method based on a large number of equipment running status data. However, the internal structure of key equipment is complex and the running environment is varied, and the running state is affected by many factors and the relationship between them is complicated. So only by establishing scientific index system can achieve the effective management of data. To solve the evaluation of complex system, the multi-layer hierarchical structure are often used to simplify things. Typical model of hierarchical structure is shown in figure 1, including the object level, criterion layer and influencing factors layer. Firstly, according to the demand of the evaluation objects, evaluation target is formulated. Then, by the system characteristics as the guidance, the evaluation criterion of equipment performance is divided, and each criterion contains a number of influence factors. At last, according to the main influencing factors of different criterions, the tree structures from top to bottom are used to hierarchically describe the relationship between the criterion and its influencing factors.

To the key equipment of rail transit system, the evaluation target is the health status (health value) of equipment. Literature in the references points out the main influence factors of equipment health value, including reliability, maintainability, detection, security, efficiency, technical performance and so on six aspects. On this basis, this paper merges the reliability, maintainability, detection and security related with RAMS into safety performance criteria, and considers the equipment operating status, operation conditions and the influence of the inherent equipment, adding physical performance criteria. The adjusted performance criteria of health status include: safety performance criteria, physical performance criteria, technical performance criteria and economic performance criteria. The analysis of the relevant criteria and influence factors can be found in the references.

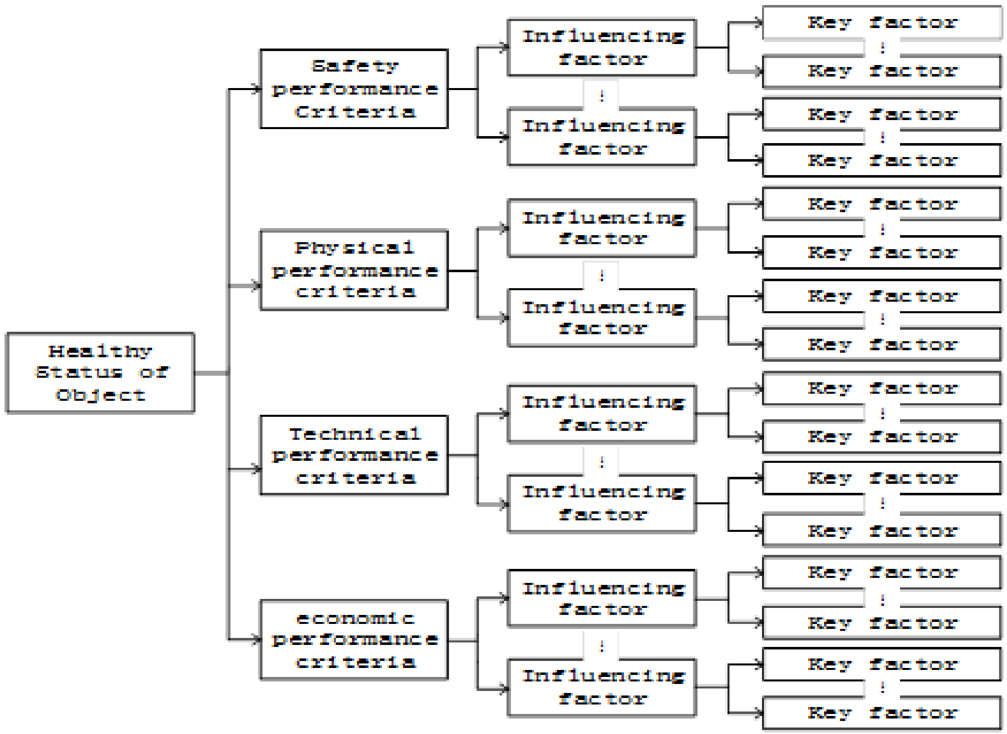

Figure 1. Hierarchical structure model of equipment health status

3.2 Comprehensive Fuzzy Evaluation

The steps of fuzzy comprehensive evaluation are as follows:

Step1: Determine the Influencing factor set U of evaluation object;

$U = \{u_1, u_2, \cdots, u_m\}$, m represents the Influencing factors of the evaluation object.

Step2: Determine the evaluation set V of levels and membership function;

$V = \{v_1, v_2, \cdots, v_n\}$, v_j represents the i^{th} evaluation subset, n represent the total number of evaluation result. This research use four evaluation subsets of A, B, C and D represent health, sub-health, sickness and serious sickness of health status.

Step2: Fuzzily evaluate the Single influencing factor to build fuzz relationship matrix R.

According to the characteristics value of the factor u_i and the membership function, the object must be evaluate/calculate the membership under the influence of u_i. That means to consideration the membership r_{ij} of fuzz evaluation subset in single factor condition.

$$r_i = \left(r_{i1}, r_{i2}, \cdots, r_{im}\right)$$

Step4: Get the fuzz relationship matrix;

The membership of every factors need to quantify for getting a fuzz relation matrix:

$$\mathrm{R} = \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{pmatrix}$$

Step5: Determine the weight vector A of the facts;

According to the hierarchical structure model, the comprehensive importance vector of model are determined by AHP.

$$A = \left(a_1, a_2, \cdots, a_m\right)$$

Step6: Calculate the result vector B by fuzzy evaluation with multiple factors.

$$\mathrm{B} = \mathrm{A} \times \mathrm{R} = \left(a_1, a_2, \cdots, a_m\right) \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{pmatrix} = \left(b_1, b_2, \cdots, b_n\right)$$

Step7: Comprehensive evaluation

1) Normalize the results of fuzz comprehensive evaluation to analysis:
2)

$$b_i = \frac{b_i}{\sum b_i}$$

2) Calculate the comprehensive evaluation operator d by each scale scalar which belong to every level.

$$C = \left(C_1, C_2, \cdots, C_n\right)$$

$$d = cB^T$$

3.3 Evaluation process

In conclusion, the overall technical process of comprehensive fuzzy evaluation for health status of key equipment is shown in figure 2, and the structure of model can be optimized according to the results of assessment. Meanwhile, in order to analyze the key influence factors of the overall hierarchy fuzzy, the comprehensive weight w_{ij} and fuzzy membership evaluation r_{ij} are considered comprehensively, and the relative importance U_{ij} is defined, as shown in the following formula, or comprehensively evaluate the relative importance of various influence factors.

$$U_{ij} = w_{ij} \cdot r_{ij}$$

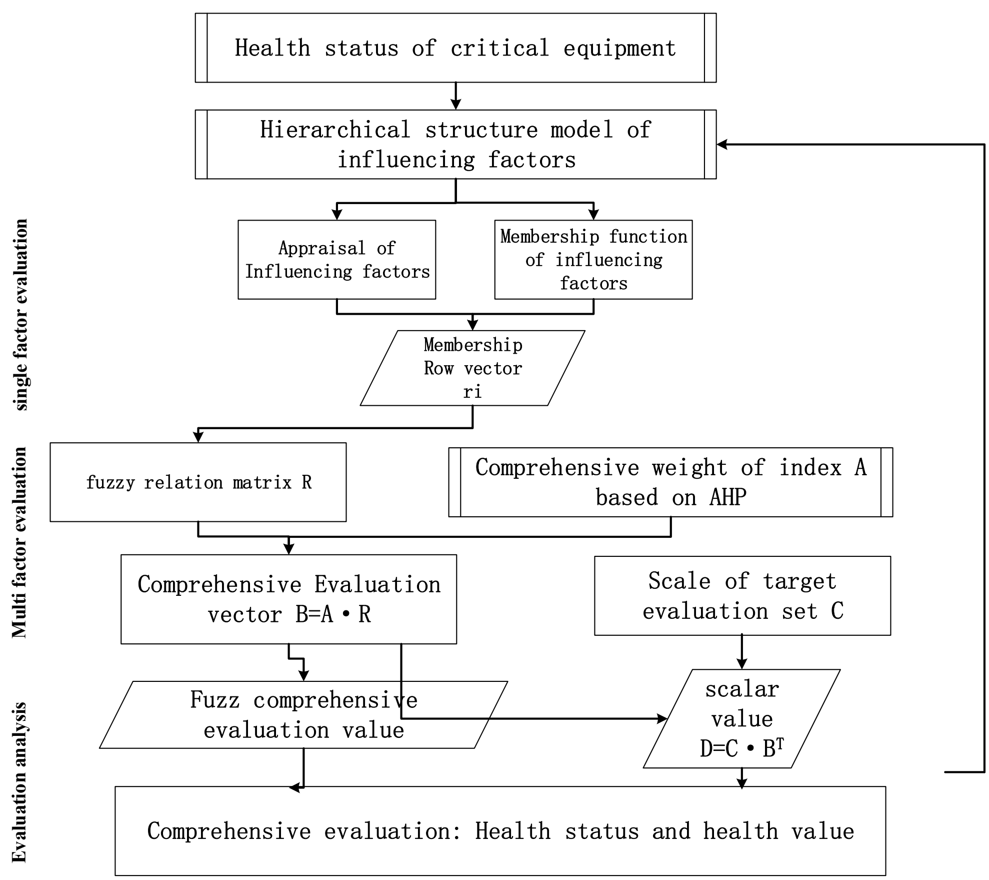

Figure 2. The technical process of fuzz comprehensive evaluation for equipment health status

4 Application

Switch is an important connection and cross devices of rail transit system. Due to the switch has the characteristics of quantity, complex structure and short service life, there is a big risk when rolling stock through, which will seriously impact the traffic safety. So a lot of resources are needed for maintenance. Taking the switch equipment of a certain line of Shanghai metro as an example, the proposed method is applied to evaluate the health status of switch equipment.

(1) Hierarchical structure model

The primary influencing factors of railway switch devices life and health value mainly include economic factors, physical life and technical life. Economic life means the time during which the user fee within reasonable bounds. Physical life means the duration from the time when a device was completely new until the time when the device can't continue to be used technically. Technical life of one device will change as the improvement of technical factors. The five-level hierarchical structural model of switch which is discussed by exports and combined the real using feature is shown in table 2:

Table 2. Five-level hierarchical structure model of switch

<table>
<tr><th>Level A</th><th>Level B</th><th>Level C</th><th>Level D</th><th>Level E</th></tr>
<tr><td rowspan="13">Evaluation criteria of health status</td><td rowspan="3">Economic life</td><td>Cost per year</td><td></td><td></td></tr>
<tr><td>Maintenance cost</td><td></td><td></td></tr>
<tr><td>running cost</td><td></td><td></td></tr>
<tr><td rowspan="10">Physic life</td><td rowspan="7">Inherent factors</td><td rowspan="4">Design</td><td>Design Working Life</td></tr>
<tr><td>Reliability design</td></tr>
<tr><td>Fail-safe design</td></tr>
<tr><td>Environmental adaptability design</td></tr>
<tr><td>Manufacture</td><td></td></tr>
<tr><td>Material</td><td></td></tr>
<tr><td>Inspection</td><td></td></tr>
<tr><td rowspan="3">Interface</td><td>Interface of permanent way depot switch</td><td></td></tr>
<tr><td>Switch machine interface</td><td></td></tr>
<tr><td>Relay interface</td><td></td></tr>
</table>

		Operating conditions	Natural environment	Gathered snow
				Gathered Water
				thunder
			Ballast bed environment	
		Running state	Current service time	
			Action times	
			General failure rate	
			Serious failure rate	
			Dangerous failure rate	
		Maintenance management	Management system	
			Replacement cycle	
			Regular maintenance	
			Technical training	
		Reform		
	Technical life	Technology renovation		

(2)Basic data collection

This paper uses the expert scoring method based on questionnaire to collect two kinds of basic data: the index weight and index evaluation of all kinds of influencing factors. In order to evaluate the object scientifically, the expert team should be professional, technical and scientific. At the beginning of the study, 20 questionnaires were sent out to five types of experts, including maintenance personnel, engineers, technicians, managers and researchers. The judgment matrix is established through index weight data questionnaire by comparing the relative importance among index at the same level. The evaluation data is scored by experts according to the actual usage. There are four fuzzy judgment, A, B, C and D. The questionnaire data is shown in table 3:

Table 3. Example: relative importance of the evaluation criteria

A	B1	B2	B3
Economic life	1	1/5	1/7
Physic life	5	1	1/3
Technical life	7	3	1

Table 4. Example: evaluation scoring of influence factors by exports

Influence factor	Fuzzy Evaluation A	B	C	D
Cost per year			√	
Maintenance cost				√
Running cost			√	

(3)Calculation the comprehensive weight of index

Affected by the difference of experts' knowledge, the scoring results of each expert are also different. So the original data should be preprocessed as follows: 1) To eliminate the abnormal data. 2) To eliminate data which is not meet the need of consistency check of level analysis. 3) For the reasonable data sets, to describe the scoring result by geometric mean. Then, the summation method of analytic hierarchy process is used to calculate the index factor weight v_n^j of each level in the hierarchy model, and the consistency inspection is done. Finally, according to the relative weight of factors in each level, the comprehensive weight a_n' relative to the evaluation target is calculated from top to bottom. The calculation principle is shown in the following formula, in which j represents number of upper father index of lower index n.

$$a_n' = \sum_j a_j \cdot v_n^j$$

(4)Fuzz comprehensive evaluation

According to the expert evaluation data of investigation, the frequency of influence factors in the evaluation of subset (A, B, C, D) are used to directly estimate the membership of the single influence factor fuzzy evaluation, and the membership of index is calculated in formula (). In the formula, - represents the membership of the j^{th} evaluation subset of the i^{th} influence factors, and C_{ij} represents the number of times of the j^{th} evaluation subset of the i^{th} influence factors under investigation.

$$r_j^i = \frac{C_j^i}{\sum_{j=1}^{4} C_j^i}$$

Then, on the basis of the comprehensive fuzzy evaluation process, the fuzzy relationship matrix between different hierarchical indexes is structured, according to the order from down to up of the hierarchical structural model. Combining the index weight marked by AHP, the comprehensive fuzzy evaluation is applied in turn to the upper index, and the final results are as follows:

$$B = A\begin{bmatrix} B_{B1} \\ B_{B2} \\ B_{B3} \end{bmatrix} = \begin{bmatrix} 0.157 & 0.562 & 0.281 \end{bmatrix}\begin{bmatrix} 0.27 & 0.6 & 0.13 & 0 \\ 0.330844 & 0.441804 & 0.183917 & 0.042528 \\ 0.27 & 0 & 0 & 0.73 \end{bmatrix}$$
$$= \{0.304195 \quad 0.342494 \quad 0.123771 \quad 0.229031\}$$

(5)Comprehensive analysis

The results show that the fuzzy membership of health status A, B, C, and D of the level one switch equipment is 0.304, 0.342, 0.124, and 0.230, respectively. If the maximum membership principle is adopted simply, the level one switch equipment is still in health status. According to the threshold of health status of equipment in table 1, the integrated health value of level one switch equipment is:

$$\text{HV} = 0.304 \times 1 + 0.342 \times 0.75 + 0.124 \times 0.5 + 0.230 \times 0.25 = 0.68$$

So the health status of equipment is sub-health, and the current some significant influence factors should be observed and maintained in the daily maintenance and management. The result shows that the fuzzy membership of the devices under different health status is 0.304, 0.342, 0.124, 0.230. As the maximum membership principle, the level one switch devices are still in a healthy status. According to the threshold of device health status, the integrated health value of level one switch is shown as following:

Table 5. Fuzz comprehensive evaluation result of influencing factors

Influencing factor	A	B	C	D	Comprehensive weight	Uij	Level
Ballast bed	0.07	0.67	0.24	0	0.1	0.024	D
Material	0.13	0.27	0.6	0	0.032	0.019	D
Maintenance cost	0.27	0.6	0.13	0	0.072	0.093	D
Technical life	0.27	0	0	0.73	0.281	0.205	C
Reform	0.91	0	0	0.09	0.084	0.008	C

5 Conclusions

This paper introduces the health status indicators of key devices, and builds the general multi-level hierarchical structure model of device health status according to the usage characteristics of key devices in railway system. The fuzzy comprehensive evaluation method of device health status is proposed. The evaluation of level one switch is verified in actual operation. The main conclusions are as follows:

(1) The evaluation result of level one switch accords with the reality of the actual situation of device management. This method is able to consider the experts' knowledge and real-time monitoring device status. By defining health state and quantifying health value, it is able to quantitatively analyze the health status of devices, which will provide decision support to device condition maintenance management.

(2) The system importance index considers the weight and fuzzy membership of index factors. It will comprehensively represent the importance of key factors, which has great implications for deciding maintenance management strategy and searching the significance, weakness and blind spot.

(3) The proposed fuzzy comprehensive evaluation of device health status has good universality. For the key devices of different level such as system level, device level and part level, users only need to define the multi-level hierarchical structure model according to the device characteristics, so as to quantitatively analyze the device health status.

(4) Fuzzy comprehensive evaluation method is significantly influenced by experts' knowledge, so the proper selection of experts will directly determine the credibility of evaluation method. In the process of practical application, a scientific evaluation manual should be established. It will guide the whole process of evaluation. The evaluation objects should be evaluated by experts for several rounds to ensure the rationality and consistency.

Acknowledgement

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References

Bin G F, Li X J and Li P. (2007). "A new method to establish index system of mechanical equipment healthy state evaluation." *Machine Tool & Hydraulics*, 35 (12), 177-179.

Bin G F, Li X J, Dhillon B S and CHU W W. (2010). "Quantitative system evaluation method for equipment state fuzzy and analytic hierarchy process." *Systems Engineering-Theory & Parities*, 30 (4), 45-49.

Li X J, Bin G F and Dhillon B S. (2007) “An evaluation method of mechanical equipment health State on the basis of fuzzy synthetic evaluation.” *Fourth International Conference on Fuzzy Systems and Knowledge Discovery*, March, 518-522.

Li L P, Zou X Y and Jin F H, et al. (2004). “The method based on fusion information entropy for quantitative assessing vibration state in large capacity rotary machinery.” *Power Engineering*, 24(2), 153-154.

Li X Y, Yan J J and Lin W C (2001). “Study on thermo-economies diagnosis method and index evaluation system for the cold-end system in steam power unit.” *Chinese Society for Electrical Engineering*, 21(09), 23-27.

WU L Z. (2005). “Assessing approach of transformer condition.” *North China Electric Power University, Beijing, China*.

Zhang J P, Liu G X and Yuan Q. (2004). “Design and realization of evaluation of health condition system for transformation equipment.” *Modern Electric power*, 21 (4), 745-750.

Fault Diagnosis for the Gearbox of a High-Speed Train on Generalized Congruence Neural Networks

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Abstract: Aiming at the existence of convergence is very slow and there are many local minima problems of BP neural network, put forward an improved generalized congruence neural network (GCNN). Improved GCNN neural network has better generalization ability, learning speed, small relative error, easy to operate. The GCNN applied to fault diagnosis examples of high-speed train gearbox, experiments show that: GCNN neural network can achieve the status of intelligent gearbox fault diagnosis effectively, recognize and classify the pattern effectively, complete fault intelligent diagnosis.
Keywords: Generalized congruence neural networks; Gearbox; Fault diagnosis.

1 Introduction

Fault diagnosis of high-speed train has very important significance. The status quo at home and abroad shows that development and research on fault diagnosis technology have importance and urgency.

Due to mass ratio fixed, transmission torque, compact structure, etc., gearbox is used to change the speed and transmit power most commonly used transmission parts, is an important part of high-speed EMU machinery and equipment, but also prone to a fault component, which runs the state has a great influence on the performance of EMU. The damage and failure of gearbox often leads to transmission system or machine malfunction, leading to major accidents. So study on Fault diagnosis technology of gearbox has a very important significance. To further enhance the accuracy and rapid of fault diagnosis, this paper based on the generalized congruence neural networks, research EMU gear operating characteristics during operation, and its fault diagnosis.

2 Generalized congruence neural network (GCNN)

So far, the ANN structure cooperating institutions combining feedforward multilayer (especially three) neural network based summation - product type neurons with back propagation (back propagation, BP) learning algorithm access to the most wide range of applications. It has proven that BP network has a multilayer neural network S-type nonlinear function can approximate any continuous function with arbitrary precision. However, BP algorithm on the performance stillexist some areas for improvement, such as the existence of convergence is very slow and there are many local minimum problems, especially in practical applications in order to ensure network capacity applicable. Not only need more massive training sample set, but also if the sample data differences, the convergence of the network will be more difficult and will reduce diagnostic accuracy.

Aiming at BP neural network exist that the convergence is very slow and there are many local minimum problems, this paper presents an improved generalized congruence neural network (Generalized Congruence Neural Networks, GCNN), apply to the high-speed train Gearbox Fault Diagnosis. Experimental results show that: Improved GCNN neural network can be effective for gearbox fault pattern recognition and classification, complete intelligent fault diagnosis.

2.1 Generalized congruence function

Improved generalized congruence excitation function is defined as follows:

$$\mathrm{a} \equiv \begin{cases} n & (\mathrm{Gmod}\ m) \qquad [|\,n/m\,|]\text{is an even} \\ m-n & (\mathrm{Gmod}\ m) \qquad [|\,n/m\,|]\text{is an old number, } a\text{nd } n \geq 0 \\ -m-n & (\mathrm{Gmod}\ m) \qquad [|\,n/m\,|]\text{is an old number, } a\text{nd } n < 0 \end{cases} \tag{1}$$

Where, a is the independent variable (input), n is the dependent variable (output), m is mold, usually m> 0; $|\cdot|$ is the absolute value of the symbol; $[\cdot]$ is the rounding function.

2.2 Bayesian regularization

This paper introduces a Bayesian regularization to improve the generalization of GCNN network. Regularization method can improve its marketing capabilities through correcting the training correction performance function of neural networks. Regularization method is an eliminating over-fitting method by limit the network weights appropriately. Regularization algorithm modifies neural network error function by setting certain constraints out the sample data, in the form of regular items added human error function. General neural network training performance function uses squared error function ED, namely

$$E_D = \sum_{i=1}^{N} (t_i - a_i)^2 \tag{2}$$

Wherein t_i and a_i are the target value and the output value of the N training samples in the i-th training time. Introduces a penalty function in Bayesian regularization method, network training performance function becomes

$$F = \alpha E_W + \beta E_D \tag{3}$$

Wherein α and β are regularization coefficient. Square summation $E_W = \sum_{j=1}^{N} \omega_j^2, \omega_j$ of all network weights is the new network weights. Regularization term added in the objective function is to make the role of the smaller connection weight tends to zero as possible, to ensure that the network meets the fitting under the premise of accuracy, ease of cutting off connection weights and the redundant neurons, thereby reducing the complexity of the network to obtain good generalization performance.

3. Gearbox GCNN network model design and training

3.1 Gearbox fault diagnosis model

The GCNN network applies to fault diagnosis of gear boxes, mainly for the accurate calculation of the amount of wear classification and gearbox wear state. The established pattern recognition GCNN network structure of gearbox wear status is shown in Figure 1.

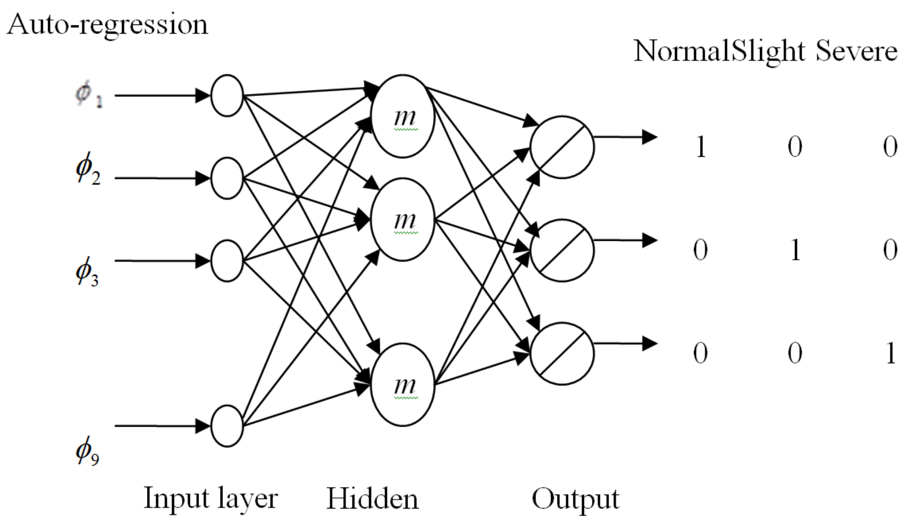

Figure 1. GCNN network structure gearbox fault diagnosis model

In this paper uses three-forward network structure: input layer, hidden layer and output layer each one. Hidden layer and output layer node three GCNN earliest definition has modulus. So, when determine the output layer node modulus, make sure its output is greater than all of the desired output of the neural network, and therefore becomes difficult to determine the value of the mold. The excitation function set in this paper, is different with the original use of network structures. Improved GCNN network structure has the modulus only in hidden layer nodes. Output layer node is the linear summer (Linear function is the simplest function of neurons can be, it's just as simple to neuronal input to the output after passing through the threshold value adjustment) in place of original generalized congruence function. Therefore, in the case of the neural network can not predict all of the desired output, linear summation is to avoid considering the output node modulus value problem. This can increase the learning ability and generalization ability of the network.

The key of troubleshooting is Gearbox vibration signal analysis and feature extraction. Applying vibration sensors mounted on the gearbox vibration signal acquisition, using the researching methods on wavelet packet autoregressive spectral, analysis out the resulting that frequency band signals can reflect changes in the amount of wear of the gearbox, and establishing nine autoregressive model based on features band signals, after wavelet packet autoregressive spectral analysis, conclude: Wavelet Packet autoregressive parameters can accurately reflect the state of the gearbox wear. This article will rank 9 gearbox wear of the situation since the regression coefficient as the original data, so the network input feature vector dimension is 9.

The error of reverse error propagation algorithm in the use of GCNN is spread through the output layer to the input layer. The more layers, the error of reverse propagation becomes more unreliable when close to the input layer. The results of the correction weights also become unreliable. As well increasing the hidden layer will cause GCNN network is too complex, greatly reduces the convergence rate GCNN. A three-tier GCNN network is sufficient to achieve arbitrary dimension n to m-dimensional hint. Therefore, we determine the number of hidden layer 1.

After determining the number of hidden layers, is how to determine the number of nodes in the hidden layer problem. Too few hidden layer nodes, patterns into the rough, may led to the network can not learn the characteristics of training sample, which will not achieve the role of feature extraction. The number of nodes being excessive, the pattern space into too small, will often result in "over-fitting" phenomenon, the network is easy to learn the details of the sample does not matter, grasp the main features. In the specific structure, the numbers of hidden layer nodes in the network are out of trial and error. Reference approximate formula, as well as several tests and commissioning, this article finally determines the hidden layer neurons 15 in this system.

Output of the network for wear state of the gearbox, mainly divides into three kinds of cases in which the normal situation, mild wear, severe wear. So, the output of the network nodes is set to 3. Expressed using the following output: normal (1,0,0), mild (0,1,0) and severe (0,0,1).

In summary, this paper has a hidden layer of the three-tier network GCNN. Use 9-15-3 GCNN network structure. Hidden layer activation function is improved generalized congruence function. Modulus value is set to 0.5. Output layer activation function chose purely linear function.

3.2 Network training and testing

The maximum number of steps in the training is set to 100, the performance parameters are 0.001, the error reverse propagation learning algorithm is 0.02.

In this paper, the sample data at different gearbox wear autoregression coefficient calculated in two parts. As a part of the training data, accounts 75% of the total amount of data. Another part of the data to test the trained network, accounts 25% of the total amount of data. During the 50 times experiment, the training results obtained are shown in Table 1 Statistics.

Table 1. Improved GCNN network straining results statistics

The number of experiments	Network structure	The minimum number of iterations	The average number of iterations	The maximum number of iterations	Success rate(%)
50	9-15-3	12	32	57	98

One training error curve in improved GCNN network training process is shown in Figure 2.

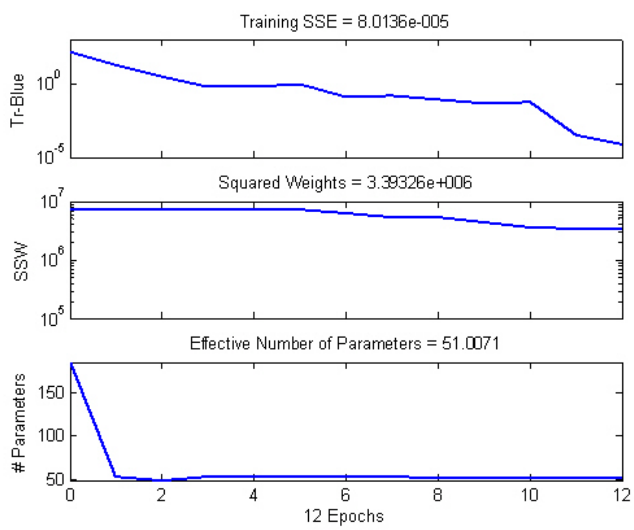

Figure 2. Training error curve in improved network of GCNN

Under the working conditions, the test sample set input trained GCNN network, analysis and diagnosis the state of wear, its desired output and the actual output results are shown in Table 2.

Table 2. Desired output and the actual output of GCNN network detected data

Fault type	Desired output			Actual outputs		
Normal conditions	1	0	0	0.8923	0.0011	0.0002
	1	0	0	0.9667	0.0003	-0.0032
Slight abrasion	0	1	0	-0.0000	0.9998	0.0085
	0	1	0	0.0079	1.0017	0.0021
Severe abrasion	0	0	1	0.0101	0.0115	0.9976
	0	0	1	-0.0012	0.0009	0.9999

As can be seen from Table 2, the improved GCNN network on the recognition result of gearbox fault condition is very accurate, i.e., the rate of diagnosis can be improved greatly. GCNN neural network being used for identify the state of the gearbox fault, modeling speed and recognition speed is very fast. it has a certain significance to solve practical problems.

4 Conclusions

Through experiments, make the following conclusions: GCNN neural network can achieve Intelligent Diagnosis of high-speed train gearbox failure effectively. GCNN network as a gearbox fault state classifiers, can be effective for pattern recognition and classification, complete intelligent fault diagnosis.

Through the experiment, but also proved the superiority of the proposed improved GCNN neural network technology. The improved network has highly prediction accuracy, simple, optimized GCNN neural network has better generalization ability. It has the advantages of that predicted speed is fast, the relative error is small, easy to operate. Examples of the analysis show that the improved GCNN neural network approach is satisfactory.

Acknowledgement

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References

Ali U.(2013). “Real-time condition monitoring and fault diagnosis in switched reluctance motors with Kohonen neural network.” *Journal of Zhejiang University-Science C(Computers and Electronics)*.

Sun Y. J. (2007). “Improved BP Neural Network for Transformer Fault Diagnosis.” *Journal of China University of Mining & Technology*.

Jin, F. (1998). “Study on Principles and Algorithms of Generalized Congruence Neueal Networks.” *Proceedings of 1998 International Conference on Neural Networks and Brain(ICNN&B’98)*.

Jin, F. (1992). “Satisfactory-solution Principle by Neural Computing.” *Proceedings of IJCNN International Joint Conference on Neural Networks Volume Ⅱ of III.*

Pong, M. X. (2012). “Wavelet Transform and Neural Networks in Fault Diagnosis of a Motor Rotor.” *International Journal of Plant Engineering and Management*.

Numerical Analysis on Welding Deformation and Residual Stress of an Aluminum Alloy Floor of EMU Bodywork

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Abstract: Numerical simulation of welding of hollow aluminum alloy profile for EMU bodywork floor was performed by using a software SYSWELD. The sparse and close finite model was used for enhancing computation efficiency and precision, the heat source model of double elliptical were utilized to simulate MIG welding, the welding deformations and residual stresses were achieved, the four schemes of weld orders are analyzed an compared, a good weld orders is obtained for reducing the welding deformations and residual stresses. The results show that a reasonable arrange of weld orders can remarkably reducing weld distortions and residual stresses.

Keywords: Weld order; Deformation; Residual stresses; Aluminum alloy floor.

1 Introduction

The EMU bodywork is widely manufactured by using hollow aluminum alloy profile for reducing weight, cost saving and easy to machining, the length of aluminum alloy profile can extend to 25m, and be widely used for making side wall, top plate and floor for EMU(Wang, P., 2012; Xu, Z.W., 2013). The manufacture processes of bodywork of EMU are largely predigested by using aluminum alloy profile, the main manufacture technique is weld jointing that it joins several aluminum alloy profiles to construct a part of bodywork of EMU, for example , a floor of EMU bodywork is make of six aluminum alloy profiles. Therefore, the weld technology and welding process are significant for reducing weld deformation and residual stress, by applying a good welding process the weld deformation and residual stress can largely be decreased and controled, and bodywork performance can be enhanced.(Han, D.H., 2013).

The weld deformation and residual stress relate to various factors, a main factor is the arrange of weld orders. There are many weld seams at the floor of EMU bodywork, a good the weld orders of weld seams can be achieved by a numerical simulation (Xue, J., 2012), the numerical simulation may only consider a local model and a content results can be recovered , this has a significance to improve the weld process. In this paper, a local FE model of floor of EMU bodywork is established, the weld numerical simulations are performed considering four weld orders of weld seams, a reasonable weld orders were achieved, which have the least weld deformation and residual stress.

2 The weld heat source model

A continuum medium with volume V and surface S, its differential equation for heat conduction can be expressed as follows

$$-\frac{\partial}{\partial x_i}(\lambda_{ij}\frac{\partial T}{\partial x_i})+Q-\rho c\frac{\partial T}{\partial t}=0 \qquad (1)$$

where T is temperature,^{0}C; $\frac{\partial T}{\partial x_i}$ is the temperature grads; λ_{ij} is heat conduction tensor, W•m^{-1}•^{0}C^{-1}; Q is heat production rate for unit volume, W•m^{-3}; ρ is density, Kg•m^{-3}; c is specific heat, J•Kg^{-1}•$^0C^{-1}$; t is time, s.

The heat input in weld process is high and concentrate near the welding local location, the heat source model of double elliptical can well simulate this kind of weld process in existing heat source models(Li, Y.N., 2010; Deng, D., 2008), the simulation results basing on this model can achieved a approving accordance with the practice weld process, it is that the shape and size of dissolving pool of the simulation is consistent with the actual weld seam. There are two parts including front and back in this heat source model, the heat distributing function for front part and back part can be expressed as follows, respectively,

$$Q_f[x,y,z]=\exp[-[\frac{x^2}{a_f^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}]] \qquad (2)$$

$$Q_b[x,y,z]=\exp[-[\frac{x^2}{a_b^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}]] \qquad (3)$$

Where Q_f and Q_b is the energy input of front heat source and back heat source, respectively; a_f and a_b is the length of front half elliptical and back half elliptical, respectively; b is a influence parameter of dissolving pool width; c is a influence parameter of dissolving pool depth.

3 The FE model and weld orders

3.1 Finite element model

A finite element model of local chassis of CRH3 EMU bodywork is established with a length of 0.5m and a half the chassis width , each weld seam position has 2 weld seams including up seam and down seam, therefore this model comprises 6 weld seams that join 3 aluminum alloy profile and side beam into a whole structure with 142402 elements and 96696 nodes, the x, y and z displacement components are constrained in on middle symmetry line labeled by ab and cd, the line labeled ef and gh which are joined to side wall are constrained at y displacement component. The finite element model is shown in Figure 1. The parameters of weld technology are as follows: the weld method is MIG weld, the weld voltage and electric current are 20~22V and 200~210A, respectively, the weld speed is 10 mm/s.

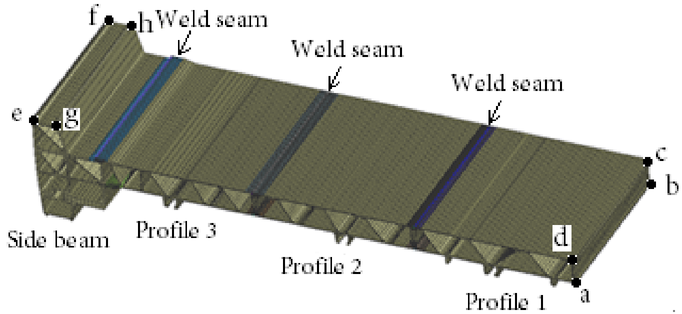


Figure 1. Finite element model

3.2 Heat source parameters

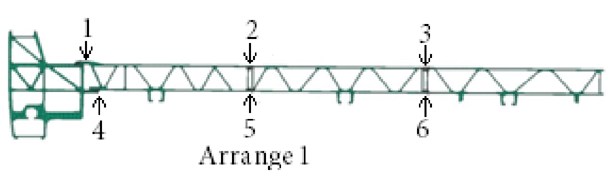
The heat source parameters mentioned above can be adjusted and obtained by using the verifying procedure of heat source in SYSWELD software when the shape and size of welded structure, heat physics properties of material and parameters of welding process are inputted into SYSWELD software. The heat source 1 is a overlap weld seam heat source with 8mm plate thickness which is used to join the side beam and profile 3, and the heat source 2 is a butt weld seam heat source with 2.8mm plate thickness which is used to join two profile. The heat source parameters are listed in Table 1.

Table 1. Heat source parameters

Parameters	Heat source 1	Heat source 2
a_f	1	6
a_b	4	80
b	4	2
c	4	3
Q_f	28.5	2.7
Q_b	23.7	5.1

3.3 Weld orders of seams

In order to research effect of the weld orders on weld deformations and residual stresses, 4 various arranges of weld orders are simulated and analyzed, which is shown in Figure 2, the 1,2,3,4,5,and 6 express the weld order, for example, in arrange 1 the 3 weld seams on the up surface are firstly welded from 1 to 3, then the down 3 weld seams are again welded from 4 to 6.



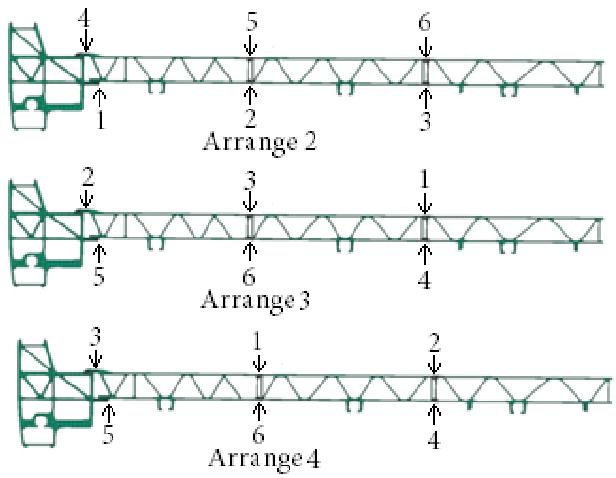
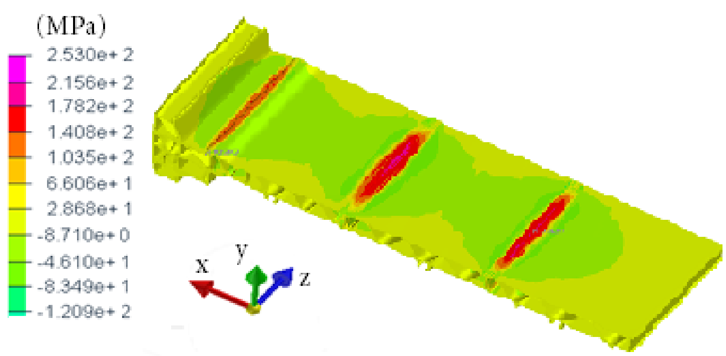


Figure 2. Arranges of weld orders

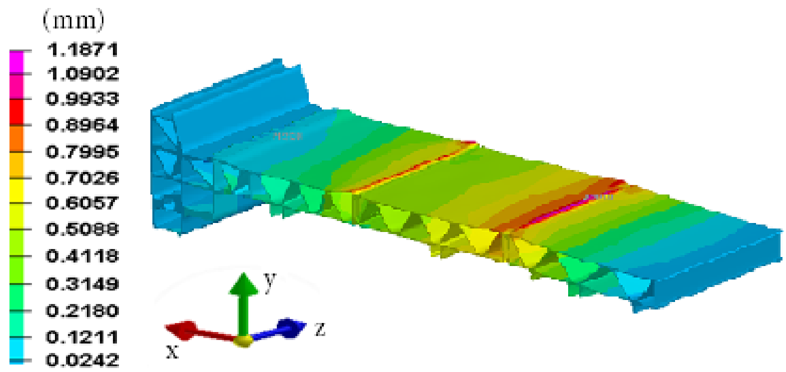
4 Simulation results

4.1 Weld deformation and residual stresses

The weld deformation and residual stresses of arrange 1 of weld orders are shown at Figure 3. Figure 3.(a) shows that there is the maximal residual stress of 178.2 MPa in the weld seam 2, and in the weld seam region hereabout tensile stresses are primary stress pattern, and away from the weld seam region compression stresses are obvious stress pattern.



(a) The residual stresses at longitudinal direction



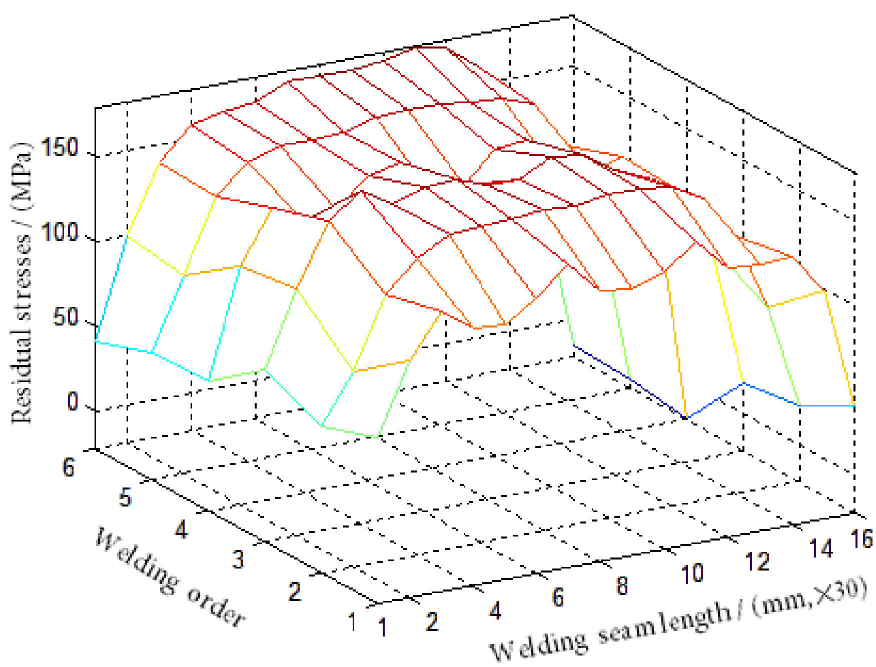
(a) The deformation at y direction

Figure 3. The weld deformation and residual stresses

Figure 3.(b) shows that a maximal weld deformations of 1.187mm are brought at weld seam 2 and 4, the primary model of deformation is buckling deformation.

4.2 Residual stresses change with weld seam length

The changes of the residual stresses of arrange 1 with weld seam length are shown in Figure 4., the maximal residual stress is produced in weld seam 6 at the center back of length direction, which is lasted one welded, and moreover the values of the residual stresses have a gradually increasing trends with the welding orders of from 1 to 6, this expresses that the residual stresses can be reduced by a good arrange of weld orders.



4.3 Compare on various arranges of weld orders

The maximal deformations and residual stresses of various weld order arranges expressed in Figure 2 are listed Table 2., the Table 2 shows that the arrange 2 has the least deformation and lowest residual stress, it is that the outer surface of EMU bodywork floor should be firstly welded, this is because of some reinforcing ribs exist on the outer surface, and therefore the outer surface has the higher rigidness.

Table 2. Maximal deformations and residual stresses

Arrange	Y direction maximal deformation / (mm)	Maximal stress / (Mpa)
1	1.187	290.059
2	0.581	281.005
3	1.181	302.524
4	1.143	291.107

5 Conclusions

This article established the finite elements model of welding simulation of EMU bodywork floor, the weld deformations and residual stresses are obtained. The results show that the weld deformations of aluminum alloy floor of EMU bodywork are primary buckling deformation , the maximal values of residual stresses exist in middle of a weld seam, and in general there exist the maximal residual stresses at the lattermost welded seam. The good arranges of weld orders can reduce the weld deformations and residual stresses, especially the weld deformations can be obviously reduced by firstly welding outer surface of EMU floor, about a half of original deformation is achieved by firstly welding surface of EMU floor.

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References

Deng,D., Murakawa,H. (2008). FEM Prediction of Buckling Distortion Induced by Welding in Thin Plate Panel Structures. Computational Materials Science , (43): 591-607.

Han, D.H., Wang, P., Chen, D.F. (2013).Numerical analysis on welding distortion of extruded shape of aluminum alloy floor for EMU, Welding Technology, 42(9):21-23.

Li, Y.N., Xie, S.M., Li, X.F. (2010). Numerical Simulation of Welding Deformation of the Middle Beam of the Container Flat Car. JOURNAL OF THE CHINA RAILWAY SOCIETY, 32(5):36-40.

Wang,P., Fang, H.Y., Han, D.H. (2012). Numerical simulation on as-welded deflection of high speed rail floor based on thermo- mechanical coupling.

TRANSACTIONS OF THE CHINA WELDING INSTITUTION, 33(6):15-19.

Xu, Z.W., Chen, H.P., Xu, H. (2013). Effect of the welding load on residual stresses of high-speed train. Electric Welding Machine ,43(7):17-19.

Xue, J., Liu, J.(2012) . Research on Current State and Prospect of Welding Deformation and Deformation Control Methods for China's High-speed Train Aluminum Alloy Carbody. Casting Forging Welding, 9:188-190.

Solutions for Plane Strain Consolidation of a Saturated Medium

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Abstract: The eigenvalue approach, Fourier transforms, and two-step backward finite difference method, has been employed to study the plane strain consolidation of an isotropic porous elastic medium, saturated by one-phase incompressible fluid. The solutions of displacements, stresses and pore pressure has been obtained by the presented method. A model has been used to study the feasibility of the solutions. The results indicate the solutions is effective.
Keywords: Plane strain; Finite difference; Fourier transform; Eigenvalue.

1 Introduction

In engineering, many can simplify to plane problems, such as embankment, wall etc. So, it is important to study the plane strain problems.

The process of consolidation was first investigated by Terzaghi for one-dimensional conditions. Subsequently, Biot extended Terzaghi's theory to three dimensional situations. However, exact solutions to problems involving the consolidation of a soil mass under three-dimensional conditions are not easy to obtain. Several exact and approximate analytical solutions have to be confined to plane strain problems. Mcnamee and Gibson expressed the stress and the pore pressure in porous medium which liquid diffusing in terms of two displacement functions, and plane strain problems of the semi-infinite body to the surface of which a uniform pressure is applied along an infinite strip is discussed. Booker and Small used the transformation of consolidation governing equations by Fourier transform to analyze the consolidation behavior of a horizontally layered soil which subjected to strip, circular, and rectangular surface loads under plane conditions. Some other authors studied the nonlinear and elasto-plastic consolidation. Zhi-yong AI used Laplace-Fourier transforms to study a plane strain consolidation of a porous elastic soil by taking into account the anisotropy of permeability. Selim and Ahmed employed the eigenvalue approach, Laplace and Fourier transforms found the analytical expressions for displacements and stresses at any point, of an inclined line load and , of an initially stressed orthotropic elastic media of a plane strain problem. Shamta Chugh *et al.* continued Selim's work obtained the displacements and stresses for an unstressed elastic media. But the pore pressure has been neglected. Nader Abbasi *et al.* developed a finite difference approach for the solution of non-linear of compressibility and permeability of clay. In their works they limited the analysis of pore pressure, displacement or stress to loading process, the features of these field variables after the load removed partially or absolutely.

In the present paper, eigenvalue approach, Fourier transform and two-step backward finite difference method have been employed to develop a semi-analytical solutions for the consolidation under plane strain conditions. And a simple model has been used to study the feasibilities of the solutions. The results was satisfactory.

2 Basic equations

Consider a homogenous and isotropic porous elastic medium saturated with a single phase incompressible fluid and subject to a small deformation. The governing equations can express as follows:

Equilibrium equations (the body force ignored)

$$\sigma_{ij,j} = 0 \tag{1}$$

Strain-displacement relations

$$\varepsilon_{ij} = \tfrac{1}{2}\left(u_{i,j} + u_{j,i}\right) \tag{2}$$

Effective Stress-strain relations

$$\sigma'_{ij} = \lambda \varepsilon_v \delta_{ij} + 2G\varepsilon_{ij} \tag{3}$$

Darcy's law

$$v_i = \frac{k}{\gamma_w} p_{,i} \tag{4}$$

Continuity equation

$$\dot{\varepsilon}_v = p_{i,i} \tag{5}$$

These equations are written in indexical notations, its meaning can refer to Y.C Li.

Based on equations (1)-(5) the equations, and utilize the conditions of plane strain consolidation, we can get the governing equations of plain strain consolidation as

$$(\lambda + 2G)\frac{\partial^2 u}{\partial x^2} + (\lambda + G)\frac{\partial^2 w}{\partial x \partial z} + G\frac{\partial^2 u}{\partial z^2} - \frac{\partial p}{\partial x} = 0 \tag{6a}$$

$$G\frac{\partial^2 w}{\partial x^2} + (\lambda + G)\frac{\partial^2 u}{\partial x \partial z} + (\lambda + 2G)\frac{\partial^2 w}{\partial z^2} - \frac{\partial p}{\partial z} = 0 \tag{6b}$$

$$-K\left(\frac{\partial^2 p}{\partial x^2} + \frac{\partial^2 p}{\partial z^2}\right) + \frac{\partial}{\partial t}\left(\frac{\partial u}{\partial x} + \frac{\partial w}{\partial z}\right) = 0 \tag{6c}$$

In these equations (6), u and w are the horizontal and vertical displacement, p is pore pressure, k is the permeability coefficient, E and ν are modulus and Poisson ratio, G is shear modulus and λ is Lame coefficient, γ_w is the density of water.

3 Transformed equations

Two-step backward finite equation with variable time increments to approximate the time derivative in equation (6c) i.e.[17]:

$$\frac{\partial u}{\partial t}=a_0u+a_{-1}u_{-1}+a_{-2}u_{-2},\ \frac{\partial w}{\partial t}=a_0w+a_{-1}w_{-1}+a_{-2}w_{-2} \tag{7}$$

Where

$$a_0=\frac{2\Delta_{-1}+\Delta_{-2}}{\Delta_{-1}\left(\Delta_{-1}+\Delta_{-2}\right)},a_{-1}=-\frac{\Delta_{-1}+\Delta_{-2}}{\Delta_{-1}\Delta_{-2}},a_{-2}=\frac{\Delta_{-1}}{\Delta_{-2}\left(\Delta_{-1}+\Delta_{-2}\right)} \tag{8}$$

Are three coefficients depending on the two-backward time increments Δ_{-1} and Δ_{-2}. Subscripts -1 and -2 denote the values of the field quantities at time $t-\Delta_{-1}$ and $t-\Delta_{-1}-\Delta_{-2}$, respectively.

We define Fourier transform $\overline{f}\left(\xi,z\right)$ and $f\left(x,z\right)$ as:

$$\overline{f}\left(\xi,z\right)=F\left[f\left(x,z\right)\right]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}f\left(x,z\right)e^{i\xi x}dx \tag{9a}$$

$$f\left(x,z\right)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}\overline{f}\left(\xi,z\right)e^{-i\xi x}d\xi \tag{9b}$$

It was known that

$$F\left[\frac{\partial}{\partial x}f\left(x,z\right)\right]=\left(-i\xi\right)\overline{f}\left(\xi,z\right),F\left[\frac{\partial^2}{\partial x^2}f\left(x,z\right)\right]=-\xi^2\overline{f}\left(\xi,z\right) \tag{10}$$

In equations (9) and (10), the ξ is parameter of Fourier transform.

Substituting equations (7)-(10) into equations (6), gives the transformed equations:

$$-\xi^2\left(\lambda+2G\right)\overline{u}\left(\xi,z\right)-i\xi\left(\lambda+G\right)\overline{w}'\left(\xi,z\right)+G\cdot\overline{u}''\left(\xi,z\right)+i\xi\overline{p}\left(\xi,z\right)=0 \tag{11a}$$

$$-\xi^2G\overline{w}\left(\xi,z\right)-i\xi\left(\lambda+G\right)\overline{u}'\left(\xi,z\right)+\left(\lambda+2G\right)\overline{w}''\left(\xi,z\right)-\overline{p}'\left(\xi,z\right)=0 \tag{11b}$$

$$-K\left[\left(-\xi^2\right)\overline{p}\left(\xi,z\right)+\overline{p}''\left(\xi,z\right)\right]+a_0\left[\left(-i\xi\right)\overline{u}\left(\xi,z\right)+\overline{w}'\left(\xi,z\right)\right]=\overline{q}\left(\xi,z\right) \tag{11c}$$

Where

$$\bar{q}(\xi,z) = -a_{-1}\left[(-i\xi)\bar{u}_{-1}(\xi,z) + \bar{w}'_{-1}(\xi,z)\right] - a_{-2}\left[(-i\xi)\bar{u}_{-2}(\xi,z) + \bar{w}'_{-2}(\xi,z)\right] \quad (12)$$

And the symbols '' ' and '" ' denotes the function's one-order and two-order differentiate respect to variable ' z ', respectively. The equations (11) are the transformed equations of a saturated soil under conditions of plane strain.

4 Solve for transformed equation

Equations (12) is a second order nonhomogeneous ordinary differential equation. In order to obtain its general solutions, we should solve the homogeneous ordinary equation corresponding to equations (12), therefore we introducing the expression:

$$\bar{u}'(\xi,z) = \bar{u}_1(\xi,z), \bar{w}'(\xi,z) = \bar{w}_1(\xi,z), \bar{p}'(\xi,z) = \bar{p}_1(\xi,z) \quad (13)$$

Rationally, we have

$$\bar{u}_1'(\xi,z) = \bar{u}''(\xi,z), \bar{w}_1'(\xi,z) = \bar{w}''(\xi,z), \bar{p}_1'(\xi,z) = \bar{p}''(\xi,z) \quad (14)$$

We use the expression, $f(\xi,z) = f$, so the equations (12) can express as:

$$\bar{u}' = \bar{u} \quad (15a)$$

$$\bar{w}' = \bar{w}_1 \quad (15b)$$

$$\bar{p}' = \bar{p}_1 \quad (15c)$$

$$\bar{u}_1' = \frac{(\lambda+2G)\xi^2}{G}\bar{u} + \frac{i\xi(\lambda+G)}{G}\bar{w}_1 - \frac{i\xi}{G}\bar{p} \quad (15d)$$

$$\bar{w}_1' = \frac{i\xi(\lambda+G)}{(\lambda+2G)}\bar{u}_1 + \frac{G\xi^2}{(\lambda+2G)}\bar{w} + \frac{1}{(\lambda+2G)}\bar{p}_1 \quad (15e)$$

$$\bar{p}_1' = -\frac{a_0 i\xi}{K}\bar{u} + \frac{a_0}{K}\bar{w}_1 + \xi^2\bar{p} \quad (15f)$$

Writing equations (16) in the vector-matrix differential equation form:

$$\bar{\mathbf{X}}' = \mathbf{A}\bar{\mathbf{X}} \quad (16)$$

Where

$$\bar{\mathbf{X}} = [\bar{u}, \bar{w}, \bar{p}, \bar{u}_1, \bar{w}_1, \bar{p}_1]^T$$

$$\mathbf{A}=\begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ \frac{(\lambda+2G)\xi^2}{G} & 0 & -\frac{i\xi}{G} & 0 & \frac{i\xi(\lambda+G)}{G} & 0 \\ 0 & \frac{G\xi^2}{(\lambda+2G)} & 0 & \frac{i\xi(\lambda+G)}{(\lambda+2G)} & 0 & \frac{1}{(\lambda+2G)} \\ -\frac{a_0 i\xi}{K} & 0 & \xi^2 & 0 & \frac{a_0}{K} & 0 \end{bmatrix}$$

So, the characteristic equation can express as follow:

$$\det(\mathbf{A}-r\mathbf{I})=\alpha_6 r^6+\alpha_4 r^4+\alpha_2 r^2+\alpha_0=0 \tag{17}$$

Where I is unit matrix and

$$\alpha_6=1,\alpha_4=-\left(\frac{a_0}{K(\lambda+2G)}+3\xi^2\right),$$

$$\alpha_2=\frac{2a_0}{K(\lambda+2G)}\xi^2+3\xi^4,\alpha_0=-\left(\frac{a_0}{K(\lambda+2G)}\xi^4+\xi^6\right)$$

The solution of equation (17) gives the eigenvalues as:

$$r_1=r_2=\xi,r_3=r_4=-\xi,r_5=\sqrt{\frac{a_0}{K(\lambda+2G)}+\xi^2},r_6=-\sqrt{\frac{a_0}{K(\lambda+2G)}+\xi^2}.$$

Let us use the expression, $r(\xi)=\sqrt{\frac{a_0}{K(\lambda+2G)}+\xi^2}$.

Using the eigenvalue method to solve the first order vector differential equation (16), the solution have the form

$$\bar{X}(z,\xi)=X(\xi)e^{r\xi} \tag{18}$$

We observe that eigenvalues $r_1=r_2=\xi$ and $r_3=r_4=-\xi$ are both of multiplicity 2. We use the following method to obtain the eigenvector for the repeated eigenvalue corresponding to $r_1=r_2=\xi$.

By using elementary row transforms to matrix $(A-\xi I)^2$, we can obtain the basic solution set of $(A-\xi I)^2\mathbf{b_0}=\mathbf{0}$ that:

$$\mathbf{b}_0^{(1)} = [-i, 1, 0, -i\xi, \xi, 0]^T, \mathbf{b}_0^{(2)} = [0, 1/\xi, 2G, -i, 0, 2G\xi]^T \tag{19}$$

The other eigenvector can obtain by

$$\mathbf{b}_1^{(1)} = (A - \xi I)\mathbf{b}_0^{(1)} = [0,0,0,0,0,0]^T, \mathbf{b}_1^{(2)} = (A - \xi I)\mathbf{b}_0^{(2)} = [-i, 1, 0, -i\xi, \xi, 0]^T \tag{20}$$

Hence, eigenvector X_1 and X_2 can express as

$$X_1 = \mathbf{b}_0^{(1)} + z\mathbf{b}_1^{(1)} = [-i, 1, 0, -i\xi, \xi, 0]^T \tag{21a}$$

$$X_2 = \mathbf{b}_0^{(2)} + z\mathbf{b}_1^{(2)} = \left[-zi, z - \frac{1}{\xi}, 2G, -i\xi\left(z + \frac{1}{\xi}\right), z\xi, 2G\xi\right]^T \tag{21b}$$

Similarly, eigenvector X_3 and X_4 can express as

$$X_3 = [i, 1, 0, -i\xi, -\xi, 0]^T \tag{21c}$$

$$X_4 = \left[zi, \left(z + \frac{1}{\xi}\right), 2G, -i\xi\left(z - \frac{1}{\xi}\right), -z\xi, -2G\xi\right]^T \tag{21d}$$

The eigenvector corresponding to eigenvalues $r_5 = r(\xi)$ and $r_6 = -r(\xi)$ can obtain by using elementary row transforms to matrix equation $A - r_5 I = 0$ and $A - r_6 I = 0$, so the eigenvector X_5 and X_6 are

$$X_5 = \left[-Ki\xi, Kr(\xi), a_0, -Ki\xi r(\xi), \frac{a_0}{(\lambda + 2G)} + K\xi^2, a_0 r(\xi)\right]^T \tag{21e}$$

$$X_6 = \left[Ki\xi, Kr(\xi), -a_0, -Ki\xi r(\xi), -\frac{a_0}{(\lambda + 2G)} + K\xi^2, a_0 r(\xi)\right]^T \tag{21f}$$

Therefore, the solution of equation (17) can be written as

$$X = (C_1 X_1 + C_2 X_2)e^{\xi z} + (C_3 X_3 + C_4 X_4)e^{-\xi z} + C_5 X_5 e^{r(\xi)z} + C_6 X_6 e^{-r(\xi)z} \tag{22}$$

Writing (23) in vector-matrix form

$$\bar{\mathbf{X}} = \mathbf{B} \cdot \mathbf{C} \tag{23}$$

Where

$$\bar{\mathbf{X}} = \left[\bar{u}, \bar{w}, \bar{p}, \frac{\partial \bar{u}}{\partial z}, \frac{\partial \bar{w}}{\partial z}, \frac{\partial \bar{p}}{\partial z}\right]^T, \mathbf{C} = [C_1, C_2, C_3, C_4, C_5, C_6]^T$$

$$\mathbf{B}=\begin{bmatrix} -ie^{\xi z} & -zie^{\xi z} & ie^{-\xi z} & zie^{-\xi z} & -Ki\xi e^{zr(\xi)} & Ki\xi e^{-zr(\xi)} \\ e^{\xi z} & \left(z-\frac{1}{\xi}\right)e^{\xi z} & e^{-\xi z} & \left(z+\frac{1}{\xi}\right)e^{-\xi z} & Kr(\xi)e^{zr(\xi)} & Kr(\xi)e^{-zr(\xi)} \\ 0 & 2Ge^{\xi z} & 0 & 2Ge^{-\xi z} & a_0 e^{zr(\xi)} & -a_0 e^{-zr(\xi)} \\ -i\xi e^{\xi z} & -i\xi\left(z+\frac{1}{\xi}\right)e^{\xi z} & -i\xi e^{-\xi z} & -i\xi\left(z-\frac{1}{\xi}\right)e^{-\xi z} & -Ki\xi r(\xi)e^{zr(\xi)} & -Ki\xi r(\xi)e^{-zr(\xi)} \\ \xi e^{\xi z} & z\xi e^{\xi z} & -\xi e^{-\xi z} & -z\xi e^{-\xi z} & \left(\frac{a_0}{(\lambda+2G)}+K\xi^2\right)e^{zr(\xi)} & -\left(\frac{a_0}{(\lambda+2G)}+K\xi^2\right)e^{-zr(\xi)} \\ 0 & 2G\xi e^{\xi z} & 0 & -2G\xi e^{-\xi z} & a_0 r(\xi)e^{zr(\xi)} & a_0 r(\xi)e^{-zr(\xi)} \end{bmatrix}$$

The parameters $C_1, C_2, C_3, C_4, C_5, C_6$ are constants defined by boundary conditions.

The expression (23) is the solution of the homogeneous equations corresponding to the nonhomogeneous ordinary differential equations (11). In the following procedure, the method of variation of constants has been employed to obtain the solution of (11), therefore, the expression of (15f) should be

$$\overline{p}_1' = -\frac{a_0 i\xi}{K}\overline{u} + \frac{a_0}{K}\overline{w}_1 + \xi^2\overline{p} - \frac{\overline{q}}{K} \tag{24}$$

Assuming C is function respect to z, utilize the (15), (23) and (24), and differentiate (24) to z, gives the equation

$$\mathbf{B}\cdot\mathbf{C}' = \mathbf{S} \tag{25}$$

Where

$$\mathbf{C}' = \left[C_1'(z), C_2'(z), C_3'(z), C_4'(z), C_5'(z), C_6'(z)\right]^T, \mathbf{S} = \left[0,0,0,0,0,\frac{-\overline{q}(\xi,z)}{K}\right]^T$$

Solving the equation (25), we found

$$C_1'(z) = \frac{1}{2a_0}\overline{q}(\xi,z)e^{-\xi z}, C_2'(z) = 0,$$

$$C_3'(z) = \frac{1}{2a_0}\overline{q}(\xi,z)e^{\xi z}, C_4'(z) = 0 \; C_5'(z) = -\frac{1}{2Ka_0 r(\xi)}\overline{q}(\xi,z)e^{-zr(\xi)},$$

$$C_6'(z) = -\frac{1}{2Ka_0 r(\xi)}\overline{q}(\xi,z)e^{zr(\xi)} \tag{26}$$

Integrating (26), gives

$$C_1(z) = \frac{1}{2a_0}\int_0^z \overline{q}(\xi,z_1)e^{-\xi z_1}dz_1, C_2(z) = 1, C_3(z) = \frac{1}{2a_0}\int_0^z \overline{q}(\xi,z_1)e^{\xi z_1}dz_1,$$

$$C_4(z) = 1 \; C_5(z) = -\frac{1}{2Ka_0 r(\xi)}\int_0^z \overline{q}(\xi,z_1)e^{-z_1 r(\xi)}dz_1,$$

$$C_6(z) = -\frac{1}{2Ka_0 r(\xi)}\int_0^z \overline{q}(\xi, z_1) e^{z_1 r(\xi)} dz_1 \qquad (27)$$

So, the particular solution of equation (11) can express as

$$\tilde{\overline{\mathbf{X}}} = \mathbf{BC}(\mathbf{z}) \tag{28}$$

Where

$\mathbf{C}(\mathbf{z}) = \left[C_1(z), C_2(z), C_3(z), C_4(z), C_5(z), C_6(z)\right]^T$

Hence, the general solution of equation (11) are

$$\overline{\mathbf{X}} = \mathbf{B}\left[\mathbf{C} + \mathbf{C}(\mathbf{z})\right] \tag{29}$$

From (29), we can express the displacements and pore pressure in the transformed domain, $\overline{u}$, $\overline{w}$, $\overline{p}$. Using inverse Fourier transform, we obtain

$$u = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} \overline{u} e^{-i\xi x} d\xi \tag{30a}$$

$$w = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} \overline{w} e^{-i\xi x} d\xi \tag{30b}$$

$$p = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} \overline{p} e^{-i\xi x} d\xi \tag{30c}$$

Furthermore, let us use Fourier transform to the stress-strain relationships, gives

$$\overline{\sigma}_x = -i\xi(\lambda + 2G)\overline{u} + \lambda\frac{\partial \overline{w}}{\partial z} - \overline{p} \tag{31a}$$

$$\overline{\sigma}_z = (\lambda + 2G)\frac{\partial \overline{w}}{\partial z} - i\xi\lambda\overline{u} - \overline{p} \tag{31b}$$

$$\overline{\tau}_{xz} = G\left(\frac{\partial \overline{u}}{\partial z} - i\xi\overline{w}\right) \tag{31c}$$

In (29), we know that $\frac{\partial \overline{u}}{\partial z}$, $\frac{\partial \overline{w}}{\partial z}$ .Substituting it into (31), we can obtain the stress in the transformed domain. Using inverse Fourier transform to (31), the stress under plain strain conditions can be expressed as

$$\sigma_x = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} \overline{\sigma}_x e^{-i\xi x} d\xi \tag{32a}$$

$$\sigma_z = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} \overline{\sigma}_z e^{-i\xi x} d\xi \tag{32b}$$

$$\tau_{xz} = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} \overline{\tau}_{xz} e^{-i\xi x} d\xi \tag{32c}$$

The expressions (30) and (32) are the displacements, pore pressure and stresses of plain strain consolidation.

5 Example

The example used to illustrate the foregoing solutions is shown schematically in Figure 1. An isotropic, homogenous layer of soil occupies the region $0 \le z \le h$. The layer is loaded along its upper surface *z*=0 by a uniform strip loading *q* with occupies the area $-l/2 \le x \le l/2$ and may be assumed to have been applied at time $t=0^+$, and thereafter held constant. Free drainage is allowed across the upper surface of the layer. Movement is either totally restricted along the base.

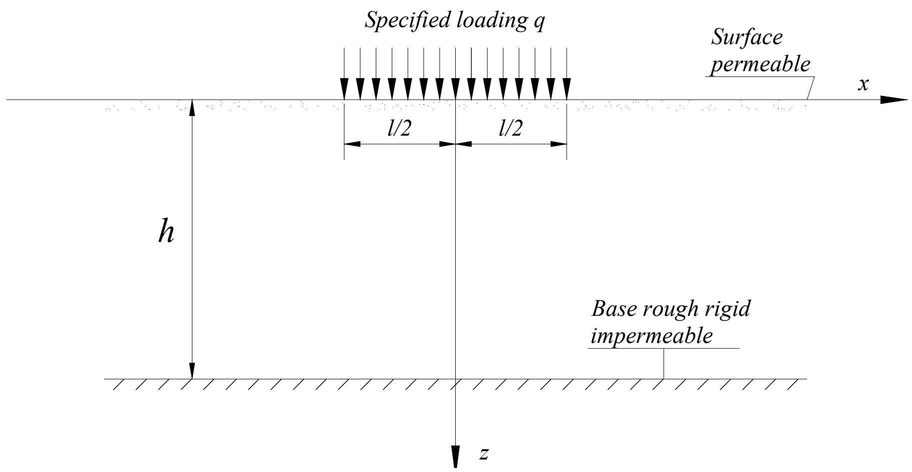

Figure 1. The schematic of the model

The details of the boundary conditions then takes the form shown in Table 1.

Table1 The boundary conditions

Surface *z*=0	Permeable	$p=0$
	Specified surface load	$\sigma_z = -q\left(-\frac{l}{2} \le x \le \frac{l}{2}\right)$,other $\sigma_z = 0$
		$\tau_{xz} = 0$
Base *z*=*h*	Impermeable	$\frac{\partial p}{\partial z} = 0$
	Rough rigid	$u=0$
		$w=0$

Obtaining the solution to such a problem involves evaluating an integral such as that given in (30) and (32). We can use two point Gaussian integrand and Simpson integrand method to approximate the integrals.

Figure 2 shows the variation of excess pore water pressure with time along the center line *x*=0 for this problem. The results show that the curve in good term to other reports, such as Booker and Small etc..

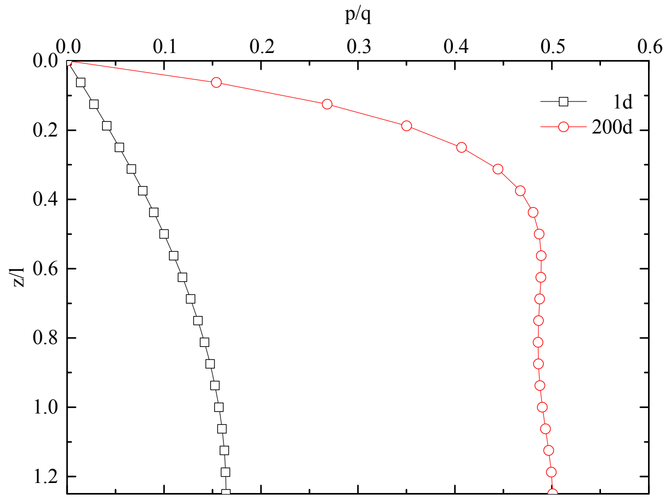

Figure 2. Pore pressure distribution at various time

6 Conclusion

The solutions of the plain strain consolidation we have been presented in this paper are effective. Using these solution some consolidation problem of other boundary conditions are available also. The success of the method can easily obtained by using numerical method.

References

CHEN Zheng-han, HUANG Hai, LU Zai-hua. (2001).Nonlinear and elasto-plasticity consolidation models of unsutured soil and applicaions. Applied Mathematics and Mechanics,Vol 22 , No.1 , 104-116.

Hélène Barucq, Monique Madaune-Tort, Patrick Saint-Macary. (2005).On nonlinear Biot's consolidation models. Nonlinear Analysis 63, 985–995.

J. R. Booker, J. C. Small. (1982).Finite layer analysis of consolidation I. International journal for numerical and analytical methods in geomechanics. Vol. 6,151-171.

John Mcnemee, R.E. Gibsson. (1960).Displacement functions and linear transforms applied to diffusion through porous elastic media. Quart. Journ. Mech. and Applied Math., Vol. XIII, Pt. 1, 1, 98-111.

John Mcnemee, R.E. Gibsson. (1960). Plane strain and axially symmetric problems of the consolidation of a semi-infinite clay stratum. Quart. Journ. Mech. and Applied Math., Vol. XIII, Pt. 2, 210-217.

K. Terzaghi, Theoretical Soil Mechanics. (1943). Wiley, New York.

M. A. Biot. (1941).General theory of three-dimensional consolidation. J. App. Phys. 12, 155-164.

M.M. Selim, M.K. Ahmed. (2006) . Plane strain deformation of an initially stressed orthotropic elastic medium. Applied Mathematics and Computation 175

221–237.

N. Manoharan , S. P. Dasgupta. (1995).Consolidation Analysis Of Elasto-Plastic Soil, Comouters & Structures Vol. 54, No. 6. 1005-1021.

N.R. Garg, R. Kumar, A. Goel, A. Miglani. (2003).Plane strain deformation of an orthotropic elastic medium using an eigenvalue approach, Earth Planet Space 55 3–9.

R.E. Gibson, R. L. Schiffman, S. L. PU. (1970).Plane strain and axially symmetric consolidation of a clay layer on a smooth imperious base. Quart. Journ. Mech. and Applied Math., Vol. XXIII, Pt. 4,505-520.

R. Kumar, A. Miglani, N.R. Garg. (2000) .Plane strain problem of poroelastictity using eigenvalue approach, Proc. Indian Acad. Sci (Earth. Planet Sci) 109 371–380.

Y.-C. LI. (1999).Finite element analysis for a finite conductivity fracture in an infinite poroelastic medium. International journal for numerical and analytical methods in geomechanics. Vol. 23,187-215.

Zhi-yong AI, Chao WU. (2009).Plane strain consolidation of soil layer with anisotropic permeability. Applied Mathematics and Mechanics, Appl. Math. Mech.-Engl. Ed. 30(11), 1437-1444.

An Assessment of Two Methods for Fatigue Life Prediction of an Aluminum Alloy Car Body

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Abstract: This article introduced respectively the equivalent structural stress method which is based on the American ASME standard and the Miner cumulative fatigue damage theory. The Miner theory uses the S-N curve of welded joints provided in the IIW standard. These two methods are applied to the specific engineering cases of the aluminum alloy car body. The comparison shows that the equivalent structural stress method should be popularized widely.
Keywords: Fatigue life prediction and evaluation; Welded structure; IIW standard; The equivalent stress method.

1 Introduction

In general, the fatigue failure of car body usually occurs in the welding joint. So the fatigue life of welded joint is the most important in the fatigue assessment of car body structure. In this paper, the fatigue life prediction of the aluminum alloy car body is carried out by the equivalent structural stress method and the IIW standard weld fatigue assessment methods. The comparison of these two methods shows that the equivalent structural stress method is more general and accurate.

2 Miner linear cumulative fatigue damage theory

In Miner's linear damage theory, the material fatigue damage is caused by the continuous cyclic load. The level of the fatigue damage is proportional to the stress cycle times. Supposing N_1 is the cycle number of the fatigue damage under a specific stress. At this time, the total network is W. When the cycle number is n_1, the absorbed network W_1 can be gotten

$$\frac{W_1}{W} = \frac{n_1}{N_1} \qquad (2\text{-}1)$$

If the number of loading conditions is m, the material fatigue damage can be expressed as

$$D = \frac{n_1}{N_1} + \frac{n_2}{N_2} + \cdots + \frac{n_m}{N_m} = \sum_{i=1}^{m} \frac{n_i}{N_i} \quad (i = 1, 2, \cdots, m) \tag{2-2}$$

Where n_i the stress cycle number at the level of is stress i; N_i is the cycle number of the fatigue damage under this stress; D is accumulative fatigue damage. If D = 1, material is damage.

The following, the life mileage of the vehicle L_L and the life period L_T are introduced. L_k is the life mileage under load spectrum k (k=1, 2 … m), β_k is the total cycle number per mile, L_y is the running mileage per year.

$$L_L = \frac{1}{\sum_{k=1}^{m} \frac{1}{L_k}} \tag{2-3}$$

$$L_T = L_L / L_Y \tag{2-4}$$

Where $L_k = 1/[\beta_k(\sum_{i=1}^{m} D_i)]$.

3 Equivalent structural stress method

The equivalent structural stress method is based on the stress transfer techniques in fracture mechanics. The equivalent structural stress is used as the controlling parameter of the fatigue stress. It requires much more stringent theoretical consideration of various fatigue influencing factors, such as plate geometry, loading effects and welding gaps etc. Besides, as the nodal force is much less sensitive than the stress in the analysis of the finite element. So, the joint force method is applied to the stress calculation. The insensitivity is the obvious advantage than the IIW standard method.The equivalent structural stress method is not restricted by the difficulty of precisely determining the concentrated stress at the welding points. Because of the insensitivity to computational mesh in structure stress calculation and the equivalent structure stress transfer technique, the method is superior to other methods in many aspects, such as flexibility in the finite element grid, reliability in stress calculation at welding points and the high accuracy forecast in fatigue stress etc.

Based on the ASME standards, the formula for fatigue life of the welded structures is,

$$\Delta S_S = Cd \cdot N^{h} \tag{3-1}$$

The equivalent structural stress can be gotten by

$$\Delta S_S = \frac{\Delta\sigma_S}{t^{(2-m)/2m} \cdot I(r)^{1/m}} \tag{3-2}$$

In which, $\Delta\sigma_S$ is the structural stress which reflects the influence of stress concentration, t is the plate thickness, I(r) represents the influence of load types. The constant m=3.6, Cd and h are the constants of S - N curve (table 3-1), N is cycle-index.

Table 3-1. The parameters of S-N curve

Statistics	C_d	h
mid-value	3495.13	
+2σ	5273.48	
-2σ	2316.48	-0.28
+3σ	6477.60	
-3σ	1885.87	

4 The fatigue resistance S-N curves of the IIW standard

IIW (The International Institute of welding) standard is for evaluating the fatigue life of the welded structures. IIW standard provides the fatigue strength S-N curves measured for the various welded joins in the laboratories. These curves consider the local stress concentration, weld size, and weld shape, stress direction, residual stress and metallurgical conditions. Therefore, these S-N curves are very practical and authoritative. According to the standard, the fatigue life can be considered as infinite under a certain stress range.

As shown in Figure 4-1, the S-N curves are expressed with stress range and the cycle number. The fatigue strength of various welded joints is expressed by the fatigue level (FAT). It represents the constant stress range after 2 million loading cycles.

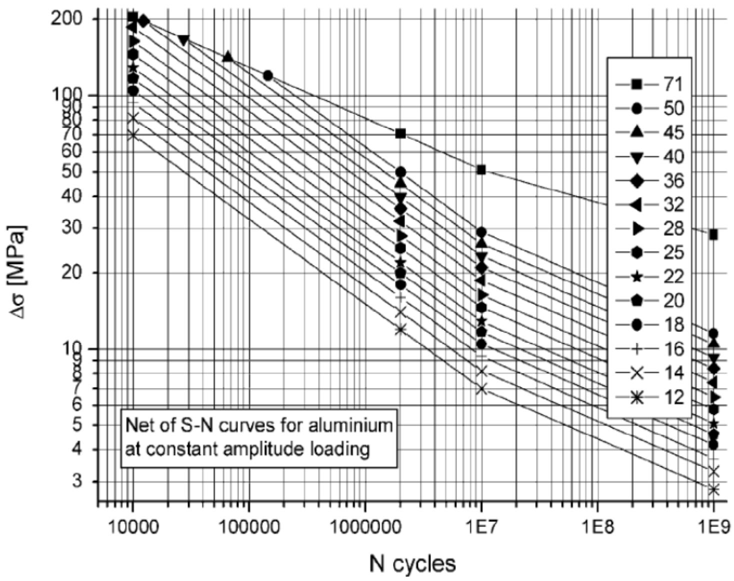

Figure 4-1. The S-N curve of IIW standard

The S-N curves of the IIW standard in the double logarithmic coordinate system are not straight line but are dual-slope lines with the inflection point being at $Nc=1\times10^7$. The fatigue strength corresponding to $Nc= N=2\times10^6$ is the FAT level. In addition, the cut-off cycle-index of the S-N curves is $N_{cut}=1\times10^9$. This means that, in fatigue experiments, the fatigue loading cycles can reach 10^9 times. So these S-N curves are high accuracy.

Figure 4-2 in the IIW standard listed the joint details of steel and aluminum alloy and the fatigue strength grade (FAT) value. These weld joint details are derived from actual engineering structures.

Firstly, select the joint geometry that corresponds to the design requirement and mechanical characteristics from these tables. Secondly, mark down fatigue strength grade FAT values in the table. Then, determine the parameters from Figure 4-2. Finally, S-N curve can be drawn according to these parameters.

Stress ranges		Values of constant C: $N=C/\Delta\sigma^m$ or $N=C/\Delta\tau^m$		
FAT class [MPa]	Stress at knee point $\Delta\sigma_{L,R,k}$ [MPa]	For stress ranges above knee point	For stress ranges below knee point Constant C: $N=C/\Delta\sigma^m$	
Δσ at 2E+6 cycles	**Δσ at 1E+7 cycles**	**m=3**	constant amplitude **m=22**	variable amplitude **m=5**
125	73.1	3.906E+12	1.014E+48	2.091e+16
112	65.5	2.810E+12	9.064E+46	1.207E+16

Figure 4-2. Fatigue parameters of the IIW standard

The life prediction algorithm of IIW standard is based on Miner's theory of damage accumulation. There are some assumptions. For a constant amplitude fatigue load spectrum, the damage increments caused by each cyclic loading are equal and independently additive. The damage increments caused by all levels of cyclic loadings are independently additive. The critical material damage is a constant, which depends only on the material properties. Let n_i be the cycle-index of the stress range $\varDelta\sigma_i$ in load spectrum, and N_i be the total cycle-index which will be damaged in the stress range, then the fatigue damage will occur when

$$D = \sum_i \frac{n_i}{N_i} = 1 \qquad (4\text{-}1)$$

In the IIW standard, damage ratio is defined as,

$$\frac{n_i}{N_i} = \begin{cases} \dfrac{n_i(\varDelta\sigma_i)^m}{C_1} & (\varDelta\sigma_i > \varDelta\sigma_1) \\ \dfrac{n_i(\varDelta\sigma_i)^{m+2}}{C_2} & (\varDelta\sigma_2 \le \varDelta\sigma_i \le \varDelta\sigma_1) \end{cases} \qquad (4\text{-}2)$$

Where, $\Delta\sigma_1$ and $\Delta\sigma_2$ are the inflection points of S-N curve, C_1 and C_2 are constant coefficients and m is the slope of S-N curve.

5 Application examples

5.1 The strength analysis by finite element

In this paper, a simplified finite element model of 160 km emus (district) aluminum alloy B car was built. ANSYS software is adopted to the static strength analysis and determine the evaluation points of dynamic stress range spectrum. The car body finite element model is shown in Figure 5-1.

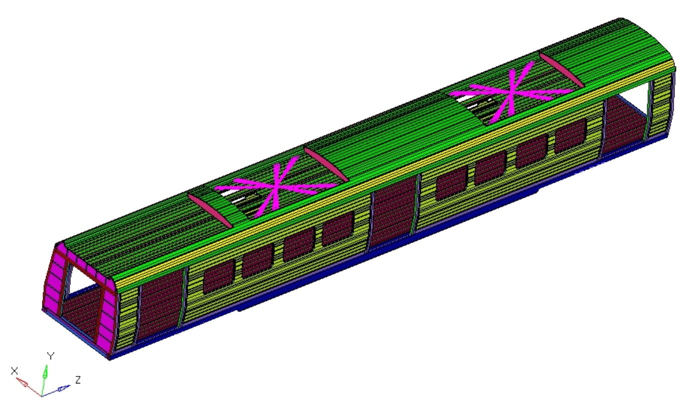

Figure 5-1. Finite element model of aluminum alloy car body

5.2 Fatigue loading conditions

The fatigue loading is applied according to "BS EN 12663-1:2010". The stress concentration and fatigue life prediction are analyzed. This means, a ±0.15g acceleration is applied vertically, longitudinally and transversely to the car body, respectively. The fatigue load conditions are as shown in Table 5-1.

Table 5-1. The load cases for fatigue strength calculation

Working condition	Describe the working conditions	X axle	Y axle	Z axle
1	longitudinal acceleration	0.3×g		
2	transverse acceleration		0.3×g	
3	vertical acceleration			0.3×g

Boundary condition and vertical constraints were imposed on the air spring seat pad, longitudinal and transverse constraints were imposed on the center pin plate.

5.3 The position of the important weld joint

In accordance with the requirements of the specification, 85 importance weld joints in the car body were identified. In this paper, two weld joints that are most concerned in the design were selected for investigation. Their positions are as shown in Figure 5-2 and Table 5-2.

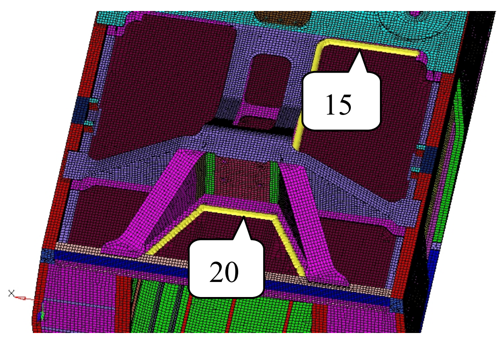

Figure 5-2. The important weld joint position

Table 5-2. The position of important weld joint

No.	Location
15	Weld joint between a side sleeper beam cover plate surface and under the chassis surface
20	Weld joint between coupler seat reinforcement on the cover plate and surface under the chassis

5.4 Analysis results

5.4.1 The result obtained by the equivalent structural stress method

By the master S-N curve method, the finite element strength analysis was carried out on the car body under the three kinds of fatigue strength condition. The fatigue analysis software FE-WELD and the Miner's linear damage theory are used to evaluate the fatigue life of the two weld joints. The equivalent structural stress curve of two welds are shown as Figure 5-3 and Figure 5-4.

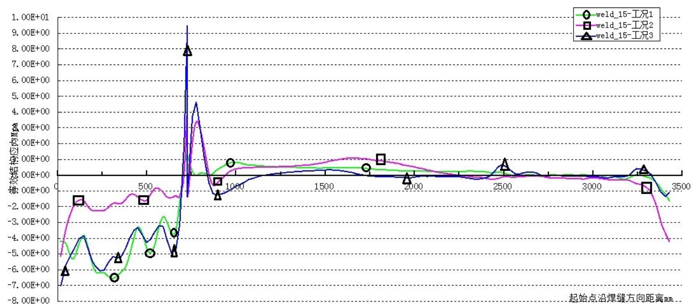

Figure 5-3. Structural stress curve changed with the weld length change of No.15 weld joint under three working conditions

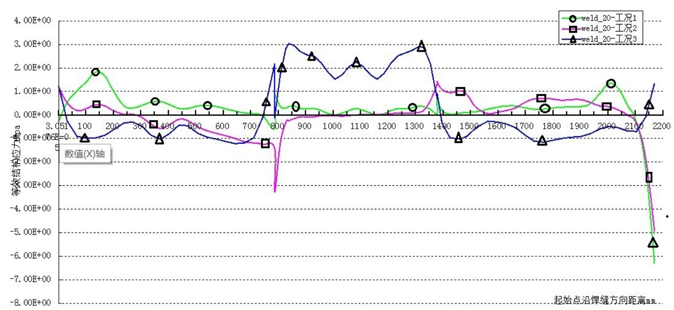

Figure 5-4. Structural stress curve changed with the weld length change of No.20 weld joint under three working conditions

Based on the calculated structural stress and the equivalent structural stress of the two weld joints, the cumulative fatigue damage ratios within 10^7 stress range are gotten by the Miner linear damage theory. The results are shown in Table 5-3.

Table 5-3. The ratio on cumulative fatigue damage of two weld joints

Weld joints	Computational item	Condition 1	Condition 2	Condition 3	Cumulative damage

Weld joints	Computational item	Condition 1	Condition 2	Condition 3	Cumulative damage
15	damage ratio	3.44344E-010	8.17131E-010	1.67102E-009	2.83249E-009
20	damage ratio	5.43717E-010	2.28139E-010	2.06180E-012	7.73918E-010

5.4.2 The result by the nominal stress method of IIW standard

Based on the joint states of the weld seams, the points with maximum stress variation range are chosen as the evaluation points. Miner cumulative damage theory is used to predict fatigue life for the two weld joints with the fatigue characteristic parameters selected in the IIW standard. The cumulative damage ratios of the two weld joints were calculated respectively under three working conditions, shown in Table 5-4.

Table 5-4. The ratio on cumulative fatigue damage of two weld joints

Weld joint	FAT Level	Condition	Variation of stresses（MPa）	Damage ratio	Cumulative damage
15	22	1	2.696473	4.04E-04	0.001630063
	22	2	3.139867	8.64E-04	
	22	3	2.638359	3.62E-04	
20	22	1	0.254468	3.02E-09	1.38887E-08
	22	2	0.282917	5.13E-09	
	22	3	0.289244	5.73E-09	

The comparison of the cumulative damage ratios between Master S-N curve and resistance to fatigue S-N curve in the IIW standard is shown in Table 5-5.

Table 5-5. The result comparison of two methods

	The equivalent structural stress method	Resistance to fatigue S - N curve in the IIW standard
NO.	cumulative damage value	cumulative damage value
15	2.83249E-009	0.001630063
20	7.73918E-010	1.38887E-08

From the table 5-5, we can see the results of fatigue life prediction based on the equivalent structural stress are lower than that on the IIW standard.

6 Conclusion

1) The results of cumulative fatigue damage is much smaller than 1 under the vertical, longitudinally or transversely loading conditions. Compared with the IIW standard weld fatigue assessment methods, the equivalent structural stress method is more accurate. The cumulative damage ratio from the equivalent structural stress method takes into account the stress concentration. This method does not need to specify the joint types, so it's more general.

2) The equivalent structural stress method fully considers the effects of the weld toe gap, the thickness of the welded joint plate and the influence of load model. It can replace the other S-N curves of various joints with a single master S-N curve. So, it can make the results more accurate.

3) The evaluation of car body fatigue life can find out the weak parts of the product. So the computation can improve the quality of the product in the design stage. The results presented in this paper are benefit to the further improvement of car body design.

Acknowledgement

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References

A. Palmgren. Die Lebensdauer von Kugellager. VDI-Zeitsehrift 58:339-341.

DONG, P. (2001). A Structural Stress Definition and Numerical Implementation for Fatigue Analysis of Welded Joints [J]. International Journal of Fatigue, 23 (10): 865-2876.

DONG, P. HONG J K. (2007). Analysis of Recent Fatigue Data Using the Structural Stress Procedure in ASME Div 2 Re-write [J]. Journal of Pressure Vessel Technology, 129: 355-362.

International Institute of Welding, (1996). The fatigue design of welded structure and components [Z]. International Institute of Welding.

M. A. Miner. (1945). Cumultive Damage in Fatigue Journal of Applied Mechnacis Trans． ASME, (12):159-164.

Structural Optimization for Head Cars of High-Speed Trains in Light of Aerodynamics

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Abstract: With the increase of train speed, aerodynamic drag as a part of running resistance becomes increasingly important for train. In order to reduce the aerodynamic drag, configuration optimization is required for train heads, especially for high-speed trains. A simulation based configuration optimization for train heads is developed in this paper on the basis of computational fluid dynamics theory. Both manual and Sculptor-software-integration curve-driven arbitrary deformation are used and compared. The optimization results state that the optimal head configuration can be obtained by combining three software; ISIGHT, Sculptor, and Fluent. Therefore, this study provides a method for optimization and design of train heads.

Keywords: Surface reconstruction; Aerodynamic performance; Numerical simulation; Optimization; ISIGHT.

1 Introduction

With the increase of train speed, the interaction between trains and air become more intensive. The aerodynamics performances of trains draw increasingly attention. Research of train aerodynamics generally involves of air resistance, pressure wave, train wind, pressure pulse resulted from train meeting, pressure wave in tunnel, aerodynamic noise and so on. Study shows that the air resistance accounts for more than 90% of total running resistance when the running speed of train reaches 350km/h in open air. Aerodynamic drag is increased with the square of train speed and the required power is increased with the cube of train speed. In the design of high-speed train, the train configuration is generally designed to be a streamline in order to effectively reduce the air resistance and improve the running efficiency. The configurations of train head and tail seriously affect the pressure drag of trains. They are closely related with the aerodynamic performance of train and are extremely important parts in the configuration design of trains. Therefore, it is an important research subject to optimize the curves of train heads and effectively reduce the influence of the aerodynamic phenomena to trains and the surrounding for the aerodynamic configuration design of high-speed trains.

There are two main methods for studying the configuration optimization of high-speed trains in the world which are experiment method and numerical simulation method. A lot of research on the above -mentioned aerodynamic problems are performed by Japanese and Germans. In their research, wind tunnel model is used as the main pattern in the simulation tests and the numerical simulation of flow field is used as a main calculation method. In the earlier research, different configurations of train heads have been analyzed using the experiment method of wind tunnel model by Japanese. Analysis results show that the train crossing pressure wave can be reduced and the effect of pressure variation caused by the train operation to the environment can also be decreased effectively, when two-dimensional configuration is used in the train head design. There are mainly two head types for German high-speed trains which are wedge shape and ellipsoid shape, respectively. Research results show that three types of train head configurations are developed based on two-dimensional ICE2 head configuration and are propitious to improve the train performance. They are the configuration of long head in which the bevel of head top is lengthened, the configuration of long and the thin head in which the head side is narrowed and the bevel of head top is lengthened, and the configuration of low roof. By using these three types of configurations, the aerodynamic drag of head car under outside-crosswind load is decreased by 5%. The aerodynamic force and rolling moment, which affect the lateral stability of head car, also can be reduced effectively. Among these three configurations, the improvement result for the configuration of low roof is the best. At present, some researchers in China give their contributions to this project. Wind tunnel experiments are performed using the method of adjusting the parameters for the configuration lines of train heads by Tian Hongqi et al. Optimal design for the streamlined configuration of train heads is achieved through adjusting the control parameters after the relationship between control parameters and aerodynamic performance is analyzed in the light of experiment results. A part of head structures and positions are changed and the improved models are analyzed using the numerical calculation software named CFX by Zhang Jingqiang and Liang Xifeng. The optimal design model is then obtained through the comparisons and analyses of the calculation results. The optimization for head configurations of high-speed trains is implemented by Zhang Xiaogang using three-dimensional turbulent flow of blunt bodies. The relationship between geometric parameters and aerodynamic drag is analyzed and verified by the experiments of wind tunnel. The optimal range of each parameter is then obtained and the optimal configuration of train head is designed according to the optimal ranges.

The study of this paper is mainly focused on the design for curve configurations of train heads based on the computational fluid dynamics. 350km high-speed train is adopted as the basic model and its curves of train head are modified using the automatic mesh deformation software named Sculptor. The flow field and the body pressure distribution are acquired by the numerical simulation and calculation. Two means of optimizations are employed. In the first method, the curve variation is driven by manual adjustment, the configuration of train head is then changed, and optimum driving scheme is explored. In the second method, software named Sculptor and software named Fluent are integrated by a multi-disciplinary optimization software ISIGHT. Automatic solving a specific optimization problem is realized through automatic accessing the fluid analysis and structure analysis and setting the constraint conditions by users. The optimization design for the configuration curves of train heads is gained. At last, the optimal configuration of train head and a new design method for the optimization design of train head are acquired through comparing and analyzing these two kinds of methods.

2 Theory and Method

2.1 Fluid field theory

The train is slender object with a large length-width ratio and has a complex configuration. Thus, the air flow around train is a complete three-dimensional motion. There is a strong vortex in the end of the train and the flow field of train is the turbulent flow. The fluid used in this paper is the uncompressible fluid, the mathematical model of calculation is the standard $k-\varepsilon$ turbulence model, and can be expressed by the control equations as follows:

$$\frac{\partial}{\partial t}(\rho k)+\frac{\partial}{\partial x_i}(\rho k u_i)=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] +G_k+G_b-\rho\varepsilon-Y_M+S_k \quad (1)$$

$$\frac{\partial}{\partial t}(\rho \varepsilon)+\frac{\partial}{\partial x_i}(\rho \varepsilon u_i)=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right] +G_{1\varepsilon}\frac{\varepsilon}{k}(G_k+C_{3\varepsilon}G_b)-C_{2\varepsilon}\rho\frac{\varepsilon^2}{k}+S_\varepsilon \quad (2)$$

Where G_k is the secondary generation term of the turbulence energy, k caused by the gradient of average velocity; G_b is the secondary generation term of the turbulence energy k caused by the floatation. For the incompressible fluid, G_b equals to zero, i.e., $G_b = 0$; Y_M represents the effect of ripple expansion of compressible turbulent to the total dissipation rate. For the incompressible fluid, Y_M equals to zero, i.e., $Y_M = 0$.

Turbulent kinetic energy is resolved by formula (2.1) and. The turbulent dissipation rate is resolved by formula (2.2).

Turbulent viscosity μ_t can be expressed as the function of k and ε. It can be described as:

$$\mu_t=\rho C_\mu\frac{k^2}{\varepsilon} \quad (3)$$

Where C_μ is the empirical constant.

The continuity equation can be written as:

$$\frac{\partial\rho}{\partial t}+\frac{\partial}{\partial x_i}(\rho u_i)=0 \quad (4)$$

Where u_i represents the velocity of flow field surrounding the multiple units; ρ is the air density; x_i represents three coordinate components.

The momentum conservation equation can be introduced as:

$$\frac{\partial}{\partial t}(\rho u_i)+\frac{\partial}{\partial x_j}(\rho u_i u_j)=-\frac{\partial P}{\partial x_i}$$
$$+\frac{\partial}{\partial x_j}\left[u\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}+\frac{2}{3}\delta_{ij}\frac{\partial u_i}{\partial x_i}\right)\right] \quad (5)$$

Where u_i or u_j is the velocity of fluid field; x_i or x_j is three coordinates; p is the pressure; δ_{ij} is Kronecker symbol; δ_{ij} has the expression of δ_{ij}=1.0 when $i=j$ and has the expression of δ_{ij}=0 when $i\neq j$; u is the aerodynamic viscosity.

Energy equation can be written as:

$$\frac{\partial(\rho T)}{\partial t}+div(\rho\mu T)=div\left(\frac{k}{c_p}gradT\right)+S_T \quad (6)$$

Where c_p represents the specific heat capacity; T represents the temperature; k is the heat transfer coefficient of fluid; S_T represents the head resource in the fluid and the thermal energy transferred from the mechanical energy of fluid due to the viscous effect. Sometimes, S_T is defined as the viscous dissipation item.

2.2 Surface reconstruction technology used in the design of high-speed train heads

The shape of the high speed train head is provided with a plurality of surface organic composition of interconnected as a whole, the correlation characteristics of these surfaces bring the phenomenon that one surface is changed and other surfaces are alternated correlatively. Streamlined train head configuration usually adopts the three-dimensional free surface which is developed based on the shape of half a free fall drop.

2.2.1 Surface reconstruction technology

Surface reconstruction technology is adopted to complete the geometric reconstruction of entities through reconstructing the contour surface. It is also one of geometric modeling technologies. Non-Uniform Rational B-Spline(NURBS) surface reconstruction method is developed based on Be'zier method and B-Spline method is widely used now. Its mathematical description can be written as:

$$P(u,v)=\frac{\sum_{i=0}^{n}\sum_{j=0}^{m}W_{i,j}P_{i,j}N_{i,k}(u)N_{j,l}(v)}{\sum_{i=0}^{n}\sum_{j=0}^{m}W_{i,j}N_{i,k}(u)N_{j,l}(v)} \quad (7)$$

Where $N_{i,k}(u)$ and $N_{j,l}(v)$ are the primary functions of B-Spline in the directions of u and v, respectively; k is the degree for the primary functions of B-Spline in the direction of u; l is the degree for the primary functions of B-Spline in the direction of v; W is the power factor sequence; note vector in the direction of u can be written as $U = [u_1, u_2, \ldots u_{n+k+1}]$ and note vector in the direction of v can be written as $V = [v_1, v_2, \ldots v_{m+l+1}]$.

2.2.2 Modeling the curve configuration of train head

The surface structure for the head of high-speed trains is extremely complex. In this paper, head surface is created through controlling lines which involving of control lines and assistant control lines. Several control lines are drawn in the horizontal section, transverse section and longitudinal section since NURBS curves are easy to be controlled and modified. These three dimensional control lines are intertwined to outline the basic contour of the train head. Smooth contour can be obtained using NURBS surface reconstruction method. Control lines used in this paper are illustrated from Figure 1 to Figure 2, respectively.

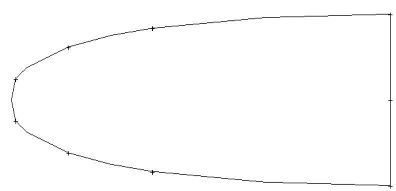


Figure 1. Configuration in the horizontal section

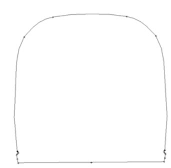


Figure 2. Configuration in the cross section

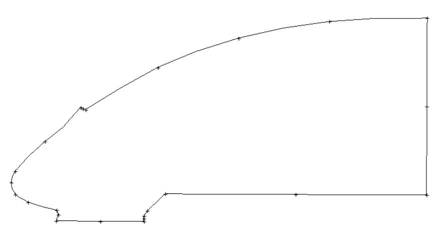


Figure 3. Configuration in the longitudinal cross section

Staggered grid lines are achieved through dominating the control lines and assistant control lines. Smooth model for head of high-speed train, as shown in Figure 4, is created using the surfaces reconstruction technology of CAD.

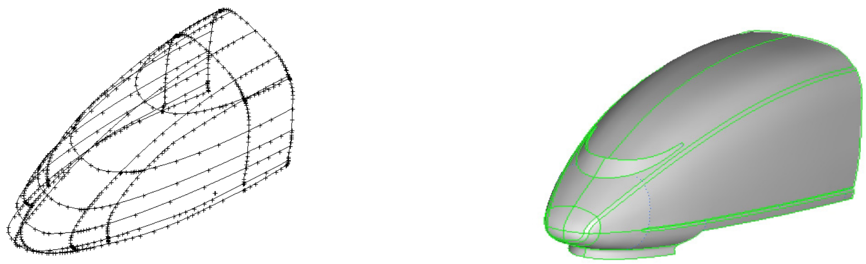


Figure 4. Staggered grid line and geometric model of train head

2.3 Optimzation model of train configuration structure

In order to reduce the aerodynamic drag of train operation and improve the aerodynamic performance when trains are running in the air, the contour surface of train head is optimized with two constraint conditions in which the head length and the maximum cross section are same as those of original train. The optimization model is introduced as follows:

design variable: $Y = \left[y_1, y_2 ......y_n \right]^T \in R_n$

objective function: min $F\left(y\right)$

constraint condition：G

Where variable Y is the coordinate of control point for the surface driving model. Only 6 control points are used in this paper; F (y) is the aerodynamic resistance value of train operation; constraint condition G includes the design variable Y which is the variation range of control point coordinate and is about 0.5m. G also involves of the length of original train head and the maximum transverse section of original train head. The essence of optimization problem is to minimize the aerodynamic resistance value of train head with certain constraints, which is realized by the curve-driven arbitrary deformation controlled by the variation of control points.

3 Optimal design for head configuration of high-speed train

3.1 Creating the finite element models of train head

The model of train head studied in this paper is symmetrical about the maximum longitudinal section and a half of train head is adopted in this paper. Since the outer space of train is infinite and cannot be simulated by computer, the finite region is substituted for the infinite region in this paper and results of the finite computational region is made to be approaching to those of infinite computational region. The computational region is defined as a hexahedron of 40m×6.2m×15m according to the size of train head where the upper calculation space is 1.5 times larger than the length of train head and the lower calculation space is 3 times larger than the length of train head. The train head and computational region are then meshed using the software named HyperMesh. The regions near the train head are meshed using the radial grid, i.e., mesh near the train head is dense and mesh is become sparse gradually from the head to the region in the distance. Mesh of train head region is shown in Figure 5.

Boundary conditions are defined as that the inlet is the velocity inlet and its inlet velocity value is 97.2 m/s. The outlet is the pressure outlet and the train wall is fixed.

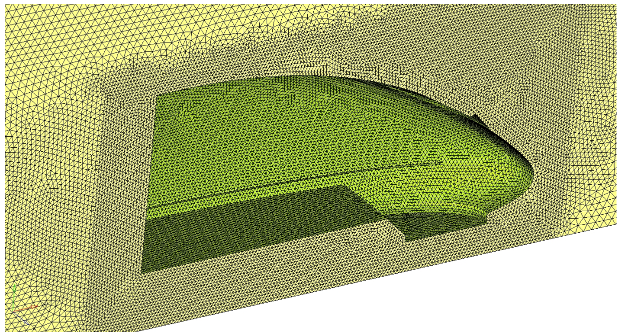


Figure 5. Finite element model of train head zone

3.2 Curve-driven modeling of train head based on software Sculptor

The design requirement for the curves of train head in this paper is to ensure the head length and the maximum cross section of the original train unchanged. In order to clarify the effect of each part of the train head on the aerodynamic drag of train, the train head surface is divided into three parts in the longitudinal direction which are the surface of nose tip, the surface of cab observation window, the transition surface between the train head and the train body. In the configuration design of train head, the train shape appearance should be beautiful and the inside region of train should have the enough space in addition to satisfying the running requirement of aerodynamic characteristics. Thus, the configuration optimization of train has a certain constraints. For example, the transition surface between the train head and train body cannot be changed. A control region is appended to the calculation model of train head using the software named Sculptor. The train head surface is changed simply and conveniently by altering the position of the control point in the control region. The automatic arbitrary deformation of model mesh can be realized, the mesh quality of reconstruction is high, and the model after reconstruction can be used to perform the numerical simulation calculation directly. The surface driving model of train head which is developed in this paper is shown in Figure 6.

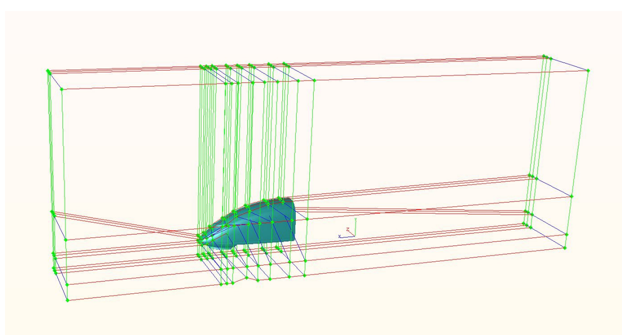


Figure 6. Curve-driven modeling of train head surface and the distribution of controlling points

3.3 Optimization process

Two methods for optimizing the configuration of train head are used in this paper. One is the mesh variation driven by the manual adjustment. Its advantage is that the head configuration could be varied randomly according to the subjective requirements and the optimal configuration model of train head can be obtained. Its drawback is that a lot of work might be needed to find the optimal model. Another is creating the work flow for the optimization design of train head with the help of intelligent optimization software named ISIGT. The optimization model is achieved by the intelligent solution of computer.

3.3.1 Optimization process in manual mode

Two head surface driving schemes are realized by using the first optimization method and are shown in Figure 7 and Figure 8 In the first scheme, the surface height of cab observation window is elevated. In the second scheme, the surface height of cab observation window is depressed.

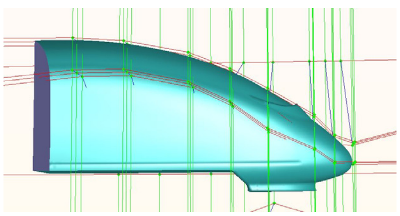
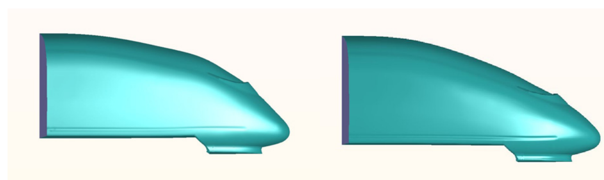


Figure 7. Curve model of original train head



Scheme One **Scheme Two**

Figure 8. Curve models of two schemes

Finite element models of two schemes are imported into the software named Fluent and the flow field analyses are then implemented. Aerodynamic drag and the pressure field analysis of two driving schemes of train head configurations are compared to find the scheme with better aerodynamic performance and obtain the optimum model.

3.3.2 Optimization process of software integration based on the ISIGHT

The automation and multidisciplinary objective optimization of the simulation process is realized by the software ISIGHT. The data model and the calculation results of software named Sculptor and Fluent T are also integrated and transmitted by the software ISIGHT. The optimization target is determined and the optimum solution is sought by its optimization algorithm.

In the optimization and analysis of head configuration, the position height (variable y) of control point on the head surface is selected as the optimization variable. While the aerodynamic drag (variable F) of train head operation is chose as the optimization object. The optimization process is realized using the software ISIGHT in which the design variables, the optimization object, and the scope of variable values are defined. The mixed integer optimization algorithm named MOST is adopted in this paper to seek the optimum solution in which the initial value of the design variable is set to be 0 and the variation range of variable y is set as $-0.5m \leq y \leq 0.5m$. The optimum solution is obtained using the integrated optimization method

ISIGHT and can be expressed as y1=-0.1738； y2=-0.1832； y3=-0.3751； y4=-0.1938； y5=-0.5； y6=-0.5.The program is stopped when the number of iteration step is 112.

4 Optimization result and analysis

After the optimizing the train head configuration by two means, each scheme is realized through changing the train head configuration. The pressure distribution contours of the flow field for the optimization models are achieved through analyzing the effect of each method on the aerodynamic drag and comparing the aerodynamic performance of each scheme. The pressure and velocity vector distribution contours of train heads for the original model and the each scheme after the optimization are illustrated as follows:

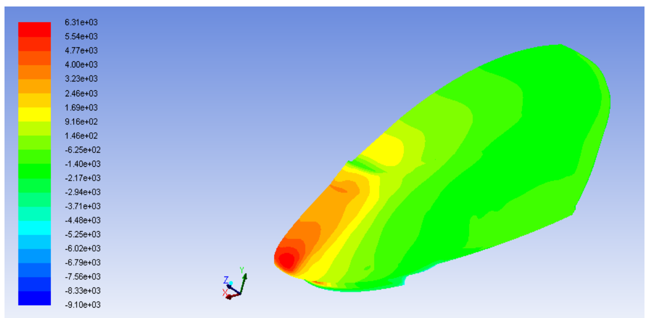


Figure 9. Pressure distribution for train head surface of original model

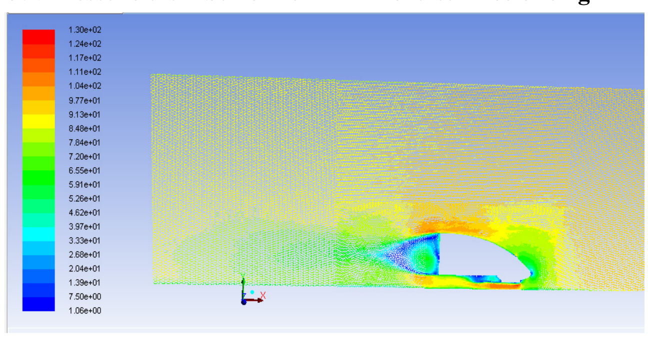


Figure 10. Velocity vector distribution on the symmetry plan of original model

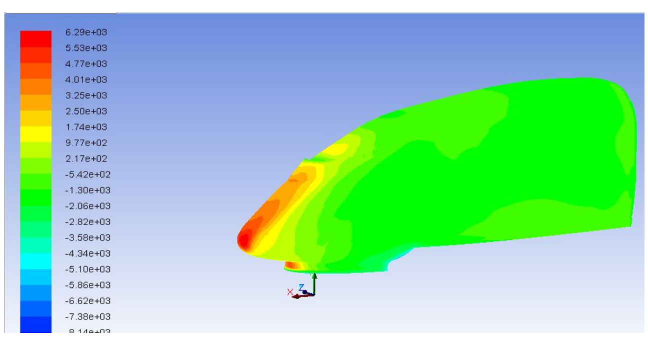


Figure 11. Pressure distribution for train head surface of scheme One

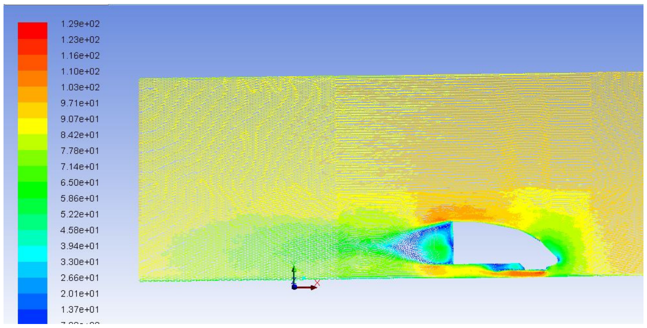


Figure 12. Velocity vector distribution on the symmetry surface of scheme One

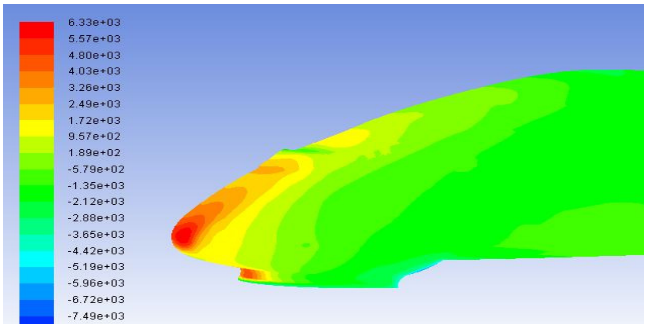


Figure 13. Pressure distribution for train head surface of scheme Two

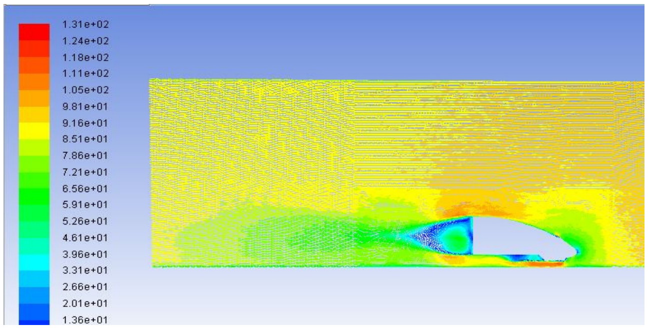


Figure 14. Velocity vector distribution on the symmetry surface of scheme Two

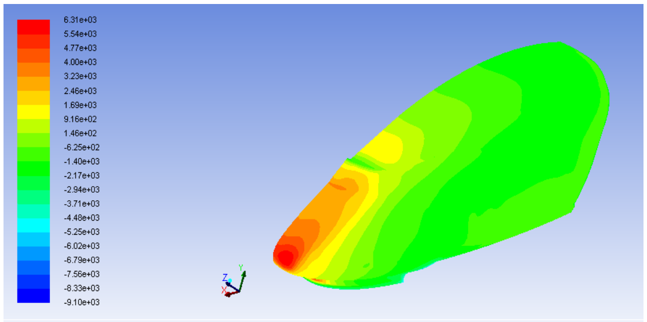


Figure 15. Pressure distribution for train head surface after optimization integration

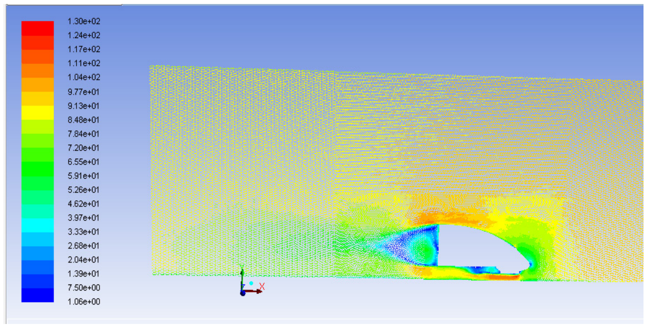


Figure 16. Velocity vector distribution on the symmetry surface after optimization integration

After analyzing the pressure distribution contour of train head, it is found that the flow field around the windward side of train head is in a state of the positive pressure due to the air compression loaded on the train head when the train is running. The pressure at the nose tip of train head is the highest. After passing the nose tip of train head, the speed of air flow is increased, the pressure is decreased, and a negative pressure zone is generated at the bottom of cab observation window. A positive pressure zone is generated at the transition part between the head of driver cab and the air deflector of train roof. The aerodynamic drag of train head is increased due to the positive pressure.

It can be seen from the distribution contour of velocity vector for the symmetry of train head, the flow is separated at the nose tip of train head. One portion of the gas stream flows upward to the roof and another portion of the gas stream flows down to the bottom of train head. The upper airflow is accelerated at the top of the nose tip, is separated at the tail, and forms a turbulent region. The lower airflow must traverse through the region between the bottom of train body and the pavement. It is converged with the upper airflow finally on the upper surface of train head. The turbulent flow is formed and the drag is generated.

The comparison between aerodynamic drag of each scheme is listed in Table1. In Scheme Two, the aerodynamic drag is reduced by abating the surface height of cab observation window. In the optimization results obtained by software ISIGHT, surface height of cab observation window is debased significantly.

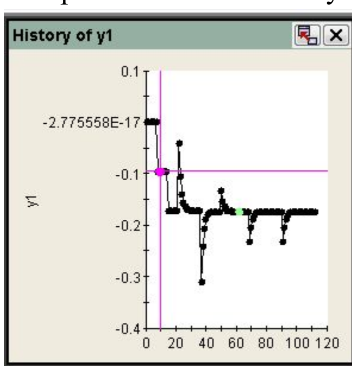
Table 1.Comparision table of aerodynamic drag for two schemes(unit：N)

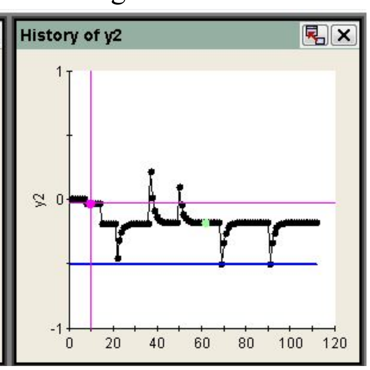
		Pressure drag	Air fraction resistance	Total drag
Train of original configuration		-2378.37	-617.48	-2995.85
Manual driving optimization	Scheme One	-2390.99	-624.89	-3015.88
	Scheme Two	-2339.644	-606.91	-2946.55

Integration optimization using ISIGHT	-2306.58	-604.98	-2911.56

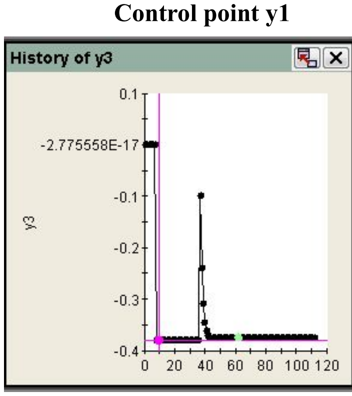
As shown in Table 1, the value of aerodynamic drag for the original model is -2995.85N. The aerodynamic drag of Scheme One is increased and the aerodynamic drag of Scheme Two is decreased by the manual driving surface method. The aerodynamic drag of train head is effectively reduced using the integrated optimization method of the software ISIGHT. It can also be seen from Table 1, the variation of pressure difference is relatively large and the variation of air friction drag is not obvious. Therefore, the aerodynamic drag of train head is reduced through affecting the pressure difference in the optimization of surface configuration of train heads.

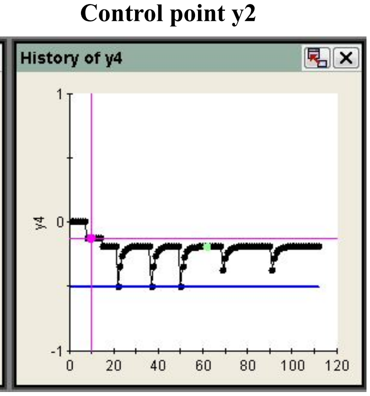
For optimizing the configuration of train heads, the integrated method using the software ISIGHT is more convenient and effective than the manual adjustment method. The monitoring means of visualization are provided in the software ISIGHT. They include the variation history diagram of each variable parameter in the integration and optimization process and the main effect chart of each design variable based on the gradient analysis. As shown in Figure 17 and Figure 18, the effects of design variables on the aerodynamic drag are illustrated. The aerodynamic drag of train head can be effectively reduced through decreasing the height of nose tip and the surface height of the cab observation window. The effect of surface variation of other positions on the aerodynamic drag is small.



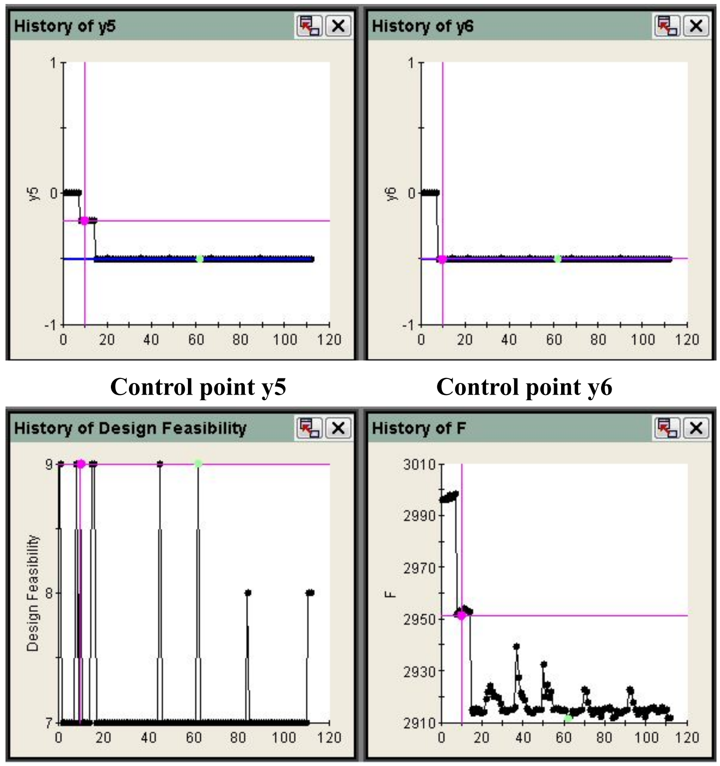


Control point y1 **Control point y2**





Control point y3 **Control point y4**



Control point y5 **Control point y6**

Design feasibility **Aerodynamic drag variable F**

Figure 17. Historical map of parameter variations in ISIGHT optimization process

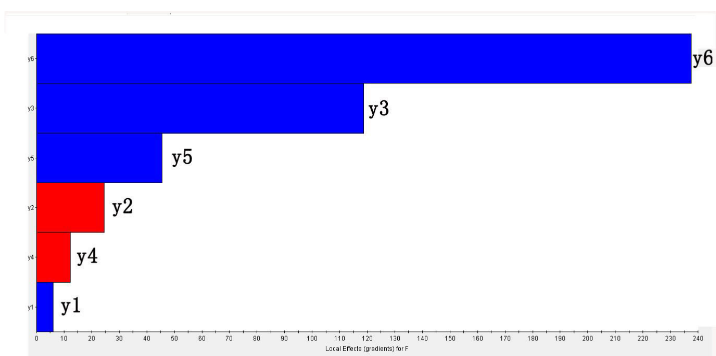


Figure 18. Effect map of design variables on aerodynamic drag

The comparison chart between the integrated optimization model obtained by the software ISIGHT and the original model is shown in Figure 19. It is obvious that using the integrated optimization method to optimize the configuration of train head is feasible. This study provides a theoretical basis for the further research of streamlined train head.

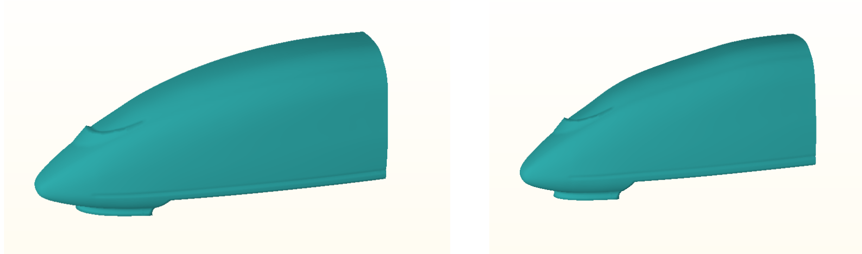


Figure 19. Comparison between the original model and optimized model

5 Conclusions

Both manual and Sculptor-software-integration curve-driven arbitrary deformation methods are used in this paper to conduct the fairness deformation of configuration surface and to improve the aerodynamic drag of train head. Although the two methods are essentially similar, comparison was carried out to investigate the advantages of ISIGHT, Fluent, and Sculptor in the process of optimization design and analysis of train head configuration. The optimization results indicate following results:

(1) The optimal configuration of head of 350-km/h high-speed train presents a better streamlined geometry. The height of nose tip of the train head and the surface height of cab observation window of the optimal configuration are significantly lower.

(2) The aerodynamic drag of the optimal configuration is only reduced by about 3%. Because only the height of a few control points are chose as variables. The results show that the number and location of control points directly affects the optimization result.

(3) Only the aerodynamic drag is considered as optimization goal in this study. More parameters would be considered in the future to achieve the overall optimization.

(4) The optimization methods in this paper are capable for the configuration optimization of high-speed train. This present study could benefit the configuration design of high-speed trains.

Acknowledgement

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References

Brockie N J W , Barker C J. (1990). The aerodynamic drag of high-speed train. *Jounal of Wind Engineering and Industria*, A eradynamics, 34: 2732290.

GUO Rensheng Et al. (2003). Application of Optimization Design, Beijing Publishing House of electronics industry.

GONG Chunlin. (2004). Research on Multidisciplinary Design Optimization Technology, Xi An：Northwestern Polytechnical University.

HE Zhengkai. (2010).Study on the Numerical Simulation of aerodynamics and the drag reduction for Multiple Units: [Dissertation of MPhil].Dalian:Department of Vehicle Engineering, Dalian Jiaotong University.

LAN Hao. (2008).Research and Application of Whole Fairing and Approximation Algorithm of NURBS Curve: [Dissertation of MPhil]．Xian：Xian University of Technolgy, 200803

LI Wen Qiao. (2002). The streamline configuration and structure design for the head of high-speed train. *Railway Locomotive & CAR*, (6):22-25

LIANG jie,Ding Yanchuang,Zhao Wenzhong. (2005). CFD Optimization Design of the Vaned Diffuser Based on iSIGHT Platform. Railway Locomotive & CAR.

NING Tao. (1993). Research on the Application technology of NURBS surface construction． Beijing: Beijing University of Aeronautics and Astronautics： Dissertation of PhD.

SU Wenhui. (2005).Car Body Design and Outer Flow Field Numerical Simulation [Dissertation of MPhil． Dalian： Dalian University of Science and Technology.

WU Qinghai. (2002). A Study on Numerical Simulation of Train Aerodynamics. *Chinese Railway Science*, 23(4):132-135

XU Ping,Tian Hongqi,Yao Shuguang. (2006). Design method of streamlined head structure. *Chinese Railway Science*, 27(1) :78-82

ZHANG Jian. (2005). Further research on optimum nose shapes of high-speed trains. *Electric Locomotives & Mass Transit Vehicles*, 28(2):5-7

ZHANG Jian. (2000). Study on the optimum configuration for the nose and tail of foreign high-speed trains. *Electric Drive for Locomotives*, (2):16-18

ZHANG Jingqiang, Liang Xifeng. (2003). Numerical calculation of aerodynamic characteristics and improvement for head shape of high speed trains. *Chinese Journal of Computational Mechanics*, 20(5):631—635

ZHANG Xiaogang, Liu Yingqing. (1994).Three-dimensional numerical simulation of turbulent flow and flow around the blunt body. *The proceeding of the fourth national wind engineering and industrial aerodynamics conference*, 350-356

Influence of Structure Parameters of Sonar Domes on Sailing Resistance

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Abstract: Sailing resistance and underwater acoustic performance are decided by the profile and structure parameters of sonar dome. In the present thesis, influence of some key structure parameters, such as length-width ratio of the maximum water surface line of a sonar dome and width-height ratio of the maximum longitudinal section, on sailing resistance of certain "I" ship was numerically researched. The numerical results show that sailing resistance of the ship installed with the sonar dome whose length-width ratio is about 3.4 ~ 3.6 and width-height ratio is about 1.1 ~1.2 is significantly smaller than installed with other sonar dome. Moreover, the drainage volume of the sonar dome is smaller than others and its comprehensive performance is best compared with other sonar dome. The numerical results agree well with the experimental data.

Keywords: Sonar dome; Structure parameters; Sailing resistance; Numerical simulation.

1 Introduction

Most modern medium and large ships are equipped with the comprehensive sonar equipments at the bottom of them. Whether the ship and submarine sailing or mooring, there are water flowing through the surface of the sonar sensor. In order to improve the signal-to-noise ratio and the detection ability of the sonar, it is necessary to avoid the boundary layer separation lest the sonar dome producing vortex noise affecting the sonar usage. Furthermore, the uneven distribution of pressure leads to the pressure pulsation on the surface of the dome when the ship sailing. To a certain extent, it will increase the sailing resistance. In other words, in addition to the size of sonar equipment, sonar performance and sailing resistance are the main parameters which decide the structure and space of the sonar dome. Sonar performance and sailing resistance are consistent with the requirements of the sonar dome's shape. Therefore, studying the external structure parameters of the sonar dome on the influence of sailing resistance has a great significance to improve the sonar detection performance and reduce the sailing resistance.

Five kinds of domes about the external structure were numerical studied by Yingdong Wang. The results show that the comprehensive performance of the dome profile with its head streamline and tail for semi-circular is the best. Based on the

Reference 5, effects of sonar dome's key structural parameters (the length-width ratio of the maximum water surface line and the width-height ratio of the maximum longitudinal section) on sailing resistance was numerically researched. This research will get the external structure parameters which can let the ship has the lowest sailing resistance. The parameters will provide a reference for the optimal design of the sonar dome.

2 Numerical model and method

2.1 The entity model

This paper studies a certain "I" ocean surveillance ship installed different sized sonar dome about its sailing conditions. The simulated conditions are as follows: full displacement, sea condition less than level 2, wind less than Beaufort level 3, host speed is 1000 r/min, the largest trial speed is 16Kn and economic speed is 14 Kn. The sonar dome is installed at the bottom of the ship between the frame 69# and 75# and coincides with the ships longitudinal center plane shown in Figure 1. The original sonar dome shown in Figure 2 has outline size of 2.52m*1.22m*1m and weight of 2500kg.

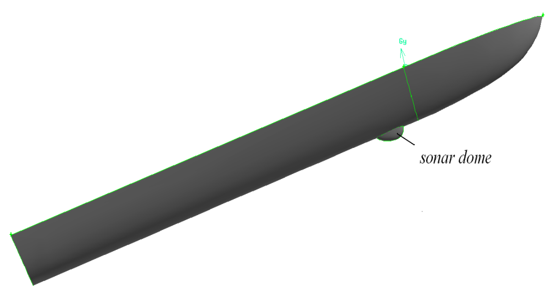


Figure 1. The part of hull under waterline

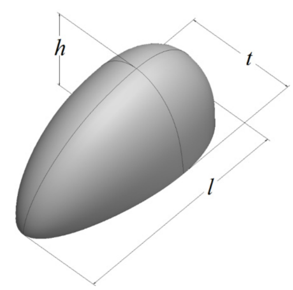


Figure 2. Model of sonar dome

After determined the optimal silhouette of sonar dome and meet the requirements of the installation of sonar equipment, the resistance of sonar dome and the underwater acoustic performance of sonar mainly depend on the key structural parameters and the proportional relationships between them shown in Figure 2. These proportional relationships include the length-width ratio of the maximum water surface line (i.e., the value of l/t) and the width-height ratio of the maximum longitudinal section (i.e., the value of t/h). The paper mainly analyzes the sailing resistance affected by sonar dome, which is based on the research of the two key structural parameters of sonar dome.

2.2 Meshing for the entity model

The boundary of the flow field is rectangular, dividing the flow field into four regions, among which Region 2 is a dynamic region including the hull, and its range constantly changes with the movement of the ship. Due to the complex shape of the ship and the sonar dome, this region is divided by a mixed mesh, generating the unstructured mesh. The other three regions are in a regular shape, and are divided into the hexahedral mesh. The mesh generation of the computing regions is shown in Figure 3.

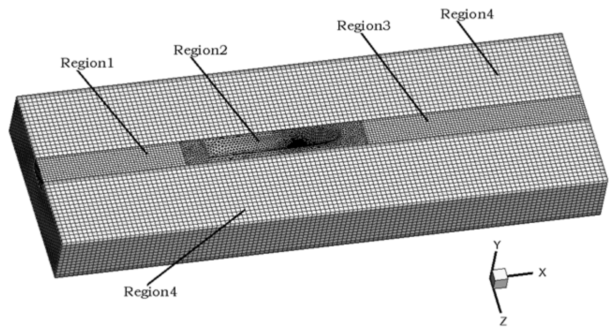


Figure 3. Full grid of the computational domain

2.3 The numerical method and the boundary conditions

According to the sailing speed, we can consider the fluid near the hull in the turbulent state, and it is also the incompressible fluid, complying with the turbulent transport equation, the turbulence model adopts a standard k-ε model. When the ship is sailing, the two phases of air and seawater are involved, so the VOF（Volume of Fluid）multiphase flow model is adopted to simulate the sailing ship. The PISO algorithm is used for the coupling calculation of the speed and pressure. In terms of numerical discrete, the second-order upwind scheme is adopted to improve the calculation accuracy. The flow field around the sailing ship can be considered as the dynamic flow field, and the hull surface is the flow field boundary of the movement, so this paper adopts the dynamic layering model and local re-meshing model of mesh deformation to simulate the ship's sailing process. The setting of boundary conditions are as follows: the outlet adopts the pressure outlet boundary condition, setting the static pressure of the outlet boundary at 0. The hull surface adopts the non-slipping boundary condition.

3 Results and discussion

The relationships between the length-width ratio and width-height ratio of the sonar dome are mainly studies based on reducing the sailing resistance under the condition and meeting the basic requirements of sonar equipment.

Table 1 The size of the sonar dome at the length-width ratio of the maximum water surface (m)

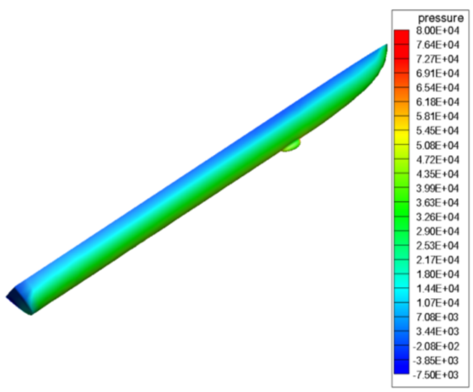
l/t	2.0	2.5	2.7	2.9	3.0	3.2	3.4

l×t×	2.44×1.22×1.05	3.05×1.22×1.05	3.29×1.22×1.05	3.54×1.22×1.05	3.66×1.22×1.05	3.90×1.22×1.05	4.15×1.22×1.05
l/t	3.5	3.6	3.8	4.0	4.2	4.5	5.0
l×t×	4.27×1.22×1.07	4.39×1.22×1.10	4.64×1.22×1.16	4.88×1.22×1.22	5.12×1.22×1.28	5.49×1.22×1.37	6.10×1.22×1.53

3.1 The effects of sonar dome's length-width ratio on sailing resistance

According to Reference 3, suppose the height "*h*" is 0.25*l* (i.e., when the length-width ratio is 4.0, the sonar dome's performance is the best). On this basis, 14 kinds of sonar domes with the length-width ratio *l/t* =2.0~5.0 are analyzed, and their structure sizes are shown in table 1.

The following introduces the ship's sailing resistance at the maximum trial speed 16Kn with the above 14 kinds of schemes.



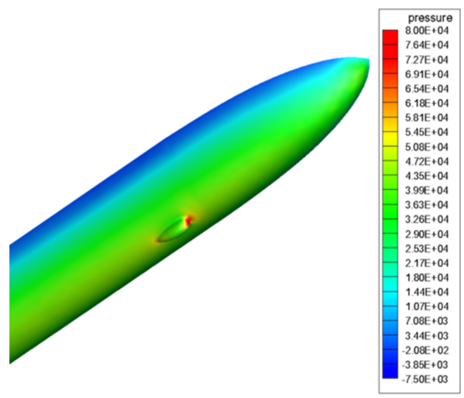


Figure 4. Pressure contours of the hull at the speed of 16Kn

Figure 5. Pressure contours around sonar dome at the speed

Take the simulation result of sonar dome's length-width ratio of 3.0 as an example, and analyze the sailing resistance of the hull and sonar dome. Figure 4 and 5 are the pressure contours around the hull, the bottom of the ship and the sonar dome. From the figures, we can see that the hull pressure is increasing from the top to the down, which corresponds to the water pressure. The bow has a compression effect on water body, which leads to the result that the pressure at the bow is higher than other locations at the same level of the hull. With the ship sailing, the stern has certain negative pressure, and also produces vortex. It is because of the positive and negative pressure difference of the bow and stern, the sailing resistance is formed. Figure 5 shows the pressure around the sonar dome. From the figure, we can see that the front part of the sonar dome also has a compression effect on water when the ship is sailing, which makes the pressure of this part increase significantly, and the rear part of the sonar dome forms certain negative pressure zone. The pressure difference of the front and the rear of the sonar dome lead to the sailing resistance increasing.

The larger the difference is, the greater the sailing resistance is.

Figure 6 shows the velocity contours of the profile when the ship is sailing. From the figure, we can see that the water velocity of the bow, sonar dome and stern increase obviously, and the velocity gradient at the stern is large and produces more vortex, which shows flow separation phenomenon appears here, and causes the increase of sailing resistance. Figure 7 shows how the resistance coefficient changes with time. We can see that the sailing resistance is not stable at the beginning of sailing, and it will basically tend to stable after about 3 seconds, which is completely consistent with the actual situation.

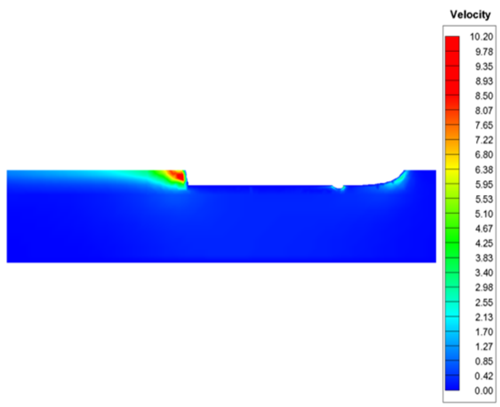


Figure 6. Velocity contours of the profile at the speed 16Kn

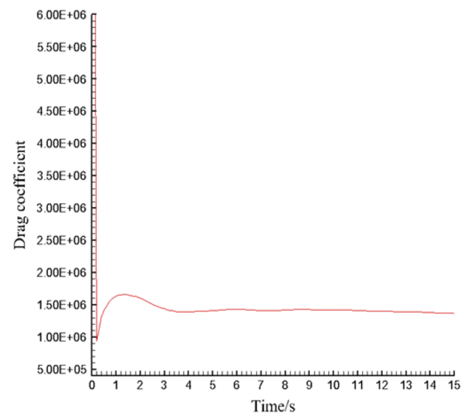


Figure 7. Resistance coefficient curve of the ship at the speed 16Kn

After the statistical analysis of the ship's sailing resistance in a stable sailing with sonar domes of different length-width ratios, the relationship between the sailing resistance and the sonar dome's length-width ratio of the maximum water surface line is shown in Figure 8.

Figure 8. The sailing resistance of the ship installed different length-width sonar dome at the speed 16Kn

According to figure 8, we can see that the sailing resistance first reduces with the increase of the sonar dome's length-width ratio, and when the sonar dome's length-width ratio increases to 3.5, the sailing resistance reaches its minimum, then with the further increase of the length-width ratio, the sailing resistance increases gradually. That is not to say, the longer the sonar dome is, the smaller the sailing resistance is. When the length-width ratio of the sonar dome is between 3.4 and 3.6, the sailing resistance is small, the total drainage volume of the sonar dome is small, and the comprehensive performance is the best. With the further increase of the sonar dome's length-width ratio, the sailing resistance increases first and then reduces, and when the ratio is 4.2, it reaches the maximum. The increase of the length-width ratio will lead to the obvious increase of the drainage volume of the sonar dome, the increase of the manufacture cost and the bad comprehensive performance.

3.2 Effects of sonar dome's width-height ratio on sailing resistance

According to the above simulation results, when the length-width ratio of the water surface line reaches 3.5, the ship's sailing resistance performance is the best, so when analyzing the influence of the sonar dome's width-height ratio of the maximum longitudinal section, we should keep the sonar dome's length-width ratio at 3.5. Take the suggestions of Reference 3, we set 9 simulation schemes of different width-height ratios *t/h* to analyze, the scheme settings are shown in Table 2.

Table 2 The size of the sonar dome at the height-width ratio of the maximum longitudinal surface (m)

t/h	0.90	0.95	1.00	1.05	1.10	1.14	1.20	1.25	1.30
h	1.36	1.28	1.22	1.16	1.11	1.07	1.02	0.98	0.94

For the above sonar domes with 9 different width-height ratios, we simulate and analyze the ship's sailing resistance at the maximum trial speed 16Kn. Take the simulation result when the sonar dome's width-height ratio of the maximum longitudinal section 1.14 as an example, and analyze the resistance when the ship is sailing.

Figure 9 and 10 are the ship's pressure contours around the hull, the bottom of the ship and the sonar dome at the maximum trial speed 16Kn with the sonar dome's width-height ratio of 1.14. From the figures, we can see that the pressure changes around the hull, at the hull bottom and near the sonar dome are basically consistent with Figure 5, but the pressure difference of the maximum positive and negative pressures of the head and tail of the sonar dome reduces obviously. That is to say the sailing resistance reduces obviously. Compared with the sonar dome with the length-width ratio of 3.0 and the width-height ratio of 4.0, the sonar dome with the length-width ratio of 3.5 and the width-height ratio of 1.14 has a smaller sailing resistance. Figure 10 shows the pressure contours near the sonar dome. From the figure we can see that the front of the sonar dome has a compression effect on water, which makes the pressure of this part rise obviously and reach the maximum positive pressure, but the rear of the sonar dome will form certain negative pressure zone. But the sonar dome is at the hull bottom, and the water pressure is large, so the negative pressure of the rear of the sonar dome is offset, forming some positive pressure.

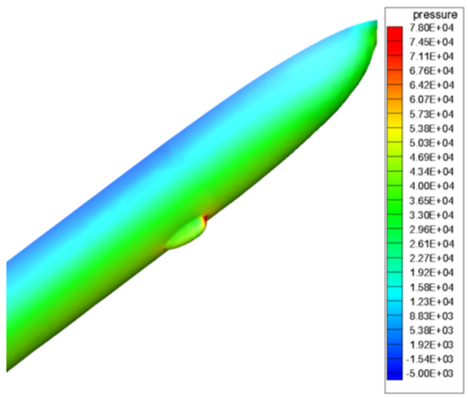


Figure9. Pressure contours of the hull with sonar dome at the width-height ratio

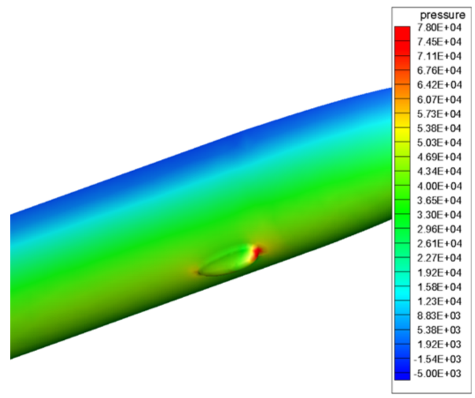


Figure 10. Pressure contours around sonar dome at the width-height ratio

After the statistical analysis of the ship's sailing resistance with sonar domes of different width-height ratios in a stable sailing condition, the relationship between the sailing resistance and the sonar dome's width-height ratio of the maximum longitudinal section is shown in Figure 11.

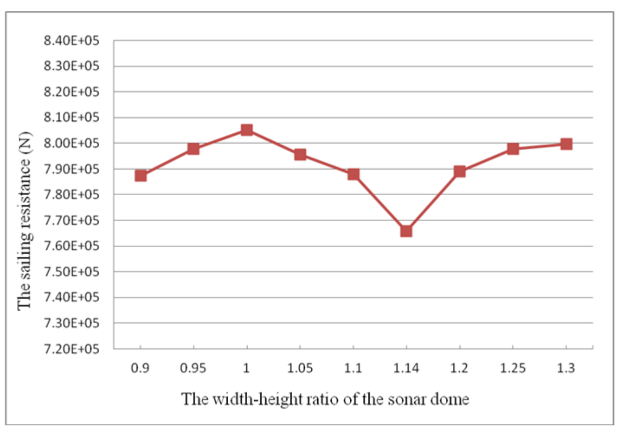


Figure 11. The sailing resistance of the ship installed different width-height sonar dome at the speed 16Kn

From the above figure, we can know that the ship's sailing resistance first gradually increases with the increase of the width-height ratio of the sonar dome, and when the width-height ratio of the sonar dome increases to 1.0, the ship's sailing resistance reaches its maximum, and then with the further increase of the width-height ratio, the sailing resistance will first reduce and then increase. When the width-height ratio reaches 1.14, the ship's sailing resistance will reach its minimum, the height of the sonar dome is 1.07m and the length-height ratio is 4.0, which meets the sonar dome's size requirements of the sonar equipment. As the width-height ratio of the sonar dome exceeds 1.14, the ship's sailing resistance gradually increases , but when the width-height ratio reaches 1.3 and exceeds it, the height of the sonar dome reduces to below 0.94m, and the small internal volume will limit the installation and using of the sonar equipment. So the sonar dome with a width-height ratio of above 1.3 has no use value. When the width-height ratio is below 1.05, the height of the sonar dome is too large, the sailing resistance performance is bad and the manufacture cost increases, so there is no practical significance.

4 Conclusions

(1) The sonar dome's structure parameters have obvious influences on its sailing resistance. Under the condition of meeting the requirements of installing sonar equipment, not the smaller the sonar dome is, the smaller its sailing resistance, but an optimal structure parameter makes its resistance performance and sonar underwater sound performance optimal.

(2) When the length-width ratio of the maximum water surface line of the sonar dome is between 3.4 and 3.6, its sailing resistance is small, and meanwhile it's total drainage volume is small, and the comprehensive performance is the best.

(3) When the width-height ratio of the maximum longitudinal section of the sonar dome is between 1.1 and 1.2, its sailing resistance is small, and meanwhile the size of the sonar dome also meets the size requirements of installing sonar equipment and the comprehensive performance is the best.

References

Chongben Ni(2011). "A comprehensive investigation of ship resistance prediction based on CFD theory". *Shanghai: Shanghai Jiaotong University* (in Chinese)

Guoqiang Fei, Wenmiao Shen(2012). "Overview of the foreign ship sonar fairing". Journal of Acoustics and Electronics Engineering. (in Chinese)

Jia Li(2007). "Numerical simulation of some hydrodynamic forces for submerged body advancing near free surface". Harbin: Harbin Engineering University. (in Chinese)

Liming Du, Jin Zhang(2013). “Numerical optimization of sonar dome profile based on reducing its sailing resistance”.Journal of Ship Science and Technology. (in Chinese)

Yingdong Wang(2008). “Form optimization of sonar fairing”. Harbin: Harbin Engineering University. (in Chinese)

Zhenbang Sheng, Zhengwei Sheng, A’kang Yang, et al(1979). “The shape design of sonar dome”. Journal of Ship Engineering.(in Chinese)

Numerical Analysis of the Internal Flow Field of a Marine Centrifugal Compressor and the Structural Optimization of a Vaned Diffuser

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Abstract: Due to coupling effect and interaction between the impeller and diffuser, internal flow field of a centrifugal compressor is very complicated. In the present thesis, numerical analysis of the internal flow field of a marine centrifugal compressor in multistage environment was carried out. The results indicate that narrow working rang and low efficiency of the prototypical compressor contributes to the eddy between outlet of the impeller and inlet of the diffuser. The coupling relationship between the impeller and diffuser was improved by reducing vane number of the diffuser and shortening the length of the blade trailing edge. The optimal results show that the stable working range of the compressor was broadened and working efficiency and pressure ratio in multistage environment were increased significantly.
Keywords: Centrifugal compressor stage; Internal flow field; Structural optimization; Vaned diffuser.

1 Introduction

Owing to influence of impellers rotating and curvature of impeller surface, whirl breakaway, flow back, secondary flow and flow separation will occur. All the phenomena make the internal flow field of centrifugal compressor very complex. Impeller is one of key components of a centrifugal compressor, by which mechanical work is converted into potential energy and kinetic energy. Boundary improvement of the impeller outlet and diffuser inlet is a feasible measure to improve working performance of a centrifugal compressor. Different from the mechanism of pressure increasing in the impellers, it is by air diffusing for the diffuser to reduce flow velocity and increase static pressure.

It is one of main purposes to recover efficiently kinetic energy which contained in the airflow in centrifugal impeller when designing a high-performance compressor is. In accordance with the principle of conservation of angular momentum, the rest of kinetic energy in the compressor can be further transferred into potential energy and make static pressure increases by the diffuser which making air way area increase or changing the radius of the average flow. However, it may cause a compressor occur flow separating, even leads to stall flutter.

The coupling effect of impellers and diffusers directly affects performance of the whole compressor. Good matching of the two key components can make internal flow fields smooth. While previous design of centrifugal compressor rely designer's experience and on-site test. The traditional design method of centrifugal compressor excessively depend on the previous designing experience and on-site test repeatedly. The method cause enormous waste of time and money, and could not predict the final results and control the developing cost. In the present thesis, numerical method was applied to analyze and optimize the structure of a marine centrifugal compressor. Internal flow field of impeller and diffuser of the compressor was analyzed in different rotating speed and optimize parts of key structure parameters of diffuser depending on the numerical results in order to improve coupling relationship between the impeller and diffuser and increase the performance parameters of the compressor.

2 Numerical model and method

2.1 Numerical model and computational mesh

In present thesis, the impeller of a marine centrifugal compressor has ten main blades and ten splitter, and its diffuser has blades. The inlet radius of the impeller tip is 100mm and the root radius is 50mm. The outlet radius and height of the impeller are respectively150mm and 15mm. Both of the inlet and outlet tip clearance are 0.6mm and impeller's outlet bending angle is 25 degrees. The specific geometric model of the compressor can be seen in Figure 1.

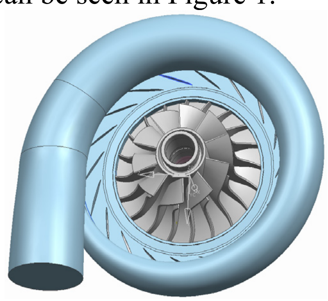


Figure1. Geometric model of the centrifugal compressor

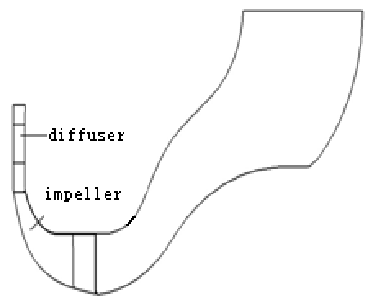


Figure 2. Meridian channel

Due to the complex structure of the compressor, some simplification was done when developing the numerical model of the compressor in the condition of without affecting simulated results. The meridian channel of the compressor was shown in figure 2. In order to reduce calculating cost, numerical grid of impeller is established only for a single channel. At the same time, the import and export of the impeller passages were extended properly, and the wall surface meshes were refined as far as possible to satisfy the y+<10 of wall first grid node. In addition, a butterfly-shaped technology grid was employed to improve the quality of the grid. In order to make the results more comparable, impeller channel grid, diffuser and volute grid of compressor with casing treatment were same as the corresponding computational grid of the solid casing compressor. The total computing grids of the centrifugal compressor is shown as figure 3.

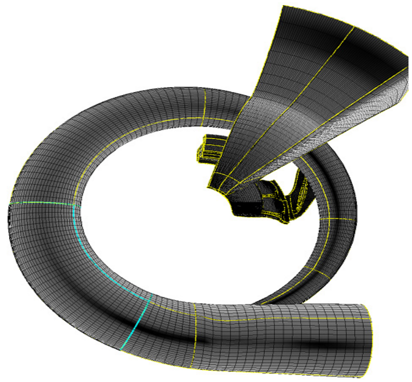


Figure 3. Computing grids of the centrifugal compressor

2.2 Numerical computation method

Compressible ideal gas was chosen as working media. Spalart-Allmaras model is selected to solve turbulence equation, which has strong fault tolerance ability and suits for complex flow for balancing accuracy and efficiency of the computation. Second-order central difference scheme in space discretization and fourth order Runge-Kutta in time discretization were used. In addition, the domain average method is utilized for rotor and stator interface. To facilitate the comparison, the outlet boundary condition was set as the mass flow. The off-design working condition was obtained by reducing gradually the outlet flow rate. The solid boundary is regarded as no-slip and adiabatic walls.

When the curve slope of compressor pressure ratio performance is negative, it is generally believed that the compressor works in unstable condition, namely the compressor falling into rotating stall or surging condition. In the simulating, when the pressure ratio reaches maximum value, convergence error decreases slowly and has obvious cyclical fluctuation, which implicates that stall flutter appears. So when pressure ratio significantly declines and residual concusses with the decreasing of export flow rate, it is believed to approach the stall point, then accurately capture will be executed.

3 Results and discussion

3.1 Analysis of compressor performance

According to experimental data, the efficiency of centrifugal compressor is 78.5% and pressure ration is 2.9 under rated conditions (Mass flow rate is 3.6 kg/s and rotation speed 26700 rpm). Table 1 shows the main performance parameters of the compressor under multiple working condition with rated rotational speed obtained by simulation. According to the table, the error between the numerical results and the experimental data is less than 5%. It indicates that the numerical method and the results in the present thesis are credible. As shown in table 1, the working range of the compressor is narrow and working efficiency and pressure ratio in the condition of big airflow are all lower than expected and it can not meet the design requirements.

Table 1. Performance parameters under variable flow rates with 26700rpm

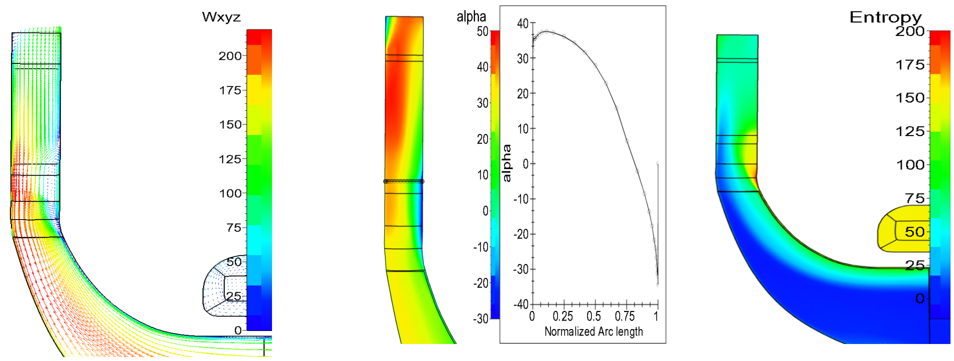
Flow rate G(kg/s)	lumped parameter	
	Pressure ratio π c*	Isentropic efficiency η is（t/t）
3.36	2.872	76.83%
3.60	2.840	77.17%
3.84	2.743	75.67%
3.96	2.632	73.05%
4.20	1.922	50.68%

In order to find the reason why the main performance parameters of centrifugal compressor are low, three research schemes (“impeller” and “impeller + vaned diffuser ” and "impeller + vane diffuser + volute") are set up in the present thesis. Aerodynamic performance of three main components of the compressor were respectively analyzed. According to the numerical results, the performance parameters of the three schemes are obtained as shown in table 2.

Table 2. Performance parameters of different parts

Character / Component	Flow rate G（kg/s）	Pressure ratio π c*	Isentropic efficiency η is（t/t）
Impeller	3.60	3.18	85.89%
Impeller and diffuser	3.60	2.92	79.82%
The compressor stage	3.60	2.84	77.17%

The table indicates that the main energy loss happens between the outlet of the impeller and inlet of the diffuser. In order to find out the main reason that the efficiency is not high enough, it is necessary to analyze respectively internal flow field of the impeller and the vaned diffuser.



(a) Meridian surface streamline of circumferentially-averaged relative velocity

(b) Flow angle distribution

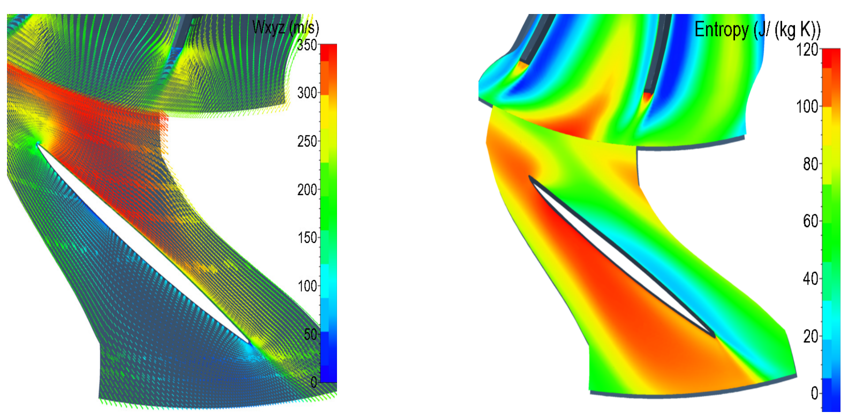
(c) Average cloud of entropy at circumferential

Figure 4. Performance parameters in meridian channel

3.2 Analysis of internal flow

Internal flow field of the compressor was simulated in rated condition in order to analyze the flow field of the impeller. Flow angle contours and circumferentially average streamline of relative velocity and circumferentially average entropy contour are shown in Figure 4. According to figure 4(a), there are some eddy significantly existed in the side of wheel cover between the outlet of the impeller and inlet of the vaned diffuse, which make distribution of flow angle along the blade height direction uneven when air flow into the diffuser, as shown in figure 4(b). It also makes entropy production between the outlet of the impeller and inlet of the diffuser is high, as shown in figure 4(c). Therefore, the efficiency of the compressor decrease quickly.

Figure 5 shows the meridian surface streamline of circumferentially-averaged relative velocity and the average cloud of entropy at circumferential at the height of 50% blade. From the picture, it can conclude that eddy generate between impeller's outlet and diffuser's inlet when centrifugal compressor runs under the rated speed. This part will seriously affect normal work of the front part and the back part. If the zone make wore, it will produce clogging. So the centrifugal compressor can't work normally.



(a) Meridian surface streamline of ıferentially-averaged relative velocity

(b) Average cloud of entropy at circumferential

Figure 5. Height of 50% blade

4 Diffuser structure optimization

4.1 Optimization of the number of diffuser blade

Based on the above analysis, some schemes of the diffuser blade number and the blade length were numerically analyzed in order to increase the whole stage efficiency and pressure ratio of the compressor and improve the coupling relationship between the impeller and the diffuser. Figure 6 shows the efficiency-flow of the compressor with four different diffuser vane numbers.

From Figure 6, it can be seen that reducing the number of the diffuser blade will improve the efficiency and pressure ratio under the large rate of the flow. But if the number of the blade is less, it will make the internal flow field disorder.

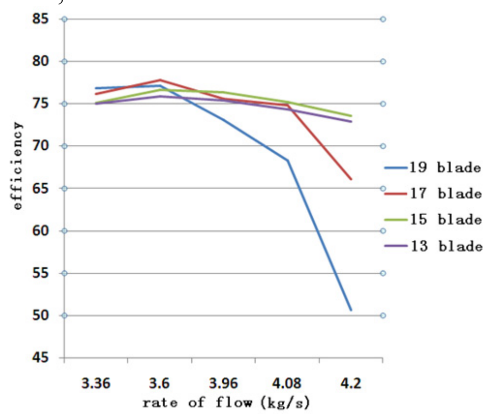
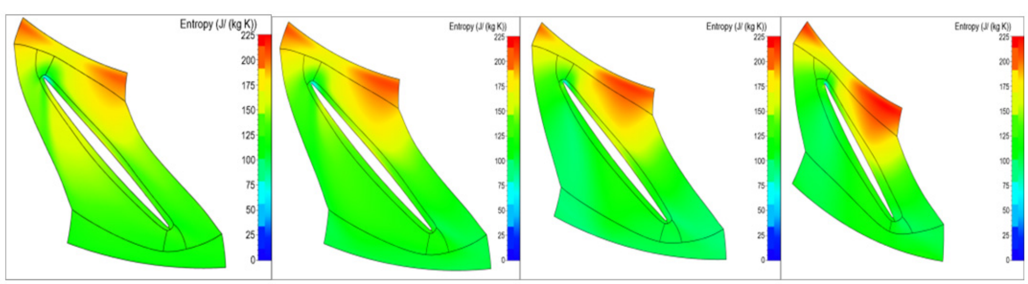


Figure 6. Efficiency-flow

In order to further analyze, the different number of blades entropy are the thesis compared in the figure 7. The blade is high consistency. When the high speed flow pass through the diffuser, there is a great impact on the front of the diffuser, so it may lead to the large loss of the energy, and it will have a great influence on the distribution of entropy in the diffuser. In the figure 7(b) and 7(c), reducing the number of the blade appropriately will improve the energy distribution of flow in each section. And it will make the loss of energy low. But in the figure 7(d), if you reduce the number of the blade much, it can transform kinetic energy into static pressure energy inadequately, it will be badly control the air flow as the preset direction and there is a high entropy section at the suction side of blade, leading to the loss of the energy and making the efficiency and pressure ratio low.



(a)19 blades (b)17blades (c)15blades (d)13blades

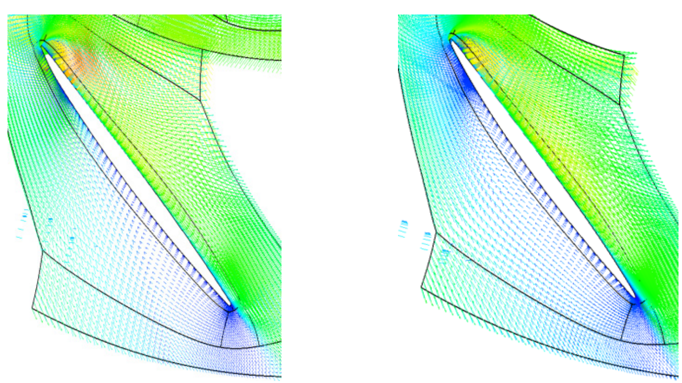
Figure 7. Entropy at the root of blades

Table 3. Performance parameters of different number of diffuser blade

Project	lumped parameter	
	Pressure ratio π c*	Isentropic efficiency η is（t/t）
Before optimization（15 blade）	2.91	75.1%
After optimization（15 blade）	2.94	76.7%

4.2 Optimization of the length of diffuser blade

Through the above analysis, the best number of blades is made, reducing the number of diffuser blade not only make the internal flow field better, but also make the working scope large. But the efficiency and pressure ratio is low at little mass flow. So the paper use the model of Design 3D to optimize the length of diffuser blade. It will improve the loss of energy by the "wake-jet", backflow and so on, and it will make the low speed area and the air flow in the diffuser better. Selecting the length of blade is geometric parameters, changing the diffuser length under the condition of diffuser blade is not distorted. And it will generate the database, then choosing the optimal results in the database as the best result. The table 3 shows that efficiency and pressure ratio under the mass flow of 3.24kg/s.



(a)Before optimization (b)After optimization

Figure 8. Height of 10% blades

In order to compare optimization with others, figure 8 is local vector at the height of 10% blade. From the figure 8, it can be seen that reducing the length of the diffuser blade can make the energy of the air distribution better. In the figure 8(a), the air with high speed and low speed mix together, but the mixture is terrible. In the figure 8(b), the air with low speed along with the suction of the diffuser blade, then it mix with the high speed air. In this case, the internal flow filed is better. If mixture is terrible, it will lead to stall and so on. After optimization, efficiency and pressure ratio is high under the condition of small flow rate. It makes the air interaction better and improves the internal flow field.

5 Conclusions

(1) The present numerical model can correctly simulate operating of the centrifugal compressor under multiple working conditions, and it shows that numerical computation method is reliable.

(2) According to the numerical results of the prototypical model, eddy zone exists between the impeller outlet and diffuser inlet, which makes the efficiency descend quickly and the airflow disorder in the diffuser.

(3) Based on the numerical results of the optimized diffusers, by properly decreasing the diffuser blade number and shorten the length of the blade trailing edge, not only the effect of the eddy zone to the diffuser and impeller can be reduced, but also the flow field of low-velocity zone at the end of the diffuser can be significantly improved, and as a result, the whole level of the parameters such as efficiency and compression ratio can be increased.

References

J.D.Denton.Loss. “Mechanisms in turbo machines”. ASME. Journal of Turbo Machinery, Vol.l15, No.1.

Liu Ruitao, Xu Zhong(2003). “The Research Development of Internal Flow in Centrifugal Turbo Machinery”. Advances in Mechanics,Vol.33(4):518-532(in Chinese)

RIBI B1(1996). “Flow in radial turbomachines”.Von Karman Institute for Fluid Dynamics Lecture Series,(1)：26-29.

Tang Hua (2005). “The Analysis of Centrifugal Compressor’S Internal Flow Field and Designing of Diffuser”. Graduate School of Chinese Academy of Sciences, (in Chinese)

Wen Suping, Zhang Chuhua and Li Jinyin (2004). “Calculation of unsteady flow for interaction between rotating impeller and vaned diffuser”. Journal of Xi’an Jiaotong University, Vol.37(7):754-757 (in Chinese)

Xu Zhong(1990). “The Principle of Centrifugal Compressor”. Beijing: Mechanical Industry Press (in Chinese)

Zhu Zhifu (2008) . “Study of Vehicle Turbocharger Centrifugal Compressor Surge Mechanism and Forecasting”. Beijing: Beijing Institute of Technology (in Chinese)

Zhu fuzhi, Ma chao, Ma chaochen, et al(2011). “Analysis of centrifugal compressor internal flow and mechanism of stall at small flow rates”. *Vehicle Engine*, (2):37-41 (in Chinese)

Characteristics of Passenger Car Side Pole Impacts

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Abstract: A total of 29 passenger car side pole impacts were analyzed for this study. Characteristics of passenger car side pole impacts were summarized in depth, including impact velocity, impact angle, impact area, force direction, injuries and deaths, injuries per body region. The passenger injury risk in different impact velocity and angel was analyzed in order to understand the injury mechanism and evaluation index. It hoped to provide reference for the setting of pole side impact standards and C-NCAP.
Keywords: Characteristic; Passenger car side pole impacts; Standards and C-NCAP.

1 Introduction

The severely injured and fatal rate accounted for 25% in vehicle side impact which was the main severely injured and fatal accident type.43%~55% of side accidents were vehicle to vehicle side impacts, and vehicle to pole side impacts accounted for 12%~16%. Side pole impact was a special side impact. Struck time was longer, vehicle body absorbed more energy and injury and death risks of passengers were higher when vehicle impacted with traffic signs pole, tree, bridge pier. Nearly 4800 persons were killed in vehicle side impact in Europe in 2009, of which 1628 persons died in pole side impact, and 3174 deaths in other side impact. The data was (1371, 4872) in America and (204, 1024) in South Korea.

Impact characteristic including impact velocity, impact angle, impact area, force direction, pole diameter, and injury characteristic including injury region, AIS rating were analyzed in-depth in this paper.

2 Statistical Analysis of Side Pole Impacts

7 side pole impacts were taken from the CIDAS database. Each case contained nearly 2000 information items about the human, vehicle, road, and environment. Beginning in July 2011, the CIDAS team surveyed accidents in-depth in Beijing, Changchun, Weihai, Ningbo, Changsha, and Foshan. Other 22 side pole impacts were from crash database of traffic police department.

The injury of which AIS rating was 1 or 2 was defined slight injuries, and the injury of which AIS rating was more than 3 was defined severe injuries.

The calculation formula about fatality rate ($R_{X.fatal}$) of x driving position in passenger car was defined as shown: $R_{X.fatal}= N_{X.Deaths}/(N_{X.Deaths}+ N_{X.Severe\ injuries}+ N_{X.Slight\ injuries}+ N_{X.No\ injured})$

Similarly, the calculation formula about severely injured rate ($R_{X.severely\ injured}$) and slightly injured ($R_{X.sightly\ injured}$) of x driving position in passenger car was defined.

2.1 Impact velocity, angle, pole diameter

29 passenger car side pole impacts were simulated by pc-crash. The average impact velocity and angle were obtained, as shown in figure 1.

Side pole impact velocity was in the range of 40~60km/h, and the average was 54.4km/h. Impact velocity was lower than 39km/h in 50% of slightly injured impacts, and 54km/h in 50% of all injured impacts, and 77km/h in 50% of severely injured impacts, as shown in figure 2. Injury severity increased with impact velocity increased. The average pole diameter was 308mm which could be used in simulation. The average impact angel was 67.6 degrees. There was no correlation found between injury severity and impact angel.

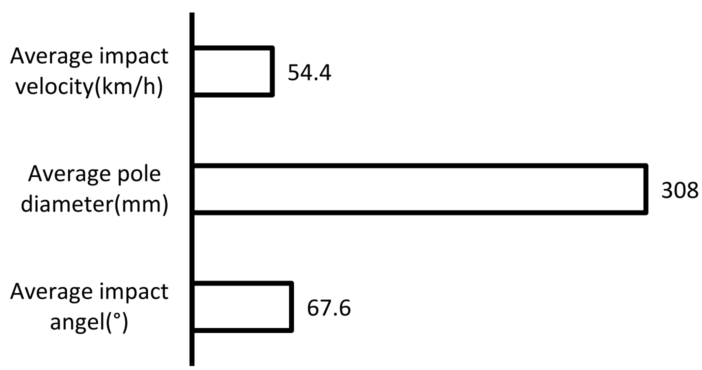


Figure 1. pole side impact parameter

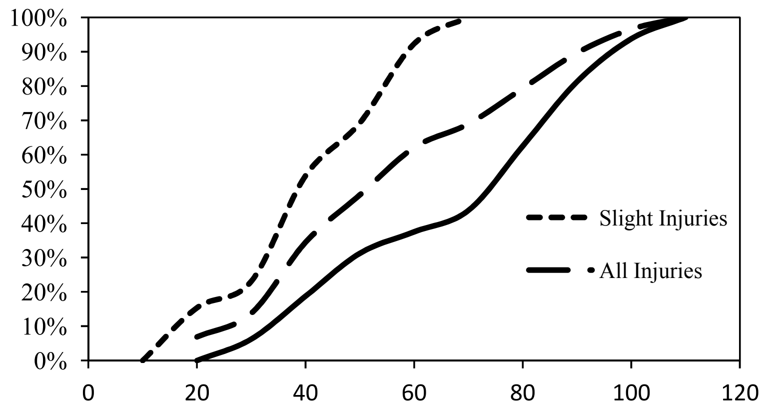


Figure 2. Cumulative impact velocity by injury severity

2.2 Impact area

As shown in figure 3, A was the front area of the car, B was the cab area, C was the area of passenger compartment, D was the rear area of the car. There were 7 impacts in A region, accounted for 24.1% of the total side pole impacts, 17 impacts were in B region accounted for 58.6%, 5 impacts were in C region accounted for 17.3%, none impact was in D region.

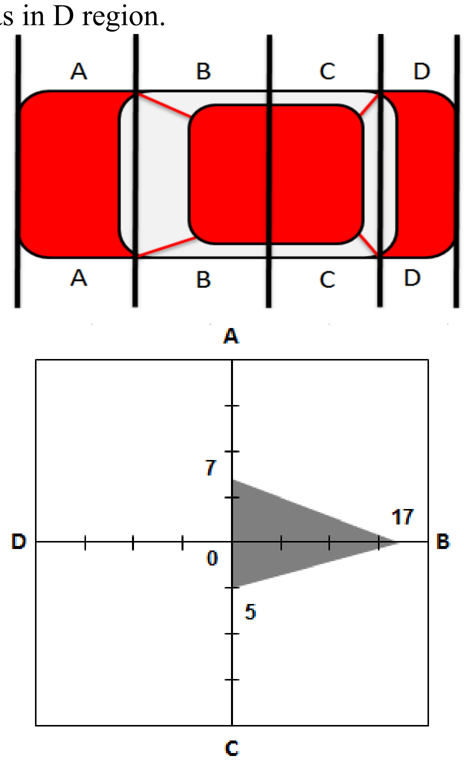


Figure 3. Impact area-Impact number

2.3 Force direction

There were three impact directions named F (forward slope), V (Vertical 90°)

and R (Backward slope) in impact region. 21 impacts on F direction accounted for 72.4% of the total side pole impacts, 8 impacts on V direction accounted for 27.6%, no R direction impact was found, as shown in figure 4.

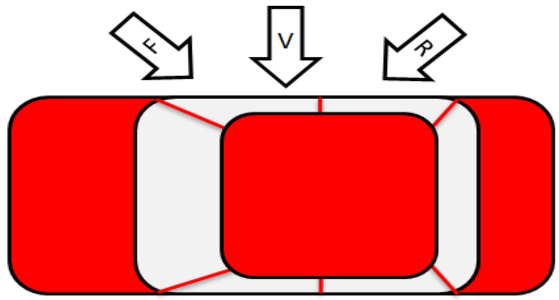


Figure 4. Force direction

Table1 was the force combination of different impact region. The number of impacts and casualties were highest in B-F combination, then A-F, B-V, C-F, A-V, C-V. The slope impact was more common and more serious than vertical 90° impact in real world accidents.

Table 1. Force combination of different region

Combination	A-F	A-V	B-F	B-V	C-F	C-V
Number of Accidents	5	2	12	5	4	1
Slight injuries	2	1	6	1	3	1
Severe injuries	1	0	5	3	1	1
Fatalities	4	2	9	5	2	0

2.4 Injuries and deaths

A total of 29 side pole impacts involved 47 passengers, including 14 slight injuries, 11 severe injuries and 22 fatalities. Side pole impact caused serious passenger casualties, the slightly injured rate was 29.9%, the severely injured rate was 23.4% and the fatality rate was 46.8%, as shown in table 2.

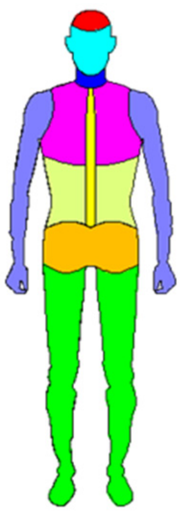
Fatality rate of each position in passenger car was almost same. Driver and back passenger were vulnerable to slight injuries relative to front passenger. 33.3% of front passengers were severely injured, which was higher than driver and back passenger.

Table 2. Injuries and deaths in side pole impacts

	Number of people	Slight injuries	Rate	Severe injuries	Rate	Fatalities	Rate
Driver	29	10	34.5%	6	20.7%	13	44.8%
Front passenger	12	2	16.7%	4	33.3%	6	50.0%
Back passenger	6	2	33.3%	1	16.7%	3	50.0%

2.5 Injuries per body region

In the 29 side pole impacts, the main injured body regions were head and thorax, most of which were severe injuries, accounting for 40.9% and 29.9% respectively. Figure 5 was the injured body region and AIS of people in passenger car side pole impact. Traumatic shock caused by severe traumatic brain injuries and chest collapse in side pole impacts were the main dead reasons according to autopsy reports of 22 deaths.



	Slight Injuries	Severe Injuries
Head	27.5%	40.9%
Face	17.8%	3.9%
Neck	1.6%	2.6%
Thorax	13.9%	29.9%
Upper Extremities	13.6%	6.5%
Spine	2.7%	3.9%
Abdomen	5.8%	2.6%
Pelvis	1.6%	6.5%
Lower Extremities	10.1%	1.3%
Others	5.4%	1.9%

Figure 5. Slight/severe Injuries per body region

3 Summary

The following conclusion can be summarized from this paper:

(1) Side pole impacts were relatively rare accidents compared to other impacts types. But the importance of side pole impacts increased by focusing on severely injuries.

(2) Injury severity increased with impact velocity increased. There was no correlation found between injury severity and impact angel.

(3) The slope impact was more common and serious than vertical 90° impact in real accidents.

(4) Front passengers were vulnerable to slight injuries relative to drivers and back passengers in side pole impacts.

(5) The main severely injured body regions were head and thorax in side pole impacts.

References

Frank A. Pintar, Dennis J. Maiman, Narayan Yoganandan. INJURY PATTERNS IN SIDE POLE CRASHES

Volker Eis, Prof. Dietmar Otte and Roland Schafer. Characteristics of Passenger Car Side to Pole Impacts-Analysis of German and UK In-depth data using different approaches

Zaouk, A., Eigen, A., Digges, K. (2001) Occupant Injury Patterns in Side Crashes. SAE Technical Paper, 2001-01-0723

Fault Diagnosis of the Rectifying Circuit of Electric Locomotives

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Abstract: The paper conducts the fault diagnosis of three section unequal semi controlled bridge rectifying circuit of electric locomotive in the context of MATLAB/Simulink and suggests the fault analysis method based on the BP Neural Network. Based on the BP Neural Network, it produces failure data by simulation analysis, extracts the character of the faults and constructs the samples of the faults after the normalization processing. This paper also creates network to analyze and recognize the character of the faults and verifies the reliability and practicability of this method by simulation results.
Keywords: Electric locomotives; Three sections of the Bridge Rectifier circuit; Fault diagnosis; BP neural network.

1 Introduction

In order to reduce the harmonic interference, reactive power and increase the power factor of phase-controlled electric locomotives, the main circuits of DC-drive locomotives usually adopt the multi-stage bridge sequence control circuit. Using the fault diagnosis technology is of practical significance and important economic value to the fault exclusion when the faults happen to the power devices in the circuit. This paper using the neural network theory to make fault diagnosis on phased three section of unequal electric locomotive rectifier circuit (Xu, G. C., 2011).

2 The analysis for three section of unequal semi controlled bridge rectifier circuit

The figure of rectifier circuit of ss8-type, ss9-type electric locomotive is shown in Figure 1. During the running of locomotive, the three sections of the bridge sequence control complete the variable voltage speed control to the locomotives (Zheng, L.Q., 2006). There are many kinds of faults among the operation fault of rectifier circuit and this paper only aims at the diagnosis of fault state when the short circuit, open circuit of thyristors and diodes happen. When the half-controlled bridge RM3 working, the open faults of thyristor or diode are divided into 4 categories. When the half-controlled bridge RM3 and the half-controlled bridge RM1 working simultaneously, the open faults of thyristor or diode are divided into 8 categories. When the half-controlled bridge RM1~3 working simultaneously, the open faults of thyristor or diode are divided into 4 categories. The open faults of a thyristor or diode can be divided into 22 categories for the rectifier circuit and the faults are encoded in Table 1 as is shown.

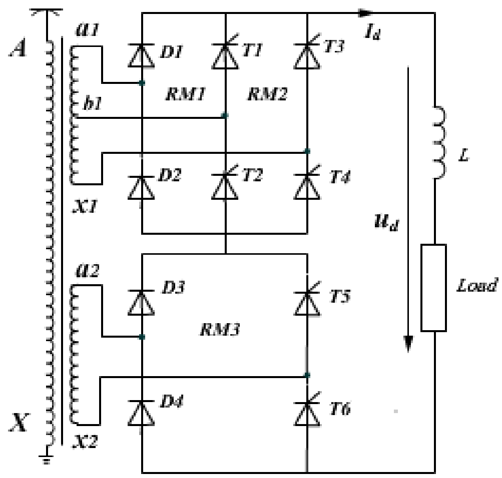

Figure 1. Three stage of unequal semi controlled bridge rectifier circuit

Table 1. Fault type codes

working bridge	fault location	sort	code	working bridge	fault location	sort	code
RM3	D3	①	0010001	RM1 RM2 RM3	D1	①	0110001
	D4	②	0010010		D2	③	0110010
	T5	④	0010011		D3	②	0110011
	T6	⑤	0010100		D4	③	0110100
RM1 RM3	D1	①	0100001		T1	④	0110101
	…	…	…		…	…	…
	T5	⑦	0100111		T5	⑨	0111001
	T6	⑧	0101000		T6	⑩	0111010

3 Circuit Simulation

According to the circuit schematic diagram for the three section of unequal semi controlled bridge, it creates a simulation model in the environment of Simulink, as is shown in Figure2. 25KV50HZ single-phase AC power for electricity, single-phase multi-winding saturated transformer is elected as traction transformer.Two trigger signals generated by setting the three-phase bridge trigger can satisfy the demands of trigger and phase-shifted control for single-phase half-controlled bridge. This model adopts RL inductive load to simulate DC motor and smoothing reactor. By measuring the voltage module and oscilloscope display voltage waveform (Sun, Z.R., 2004).

In the simulation process, the phase shifting sequence control to three section bridge is completed by regulating the given control angle of triggers Pulse1~3. Some typical types of output waveforms of fault voltage are shown in Figure 3.

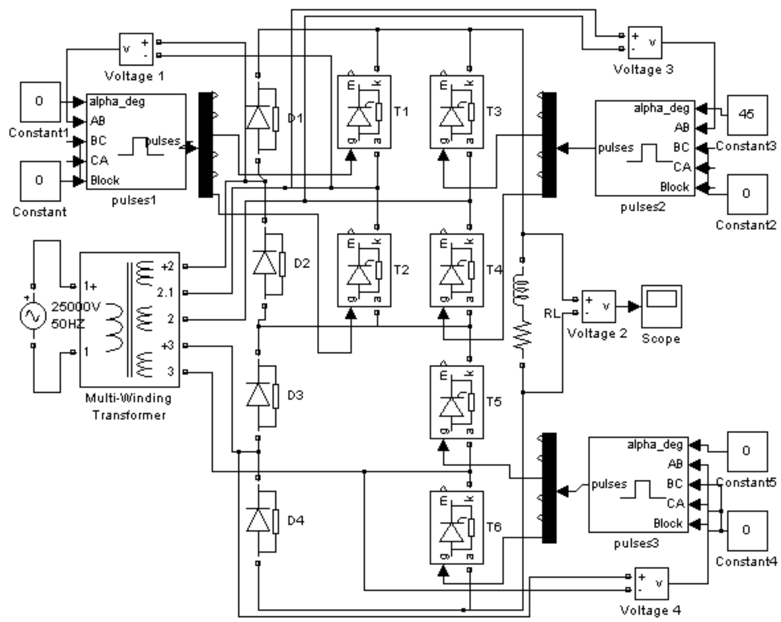

Figure 2. Rectifier circuit simulation model

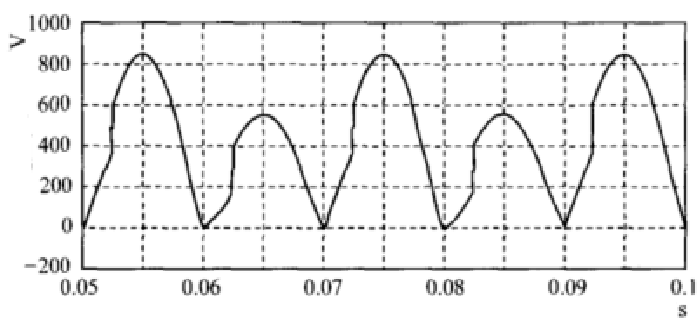

Figure 3. Output voltage of T5 fault when third district trigger angle 45 °

4 Fault analysis based on the neural network

The neural network for fault diagnosis is a kind of multilayer feedforward network (BP Neural Network) trained by back propagation algorithm and its guiding ideology is the correction for network weights and thresholds to make the error function decline in the negative gradient direction and stop the training when the error achieve the desired accuracy. The derivation is detailed in related literatures, not repeat (Gao, J., 2003). And its topology is shown in Figure 4. Input: X1,X2⋯Xn; Output: Y1,Y2,…Yn; the number of hidden nodes: m; W^2_{kj} denotes the correlation between output layer neurons k and hidden layer j; W^1_{ji} denotes the correlation between hidden layer neurons j and input layer neurons i.

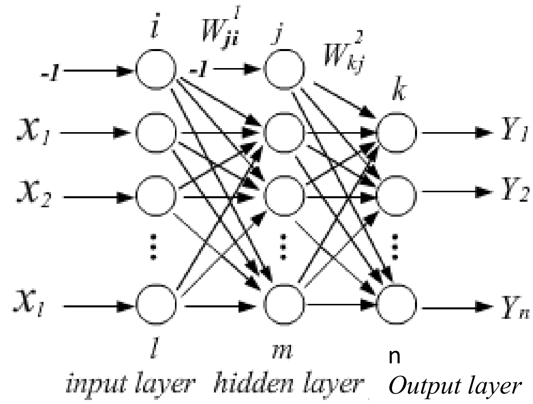

Figure 4. Typical single hidden layer BP algorithm topology

(1) Data preparation

This test simulates the faults of all kinds in the regulating process of three section bridge according with circuit model. It conducts equal interval sampling of output voltage for every faults and obtains the input data of samples. Here, we collect 50 data points per period and scan interval is 0.4ms. And then, it normalizes these data by normalization processing (in the range of[-1,1]) to obtain the input sample of diagnosis system as characteristic quantity to construct the corresponding eigenvectors to correspond the 22 open fault in the circuit. Some samples are shown in Table 2 and these contents conduct as an artificial neural network input sample X[50,22].

Table 2. Training samples

Sample	Fault1	Fault2	Fault3	…	Fault22
X1	0.0296	0.9963	-0.9012	…	-0.8657
X2	0.2671	0.3627	-0.4621	…	-0.7412
X3	0.4766	0.2157	-0.2145	…	-0.2586
…	…	…	…	…	…
X50	-0.9578	-0.1725	0.9635	…	0.4523

(2) Network design

The system adopts 50 input nodes, 15 nodes of hidden layer, 7 output nodes, and uses MATLAB to generate neural networks: net=newff(minmax(X), [15 7], ｛'logsig' ,'logsig'｝, 'trainlm'). It uses the samples in the Table 2 to train the network. So, correspond network parameters are:

net.trainParam.mc=0.85;

net.trainParam.epochs=25000;

net.trainParam.show=2500;
net.trainParam.goal=0.0001;
net.trainParam.lr=0.2.

The output samples of network are taken from the codes of every corresponding faults T[7,22]. The specific eigenvalue are the codes in the Table 1. The neural networks are trained after initialization and its matlab realization is [net.tr]=train(net,X,T). Error analysis for networks are shown in Figure 5.

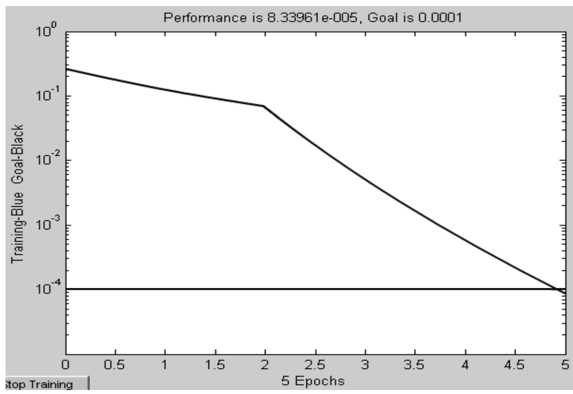

Figure 5. Error curve of training results

(3) Experimental verification

To test reliability and practicability of the program, we conduct an experimental research on three section semi controlled bridge. Break the thyristor T5 of semi controlled bridge RM3, set RM3 firing angle 45° during the third regulator, take 50 sampling points of output fault voltage wave and conduct normalization processing, as is shown in Table 3. Put the data into the trained neural networks: the input fault samples are wrong [50,1], the diagnostic program correspond to the fault samples are result= sim(net, wrong). After the diagnosis, the result data is shown in Table 4. Under the 0.85 threshold condition, we can get the ninth fault of the third regulator district, i.e., the Open circuit result of thyristor T5.

Table 3. Input faults mode

Input nodes	1	2	3	…	49	50
data	0.1766	0.2855	0.3816	…	-0.1850	-0.0986

Table 4. Neural network output nodes

output nodes	1	2	3	4	5	6	7
Point values	0.0180	0.9241	0.8692	0.9104	0.0251	0.0053	0.9173

5 Conclusions

This paper introduces the fault diagnosis of three section bridge rectifying circuit of electric locomotive and create simulation models of rectifying circuit. It analyses the possible failure mode of the switching devices during the regulating process of sequence control for three section bridge and diagnoses the open circuit fault of the devices in the circuit by BP Neural Network. The results show that neural network fault detection can build mappings between the fault voltage and fault type and diagnose the faults accurately. All of these are of great practical significance and certain application potential to the fault diagnosis of AC drive electric locomotive and the main circuit of CHR.

References

Cai, T., Duan, S.X. and Kang, Y. (2008). "Diagnostic techniques of power electronic systems failure." Electrical Measurement & Instrumentation, 45(509):1-7.

Gao, J. (2003). "Artificial Neural Network Theory and Simulation instance." China Machine Press, 2.1-3.4.

Sun, Z.R., Jia, Y.J., Fang, Y. S. and Sun, Y.Z. (2004). "Application of Matlab neural network toolbox in mechanical fault diagnosis." Journal of Lanzhou Institute of Technology, 11(4):12-15.

Wang, C. and Xie, Y.L. (2005). "Fault Diagnosis in Analog Circuits Based on Principal Component Analysis and Neural Networks." Journal of Electronic Measurement and Instrumentation, 19(5):14-16.

Xu, G. C., Xie, L.L. and Cai, D.Z. (2011). "Simulation and Analysis of Electric Locomotive Fault Diagnosis of rectifying circuit." Measurement & Control Technology, 30(12):95-98.

Zheng, L.Q., Zou, T. and Lou, H. L. (2006). "Fault Diagnosis of Power Electronic Circuits Based on Wavelet Transform and Neural Network." *High Voltage Engineering*, 32(3):84-86.

Safety Evaluation of a Bridge-Tunnel Connecting Section of Mountainous Highways Based on Drivers' Heart Rate

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Abstract: With the terrain restrictions, there are quantities of bridge-tunnel connecting sections on mountainous highways, and the traffic accident rate of the bridge-tunnel connecting sections in mountainous highways have always been very high in China. Therefore, the study about safety evaluation of the bridge-tunnel connecting sections of mountainous highways has an important significance for reducing the highway traffic accident rate. Firstly, this study propose a definition about bridge-tunnel connecting sections in mountainous highways. From the aspect of integrated system of bridges and tunnels, this study analyzed the traffic accident characteristics and influencing factors of the bridge-tunnel connecting sections. Based on engineering design data of a typical bridge-tunnel connecting section, a driving simulation test with a model of bridge-tunnel connecting section ("tunnel-bridge-tunnel" type) and simulated foggy weather was carried out using UC-win/Road software. Through the design of appreciate simulation scene and driving simulation experiment, we obtained the drivers' driving speed and heart rate value under the specific connection bridge-tunnel scene. Then the relationship between the driving speed, foggy weather and the driver's heart rate variability is found. Finally, a safety evaluation index of the bridge-tunnel connecting section design on mountains highway is proposed, which is based on characteristics of drivers' heart rate.
Keywords: Bridge-tunnel connecting section; Driving simulation; Safety evaluation; Heart rate; UC-win/Road.

1 Introduction

With the implement of China western development strategy and the rapid growth of economy in the western region of China, the construction of mountainous highways in the western region also is in the period of large-scale expansion. In the design of mountainous highways, it is unavoidable to adopt the form of bridge-tunnel connecting sections which is the chief measure to optimize the road alignment and avoid geological disasters. In recent years, the number and length of bridge and tunnel sections increases continuously and the proportion of bridges and tunnels becomes larger in the mountainous highways in China. Meanwhile, some new problems arise about the traffic safety of the bridge-tunnel connecting section in the mountainous highways. In order to reduce the death rate and the loss of traffic accident, it is very necessary to analyze the driving safety of the bridge-tunnel connecting section of mountainous highways. This article established a driving simulating experiment platform of the bridge-tunnel connecting section by UC-win/road. Then, through the driving simulation experiments, the driver's heart rate index is used for the safety evaluation of the bridge-tunnel connecting section.

2 Literature Review

Until now, expect some studies of driving safety focus on road-bridge and road-tunnel transition sections in common highway, there is few researches about bridge-tunnel connecting section in mountainous highway.

Du et al. (2006) and Lou et al. (2006) established the comprehensive evaluation index system of the tunnel traffic safety evaluation considering the “human, vehicle, road, environment, traffic characteristics”, and used this model to evaluate an operation tunnel in highway through the fuzzy mathematic theory. Xu et al. (2006) studied traffic safety evaluation of mountainous highway using set-valued statistics method of the fuzzy statistical, in order to overcome the problem that it is not accurate to use the grade proportion method and expert score method to evaluate fuzzy and non-quantitative index.

Liu (2009) and Xue (2010) studied the characteristic, safety evaluation and safety improvement measures of the bridge-tunnel connecting section in mountainous highway. Wang and Jia (2006) and Koh et al. (2014) suggested that the main factors affect the safety of mountainous highway are the geometric linear transition, the road surface characteristics transition, luminance transition and the traffic safety facilities. Pan et al. (2012) evaluated the safety driving in the bridge-tunnel connecting section using multiple levels and multiple factors analysis method.

Johansson (1970) and Amundsen and Ranes (2000) studied the visibility of traffic signs under different driving speed according to driver's cognitive ability. Fleyeh (2006) studied the influence of the colors and brightness of traffic signs to the driver reaction time and proposed suggestions about the design and location of traffic signs. Scott-Parker et al. (2015) and Blaszczyk et al. (2014) analyzed the influence factors of the traffic safety of tunnel entrance based on the system of "human, vehicle, road and surrounding environment".

Based on the previous study, road alignment, driving speed, driver's mental and physiological changes, adverse weather influence the occurring of accidents on bridge-tunnel connecting section. And this paper explored the modeling and the driving simulation experiments of bridge-tunnel connecting section.

3 Safety Evaluation of the Bridge-Tunnel Connecting Section of the Mountainous Highway Based on Drivers' Heart Rate

3.1 Mountainous area highway tunnels connecting section definition and classification

Xue (2010) defined the bridge-tunnel connecting section from the construction of bridge-tunnel engineering, however traffic safety of bridge-tunnel connecting section was not considered sufficiently. Zeng (2013) divided bridge-tunnel connecting section in mountainous highway into adjacent interchange connection, the connection between interchange and tunnel, and the connection between tunnel and tunnel. The above point that prescribes the bridge and tunnel is not in complete accord with the fact. So the exact definition of the bridge-tunnel connecting section can be proposed based on the definition of the connecting section in mountainous highway.

From the integrity of traffic system, the bridge-tunnel connecting section in mountainous highway can be classified three classes.

The first form is only connected a bridge and a tunnel directly, which is shown in Figure 1.

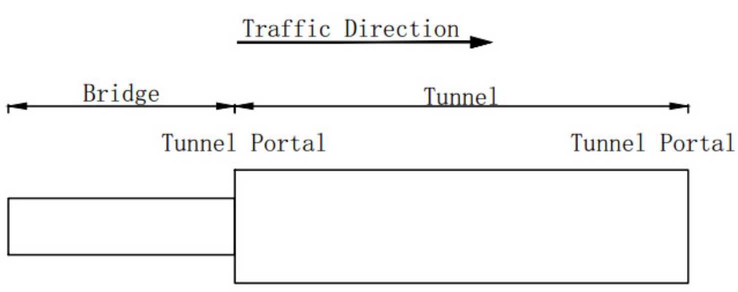

Figure 1 Bridge-tunnel connecting section

The second is the tunnel-bridge-tunnel form and which is shown in Figure 2.

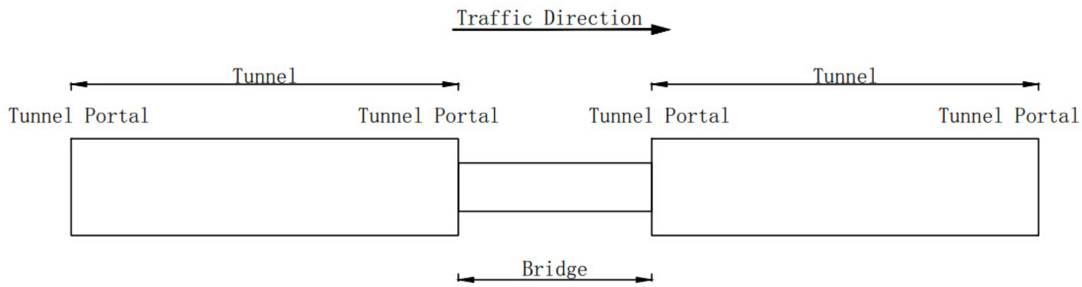

Figure 2 Tunnel-bridge-tunnel connecting section

The last one is the bridge-tunnel-bridge form which is shown in Figure3.

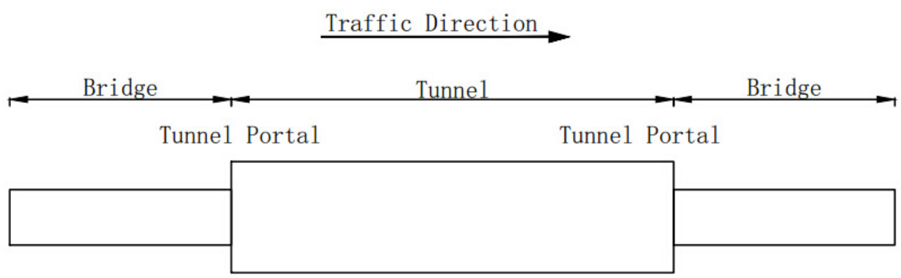

Figure 3 Bridge-tunnel-bridge connecting section

3.2 Driving simulation experiment design and experiment data analyze

Driving simulation is to make the drivers can be in a virtual environment where you can feel the driving experience close to the real effect of visual, auditory and somatosensory. This paper design the scene of Bridge-Tunnel connecting section of mountainous Highways by UC-win/Road.

3.3 Experiment aim and procedures

This experiment simulated single car driving in the bridge-tunnel connecting section of mountainous highway though the UC-win/Road software. The driving speed and heart rate of the drivers were measured during driving in the bridge-tunnel connecting section, then the data was analyzed using the method of statistical analysis.

Experiment procedures

First, UC-win/Road model were debugged, then test personnel got familiar with the driving simulation. Second, test personnel wore heart rate meter, sitting before a driving simulation screen and waiting for the start of the driving simulation test. Third, the test began: the driver simulated driving in the left and right line of bridge-tunnel connecting section respectively by 60 km/h and 80 km/h, and driving speed remains constant as far as possible. Heart rate meter automatically recorded the drivers' heart rate value and video recorder filmed simultaneously. Final, fog scene was added into the driving simulation, then above three steps were repeated.

3.3.1 Driving speed effect on the heart rate changes

In simulated driving tests, in order to determine the influence of the driving speed on drivers' heart rate change, the two groups controlled trials were implemented. Test speed was controlled in 60 km/h and 80 km/h respectively, and the heart rate per second in the process of drivers' driving is recorded. Though everyone has different driving habits and heart rate reference value, the change of heart rate can reflect the psychology when the driver was disturbed by external stimuli. Therefore the index of heart rate variability was used to analyze.

Heart rate variability means the ratio of the driver' heart rate in the process of driving at a time to the driver's average heart rate value stationary state. The following is the calculation equation of the heart rate variability.

$$N_i = \frac{n_i - \bar{n}}{\bar{n}} \times 100\%$$

N_i –*Heart rate* variability *of driver at a time in the process of driving , %*

n_i –*Heart rate value of driver at a time in the process of driving, bpm*

$\bar{n}$ –*The driver's average heart rate value stationary state, bpm*

When ten testers drove the car in the left of the tunnel-bridge-tunnel section and the speed was controlled 60km/h, the heart rate variability is shown in Figure 4.

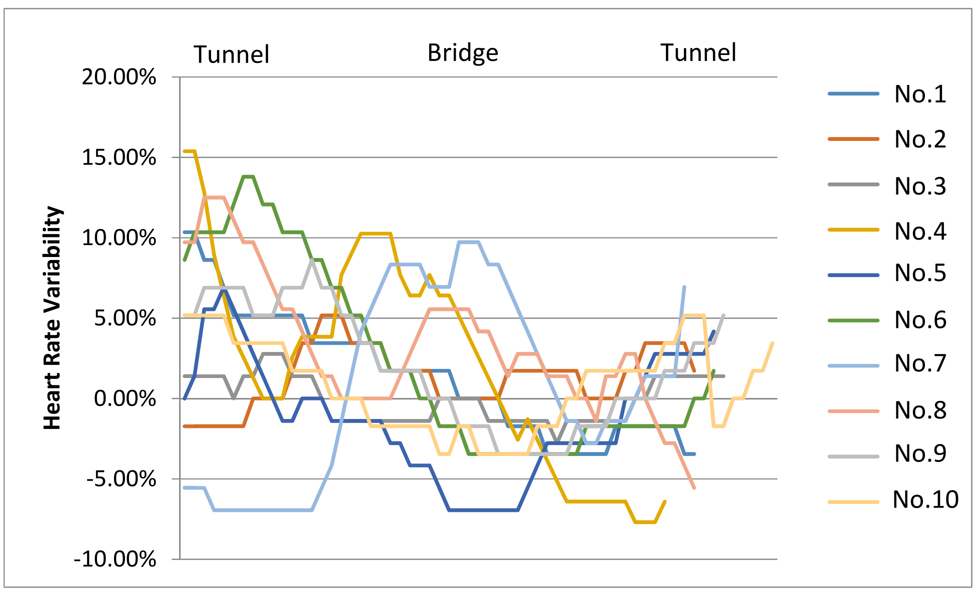

Figure 4 Drivers' heart rate variability (left line of bridge-tunnel connecting section, driving speed 60km/h)

The drivers' heart rate variability for all drivers was averaged and an obvious change trend appeared, which is shown in Figure 5.

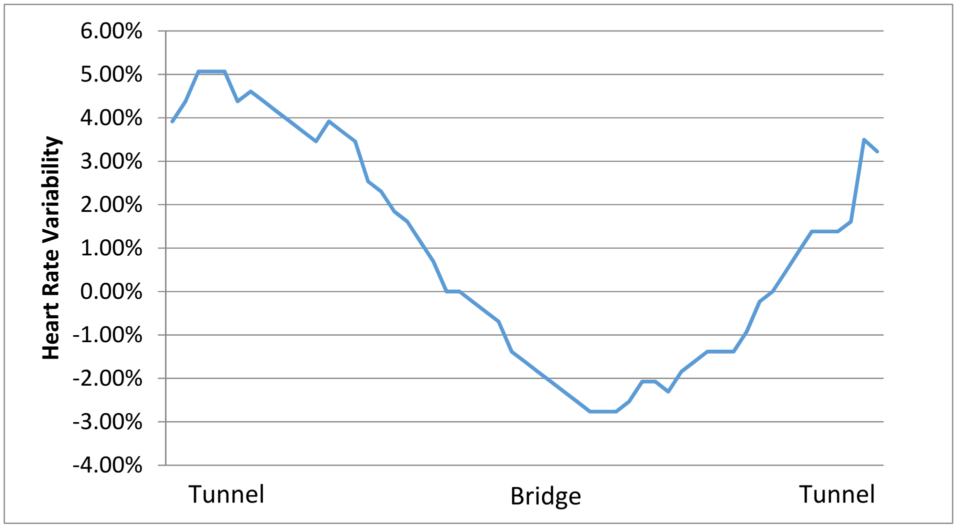

Figure 5 Drivers' average heart rate variability (left line of bridge-tunnel connecting section, the speed 60km/h)

According to Figure 4 and Figure 5, it indicated that the driver was unconformable and nervous, when the car began to drive into the mountainous tunnel, as a result of changing from normal sections into closed environment of tunnel. Then, after the driver adapt to the tunnel environment gradually, the change of heart rate tended to calm slowly. Driving in the bridge section, due to well road conditions and open driving vision the heart rate variability would stay in the range of -3% ~ 3%. When the driver drove into the tunnel second time, the heart rate variability was lesser than that of the first one due to the driver had got a certain tunnel driving experience.

When the driving speed was controlled 80km/h, the averaged heart rate variability for all drivers is shown in Figure 6.

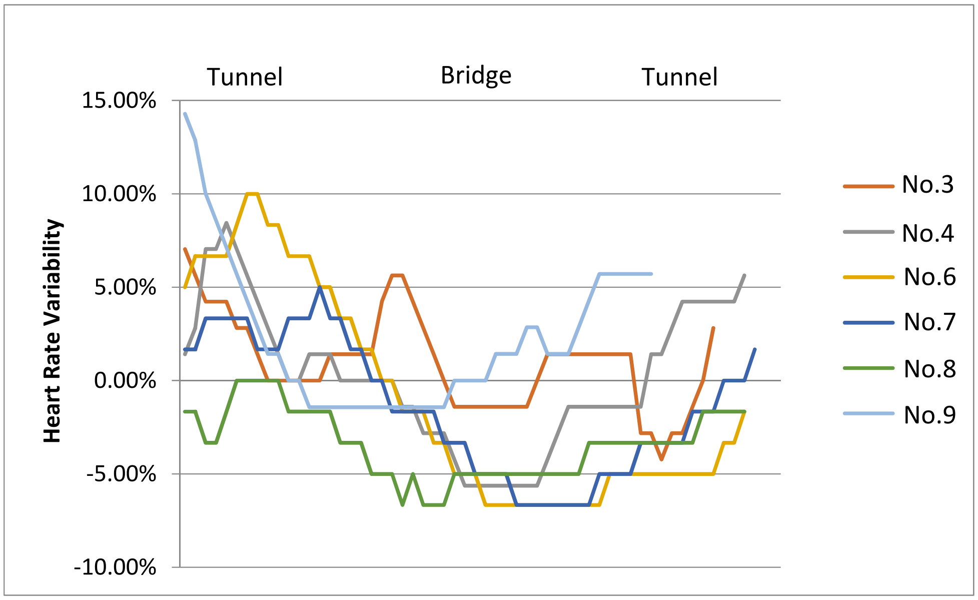

Figure 6 Drivers' heart rate variability (left line of bridge-tunnel connecting section, driving speed 80km/h)

And the driving speed was controlled 80km/h, the average heart rate variability is shown in Figure 7.

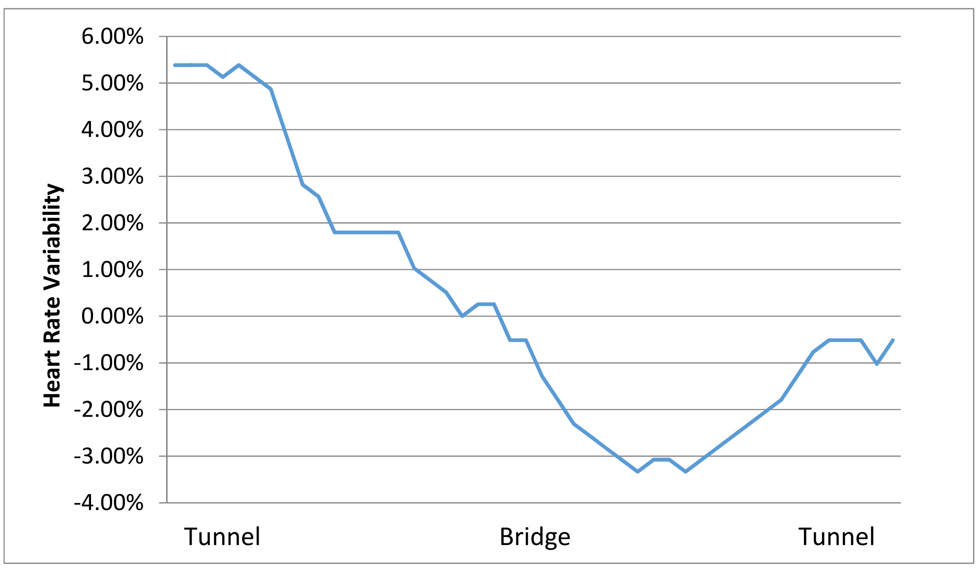

Figure 7 Drivers' average heart rate variability (left line of bridge-tunnel connecting section, driving speed 80km/h)

Compared between Figure 5 and Figure 7, it can be found that the higher the driving speed is, the larger the heart rate variability range driving in the bridge-tunnel connecting section.

3.3.2 The fog effect on the heart rate variability

Adverse weather, such as rainstorm and fog, which often appear in the mountainous area highway, has a serious impact for driving safety. In order to explore the fog impact for safe driving on bridge and tunnel connecting section, scene of bridge section affected by heavy fog was added into the driving simulation experiments, and the influence of the weather for the driving safety can be obtained through comparing to the driver's heart rate variability of the normal weather and that of the fog.

The change curve of heart rate driving in the left line at 60km/h in the fog was shown in Figure 8.

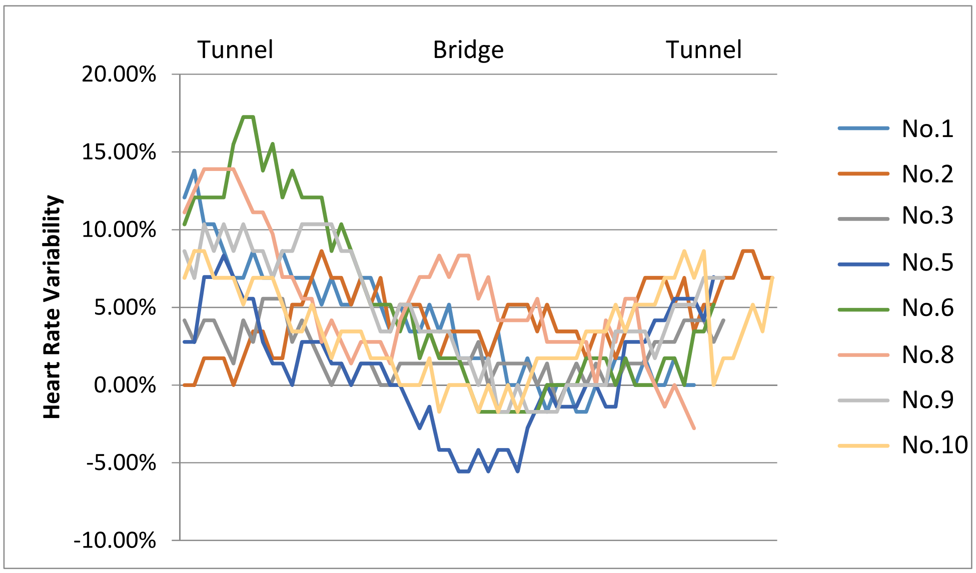

Figure 8 Drivers' heart rate variability under foggy weather conditions (left line of bridge-tunnel connecting section, the speed 60km/h)

Figure 9 is a control group data in normal weather.

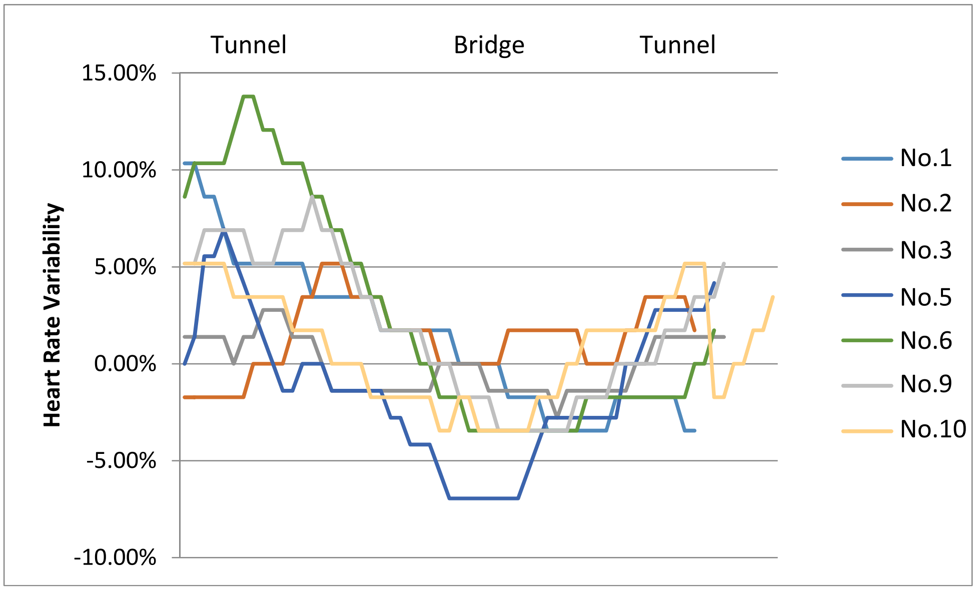

Figure 9 Drivers' heart rate variability under normal weather conditions (left line of bridge-tunnel connecting section, the speed 60km/h)

Compared Figure 8 with Figure 9, it is obvious that heavy fog weather brought great influence on driving in the bridge section and driver's heart rate variability increased significantly. During driving in the tunnel the driver wanted to drive out and expected the highway condition to improve out of the tunnel, while the fog weather made the visibility low and gave the driver with a high psychology dropout. Therefore the change of the heart rate variability is more significant than normal weather.

Thus, through the driving simulation, the relationship between the driving speed and the drivers' heart rate variability of the connection in the tunnels was analyzed.

3.4 Research of evaluation index of the bridge-tunnel connecting section based on drivers' heart rate

Safety evaluation methods can be roughly divided into two categories: firstly, direct evaluation method based on accident data; secondly, indirect evaluation method that is through the relationship establishment among road conditions, driving speed, drivers' psychological and physiological indexes, Building the relationship between intermediate targets and the traffic safety, we indirectly get the relation between road condition and traffic safety. This paper uses the heart rate variability as the connection section of the safety of mountain area highway tunnels intermediate targets, the connection section of the safety evaluation of tunnels.

Zhao (2012) established the relationship of heart rate and curve segment lateral force coefficient and proposed comfortable threshold of driver's heart rate variability driving on the curves with radius 100m-400m. The analysis of driver's comfortable threshold is showed in Table 1.

Table 1 Comfortable threshold of heart rate variability

Grow rate of heart rate	Driving condition on the curve segment
＜4.5	Driver feel no curve, and no any tension
6.5	Driver feel along the curve, slightly and smooth, but feel no any uncomfortable
8.5	Drivers obviously feel drive along the curve and a little unstable
10.5	40% of drivers feel uncomfortable driving on the curve
12.5	All drivers through the curve feel uncomfortable
14.5	Driver feels curve existent and unstable, tension is increased
＞16.5	Driver felt very unstable, and the risk of rollovers exists

Based on the above research result and the conclusion, the index of bridge-tunnel connecting section evaluation were presented in the Table 2.

Table 2 Evaluation index based on heart rate variability

Safety level	Mutation rate of heart rate n/%	Evaluation standard description
Excellent	$\vert n\vert<4.5$	High security level of bridge-tunnel and the length of the structures and plane geometry alignment combination is well.
Good	$4.5\ll\vert n\vert<8.5$	Security level of bridge-tunnel is acceptable and the length of the structures and plane geometry alignment combination is general.
Fair	$8.5\ll\vert n\vert<12.5$	Security level of bridge-tunnel are poor and the length of the structures and flat vertical linear combination should be modified.
Poor	$12.5\ll\vert n\vert<16.5$	Security level of bridge-tunnel are very poor and the length of the structures and flat vertical linear combination should be improved.
Danger	$\vert n\vert\gg16.5$	Driving in bridge-tunnel is dangerous and may lead to accident.

Thus, the safety evaluation process of bridge-tunnel connecting section can be presented as follow:

(1) Based on the modeling of bridge-tunnel connecting section, the simulation drive test was organized (the driving speed was controlled in design driving speed) and the driver’s heart rate was recorded in the driving process.

(2) The mean of the driver's heart rate at the bridge-tunnel connecting section can be calculated using mathematical methods. Then, the curve of heart rate variability is depicted.

(3) According to the evaluation criteria in Table 2, the safety level of the bridge-tunnel connecting section is evaluated.

(4) According to the evaluation results the corresponding safety advice is put forward.

3.5 Suggestion of the safeguard measures about the bridge-tunnel connecting section

Mountainous area highway transportation system which is composed of the people, vehicles, road and surrounding environment is a complex system. Below, from people, vehicles, road and surrounding environment aspects, the proposal to protect the safe operation of the bridge and tunnel connecting segment can be explained as following.

(1) Setup of the guided guardrail

The bridge cross-section is composed of driveway, passing lane and emergency stop road, and the tunnel cross-section is only composed of driveway and passing lane because of limited investment cost. So the cross-section wide of tunnel is narrower than that of bridge, and the traffic accident will perhaps occur in transition section of bridge and tunnel cross-section. Therefore, in order to guide the driver’s sight and make the bridge and tunnel section naturally connected, adding the guided guardrail within a certain distance in front of the tunnel entrance can be considered (Figure 10 and Figure 11).

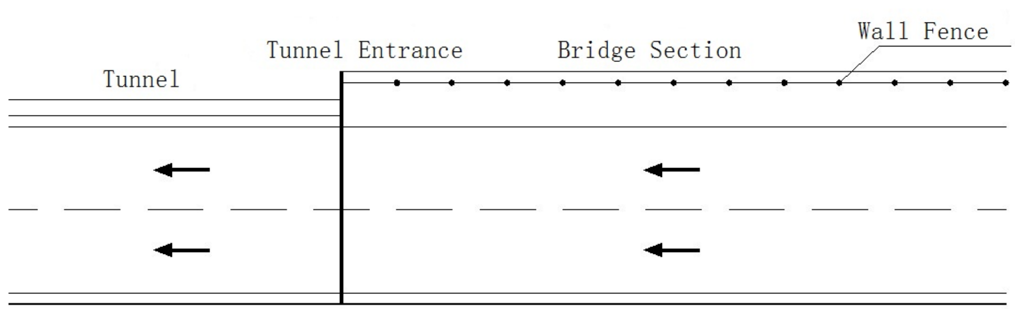

Figure 10 The guardrail position at tunnel entrance before improvement

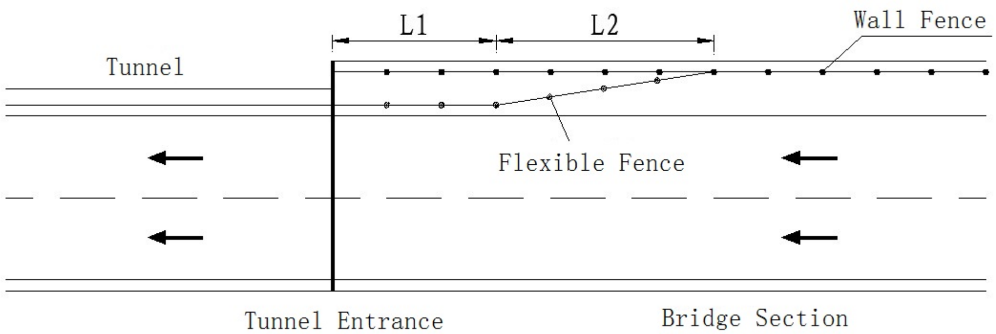

Figure 11 The guardrail position at tunnel entrance after improvement

(2) Setup of tunnel inducing facilities and variable information board

In order to avoid the vehicle crashing into the road shoulder of tunnel, inducing facilities within the tunnel should be setup (LED induction lamp, etc., as shown in Figure 12), and hanging variable information board (as shown in Figure 13) should be setup in a certain distance from the tunnel exit, warming the driver the weather conditions outside the bridge road and tunnel.

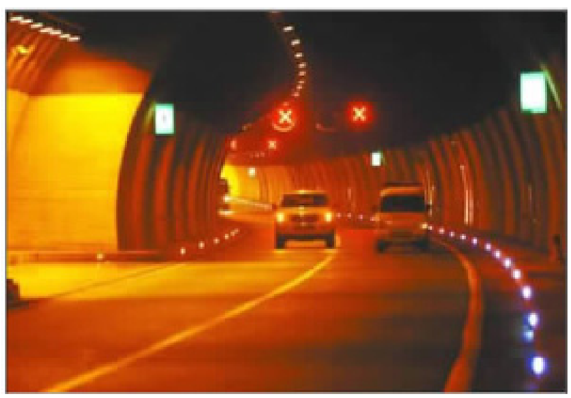

Figure 12 Effective vision inducing facilities in tunnel

Figure 13 The variable information board in tunnel

(3) Setup of lighting processing and deceleration zone in entrance and exit of tunnel

In order to avoid drivers' vision black hole phenomenon when entering the tunnel in daytime, the tunnel lighting should be fully guaranteed during the day and a sign at the entrance of tunnel should be setup to remind the driver to open the headlights in tunnel. Meanwhile, to reduce the drivers' uncomfortable when driving out of tunnel in dark night, tunnel lighting intensity should be weakened.

From the engineering angle, deceleration shock marking should be setup in the tunnel entrance to reduce the driving speed. The setting programs are showed in Figure 14-17.

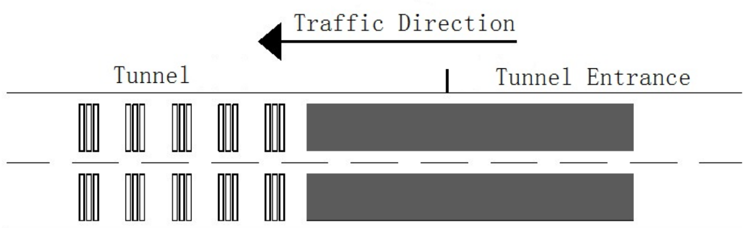

Figure 14 Uphill road of tunnel entrance vibration and deceleration marking settings

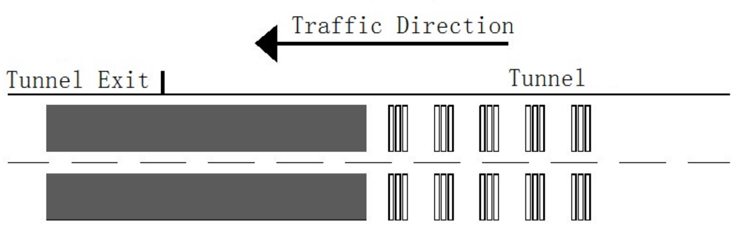

Figure 15 Uphill road of tunnel exit vibration and deceleration marking settings

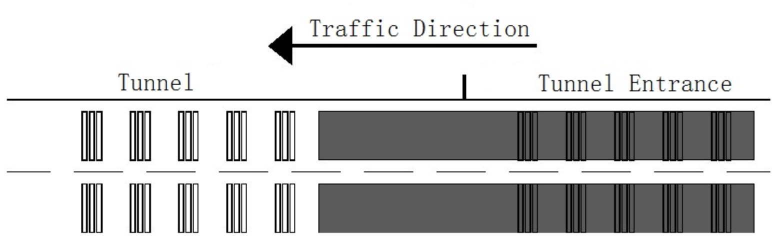

Figure 16 Downhill road of tunnel entrance vibration and deceleration marking settings

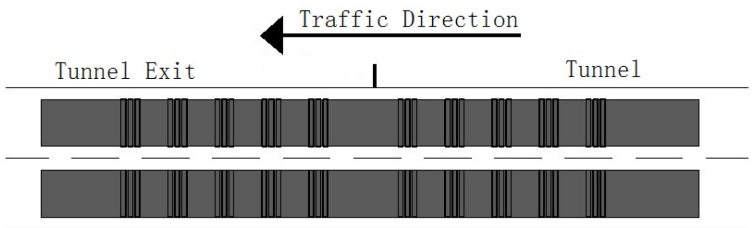

Figure 17 Downhill road of tunnel exit vibration and deceleration marking settings

Conclusions

Based on the mountainous area highway as the research object, a virtual modeling driving simulation is realized.

(1) A clear definition of the connection section of mountainous highway tunnels was put forward, and the bridge-tunnel connecting sections were classified based on the integrity of the bridge and tunnel system.

(2) Based on engineering design data of a typical bridge-tunnel connecting section, a driving simulation test with a model of bridge-tunnel connecting section ("tunnel-bridge-tunnel" type) and simulated foggy weather was carried out using UC-win/Road software.

(3) Based on the model of bridge-tunnel connecting section, the driving simulation was realized. Through analyzing the data of drivers' heart rate measured in experiment, the relationship between the drivers' heart rate variability and driving speed and the fog weather can be put forward. And the safety evaluation criteria based on the drivers' heart rate variability in the bridge-tunnel connecting section were set up.

Acknowledgement

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References

Amundsen F. H. and Ranes G. (2000). Studies on Traffic Accidents in Norwegian Road Tunnels. *Tunneling and Underground Space Technology*, 15(1), 3-11.

Blaszczyk, P, Turek, W. and Cetnarowicz, K. (2014). Extensible platform for studying the behavior of drivers in urban traffic. *IEEE*, 8-11.

Du Yiwen, Han Zhi, Hang li, et al. (2006). Fuzzy Evaluation Method for Road

Tunnel Safety. *Technology of Highway and Transport*, 8(4)120-123.

Fleyeh, H. (2006). Shadow and highlight invariant colour segmentation algorithm for traffic signs. *IEEE*, 1-7.

Johansson Backlund (1970). Drivers and road signs. *Ergonomics*, (13), 749-759.

Koh, P. P., Wong, Y. D., Chandrasekar, P. (2014). Safety evaluation of pedestrian behaviour and violations at signalised pedestrian crossings. *Safety science*, 143-152.

Liu Xiubai (2009). Research on Safety Evaluation and Improvement Measures of Mountainous Freeway Bridge-Tunnel Sections. Changan University.

Luo Yuping, Gao Guifeng, Wu Hongli. Study on Fuzzy Evaluating System of Traffic Safety in Highway Tunnel. *Journal of Shi JiaZhuang Railway Institute,* 19(3), 75-79.

Pan Xiaodong, Fu Zhibi, Yu Zewen (2012). The Connecting Section Between Tunnels and Bridges in Mountainous Highway Traffic Safety Evaluation Model. *Highway Engineering*, 37(3), 1-4.

Scott-Parker B., Goode N. and Salmon P. (2015). The driver, the road, the rules ... and the rest? A systems-based approach to young driver road safety, *Accident analysis and prevention*, 74, 297-305.

Wang Hui, Jia Jia (2006). Road safety in mountainous area highway design concept. *Chinese and foreign road*, 26(2), 7-10.

Xu Hongguo, Liu Zhaohui Wang Chao, et al. (2006). Safety Evaluation of Highway in Mountainous Area Based on Fuzzy Statistics. *China Safety Science Journal*, 16(10), 116-119.

Xue Jie (2010). The Crucial Technology Research of Bridge and Tunnel Linked Segment of Mountain Highway. Wuhan University of Technology.

Zeng Hongxia, Yao Hongyun, Liu Langtao. (2013). Research on Safety Evaluation Index System for Connection Sections between Expressway Bridges and Tunnels. *Technology of Highway and Transport*. 6(3), 139-142.

Zhao Ming (2012). Evaluation Model of Driving Safety at Curves on Mountainous Highways Based on Driving Behaviors and Physiological Activities Analysis. *Tongji University*.

Sensor Fault-Tolerant Control of Electric Power Steering for Electric Vehicles

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Abstract: The existing research of the electric power steering (EPS) system less focuses on the safe and reliable operation. Especially the application of fault-tolerant theory to EPS of electric vehicles (EV) actually. In this paper, EPS is built based on sensor fault-tolerant control for EV. Then, the riccati equation is introduced constantly correcting weight matrix Q and R. Finally, a co-simulation analysis is conducted in MATLAB to evaluate the proposed fault-tolerant controller. It is shown that the design had a positive effect in that it could effectively improve performance due to sensor failure. And, a rapid control prototype is built based on dSPACE, a hardware-in-the-loop simulation platform, in order to conduct a real EV test. The results of test are consistent to the simulation and verified the correctness of simulation. The proposed research ensures the steering safety, enhances the EPS stability, and improves the driving comfort.
Keywords: Electric power steering; Fault-tolerant control; Electric vehicles; Sensor failure.

1 Introduction

Electrified vehicles, including electric vehicles (EV) and hybrid electric vehicles (HEV), powered by batteries can achieve quieter and pollution-free operation, which has offered a solution to next generation vehicles. Unlike internal combustion engine vehicles, EV is zero emission but needed to improve the safety and save the fuel consumption (S. W. Yoon, M. D. Glover, K. Shiozaki, 2013).

For advanced vehicles today, many technologies embedded in the micro-controller unit (MCU) enhance the vehicle stability and handling performance in critically dynamic situations. For example, the antilock braking system (ABS) (C. B. Patil, R. G. Longoria, J. Limroth, 2003), electronic differential

(ED) (M. C. Tsai, J. S. Hu, 2007, 2008), and so on, are all solutions implemented to improve both safety and handling. As a necessary part of EV, EPS system has been developing rapidly and becomes one of the safe-critical systems. To compare with the hybrid-power assisted steering system, EPS system promises weight reduction, fuel savings and package flexibility, at no cost penalty(W.Zhao, G.Shi, Y.Lin, etc, 2011).

Although there are many benefits for the EPS car, the research considering practice for safe and reliable operation is still less and there is no more retrievable information at present, so it is urgent to develop the EPS system with steering performance and achieving safe handing(C.Tian, C.Zong, X.Wang, etc, 2009).

The sensor failures such as deadlocking, gain change and so on, might result in severely consequences.So, it is significant value for high reliability design of EPS that the fault-tolerant control is introduced.(G.Xie, D.Tian, G.Yin, 2006) When one or more than one component of system fails, the system does not need to be reconstructed with fault-tolerant control. It makes full use of the remained parts to keep the system stable operation and the prescriptive performance or performance index decreasing slightly (but it is acceptable) to fulfill the tasks safely.

Vehicle reliability and a"limp home" functionality are important considerations for the automotive industry, within the electrified vehicles field this topic is covered in the fault tolerance strategies. A fault-tolerant operation method for a dynamic electric vehicle propulsion system using variable torque versus speed characteristics is also presented. The electrically powered vehicle can continue driving with a minimum performance reduction, and without the need for redundant systems on machine or electronics level.(T.Gerrits, C.G.E.Wijnands, J.J.H.Paulides, etc, 2012).

In this study, EPS is built based on sensor fault-tolerant control for EV. Then, the matrix of the vehicle steering dynamics is introduced. Finally, a co-simulation analysis is conducted in MATLAB to evaluate the proposed fault-tolerant controller. It is shown that the design had a positive effect in that it could effectively improve performance due to sensor failure. And, a rapid control prototype was built based on dSPACE, a hardware-in-the-loop simulation platform, in order to conduct a real EV test. The test results were consistent with the simulation results, thus verifying the simulation.

2 Fault-Tolerant Control

2.1 Problem description

Considering linear continuous system as follows:

$$\dot{x}(t) = Ax(t) + Bu(t) \tag{1}$$

$$Y(t) = Cx(t) + Du(t) \tag{2}$$

Where,x(t)is state variable; u(t) is input; A, B, C, and D is coefficient matrix;(A,B) is controllable matrix.

The state feedback control :

$$u = -Kx \tag{3}$$

For the sensor faults that are probably appeared**,** switch matrix F is introduced, the form is as following:

$$F = diag(f_1, f_2, \cdots, f_n)\,,\; f_i = \begin{cases} 1 & \text{(normal)} \\ \gamma(0<\gamma<1) & \text{(partial failure)} \\ 0 & \text{(complete failure)} \end{cases} \tag{4}$$

When considering sensor faults, closed-loop system is expressed as the following equation:

$$\dot{x}(t) = [A - BKF]x(t) \tag{5}$$

The design problem can be described as: when sensor faults occur, it will look for proper state feedback control matrix K which can make closed-loop system (5) remain stable for all possible as shown in figure 1.

2.2Design of fault-tolerant controller

Fault-tolerant control based on riccati equation can constantly correct weight matrix Q and R by means of an iterative, which makes the solution of riccati equation satisfy special condition(sensor is normal or fault).Then, the feedback control matrix K is gained to improve the reliability of system by adopting, as follows:

For above linear system, state feedback matrix is designed as follows:

$$K = R^{-1}B^{T}P \tag{6}$$

Where, P is symmetric positive definite solution of algebraic riccati equation

$$(\alpha I + A)^T P + P(\alpha I + A) - PBR^{-1}B^T P = -Q \tag{7}$$

For the nominal system as Eq.(1),state feedback control as Eq.(3) can minimize quadratic performance index function

$$J = \int_0^\infty e^{2\alpha t}(x^T Q x + u^T R u)dt \tag{8}$$

In which, weight matrix Q is non-singular matrix, R is diagonal matrix.

When,

$$\mathrm{Re}\{\lambda(A - BKF_i)\} < -\alpha \tag{9}$$

The closed-loop control system has fault-tolerant ability to each kind of sensor fault mode as $F_i \in F$;Where, $\lambda(A - BKF_i)$ represents the system poles of closed-loop under any fault mode ,α is stability margin of system.

3 Road Test and Result

3.1 Test Device and System

The tests were performed using the control system. It comprises a rapid control module, an actuator system, and a sensor system. The SC unit is used for communication between the sensor system and the main controller unit. The PU is used for communication between the actuators and the main controller unit. The 1401/1505/1507 MicroAutoBox is used as the main controller unit. In the actuator and dSPACE system, the input power of 12 V is obtained from the car battery. The entire control loop is closed by the driver in the real EV.

3.2 Road test and analysis

To prove the validity of the control, a parking steering as well as various S-shaped working conditions are adopted to perform joint simulation at torque sensor failures for fault-tolerant control (FC) and not fault-tolerant control (NFC), respectively. This car equipped with the original passive suspension system and the active suspension system with the chaos control, respectively. The primary variables measured during the simulation are the steering wheel turning angle, the steering wheel torque and the moving velocity of the vehicle.

3.2.1 Parking Steering Working Conditions

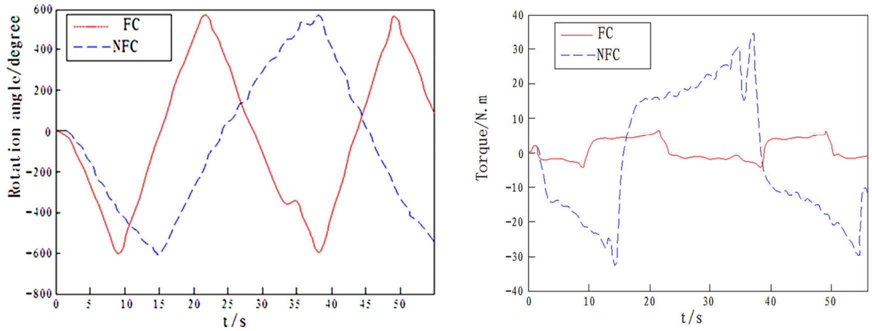
The test analysis on the parking steering working conditions can be employed to illustrate the improvement status for the EPS established over the steering performance for the vehicle.

3.2.2 The S-shaped Working Condition Simulation

The state standards "Vehicle Handling and Stability Test Methods Experiments on Turning Convenience" regulates to carry out simulation on the road surfaces with vehicle speed of 30±2km/h.

3.3 Discussion

Fig. 1(a, b) and Fig. 2(a, b) show that the fault-tolerant controller (FC)applied on the EPS effectively reduces the steering torque. It has better results than a traditional EPS without fault-tolerant control(NFC) especially on an Parking Steering and S-shaped Input. When torque sensor faults occur, the maximum steering wheel angle does not change. But the maximum torque and average torque of traditional EPS are more higher than EPS with fault-tolerant control as shown in Tables. 1 and 2.From the results presented above, it has indicated that the proposed control method can suppress the sensor faults effectively.

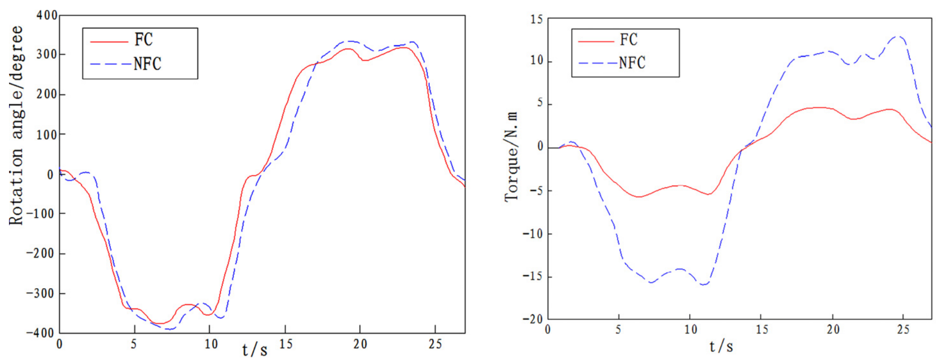


(a)steering wheel angle (b) steering torque

Figure 1 .Comparison chart of Parking Steering

Table 1. Results of Parking Steering

performance indexes	NFC	FC
Maximum wheel angle/°	600	600
Maximum torque /N.m	34.71	6.58
average torque/N.m	16.47	2.79



(a) steering wheel angle **(b) steering torque**

Figure 2. Comparison chart of S-shaped Input

Table 2. Results of S-shaped Input

performance indexes	NFC	FC
maximum wheel angle/°	389.3	376.6
maximum torque/N.m	15.99	5.77
average torque/N.m	9.34	4.44

4. Conclusions and future work

In this study, we focus on fault-tolerant technology which is the key technologies for EPS in EV. Linear system is described, on the basis of which the riccati equation of fault-tolerant controller is introduced. Co-simulation and road test are carried out on some conditions of sensor failures. Result shows that EPS with fault-tolerant could maintain stability. But there are some shortcomings such as fast response, no gain change and non-oscillation, the problems, and so on. In the future work, we will continue to improve control precision and performance robustness further.

References

C.B.Patil, R.G.Longoria, J.Limroth (2003). Control prototyping for an anti-lock braking control system on a scaled vehicle. *In Proceedings of the IEEE Conference on Decision and Control*, 42 (5), 4962-4967.

C.Tian, C.Zong, X.Wang, P.Zhang (2009). Research on the sensor fault rebuilding based on riccati-type equation for steer-by-wire system. *China Mechanical Engineering*, 20 (21), 2637-2641.

G.Xie, D.Tian, G.Yin. Research on fault tolerance control technology for sensor failure of electric power-steering system (2006). *China Mechanical Engineering*, 14 (17), 1532-1535.

M.C.Tsai, J.S.Hu (2007). Pilot control of an auto-balancing two-wheeled cart, *Advanced*, 21, 817–827.

R.Loureiro, R.Merzouki, B.O.Bouamama (2012). Bond graph model based on structural diagnosability and recoverability analysis: Application to Intelligent Autonomous Vehicles, IEEE Transactions on Vehicular Technology, 61(3), 986-997.

S.W.Yoon, M.D.Glover, K.Shiozaki (2013). Nickel-tin transient liquid phase bonding toward high-temperature operational power electronics in electrified vehicles, *IEEE Transactions on Power Electronics*, 28 (5), 2448-2456.

T.Gerrits, C.G.E.Wijnands, J.J.H.Paulides, J.L.Duarte (2012). Fault-tolerant operation of a fully electric gearbox equivalent, *IEEE Transactions on Industry Applications*, 48 (6), 1855-1865.

W.Zhao, G.Shi, Y.Lin, H.Nie (2011). Tracking performance of electric power steering system based on the Mixed H2/H∞Strategy, *Chinese Journal of Mechanical Engineering*, 24 (4), 584-590.

Reliability Evaluation of a Freeway Guidance System

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Abstract: In order to evaluate the reliability of freeway guidance-system accurately, the indicators about it were studied quantitatively. Firstly, the indicators system, which consists of time reliability, information integrity, information accuracy, coverage area, compliance rate to the guidance-system, was constructed. The meanings of all indicators were illustrated and the relationships among indicators were analyzed. Secondly, the model for calculating the guidance-system reliability of the freeway section was set up by using the probability theory and the structure system reliability method. The statistical method to calculate the guidance-system reliability of freeway networks with the same-service-level sections or different-service-level sections was presented. The probability model of the compliance rate (E_5) which was the strongest random event was proposed. Finally, a freeway guidance-system was employed as an example, $P(E_5)$ was selected as the whole system reliability after monitoring and analyzing the guidance-system. The consequence was verified by the traditional vehicle-statistics theory, the differences between forecast and actual outcome are in [0.06, 0.14]. The result shows the model has higher credibility.

Keywords: Freeway; The guidance-system; Reliability; Evaluation; Probability theory.

1 Introduction

Stable and reliable freeway guidance system can balance the traffic flow, improve traffic conditions, increase the utilization rate and ensure safety of freeway. But the existing traffic guidance system is vulnerable to the influence of traffic dynamic randomness and it is difficult to evaluate accurately by specified indicators. As a very important probability measure indicators (Marvin Rausand,2010),reliability can be used to evaluate the running quality of the guidance system .It is significant to the traffic control, capacity and traffic demand balance, emergency rescue and other management of freeway.

Reliability degree is the characteristic value of reliabilityand it is also an important indicators to measure system performance(GAO S S, ZHANG L X, 2002). The study on reliability degree began in 1930s, the aircraft security research was the mainly point at that time (Marvin Rausand,2010). But in road transportation, the network reliability concept was first proposed by Japan 's Mine and Kawai Mine H, in 1982 (Kawai H,1982), Asakura and Kashiwadani proposed the concept of run-time reliability in 1991(Asakura Y, Kashiwadani M,1991). Anthony Chen proposed the concept of the capacity of the road network reliability(Chen A, Lo H K, Yang H, et al,1999,2000). Recently, reliability has been initially applied in road transportation system and public transport system. Chinese scholars studied the reliability of urban roadway network from the capacity, travel time, connectivity and accessibility, and made a lot of achievements. For example, Dai Shuai, from running time, waiting time, service quality, studied the reliability of public transport systems(DAI S, CHEN Y Y, RONG J, LIU X M,2006). Xiao Dianliang analysed the reliability of freeway emergency rescue system(XIAO D L,2008). But few studies are on the reliability of freeway guidance system.

This paper discussed evaluation indexes and calculation methods for the reliability of freeway guidance system, expecting to play a positive role in this field.

2 Evaluation indicators of guidance-system reliability

2.1 Guidance system

Based on guidance system facilities, freeway guidance systems centre on participants and balancing the freeway network traffic flow. It can reduce the travel time and travel distance, avoid some special events (accident, etc.), and improve the efficiency of freeway transportation (ZHANG X J,2008). Freeway guidance system is divided into static and dynamic guidance system.

This paper is emphasized on the dynamic guidance system, and defined it as a technical system. Including: system, system boundary, the output (consists of two parts: (1) the specified output, (2) non-specified output), the input(①the specified input ② non-specified input), boundary conditions.

2.2 Evaluation indicators

The reliability of freeway guidance system is the ability to fulfill the guidance tasks for traffic or transport under the certain service-level and dynamic traffic conditions. The quantitative evaluation indexes system which consists of time reliability, information integrity, information accuracy, coverage area, compliance rate to the guidance system, was constructed in the paper.

Defining the comprehensive guidance-system-reliability is a function of all above reliability indicators. The function can be expressed as $GSRI_i = f(T_i, F_i, R_i, C_i, O_i)$

where: T_i is the time reliability，it is the ability of the guidance information to transmitted timely, it can be expressed as:

$$T_i = \frac{t}{t_i} \times 100\% \tag{1}$$

Where t is the time threshold from information detected to published under given conditions; t_i represents the real time from information gathered to published in time i. The greater T_i, the higher reliability.

F_i : Information integrity, is the ability that the information loss rate is not greater than the time threshold during information transfer. Formula is:

$$F_i = \frac{f_i}{f} \times 100\% \tag{2}$$

Where f_i is the amount of information transferred to the objective guidance terminal in time i (expressed with the number of transferred data packet)under given conditions. f is the amount of information should be transmitted to guidance terminal under given conditions and within the specified time. The greater proportion means the higher reliability of information integrity.

R_i: The information accuracy reliability, is the ability that the ratio of the correct information transferred to the objective of guidance terminal to the total amount of information (number of packets) is not less than the given time threshold during information transfer. Formula is:

$$R_i = \frac{r_i}{r} \times 100\% \tag{3}$$

Where r_i and r respectively is the amount of correct information sent to each guidance terminal in time i (expressed with the number of data packets) , the amount of all the correct information in real time monitoring under given conditions and within the specified time.

C_i: Coverage reliability, is the ability that the rate of the information coverage area transferred to the guidance terminal to the normal cover area is not less than the given value. Formula is:

$$C_i = \frac{s_i}{s} \times 100\% \tag{4}$$

Where s_i and s respectively is the area of guidance information covered in time i and normal cover area under given conditions, within the specified time.

O_i:Compliance reliability of guidance-system. It refers to the ability that the rate of traffic participants received guidance information to all traffic participants in the coverage area of guidance-system is not less than a given value. Formula is:

$$O_i = \frac{o_i}{o} \times 100\% \tag{5}$$

Where o_i is the number of traffic participants which choose to receive guidance information in time i, o is all traffic participants in the coverage area of guidance-system. The Freeway traffic guidance-information is not mandatory, but suggestive, it can be followed or not by drivers, so O_i can evaluate the operation quality of freeway guidance-system and influence the traffic flow of freeway.

3 Reliability Calculation

3.1 Calculation Method

3.1.1 Calculation method of highway-section Guidance-system

Each parameter of the guidance-system represents the running state of a subsystem, one indicators' invalidation leads to poor running state of the subsystem, and then other related subsystems' running states are badly affected. Viewed from system theory point, once one parameter fails, the entire system will lose its guidance ability, so it is reasonable to establish a system model made up of sub-units in series, and to predict the guidance reliability of highway-section system according to the series system.

(1) The reliability calculated according to series system

Let the event of time reliability as E_1, and the corresponding reliable probability as $P(E_1)$, the reliability of information integrity, information accuracy , coverage area, compliance rate in the corresponding time as E_2, E_3, E_4, E_5 respectively, and the reliable probability as $P(E_2), P(E_3), P(E_4), P(E_5)$. If one of the five indicators fails, the whole system fails, it means the logic gate is in line with the "or gate", that is to say any failure of any event E_i in system can cause the failure of the whole system, which can be shown in Fig.1.

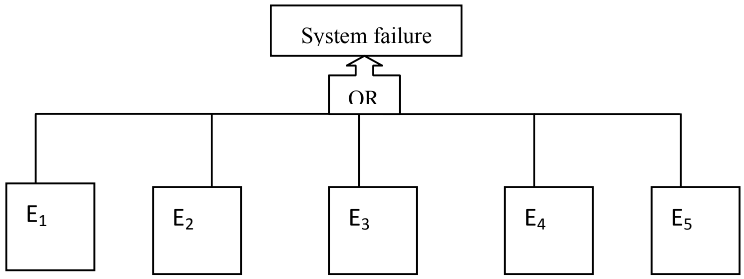

Figure 1. The diagram of Logic gate

According to probability theory, the reliability events of series system E_f can be written as:

$$E_f = E_1 \cap E_2 \cap E_3 \cap E_4 \cap E_5$$

If and only if all the elements of the system work properly, the series system can work normally. System reliability $P\left(E_f\right)$ is the product of the probability of all the events, namely

$$P\left(E_f\right) = P(E_1 \cap E_2 \cap E_3 \cap E_4 \cap E_5)$$

In the case of these events statistical independence mutually, according to the multiplication rule, it can be simplified as:

$$P(E_1 E_2 E_3 E_4 E_5) = \prod_{i=1}^{5} [P\left(E_i\right)]$$

And the system reliability is:

$$R_S = \prod_{i=1}^{5} [P\left(E_i\right)]\left(0 \le P\left(E_i\right) \le 1\right) \tag{6}$$

From the above equation we know the reliable probability is less than 1.0, which was made even less with the product. The method is suitable for the guidance-system whose subsystems have high degree of reliability, and in this case the results won't be seriously downsized.

(2) calculating system reliability with the minimum parameter

Theoretically, system reliability should be the product of five units' reliability, but when all the reliabilities of indicators in the selected guidance-system are low, in order to avoid the excessive downsizing of the results, the unit with the smallest reliability in the series system can be chose to serve as internal reliability of the system, i.e.

$$R_S = \min\{P(E_i), \ 0 \le P(E_i) \le 1\} \quad (7)$$

3.1.2 Calculation for Guidance-system Reliability of Freeway Networks

Guidance-system reliability of the freeway network can be calculated with statistical methods, namely, it is the weighted average of regional sections' guidance-system reliability.

(1) The guidance reliability of freeway network with same-service-level subsystem

When the service levels are in same, the network can be looked as a whole, making the weighted average of the guidance range of each local guidance-system, and the reliability of the whole freeway system in certain time under certain service level R_s is showed as following:

$$R_s = \frac{\sum_{i=1}^{n} R_{s_i} \bullet s_i}{\sum_{i=1}^{n} s_i} (i = 1, 2, \ldots n) \quad (8)$$

Where: s_i is the coverage area of i section's guidance information in certain time; n is the number of the sections in the whole freeway network under the same service level; R_{s_i} is the traffic guidance-system reliability of section i in certain time.

(2) The guidance reliability of freeway network with different-service-level subsystem

When the freeway network has different-service-level subsystems, it is also considered as a whole. Assumed that the freeway network has 6 different-service -levels, the guidance reliability of the whole freeway network R_s is showed as following:

$$R_s = \sum_{m=1}^{6} \frac{\sum_{i=1}^{n} R_{s_i} \bullet s_i}{\sum_{i=1}^{n} s_i} \bullet \partial_m (i = 1, 2, \ldots n; m = 1, 2, 3, 4, 5, 6) \quad (9)$$

Where: ∂_m is the weighted average for grade m (contributions made by different service levels to guiding vehicles), which can be determined by the value of $P(E_5)$; s_i refers to the guidance-information-coverage area of section i in certain time; R_{s_i} refers to the traffic guidance-system reliability of section i in certain time; n is the number of the sections in the whole freeway network under the same-service-level; m is the service level of a certain freeway.

As the freeway guidance-system reliability belongs to the probability problem, it is related closely to the survey cycle, survey times and survey accuracy. Therefore, in practice, increasing the survey times can improve the survey accuracy.

3.2 Calculation Model of $P(E_5)$

The calculations are given as following:

If participants received guidance information over sixty percent of all traffic participants, then event E_5 will effective. Assume the service level of freeway system is A, namely, vehicles run freely, use event B to present arriving x cars, event C to present cars accepted guidance information. B and C are independent to each other. Arriving vehicles follow the Poisson distribution which the arrival rate is λ, that is

$$P(x) = \frac{(\lambda t)^x e^{-\lambda t}}{x!},\ (x = 0,1,...,n) \tag{10}$$

The occurrence probability of event C is $P(c)$, X presents the number of cars accepted service less than forty percent of x, and event C only has two choices: to accept information or not . So $P_b = 1/2$, that is $X \sim C(n, P_b)$, and here we get:

$$\sum_{i=0}^{0.4x} p_b = \sum_{i=0}^{0.4x} c_x^i {p_b}^i (1-p_b)^{x-i} = P(C) \tag{11}$$

$$P(BC) = P(B)P(C) = P(x) = \frac{(\lambda t)^x e^{-\lambda t}}{x!} \bullet \sum_{i=0}^{0.4x} c_x^i {p_b}^i (1-p_b)^{x-i} = 1 - P(E_5) \tag{12}$$

$$P(E_5) = 1 - P(BC) \tag{13}$$

4 Examples

The instance freeway is two-way four-lane, the research length is 6km, and design speed is 100km / h, the direction nonuniform coefficient is 0.6 (uplink direction as the main driving direction), traffic volume of each lane less than 1000pcu/h. Vehicle detectors, meteorological monitoring devices, out-field cameras, variable message signs, etc. are all equipped.

The detection showed that E_5 is not as stable as E_1, E_2, E_3, E_4 in the detecting period , also these parameters value is low. To avoid the excessive downsizing the system's reliability, this paper choose the minimum value of evaluation parameter. Finally to verify the value with the percentage of vehicles accepted guidance service to all vehicles in the freeway network under certain conditions . Formula is showed as:

$$R_s = \frac{\sum q_c}{Q} \times 100\% \tag{14}$$

R_s is the integrated reliability of the guidance-system; q_c refers to the number of vehicles accepted right guidance , Q is the average number of vehicles running on the freeway network in survey period. Comparing the calculation, the results are shown in table 1.

Table 1. results contrast

classes	Up link1	Down link1	Up link2	Down link2	Up link3	Down link3	Up link4	Down link4	Up link5	Down link5
actual-survey value	0.32	0.38	0.32	0.31	0.32	0.29	0.34	0.29	0.29	0.3
Predicted value	0.4	0.44	0.21	0.21	0.18	0.2	0.21	0.18	0.2	0.4
difference	0.08	0.06	0.11	0.1	0.14	0.09	0.12	0.11	0.09	0.1

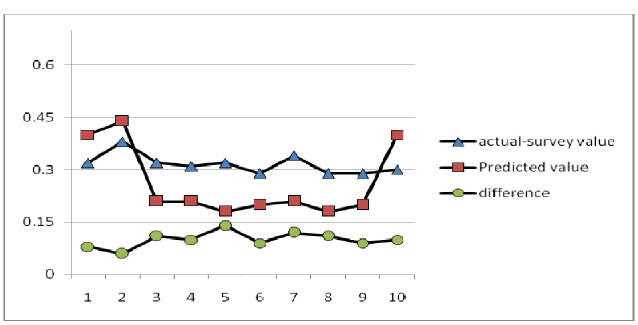

Figure 2. Actual survey and predicted comparison chart

The result shows, differences between the survey data and the predicted results are in the range of [0.06, 0.14]. The results of down line are much closer to the survey data, while the results of up line are much more stable. The predicted value differs greatly at the beginning and the end. It is because that the traffic volume of the freeway is small, but direction distribution are obvious difference, so, the predicted result difference of the uplink and downstream is relatively large. The down line traffic volume is smaller than the up line's, and inter-affects of cars are small, better information guidance effect is gained at the same time, so the predicted result of down line is much closer to the actual value. The traffic flow of the up line is much larger and more steady, so the reliability of it is more stable. Traffic incidents occur in the beginning and the end of the survey, so there are high fluctuations in the predicated values. Overall, the reliability of the freeway guidance-system varies in the range of [0.29,0.38], and the reliability is relatively low. Further construction and adjustment to the guidance-system is needed.

The boundary conditions, inputs and outputs of guidance-systems of different freeway sections are different, the reliability indicators are different, so the evaluation method for the reliability is determined by specific situations, and the minimum method of evaluation indicators can not be selected blindly. Since to obtain the information of large freeway network guidance-system is difficult, no instance analysis for its reliability is studied in this paper.

5 Conclusions

Based on the reliability theory, the reliability on the traffic guidance-system of freeway was discussed and the evaluation model was established in this paper. The example shows the model to calculate $P(E_5)$ is reasonable and conform to the actual situation.

The further studied directions can be summarized as follows:

(1)With the development of science and technology of transportation, and the changes of participants' demand, the improvement of guidance-system, the evaluation method of the guidance reliability must be updated and improved.

(2)Traffic guidance-system is a huge system, in order to increase the success rate and reduce unnecessary loss of property during the system construction ,the viable testing methods for the appropriate scale of system is imperative.

(3)The evaluation method of the guidance reliability for large freeway-network-guidance-systems is an important research direction.

Acknowledgement

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References

Asakura Y, Kashiwadani M(1991). Road network reliability caused by daily fluctuation of traffic flow. *PTRC Summer Annual Meeting, 19th, University of Sussex, United Kingdom.*

Chen A, Lo H K, Yang H, et al(1999). A capacity related reliability for transportation networks. Journal of Advanced Transportation, 33(2): 183-200.

Chen A, Lo H K,Yang H, et al(2002). Capacity reliability of a road network: an assessment methodology and numerical results. Transportation Research Part B: Methodological, 36(3): 225-252.

DAI S, CHEN Y Y, RONG J, LIU X M(2006). Study on System Reliability of PublicTransportation. Journal of Beijing University of Technology. 32(9): 813-816.

GAO S S, ZHANG L X(2002).Reliability theory and engineering application. National Defense Industry Press.

Mine H, Kawai H(1982). Mathematics for reliability analysis. Tokyo: Asakura-shoten.

Marvin Rausand(2010).System Reliability Theory. National Defense Industry Press.1-7.

XIAO D L(2008). Research on Reliability Analysis of Freeway Emergency Rescue System. Master Degree Thesis, Chang'an University ,6.

ZHANG X J(2008). Intelligent Traffic Guidance-system. Master Degree Thesis, Shenyang University of Technology.

Press-Assembly Depth Analysis of the Sealed Cowling for Freight Car Bearings

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Abstract: Elastic and plastic finite element analyses of the press-assembly process are performed by using the finite element analysis software named ABAQUS for the sealed cowling of freight car bearing. A conclusion that the insufficient press-assembly depth is one of reasons of sealed cowling prolapse is obtained. Reasonable press-assembly depth of the sealed cowling is obtained by the finite element analysis. Related experiment is implemented and the experiment result verifies the correctness of finite element analysis result.
Keywords: Sealed cowling prolapsed; Elastic and plastic finite element analyses; Equivalent plastic strain and stress; Pressing depth.

1 Introduction

Since 2006, sealed cowling prolapse has been repeated in 352226X2-2RZ rolling bearings (Gong Hui, 2007). This not only affects the normal traffic order, but also causes the poor lubrication in bearings and then can endanger the traffic safety. It is essential to solve the problem of sealed cowling prolapse. There are many reasons for the prolapse of sealed cowling. Practical experience shows that the insufficient depth of cover pressing is one of main reasons of the prolapse. According to Maintenance and Management Rules of Chinese Railway Wagon Axle Assembly (China Railway Publishing House,2007), after the completion of the press-assembly, the pressure mounting surface of the sealed cowling shall not exceed the end face of the outer ring of bearing. At present, the press-assembly depth using at the actual site is 0.2mm, that is, after the completion of the press-assembly, the pressure mounting surface of the sealed cowling is 0.2mm lower than the end face of the outer ring.

But actual survey results show that when the press-assembly depth is 0.2mm, the prolapse phenomenon is often generated. This is because during the actual press-assembly process, the sealed cowling under the large press-assembly force has undergone the plastic deformation. The sealed cowling cannot fully enter the outer ring thread. In order to obtain the minimum press-assembly depth which can prevent the prolapse of sealed cowling from generating, the elastic and plastic finite element analyses of the press-assembly process are performed by using the finite element analysis software named ABAQUS for the sealed cowling of 352226X2-2RZ rolling bearings in this paper. After acquiring the minimum press-assembly depth by using the finite element analysis, YN-2 type torque measuring machine of sealed cowling press-assembly is then used to check the analysis result. Test result verifies that the theoretical analysis results of this article are correct.

2 Finite Element Analysis

2.1 finite element analysis model

Elastic and plastic analyses of the press-assembly process between the sealed cowling and the outer ring are performed by using the finite element analysis software named ABAQUS. Because both sealed cowling and outer ring are axially symmetric structure, their element types are defined as a Four-Node Quadrilateral Bilinear Nonconforming Axisymmetric Element CAX4I. The revolving axle is Y-axis. Figure 1 shows the finite element analysis model. The material of sealed cowling is 08AlP. Its material properties are as follows: yield strength is 180MPa, tensile strength is $\sigma_b = 420MPa$, elastic modulus is 186GPa, and Poisson's ratio is 0.3 (Mechanical Industry Press,1996). The relationship expression of plastic stress-strain is $\sigma = 553.47 \times e^{0.234} + 180$ (Xia,2007). The material of outer ring is bearing alloy steel with the elastic modulus of 210GPa and Poisson's ratio of 0.3.

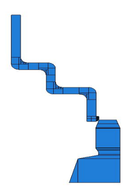


Figure 1. Finite element analysis model

Constraint conditions and loads applied in the model are as follows: the upper end face of sealed cowling with the diameter of $\Phi 179.4^{+0.10}_{-0.15}$ can only move along the direction of the Y-axis. The rest five degrees of freedom are constrained. Six degrees of freedom at the bottom of outer ring are constrained. According to the actual working conditions of the sealed cowling, the downward displacement along the Y-axis is exerted on the upper end face of sealed cowling with the diameter of $\Phi 179.4^{+0.10}_{-0.15}$.

2.2 prolapse reason analysis

The press-assembly process of the sealed cowling is the multi-point frictional contact process between the sealed cowling and outer ring inlet, outer ring thread, and thread groove of outer ring. In order to analyze the prolapse reason intuitively and consider the very violent interaction between the upper and lower end faces of sealed cowling and the outer ring surfaces, three units of the upper and lower end faces of the sealed cowling lug are selected as the feature units and their equivalent plastic strains and stresses are analyzed. The location of the selected feature units is shown as Figure 2.

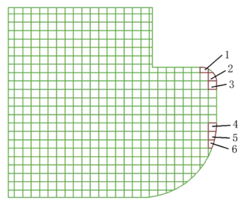
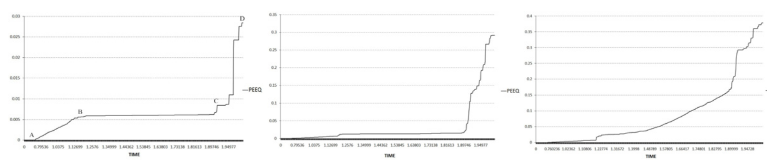


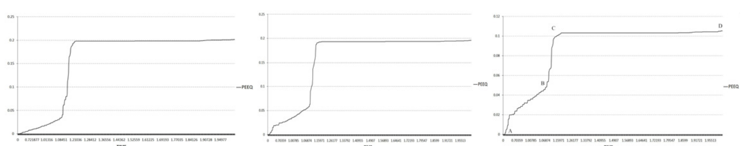
Figure 2. Selected feature units

The variation curves of equivalent plastic strains for six feature units are shown in Figure 3. The variation trends of equivalent plastic strains for feature units 1, 2, and 3 have reached an agreement as shown in Figure 3(a-c). Feature unit 1 is selected as an example to analyze the strain variation. Its values of equivalent plastic strains are given in Table1 and the related variation principle is described as follows: (1) a large plastic strain is produced in the period of outer ring inlet. The value of plastic strain increases from 0 to 0.0058mm, because the violent extrusion and friction are generated between the upper end of sealed cowling lug and the outer ring inlet under the large press-assembly force; (2) the value of equivalent plastic strain keeps increasing and varies from 0.0058mm to 0.0063mm in the period of outer ring thread. But the variation is relatively stable, since the upper end of the sealed cowling lug has already produced a large plastic strain and its interaction with the outer ring is obviously weakened. The plastic strain amplification of the sealed cowling is reduced; and (3) the value of the equivalent plastic strain increases from 0.0063mm to 0.0284mm rapidly and keeps basically unchanged finally in the period of thread groove. The mechanical model of press-assembly part of the outer ring can be equivalent to a cantilever beam. The outer ring inlet is the free end of the cantilever beam and the bottom of thread groove of outer ring can be equivalent to the fixed end of the cantilever beam. The stiffness at the thread groove is much larger than those of inlet and thread. At the moment that sealed cowling enters from the thread into the thread groove, the stiffness of outer ring increases rapidly and the contact area decreases rapidly. The plastic strain of the upper end of sealed cowling lug increases rapidly. When the sealed cowling enters into the thread groove completely, the interaction between them keeps constant. The equivalent plastic strain of the upper end of sealed cowling lug remains unchanged basically.

Figure 3 (d-f) shows that the variation tendencies of the equivalent plastic strain for feature units 4, 5, and 6 are consistent. Feature unit 6 is selected as an example for analysis. Its values of equivalent plastic strains are given in Table 1 and the related variation principle is described as follows: (1) the value of equivalent plastic strain increases from 0 to 0.038mm rapidly in the period of outer ring inlet and outer ring thread. The variation reason is the same as that of feature unit 1; (2) the value of plastic strain increases gradually from 0.038mm to 0.039mm and then remains basically unchanged in the period of thread groove of outer ring. This is because the main interaction produced between the upper end of lug and thread groove of outer ring is relatively weak, when the sealed cowling enters into the thread groove of outer ring. The plastic strain amplification of the sealed cowling is reduced. When the sealed cowling enters into the thread groove of outer ring completely, the interaction between them keeps constant and the plastic strain of the lower end of sealed cowling lug remains basically unchanged.



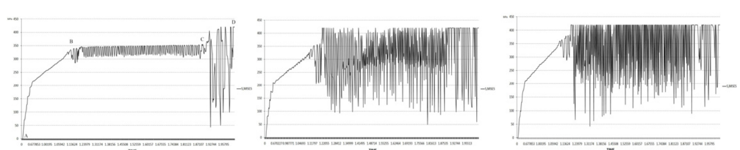
(a) feature unit 1 (b) feature unit 2 (c) feature unit 3



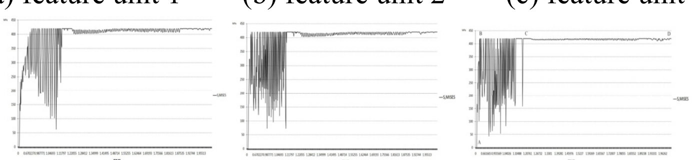
(d) feature unit 4 (e) feature unit 5 (f) feature unit 6

Figure 3. Variation curves of equivalent plastic strains for six feature units

The variation curves of equivalent plastic stresses for six feature units shown in Figure 4 are very similar to those of plastic strains.



(a) feature unit 1 (b) feature unit 2 (c) feature unit 3



(d) feature unit 4 (e) feature unit 5 (f) feature unit 6

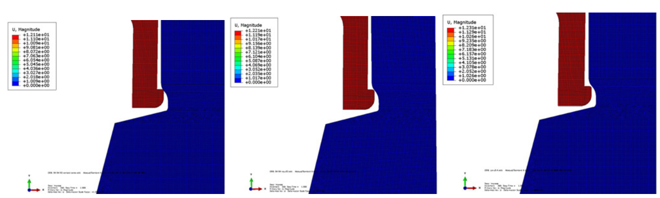
Figure 4. Variation curves of equivalent plastic stresses for six feature units

Table 1. Equivalent stresses and strains of the six feature units

Unit NO.	special position	A	B	C	D
1	Equivalent strain	0	0.0058	0.0063	0.0284
	equivalent stress（MPa）	0	347	351	420
6	Equivalent strain	0	0.023	0.038	0.039
	equivalent stress（MPa）	0	420	420	420

2.3 reasonable press-assembly depth

From the analysis result of the equivalent plastic strain variation principle for the sealed cowling, it can be seen that the large plastic strain is generated during the press-assembly process. As shown in Figure 5(a), when the press-assembly depth of sealed cowling is 0.2mm, the lug of sealed cowling cannot completely enter into the thread groove of the outer ring. The correct occlusion relationship between sealed cowling and bearing outer ring cannot be formed. In order to obtain the reasonable press-assembly depth, the press-assembly processes with the depths of 0.3mm and 0.4mm have been conducted by the finite element simulation, respectively. The final positions of sealed cowling in two kinds of press-assembly depth are shown as Figure5 (b) and (c), respectively.



(a) 0.2mm (b) 0.3mm (c) 0.4mm

Figure 5. Final positions of sealed cowling when press-assembly depth is 0.2mm, 0.3mm and 0.4mm

As shown in Figure 5(b), when the press-assembly depth is 0.3mm, the enter depth of the lug part of sealed cowling into the thread groove of outer ring is increased significantly compared with the case for the depth of 0.2mm. However, the lug has not entered into the thread groove of outer ring completely. As shown in Figure 5(c), when the press-assembly depth is 0.4mm, the lug has entered into the thread groove of outer ring completely. A good matching relationship between the sealed cowling and the outer ring of bearings is generated and the prolapse problem can be improved.

3. Experimental Study

YN-2 type torque measuring machine as shown in Figure 6 is used to check the press-assembly effect of sealed cowling of bearing. According to Chinese Railway Wagon Axle Assembly (China Railway Publishing House, 2007), the torque of

122.5N/m is applied on the sealed cowling in the assembly process. Whether there is the relative rotation between the sealed cowling and outer ring is considered as the criterion to determine the reasonable press-assembly depth of sealed cowlings. The experimental results show that there is the relative rotation between the sealed cowling and outer ring, when the depth of press-assembly is 0.2mm and 0.3mm, respectively. When the depth is 0.4mm, there is no relative rotation between them. Therefore, the reasonable depth should be larger than 0.4mm, which is in agreement with the theoretical analysis result.

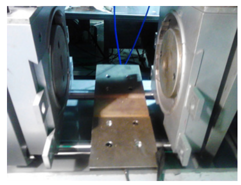


Figure 6. YN-2 type torque measuring machine

4. Conclusions

Elastic and plastic finite element analyses of the press-assembly process for the sealed cowling are performed firstly. The variation curves of equivalent plastic strains for six feature units are acquired. It can be seen from curves that due to the large shearing deformation and plastic strain of the sealed cowling during the press-assembly process, the lug cannot enter into the thread groove of the outer ring completely. The reasonable press-assembly depth should be more than 0.4mm, which is verified through the YN-2 type torque measuring machine. But during the finite element analysis is performed in this paper, the friction coefficient between the sealed cowling and the outer ring is assumed as 0.2, which needs the further experimental verification. At the same time, it needs further optimization analysis when determining the depth of the press-assembly.

References:

China Railway Publishing House. (2007). Maintenance and Management Rules of Chinese Railway Wagon Axle Assembly, Beijing.

Gong Hui. (2007). Cause analysis and preventive measures of the fault in wagon's rolling bearing sealing device. Shanghai Railway Technology, 2:25-26.

Mechanical Industry Press. (1996). Handbook of Mechanical Engineering (the second edition), Beijing.

Xia Y. Q. et al(2007) . Analysis of stress and strain on deep drawing process of breaking-hub dust cover. Forging & Stamping Technology, 32(4):12-15.

Effect of Lubricating Material on the Slewing Performance of a Sliding Slewing Bearing

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Abstract: The common slewing bearings used by large tonnage cranes are bogie slewing bearing and roller slewing bearing. They have different characteristics that affect the lifting capacity. Sliding slewing bearing is a new type of slewing bearing with compact-sized, low barycenter, high stability, large bearing area and good bearing capacity. However, there are some problems need to be studied, such as the rail pressure balance between the slides and the fixed orbits, sliding friction in slewing condition, etc. Polytetrafluoroethylene (PTFE) is a lubricating material with low friction coefficient and high endurance. Contact analytical mode of the sliding slewing bearing and the lubricating layer is established in FEM (Finite Element Method). Frictional resisting moments are analyzed by transient analysis method in two sliding friction condition: steel-steel contact between the slides and the fixed orbits; add lubricating material between the sliding surfaces. The effect of lubricating layer on the rail pressure distribution of the slide in the circumferential direction and the radial direction has been studied. After adding the lubricating layer, there is a significant decrease in the frictional resisting moments of the slewing bearing and the contact regions have been expanded from the below of the reinforcing plate to the whole bearing surface, which makes the rail pressure distribution of the bearing surface more balanced.
Keywords: Slide crane; Slewing bearing; Lubricating layer; Rail pressure; Balance.

1 Introduction

As the offshore exploration and exploitation are being approached from shallow water to deepwater, there are growing demands for crane performance in offshore platform construction and deepwater pipe laying operations (LIU Weihui,2007). Slewing bearing is the vital bearing part of slewing crane whose mechanical property are one of the key factors that determine the lifting capacity, operate safety and stability. There is extremely high requirement for the bearing capacity of slewing bearings in ultra large full-circle slewing cranes.

The early full-circle floating cranes commonly use bogie slewing bearing whose equalizing beams average load to every roller and the wheel pressure distribution is even. However, for large tonnage lifting requirement, the equalizing beam stage and wheel number need to be increased, which makes the structure more complex, high barycenter and bad stability (WANG Yuemin,2009). Ultra large full-circle slewing cranes are commonly adopt roller slewing bearing in present. The device is composed of several rows of roller on the circular track which has the advantages of compact structure, low barycenter, high stability and easy for manufacture and assembly (WANG Shouying,2010). However, some rollers bear too much load while some rollers bear little force due to the complex roller load and the uneven wheel pressure distribution, which affects the safety and lifting capacity of the machine seriously.

Plane strain elements (GUI Zheng,2010) were used to establish the hollow designed bearing roller models used in large crane. The research pointed out that this design can not only increase the radial direction flexibility of the roller, make the load more uniform, but also reduce the wheel stress and improve the bearing capacity. Under different compression stiffness of rubber pads used in rotary bearing (DING Zhendong,2010), uniformity of forces applied on wheels is studied. The results show that rubber pads deformation can reduce the max wheel pressure, the wheel load is uniform. However, oversize deformation would also increase the running resistance, which affects the service life of the rubber pads.

Sliding slewing bearing is a new type of slewing bearing that uses slide instead of roller slewing on the fixed orbits. The structure is more compact, lower center of gravity, higher stability than bogie or roller slewing bearing. The plane-to-plane contact type can increase the bearing capacity effectively (GUO Jitan,2013). However, the sliding friction way increases the contact area of the sliding surface and the frictional resisting moment meanwhile. Under the effect of complex combined loads and imbalanced track beam stiffness distribution, the rail pressure distribution on the sliding surface is imbalance. The region where rail pressure is larger abrades heavily, which affect the safety and service life of the whole machine. Rail pressure balance problem (LI Songfeng,2013) of the slide slewing bearing has been studied and the result shows that adjust the position of the upright or adjust the stiffened plate's distribution can improve the rail pressure balance effectively.

In this article, frictional resisting moments are analyzed by transient analysis method in two sliding friction condition: steel-steel contact between the slide and the fixed orbits; add lubricating material between the sliding surfaces. Lubricating layer has low friction coefficient and weak stiffness. The deformation of the lubricating layer can affect the load distribution on the sliding surface and then affect the rail pressure balance. The effect of lubricating layer on rail pressure distribution of the slide in the circumferential direction and the radial direction has been studied by finite element contact analysis.

2 Calculation model

2.1 Finite element model

Slide slewing bearing is box-like structure and is welded by steel plates. Shell element is used to model the main structure. The slides of the slewing bearing are clinging to the track beam and be divided into outer slide and inner slide. Circular orbits are rigidly fixed on the offshore platform, lubricating layers are fixed on the fixed orbits based on the stiff foundation and are laid between the slides and the fixed orbits to reduce the frictional resistance of the sliding surfaces when slewing bearing rotates. In order to reflect the actual stress states of the slide-lubricating layer-orbit, solid element is used to model the slides and the lubricating layer according to the actual structure. The fixed orbits can be seen as rigid body for whose stiffness is much bigger than the slides. According to test results, young's modulus of PTFE material is 492MPa; density is 2.158 g/mm^3; friction coefficient is 0.05; compressive yield strength is 25MPa.

For comparative purposes, 4 edges of the slides are selected and are named Ⅰ edge, Ⅱedge, Ⅲ edge and Ⅳ edge from outside to inside. Two centerlines of the outer and inner slide are named centerline1 and centerline2. Then we can extract contact pressure of the nodes in each line and compare the circumferential rail pressure distribution and the radial rail pressure distribution through the rail pressure curves. FE model of the slide slewing bearing is shown in Figure 1.

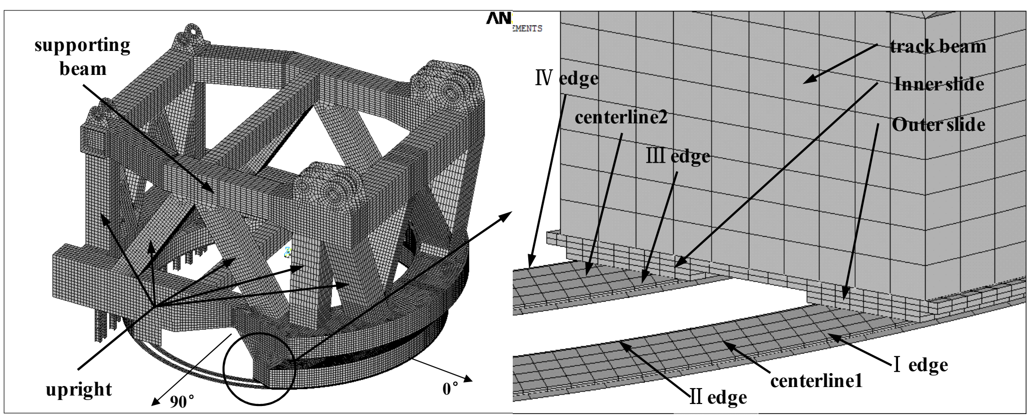

Figure 1.Finite element model

In order to study the effect of lubricating layer on rail pressure, two analytical models were chosen in this article: one with lubricating layer and one with non-lubricating layer. Rigid-flexible contact pairs are established between the slides and the fixed orbits in the model with non-lubricating layer. In the model with lubricating layer, flexible-flexible contact pairs are established between the slides and the lubricating layers and rigid-flexible contact pairs are established between the lubricating layers and the fixed orbits.

2.2 Boundary conditions

In finite element analysis, the slewing of the structure can be seen as the slewing of the fixed orbits accordingly. The fixed orbits can be set as discrete rigid body whose rotation can be controlled by the reference points. Displacement constraints are applied at the position of the drive motor in the meanwhile.

2.3 Load conditions

The effect of the boom and the A-frame on the slide slewing bearing can be seen as external forces and can be applied to the turning joints. The maximum load of the crane is 8000t.

3 Calculation results

3.1 Rail pressure distribution of static load condition

In order to reflect the numerical regularity of rail pressure distribution intuitively and easier to compare and discuss at the same time, we extract contact pressure of the nodes in each sampling lines (Figure 1) and draw the rail pressure curves. Due to the symmetry of the structure and the loads, we only take half of the sliding surface as the research object.

The rail pressure contrast curves of outer slide with and without lubricating layers are shown in Figure 2. The “+” in the legend refers to the FEM model with lubricating layers.

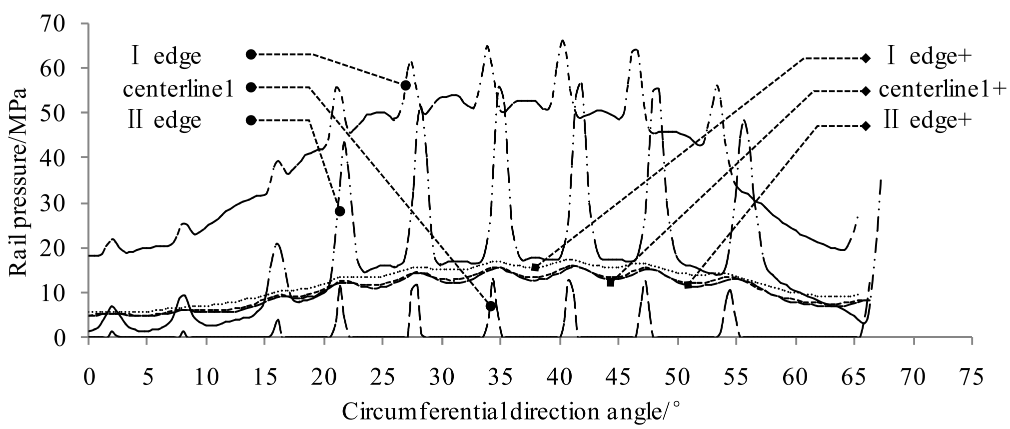

Figure 2.Outer slide rail pressure contrast curve

The rail pressure contrast curves of inner slide with and without lubricating layers are shown in Figure 3. Similarly, the “+” in the legend refers to the FEM model with lubricating layers.

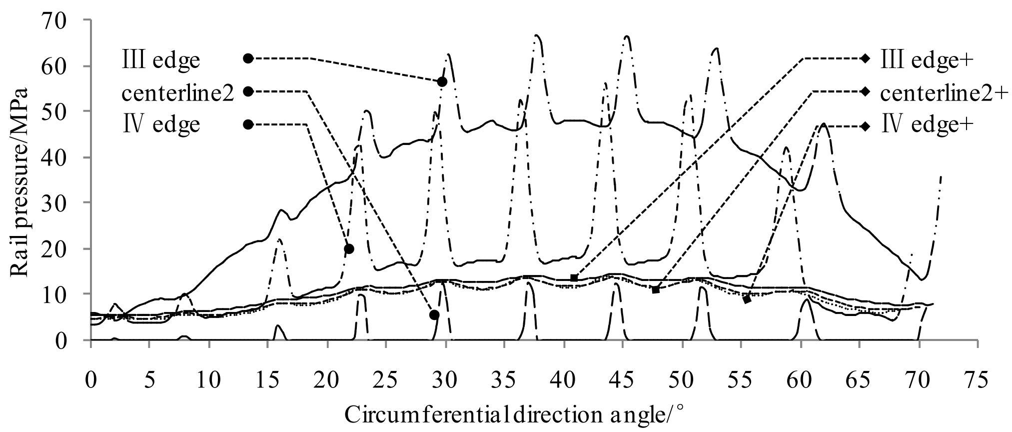

Figure 3.Inner slide rail pressure contrast curve

Along the horizontal axis (circumferential direction) we can see:

(1) With non-lubricating layers, both side of the slide bear load while mid-span area hardly bear load. Rail pressure is great under the upright. Besides that, there are sudden changes occur at the intersection of the web and the rib plate.

(2) With lubricating layer, rail pressure near the mid-span area has increased obviously while it dropped below 20MPa near the 4 edge, cuspidal point of the rail pressure curve disappear, circumferential rail pressure gets a better balance.

Along the vertical axis (radial direction) we can see:

(1) With non-lubricating layer, rail pressure were significant difference to each edge with different values at any angle, radial rail pressure has very uneven distribution which may cause the slide material wear heavily.

(2) With lubricating layer, rail pressure difference reduces significantly. This means that with the deformation of the lubricating layers, mid-span area begins to bear load and share the rail pressure near the edges, radial rail pressure gets a better balance.

3.2 Rail pressure distribution of slewing condition

Both sides of the track beam are near to the uprights where the loads are concentrating. In the mean time, lubricating layer intends to deformation after been pressed. When the sliding slewing bearing is slewing under load, it may cause great stress at the end of the slide in the slewing direction, which can makes the lubricating material wear and tear. This may affect the safety and stability of the crane seriously.

Given the fact that rail pressure of both slides has similar distribution, rail pressure distribution curve of outer slide in slewing condition is given only in Figure 4.

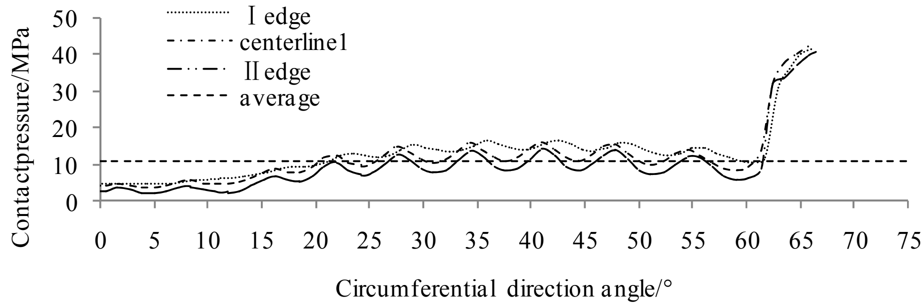

Figure 4.Outer slide rail pressure distribution curve of slewing condition

When slewing bearing slewing, whole rail pressure level remains below 20MPa beside the end of the slide. Rail pressure increases to 40MPa at the end of the slide.

3.3 Frictional resisting moments

The structure of the slewing bearing is ultra large and the load transmitted to the sliding surface is extremely complex. In this article, FEM is used to model the slewing motion of the slewing bearing and then obtain the frictional resisting moments. The result shows that: when bearing 8000t, the frictional resisting moment is 4.0×10^5kN • m with non-lubricating layer and 2.06×10^5kN • m without lubricating layer, which is 51.5% of the non-lubricating layer condition. This means that lubricating layer can reduce the frictional resisting moment and improve the slewing stability effectively.

4 Conclusions

Considering the above analysis, we can draw the conclusions that after adding lubricating layers between the slides and the fixed orbits:

(1) Circumferential rail pressure distribution curves become smooth and the cuspidal point of the rail pressure curve disappear. Circumferential rail pressure gets a better balance.

(2) Due to the fabrication error and week stiffness of the track beam, the rail pressure distribution is imbalance. Lubricating layer intends to deformation after been pressed which makes mid-span area begins to bear load, rail pressure difference reduces significantly from all angles. Radial rail pressure gets a better balance.

(3) Lubricating layers have lower friction coefficient and high endurance which can reduce the frictional resisting moment, improve the slewing stability effectively.

It should also be noted that when structure is slewing, stiffness mutation exists at the end of the slide, rail pressure has a sudden increase at the slide end, the structure need to be further optimized.

References

DING Z. D. (2010). “The effect of compressing rigidity of track rubber pads of rotary mechanism of 7500t floating crane on the force applied on wheel.” *Hoisting and Conveying Machinery*, (3), 39-41.

GUI, Z. (2010). “Hollowness analysis for wheels in large crane revolving support.” *Journal of machine design*, 27(4), 91-93.

GUO, J. T. (2013). “The research of the slewing bearing force balance of the super large lifting equipment.” *Advanced Materials Research*, vols.671-674, pp888-892.

LI, S. F. (2013). “The research of the sliding slewing bearing contact force balance of the super large lifting equipment.” *Dalian Jiao Tong University* (in Chinese).

LIU, W. H. (2007). “Pipe laying barge—worldwide development and application.” *Oil & Gas Storage and Transportation*, (6), 11-15.

WANG, S. Y. (2010). “Study on pressure of loaded wheel of jacketed roller slewing bearing in large scale of full slewing crane.” *Port Operation*, (3), 10-13.

WANG, Y. M. (2009). “Enabling technologies for new rotary support device of ultra-large-scale rotary floating cranes.” *Chinese Journal of Construction Machinery*, 7(2), 180-184.

Reliability Prediction Method of an EMU Bogie

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Abstract: One reliability prediction method of combining evidence theory interval fusion with Pignistic probability transformation is proposed based on the existing failure rate of similar products. According to the Pignistic probability transformation, the evaluation results of weight evaluated by experts and its confidence lever are converted into gambling probability function. Using evidence theory interval fusion technology conducts synthesis calculation. Interval point estimates are calculated by inverse operation of Pignistic probability transformation and normalized. The weight values of subsystems are obtained and the results of reliability prediction are known. The proposed method is applied on EMU bogie to conduct reliability prediction. The case indicates that the proposed method both considerate the existing failure rates of similar products and combined the evaluation of experts to the subsystems. The reliability prediction results show that this method is more objective.

Keywords: Reliability prediction; Dempster rule; Pignistic probability transformation; EMU bogie.

1 Introduction

Reliability prediction is to predict the system reliability according to data information of the subsystem reliability. The methods (Yalan, 2013; Qingbo, 2012; Jianing, 2014) of reliability prediction include similar products, scoring, stress analysis, mathematical model, Boolean method, and Monte Carlo method and so on. With the development of the EMU, its components have certain product series and inheritance, the most frequently used reliability prediction method is similar products in the EMU bogie design. This method uses specific experience gained from the similar bogies with existing reliability data to determine the new design of bogie reliability. However, due to the incomplete data information, the traditional similar product method is hard to obtain a reasonably expected result. The reliability prediction of bogie is expected to find that the main factors affecting its reliability, and then find out the weak link in the system. Then take some design measures to improve the reliability of the bogie. Therefore, a new method of combining evidence theory fusion range (Deqiang, 2014) with Pignistic probability transformation (Wanqing, 2013) is proposed to estimate reliability of the EMU bogie.

2 Reliability prediction model

2.1 Dempster rules of evidence theory

According to Dempster rules (Jing, 2012), when several experts distribute basic confidence of the same variable, synthesize evaluation results can be expressed as:

$$m(A)=\frac{\sum_{C_i\cap C_j=A} m_1(C_i)m_2(C_j)}{1-\sum_{C_i\cap C_j=\varphi} m_1(C_i)m_2(C_j)} \qquad (1)$$

Specific Dempster rules model is given as below. There are range evaluation results presented by two experts. Use number axis to describe the synthesis evaluation result. A full Dempster interval synthetic rules is shown in Fig. 1.

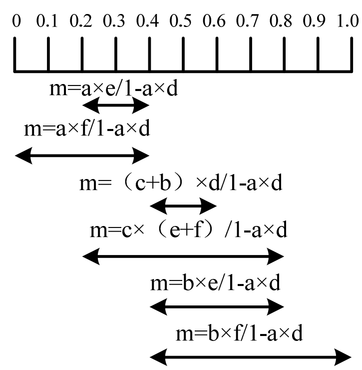

Fig. 1 Assessment result combined two experts

2.2 Pignistic probability transformation

The purpose of Pignistic probability transformation is to reallocate the interval confidence of evaluation system, then get an expected decision-making model. The formula is:

$$BetP(A)=\sum_{B\in U} m(B)\frac{A\cap B}{|B|} \qquad \forall A\in U \qquad (2)$$

Pignistic probability transformation can meet probability calculation with different framework recognition. Dempster rules is an interval fusion arithmetic when the data meet the recognition framework is $\Theta\rightarrow[0,1]$. Uniting Pignistic probability transformation and Dempster rules is used to establish mathematical model to solve the interval fusion problem.

2.3 Determination of subsystem weight

Hired five experts considering affecting factors and their own experience to conduct interval estimation of each subsystem. Give a confidence level of each evaluation result. The procedure proposed for predicting weight is as follows:

Step 1: Convert evaluation results and the given confidence level into gambling function.

Step 2: Use Dempster rules to conduct evidence fusion of the five evaluation results.

Step 3: Use in reverse Pignistic probability transformation model and obtain gambling probability distribution function.

Step 4: Draw a graph of the gambling probability distribution function, and figure out the point estimation of distribution function.

Step 5: Normalize the corresponding point estimation and get the weight of each subsystem.

2.4 Reliability prediction

The relative weight of each subsystem to system reliability is transformed into the weight coefficient of failure rate. Use the reliability data of similar bogie in the production. Find the higher similarity subsystem and the failure rate value. The failure rate value of the system is the ratio between similar subsystem failure rate values and corresponding weight coefficient of similar subsystem.

3 Bogie reliability prediction

Subsystem of Bogie is denoted by S, namely, bogie frame, wheel, axle box, primary suspension, secondary suspension, drive device, brake device. Let $S\{S_1, S_2, S_3, S_4, S_5, S_6, S_7\}$ symbolizes the above subsystems respectively. The five experts is $\{A_1, A_2, A_3, A_4, A_5\}$. The weight results are shown in table 1.

Table 1. Weight results from five experts

	A_1	A_2	A_3	A_4	A_5
S_1	(0.40 0.60)	(0.50 0.60)	(0.30 0.50)	(0.40 0.50)	(0.45 0.55)
S_2	(0.10 0.20)	(0.05 0.15)	(0.10 0.15)	(0.09 0.15)	(0.15 0.25)
S_3	(0.05 0.10)	(0.06 0.10)	(0.03 0.10)	(0.08 0.20)	(0.05 0.20)
S_4	(0.04 0.09)	(0.03 0.09)	(0.03 0.10)	(0.05 0.10)	(0.01 0.10)
S_5	(0.00 0.10)	(0.03 0.05)	(0.03 0.05)	(0.01 0.05)	(0.03 0.10)
S_6	(0.02 0.05)	(0.00 0.05)	(0.02 0.10)	(0.02 0.10)	(0.05 0.10)
S_7	(0.10 0.20)	(0.05 0.15)	(0.05 0.20)	(0.10 0.15)	(0.10 0.20)

Weight evaluation confidences of the five experts from 1 to 5 respectively is: $\{0.95 \quad 0.90 \quad 0.85 \quad 0.80 \quad 0.75\}$.

Bogie frame S_1 as an example is analyzed. Using the established model calculates the point estimation values of weight evaluation. The process is as follows:

(1) First expert's evaluation result for bogie frame S_1 is $[0.4\ 0.6]$. The interval confidence is 0.95. Due to the weight universe is $[0\ 1]$. The gambling function is established in the interval of $[0\ 1]$. The confidence of the evaluation result is reflected in the intervals of $[0.4\ 0.6]$ and $[0\ 1]$. Therefore, the corresponding gambling probability functions are respectively:

$$\frac{0.6-0.4}{1-0}\times m_1[0\quad 1] \qquad \frac{0.6-0.4}{0.6-0.4}\times m_1[0.4\quad 0.6]$$

Then the following equation is established.

$$\begin{cases} m_1[0\quad 1]\times 0.2 + m_1[0.4\quad 0.6] = 0.95 \\ m_1[0\quad 1] + m_1[0.4\quad 0.6] = 1 \end{cases}$$

The solution of equation is ：

$$\begin{cases} m_1[0.4\quad 0.6] = 0.9375 \\ m_1[0\quad 1] = 0.0625 \end{cases}$$

In the same way, the other four experts, evaluation results can be solved as:

$$\begin{cases} m_2[0.5\quad 0.6] = 0.8890 \\ m_2[0\quad 1] = 0.1110 \end{cases} \qquad \begin{cases} m_3[0.3\quad 0.5] = 0.8125 \\ m_3[0\quad 1] = 0.1875 \end{cases}$$

$$\begin{cases} m_4[0.4\quad 0.5] = 0.7780 \\ m_4[0\quad 1] = 0.2220 \end{cases} \qquad \begin{cases} m_5[0.45\quad 0.55] = 0.7222 \\ m_5[0\quad 1] = 0.2778 \end{cases}$$

(2) Fused by Dempster rules of the evidence theory, the distribution function of the basic confidence is:

$$\begin{cases} m[0.45\quad 0.55] = 0.0219 \\ m[0.45\quad 0.5] = 0.1853 \\ m[0.5\quad 0.6] = 0.0684 \\ m[0.4\quad 0.5] = 0.1963 \\ m[0.3\quad 0.5] = 0.0023 \\ m[0.4\quad 0.6] = 0.0081 \\ m[0\quad 1] = 0.0067 \end{cases}$$

(3) Converted the distribution function of the basic confidence by Pignistic probability transformation, the gambling probability distribution function is:

$$\begin{cases} 0.0067x & 0 \le x < 0.3 \\ 0.0182x - 0.0035 & 0.3 \le x < 0.4 \\ 12.2452x - 4.8943 & 0.4 \le x < 0.45 \\ 5.9467x - 2.0599 & 0.45 \le x < 0.5 \\ 0.9502x + 0.4383 & 0.5 \le x < 0.55 \\ 0.7312x + 0.5588 & 0.55 \le x < 0.6 \\ 0.0067x + 0.9935 & 0.6 \le x < 1 \end{cases}$$

(4) The graph of the gambling probability distribution function is shown in Fig. 2.

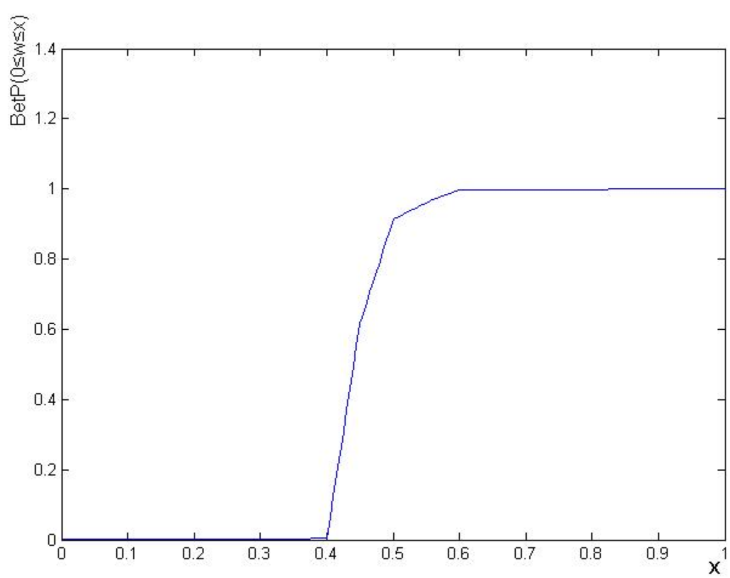

Fig. 2 The gambling probability distribution function

(5) By this measure, the point estimate value of bogie frame is 0.4494.

As the same way, the point estimate value of other subsystem are shown in table 2.

Table 2. Point estimate of assessment result for each system

Subsystem	Frame	Wheel	Axle box	Primary suspension	Secondary suspension	Drive device	Brake device
Point estimate	0.4494	0.1257	0.0878	0.0691	0.0402	0.0353	0.1255

The point estimate value of each subsystem is normalized. The weight of each subsystem is obtained, as shown in table 3.

Table 3. Weight of each subsystem

Subsystem	Frame	Wheel	Axle box	Primary suspension	Secondary suspension	Drive device	Brake device
Weight	0.4816	0.1347	0.0941	0.0741	0.0431	0.0379	0.1345

(6) Reliability prediction

According to the reliability data of the similar EMU bogie, we know that the wheel is subsystem of higher similarity. The failure rate is 0.1938×10^{-5}. The system working time is 12000h. Based on the above weight value of bogie subsystem, the failure rate and reliability of each subsystem are calculated, as shown in table 4.

Table 4. Reliability prediction results for the subsystem of EMU bogie

Reliability index	Frame	Wheel	Axle box	Primary suspension	Secondary suspension	Drive device	Brake device	Total
Failure rate($\times10^{-5}$)	0.0707	0.1938	0.1939	0.2517	0.3042	0.3167	0.1941	1.56
Reliability	0.9915	0.9808	0.9770	0.9702	0.9641	0.9627	0.9770	0.8293

By using the evidence theory synthesis and Pignistic probabilities convert method can predict the reliability level of the bogie quantitatively, and determine whether the result is expected to conform to the requirements of the reliability index, and provide data basis for the implementation of reliability allocation as well.

4 Conclusions

Reliability prediction of EMU bogie is conducted based on combining evidence theory fusion range with Pignistic probability transformation. For reliability prediction, the weight of the each subsystem is determined by the mathematical model that established by means of interval evidence theory fusion based on the Pignistic probability transformation.

The wheel failure rate compared with the existing high similarity bogie system is given. Based on the proposed method in this paper, reliability indexes of the EMU bogie subsystems is calculated. The case has been proved that this method can eliminate the subjective influence of uncertainty factors to some extent and make the results of reliability prediction more objective. At the same time, the reliability prediction results also provide data basis for the implementation of reliability allocation.

Acknowledgement

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References

Chen Y.L., Luo J., Li X.H. (2013). "An overview of reliability prediction methods for electronic equipments". *Microelectronics*, 43(2), 242-249.

Hao Q.B., Yang Z.J., Chen C.H. et al. (2012). "Reliability prediction for NC machine tool based on interval AHP". *Journal of Jilin University (Engineering and Technology Edition)*, 42(4), 845-850.

Han D.Q., Yang Y., Han S.Z. (2014). "Advances in DS evidence theory and related discussions". *Control and Decision*, 29(1), 1-11.

Wang W.Q., Zhao Y.J., Huang J. et al. (2013). "Transformation of basic probability assignment to probability based on uncertainty degree". *Control and Decision*, 28(8), 1214-1218.

Wu J.N., Yan S.Z. (2014). "An approach to system reliability prediction for mechanical equipment using fuzzy reasoning Petri net". *Journal of Risk and Reliability*, 228(1), 39-51.

Yang J., Lin Y., Hong L. et al (2012). "Improved method to D-S evidence theory based on weight and matrix". *Computer Engineer and Applications*, 48(20), 150-153.

Safety Limit Study of the Gravity Center Height for a Loaded Wagon under Cross-Wind

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Abstract: The application conditions of the safety limit of height of gravity center of loaded wagon in “The railway freight loads and firms regulation” are not described in detail. In this paper, we established the particular three-dimension dynamic model for the container flat car and the container to simulate the dynamic behavior of freight wagon through the curve under cross-wind. We analyzed safety of loaded wagon under different height of gravity center and obtained the safety limit of height of gravity center of loaded wagon under cross-wind. From the analysis of calculation results, we can know that the height of gravity center can reach 2.2 m or higher when the wind speed is lower than 9 grade; when the wind speed is 9 grade, loaded wagon should run with speed limit while the height of gravity center is over 2.2 m; when the wind speed is 10 grade, loaded wagon should run with speed limit while the height of gravity center is over 1.9 m; when the wind grade is 11 or above, loaded wagon should run with speed limit or stop running.

Keywords: Railway freight transportation; Cross-wind load; Limit of height of gravity center; Dynamic model.

1 Introduction

As the running speed of freight train increased, effects of the cross-wind on the safety of railway freight transportation increasing, the requirements of the height of gravity center of loaded railway wagon and offset of gravity center of goods loading under cross-wind are more strictly. At present, the work of loading and firming for railway freight in our country is to calculate and make decision of the safe loading and securing plan, generally according to the rules of “The railway freight loads and firms regulation (the shorter form “loads-regulation”)”, for the actual freight transportation. The height of gravity center of loaded wagon can’t over 2000 mm in “loads-regulation” else the wagon must be running with speed limit. Because of the regulation made on the earlier time, suitable speed level of railway wagon and running environment were not stated. The freight wagon will be affected by cross-wind in the running inevitably. When the wind grade is increasing, the freight wagon will be affected by more cross-wind force, and it can make freight wagon more dangerous. What’s more, the higher the gravity center of a loaded wagon, the greater risk of overturning, and it will cause serious damage. In the study of the safety limit of height of gravity center of loaded railway wagon today, only a few scholars discussed the effects of the height of gravity center of loaded wagon on the safety of railway freight transportation under cross-wind. They usually adopt quasi static method to study, and the model is relatively simple. In this paper, the detailed three-dimension dynamic model was established for the container flat car and the container to simulate the dynamic behavior of freight wagon through the curve under cross-wind. We used safety evaluation indexes of freight wagon, such as derailment coefficient, wheel unloading rate, lateral wheelset force and overturning coefficient, to analyze safety of loaded wagon under different height of gravity center, and obtain the safety limit of height of gravity center of loaded wagon under cross-wind.

2 Modeling of container flat car system

Container flat car system is considered as a complex dynamic system with three parts – bogies, railway flat car body and the container. In order to establish three-dimension dynamic model of container flat car system, we can simplify the whole system to a multi-body system composed of a series of rigid body, force element and constraint. The mathematical model of this system can be described as differential algebra equation.

First, we analyzed the topology of the whole container flat car system, as shown in figure 1. Topological graph can clearly reflect the correlation between every parts of the system, and it is the foundation to establish dynamic model correctly. As shown in figure, we can know that wheelset, bogie frame and bolster are connected by force element, such as spring and friction damper, to form a bogie. The model of container flat car system is composed of bogies, car-body and the container which are connected by force element and joint. And relative to track, wheelset, bogie frame and car-body each have six degrees of freedom. Relative to car-body, the container has no degree of freedom. Relative to car-body, each bolster has three degrees of freedom. Between the wheelset and track are wheel-rail force elements, and guiding frame and rubber bearing are between the wheelset and bogie frame. The central suspension is between bogie frame and bolster which concludes spring and friction wedge unit. The bolster and car-body are connected by side bearings and center plate. Besides, the container and car-body are firmly connected by connecting pin.

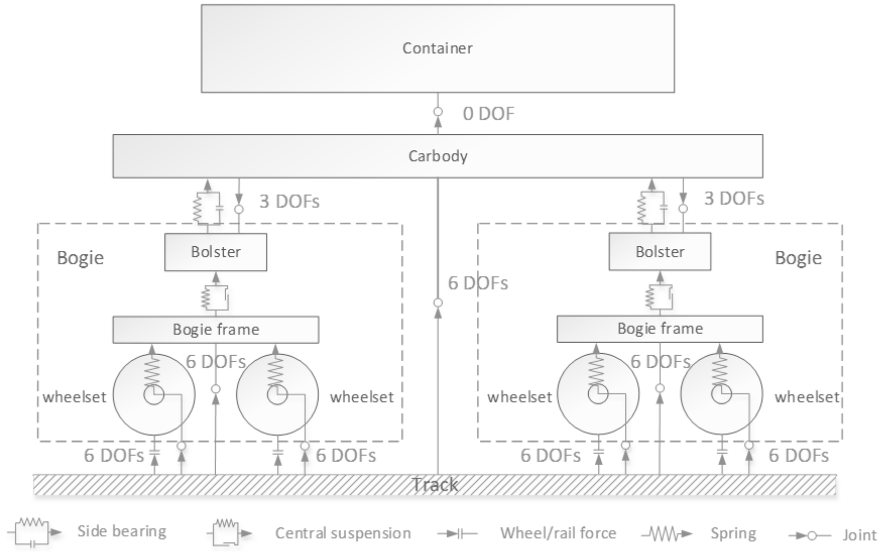


Figure 1. Topological graph of container flat car system

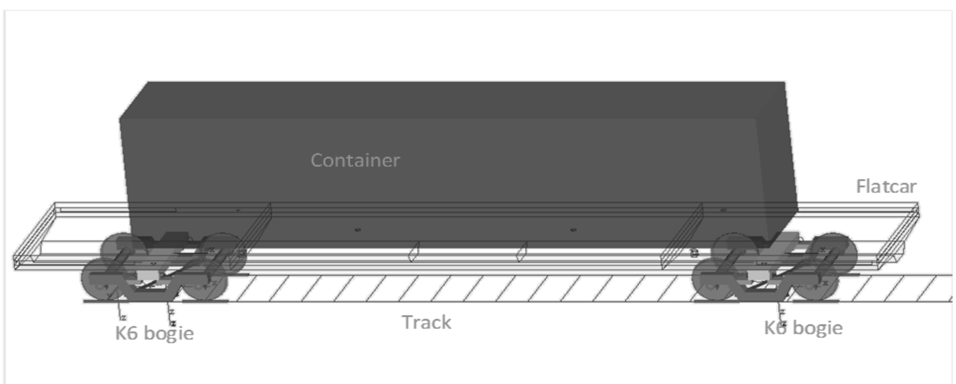


Figure 2. Dynamic model of container flat car system

According to the topological graph of the system, we used dynamic software SIMPACK to establish dynamic model of container flat car system. As shown in figure 2, it includes track, K6 bogie, flat car body and the container. The mathematical model of the system can finally be expressed as the following differential algebraic equations.

$$\begin{cases} \mathbf{M}\ddot{\boldsymbol{q}}+\boldsymbol{\Phi}_{\boldsymbol{q}}^{\mathrm{T}}\boldsymbol{\lambda}=\boldsymbol{F}+\boldsymbol{F}_{\mathrm{wr}}+\boldsymbol{F}_{\mathrm{w}} \\ \boldsymbol{\Phi}(\boldsymbol{q},\mathrm{t})=\boldsymbol{0} \end{cases} \quad (1)$$

Where $\boldsymbol{q}$ is generalized coordinates vector, $\mathbf{M}$ is generalized mass matrix, $\boldsymbol{F}_{\mathrm{wr}}$ is generalized force vector of wheel-rail force, $\boldsymbol{F}_{\mathrm{w}}$ is generalized force vector of cross-wind, $\boldsymbol{F}$ is other generalized force vector, $\boldsymbol{\Phi}$ are constraint algebraic equations,

$\mathbf{\Phi}_q$ Jacobi matrix corresponding to constraint equations.

The whole system has 68 degrees of freedom, and it contains a large number of nonlinear factors such as friction, clearance and piecewise linear spring. All of this increases the difficulty of system solving.

3 Calculation of cross-wind load

According to the force area of the container and relationship between wind pressure and speed, we calculated the wind load on the container flat car system corresponding to different wind grades.

The relationship between wind speed and wind pressure on unit area generated by free-stream can be calculated by the following equation.

$$w=\frac{1}{2}\rho v^2=\frac{\gamma}{2g}v^2 \tag{2}$$

Where w is said wind pressure per unit area, and v is said wind speed. γ is said weight of air per unit volume, and g is said acceleration of gravity. In this paper, we take γ = 0.0129 kN/m³, and g = 9.8 m/s².

We assumed that cross-wind was applied perpendicular to the side of container. The dimensions of 40 ft container are 12192 mm, 2438 mm and 2591 mm, respectively. Side area of the container is 31.59 m^2. Using Eq. 2, we can calculate wind pressure corresponding to wind above 5 grade and maximum of equivalent load of each wind grade. According to the standard CJJ96-2003, wind load used in calculation is equal to maximum of equivalent wind load multiplied by safety coefficient of 1.5. And the calculation results are shown in Table 1.

Table 1. Wind speed, wind pressure and wind load

Wind grade	Wind speed (m/s)		Wind pressure (Pa)		Maximum of equivalent wind load (N)	Wind load used in calculation (N)
	Min.	Max.	Min.	Max.		
5	8.0	10.7	42.12	75.35	2380.40	3570.60
6	10.8	13.8	76.77	125.34	3959.51	5939.27
7	13.9	17.1	127.16	192.45	6079.61	9119.42
8	17.2	20.7	194.71	282.02	8908.90	13363.35
9	20.8	24.4	284.75	391.84	12378.35	18567.53
10	24.5	28.4	395.06	530.84	16769.49	25154.24
11	28.5	32.6	534.59	699.47	22096.24	33144.36
12	>32.6		>699.47		>22096.24	>33144.36

The wind load on the side of container is equivalent to concentrated load which applied to the centroid of the side of container. We can use dynamic model of container flat car system and cross-wind load to obtain the safety limit of height of gravity center by simulation and analysis.

4 Evaluation indexes of safety

This article adopts four indexes commonly used for railway vehicles to measure the safety of container flat car. Those are derailment coefficient, wheel unloading rate, lateral wheelset force and overturning coefficient. According to GB5599-85, the definition and limit of four indexes are as follows:

(1) Derailment coefficient is the ratio of lateral wheel-rail force and vertical wheel-rail force, namely Q/P.

The first limit: $Q/P<1.2$, the second limit: $Q/P<1.0$

Where, Q is lateral wheel-rail force generated on the climb rail side, and P is vertical wheel-rail force generated on the climb rail side.

(2) Wheel unloading rate is the ratio of wheel unloading value and average wheel load of wheelset, namely $\Delta P/\overline{P}$.

The first limit: $\Delta P / \overline{P} \le 0.65$, the second limit: $\Delta P / \overline{P} \le 0.6$

Where, ΔP is wheel unloading value, $\overline{P}$ is average wheel load of wheelset. The first limit is the qualified criteria to evaluate vehicle running safety, and the second limit is the criteria which increased safety margin. This paper adopts the first limit as safety evaluation standard.

(3) Lateral wheelset force is the sum of lateral wheel force of both sides, $H = Q_1 + Q_2$. And it should meet the following condition:

$$H \le 0.85(15 + \frac{P_{st1} + P_{st2}}{2}) \tag{3}$$

Where: H is lateral wheelset force, kN. P_{st1}, P_{st2} are static loads of left and right wheel (wheel load), kN. The limit of lateral wheelset force is 70.5 kN according to the Eq. 3.

(4) Overturning coefficient is used to identify whether it will lead wagon to overturn while lateral wind, centrifugal force and inertia force of lateral vibration are applied to the wagon at the same time. The critical condition of overturning is as follows:

$$D = \frac{P_{\mathrm{d}}}{P_{\mathrm{st}}} = 1 \tag{4}$$

Where: D is overturning coefficient, P_{d} is dynamic loads of wheels on the same side of vehicle, kN. P_d is static loads of the corresponding wagon. The limit of D is below 0.8.

5 Dynamic simulation and results analysis

5.1 Working condition of Calculation

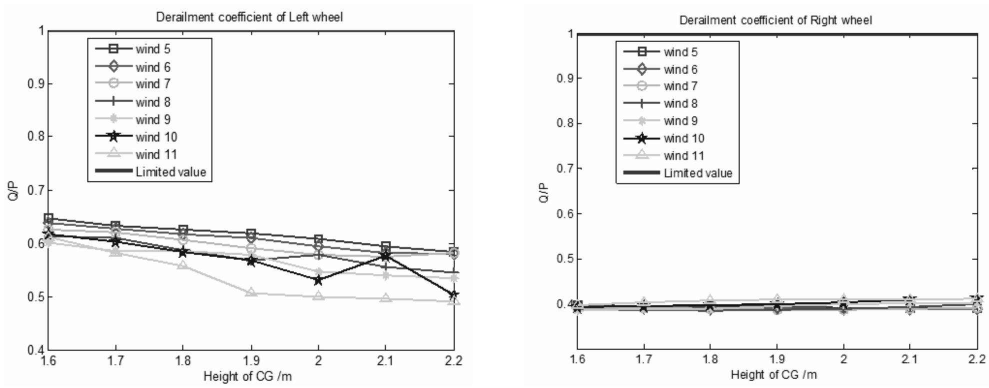
Weight of loaded wagon is 55.4 tons, and weight of the container and goods is 25 tons. This article assumes that the total weight of the container and goods remains the same, and different loading just cause the gravity center to change in vertical. In this paper, the height of gravity center is between 1.6 and 2.2 meters, and loaded wagon passes through the curve which radius is 300m with speed of 70km per hour. The curve superelevation is 120mm and the biggest deficient superelevation is 72.7mm. The direction of wind load is from the medial to the lateral of curves, and wind load and centrifugal force are superposed. It is a relatively bad working condition.

5.2 Simulation results analysis

Different wind speed and the height of gravity center are combined to 49 conditions, and the calculation results are shown in the figures below. The first wheelset is the leading wheelset of the leading bogie in the traveling direction and its indexes are the biggest. So we only give derailment coefficient, wheel unloading rate and lateral wheelset force of the first wheelset.

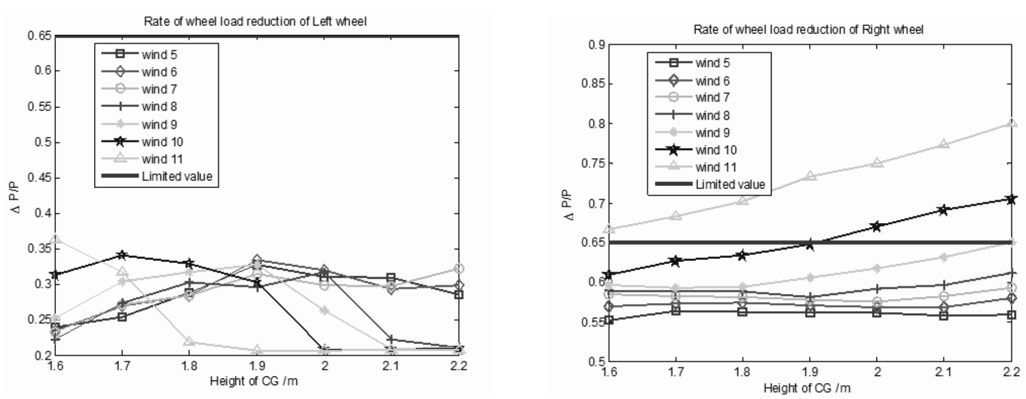
Figure 3 shows derailment coefficient of the first wheelset, and derailment coefficient of left and right wheel are all below the limit of 1.0. As wind speed and gravity center increasing, derailment coefficient of left wheel shows a trend of decrease, mainly because of the increasing of increased load of vertical wheel-rail force in this condition. Derailment coefficient of right wheel is small and the change isn't obvious. Figure 4 shows wheel unloading rate of the first wheelset. Left wheel is the increased load side of wheelset, so wheel unloading rates are small and they are below the limit of 0.65. And right wheel is the reduced load side. As wind speed and gravity center increasing, reduced load is increasing. When the wind speed is lower than 9 grade, wheel unloading rates are all below the limit within the calculated height of gravity center. When the wind speed is 9 grade, wheel unloading rate is on the limit while height of gravity center is 2.2m. When the wind speed is 10 grade, wheel unloading rates are above the limit while height of gravity center is 1.9 m. When the wind speed is 11 grade, wheel unloading rates are all above the limit within all of calculated height of gravity center. So, when the wind speed is 11 grade, the vehicle should reduce speed or stop running. Figure 5 shows lateral wheelset force of the first wheelset, and all of them are below the limit of 70.5kN in the calculated conditions. Figure 6 shows overturning coefficient of the loaded wagon, and its trends are the same with wheel unloading rate of right wheel basically. They are all below the limit of 0.8.

One of four safety indexes is above the limit, and it means that loaded wagon is in an unsafety state. So, according to the results of wheel unloading rate of right wheel, we can obtain the safety limit of height of gravity center under different wind grades.



(a) Derailment coefficient of left wheel (b) Derailment coefficient of right wheel

Figure 3. Derailment coefficient of the first wheelset



(a) Wheel unloading rate of left wheel (b) Wheel unloading rate of right wheel

Figure 4. Wheel unloading rate of the first wheelset

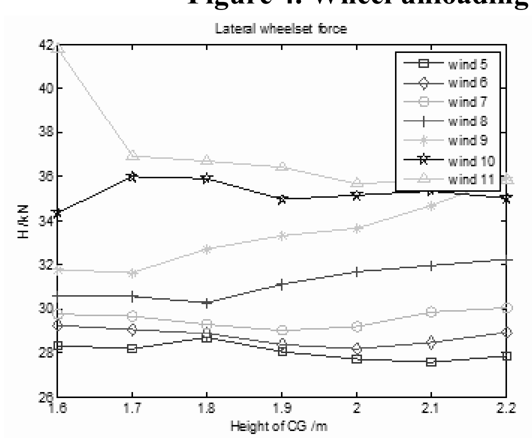


Figure 5. Lateral wheelset force of the first wheelset

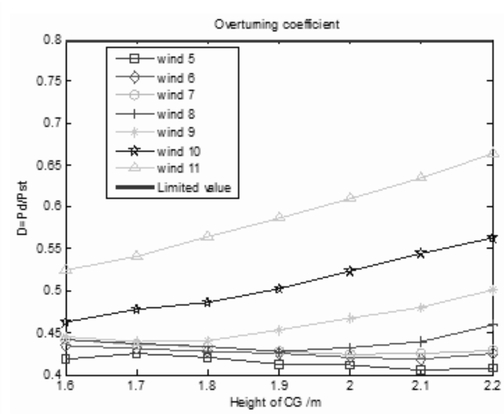


Figure 6. Overturning coefficient of the loaded wagon

6 Conclusions

In this paper, we established detailed dynamic model of container flat car system to simulate the loaded wagon passing through the curve which radius is 300 m. We calculated different working conditions combined 5-11 grades wind with height of gravity center of 1.6-2.2 m, using derailment coefficient, wheel unloading rate, lateral wheelset force and overturning coefficient as safety evaluation indexes of freight wagon, and finally obtained the safety limit of height of gravity center of loaded wagon under different wind speed.

When the wind speed is lower than 9 grade, the height of gravity center can reach 2.2 m or higher; when the wind speed is 9 grade, loaded wagon should run with speed limit while the height of gravity center is over 2.2 m; when the wind speed is 10 grade, loaded wagon should run with speed limit while the height of gravity center is over 1.9 m; when the wind grade is 11 or above, loaded wagon should run with speed limit or stop running.

References

CHEN Chao (2011). Study on Permitted Height of Gravity Center Railway Loaded General Wagon. *Beijing Jiaotong University, PhD Thesis.*

DU Ying (2010). Study on the Safety of Railway Freight Cars with Different Height of Gravity Center Running on Sharp Curves. *Beijing Jiaotong University Master Degree Thesis.*

GB/T 5599-1985 (1985). Railway vehicles Specification for Evaluation the Dynamic Performance and Accreditation Test. *BEIJING*.

LI Jianwen (2013). Research and Experiment of the Reasonable Gravity Center Height limit of Railway Loaded Wagons. *JOURNAL OF BEIJING JIAOTONG UNIVERSITY*: 67-71.

Mohammad Reza Ghazavi , Majid Taki (2008). Dynamic Simulations of The Freight Three-piece Bogie Motion in Curve. V*ehicle System Dynamics*, 46:955-973.

Roman Kovalev, Nikolay Lysikov (2009). Freight Car Models and Their Computer-aided Dynamic Analysis，*Multibody System Dynamic*, 22: 399–423.

YI Lan (2013). The Railway Cargo Loading Modeling and Dynamics Simulation. *Southwest Jiaotong University Master Degree Thesis.*

Elastic-Plastic Analysis on the Contact of Wagon Wheels and Heavy Haul Frogs

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Abstract: The phenomenon of spallings on the frog used in the heavy haul railway occurs easily, which reduced the service life of frog. The worn profiles of No.12 unmovable frog with 75 kg/m rail and wagon wheels used in Datong-Qinhuangdao have been measured. They are used to established an elastic-plastic finite element model to study the contact problem of wheel and frog at different location. The contact patches, the equivalent Von Mises stress and the variation of contact path have been analyzed. The results indicate that the contact patch on the nose rail is near the center line of top surface when the wheel contact with the standard frog and it is on the edge of nose rail when the wheel contact with the worn frog. The equivalent Von Mises stress exceeds the yield limit into the plastic deformation stage. When the wagon passes the standard frog, the wheel contacts with the wing rail, then transits to the nose rail gradually. However, when the wheel runs over the worn frog, the contact point shifts from wing rail to nose rail and then moves to the wing rail again. The contact status of wheel and frog changes between one point contact and two point contact, which causes the variation of equivalent Von Mises stress of the wing and nose rail. Besides, the wheel displacement has a great effect on the equivalent Von Mises stress and therefore it should be taken into consideration when designing the match of wheel and frog. The research provides a theoretical basis for the design of wheel and frog profiles used in the heavy haul railway.
Keywords: Heavy haul frog; Finite element method; Elastic-plastic contact; The equivalent Von Mises stress; Contact patch.

1 Introduction

Switch should have the function of ensuring trains to transfer smoothly on railway. It also should meet the reliability, stability, long service life, low maintenance and repair work under the condition of mass transit (FAN Q. A. 1999). The structure of switch is more complex than other track components. Therefore, switch need more maintenance. The damage mechanism of the wheel and switch are wear, rolling contact fatigue and large accumulated plastic deformation (Kassa E. and Nielsen J. 2008).

Daqin is short of Datong-Qinhuangdao heavy haul railway which is a special line of coal transportation. Its total length is 653 km. It enjoys the reputation of the largest coal cargo and the highest transport efficiency in the world. With the development of the national economy, the demand of coal transportation continues to grow. The transport task of Daqin railway is becoming more and more heavy. There are large capacity, high density and heavy axle load in Daqin, which makes frog more likely produce the phenomenon of falling off and greatly shorten the service life. The wear problem of frog is the most important and major issue to be resolved.

Experts and scholars at home and abroad have done far-ranging research on the wear problem of frog used in Daqin railway. Based on the problems of horizontal crack, vertical crack and vertical abrasion of No. 12 frog with 75 kg/m rail, the finite element models were established by Chen Rong to study the mechanical performance of three-kind frogs under the ultimate load and fatigue load. (CHEN R. and WANG P. 2009). M. Wiest and Martin P. are always studying a finite element model to simulate the wheel passing through the frog. And the dynamic response, the changing rules of the contact stress and the contact spot area are obtained (M. Wiest 2008, Martin P. 2008). As there is inevitably problem which is called "harmful space" in the unmovable frog, the frog with the movable nose rail is considered. While the cost of the movable frog is too high. And the movable frog demands more maintenance and repair and it's difficult to replace. So the movable frog doesn't adapt to the operating condition. Therefore the unmovable frog accounts for the vast majority in the heavy haul railway (ZHAO H. Y. 2010). It's necessary to study the contact situation between the wheel and the unmovable frog.

In this paper the profiles of No.12 unmovable frog with 75 kg/m rail and the worn profiles of wagon wheels used in Daqin have been measured. The finite element models were established to study the changing rules of the contact patch and the equivalent Von Mises stress.

2 Profiles Analysis of the Wheel and the Frog

With the increasing of passages, the profiles of wheel and frog changed with the accumulated wear. A series of tests were carried out to track the evolution of the profile. Some representative worn profiles are utilized in this study. The standard profiles of wheel and frog are used for comparison. The standard profile and representative worn profile of wheel are illustrated in Figure 1. It can be seen that the wear on the tread is severe, whereas the flange wear is mild. This phenomena has great influence on the contact behavior of wheel and rail, which is going to discuss in the next sections.

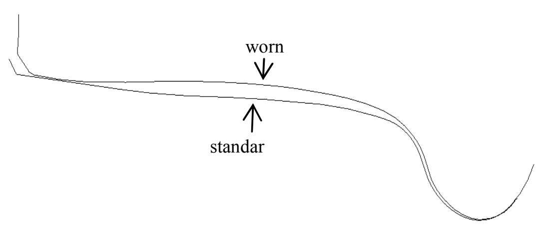
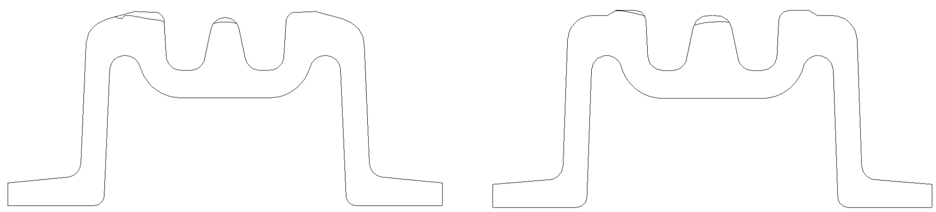


Figure 1. The standard and worn profiles of wagon wheel

Based on the research results, the frog profiles at the 360 mm and 480 mm distance away from the theoretical nose of crossing wear seriously which are shown in Figure 2. From the figure, it can be seen that the worn wing rail is approximately an oblique line and the curvature of the nose rail top after wearing has become small. The largest vertical abrasion value of the wing rail is 7.483 mm and the one of the nose rail is 4.492 mm at the 360 mm distance away from the theoretical nose of crossing. And at the 480mm the greatest vertical abrasion value of the wing rail is 2.987 mm and the one of the nose rail is 6.570 mm. It can be seen that the wing rail wear more seriously than the nose rail. The wing rail of the standard frog is higher than the nose rail. In the figure the nose and wing rail are all worn. It can be predicted that some wheels contact with both the wing rail and the nose rail. In the facing and trailing moves, vehicles contact with one side of the nose rail respectively. When the vehicle with full load passes the frog, the wheels flange contact with the left of the nose rail which causes the nose rail to wear into the profile shown in Figure 2(b).



(a) 360 mm (b) 480 mm

Figure 2. Standard and worn frog profiles

3 Modeling

In order to investigate the elastic-plastic contact behavior between wheel and frog, the finite element method is employed. The three-dimensional wheel-frog models for different profiles are established. To save calculation time, the model considers half of the wheelset and the track, i.e. a single wheel with the frog on one side, for the symmetric of the wheelset and track systems and load condition.

HX_D2 electric locomotive and C80 wagon under the axle load of 25 t are applied to Daqin railway. As using the single wheel to calculate, half of the axle load 125000N is applied on the axle head. The longitudinal direction is the running direction of the wheel. At the same horizontal plane the lateral direction is perpendicular to the longitudinal direction. The horizontal and vertical displacement of the axle head nodes are restricted to prevent the wheel of the horizontal and vertical rigid displacement. The X, Y and Z directions of linear displacement of nodes on the frog bottom are limited to stop the three directions displacement.

4 Results and Discussion

4.1 Analysis of the contact patch

The elastic-plastic contact calculation between the standard and worn wheel profiles and the standard and worn frog profiles at different positions have been proceeded. It is known that when the wagon wheel contacts the standard frog, the contact patch is long and narrow, the long axis is along the longitudinal direction and the short axis is along the lateral direction. The contact patches are on the head of the nose rail which causing the nose rail head to press and damage. With the wheel running on the facing move, the contact patches expend at the lateral direction. When the wagon wheel contacts the worn frog, the contact patch is longer and more narrow. The contact patches are on the edge of the rail.

The contact area of the worn wagon wheel and the standard frog at the different positions is shown in the Figure 3. From the figure, it could be predicted that when the worn wagon wheel is on the facing move through the standard frog, the wheel contacts the wing rail firstly and the contact area becomes small. At the 480 mm distance away from the theoretical nose of crossing, the wheel contacts with both the wing rail and the nose rail. The contact area is about 50 mm^2. At the 600 mm distance away from the theoretical nose of crossing, the wheel only contacts the nose rail.

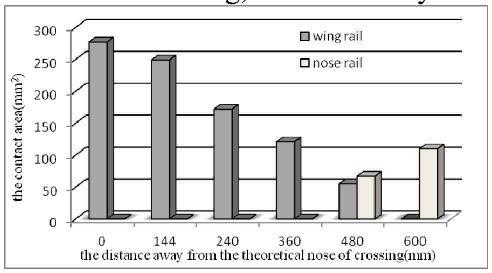


Figure 3. Contact area of wagon worn wheel and standard frog

The contact area of the worn wagon wheel and the worn frog at different positions is shown in Figure 4. When the wheel is on the facing move through the worn frog, the contact area on the wing rail becomes small. At the 480 mm distance away from the theoretical nose of crossing, the frog wears seriously and the lower value of the nose rail top reaches 6.57 mm. Besides, the tread of the worn wagon profile wears seriously. So at the position the wheel contacts the wing rail and then completely transits to the nose rail.

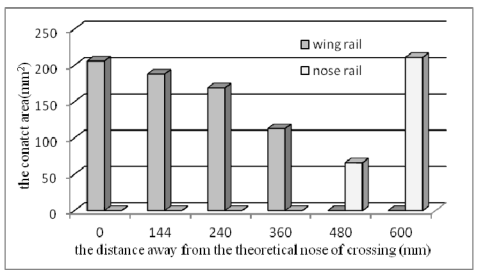


Figure 4. Contact area of wagon worn wheel and worn frog

Every wheelset runs from the throat area of the frog to the theoretical nose of crossing, then rolls onto the nose rail when passing a frog. In the process, the contact state changes between one-point and two-point contact. One is the contact between the nose rail and the wheel flange, the other is the contact between the wing rail and the wheel tread. At last, the wheel only contacts the nose rail. According to above, the contact state of the wheel and the frog is quite complex and is changing constantly. Therefore the contact stress on the wing and nose rail and the basic rail is reallocated.

4.2 Analysis of the equivalent Von Mises stress

4.2.1 Analysis of the equivalent Von Mises stress at the middle position

When wheel runs on the standard or worn frog, the stress is concentrated on the contact region. Table 1 shows the equivalent Von Mises stress of wheel under the 25 t axle load contacting frog at different positions. From Table 1, it could be seen that the equivalent stress exceeds the material yield limit, which causes the plastic flow. And there is no plastic deformation on the surrounding frog material, so it has certain constraint effect on the contact region. When the wheel contacts the standard nose rail, the contact patch is on the top. The nose rail is flattened or damaged. While the wheel contacts the worn frog, the contact patch is on the edge of the wing and nose rail. One side without plastic flow has constraint effect and the other side has large deformation because of no constraints. Where could create "flash" wears seriously.

Table 1. The equivalent Von Mises stress of the wheel and frog/MPa

the distance away from the theoretical nose of crossing (mm)	standard wheel and standard rail	worn wheel and standard rail	standard wheel and worn rail	worn wheel and worn rail
0	908.4	697.4	768.4	673.5
144	1036	703.1	1702	802.2
240	1034	768	1704	1076
360	1033	844.3	1081	1232
480	994.3	1519	1058	1434
600	1146	1349	713.7	691.9

4.2.2 Analysis of the equivalent Von Mises stress with different displacement

Taking the contact between the standard wheel and the standard No.12 frog with 75 kg/m rail at the 360 mm distance away from the theoretical nose of crossing for example, the equivalent Von Mises stress of the wheel and the frog with different displacement is calculated. The effect of contact position on the equivalent Von Mises stress between the wheel and the frog is summarized. The limited position of the wheel on the frog is determined firstly. The distance size chart of the wheel and the frog in the middle position is shown in Figure 5. This position is denoted by 0 mm.

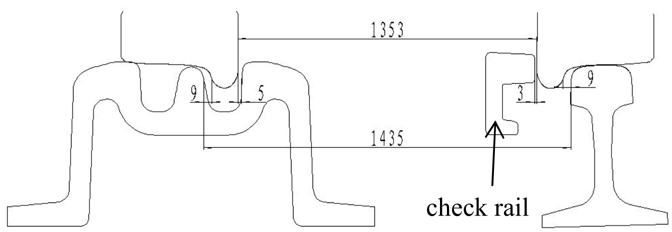


Figure 5. Distance size chart of wheel and frog in the middle position

Because the limited wear value of the check rail is 3mm, the maximum displacement of the wheel near to the frog is 6 mm. The 3 mm and 6 mm displacement of the wheel near to the frog is denoted by -3 mm and -6 mm respectively. The 2.5 mm and 5 mm displacement of the wheel away from the frog is denoted by +2.5 mm and +5 mm respectively. The models of the wheel contacting the frog at five positions are established to analyze the equivalent Von Mises stress, shown in Figure 6.

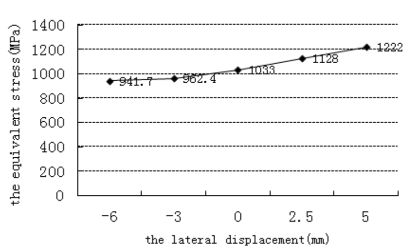


Figure 6. The equivalent Von Mises stress

The maximum equivalent Von Mises stress at the -6 mm displacement on the nose rail is 941.7 MPa which is the smallest one and at the 5 mm displacement is 1222 MPa which is the largest in five values. When the wheel runs away from the frog, the maximum equivalent Von Mises stress gradually increases. This is because the curvature of the nose rail at 360 mm distance away from the theoretical nose of crossing is large and the curvature of the standard wheel profile at the contact point becomes small. With the wheel running away from the frog, the contact area increases. The equivalent stress is small due to the large contact area under the same axle load. The smallest stress also exceeds the material yield limit and the plastic flow happens on the nose rail.

5 Conclusions

The elastic-plastic contact calculation is carried out which is about the standard and worn wheel contacting with the standard and worn No.12 unmovable frog with 75 kg/m rail at different positions under the axle load. The changing rules of the contact patch and the equivalent stress are analyzed. The above facts insist on the following conclusions.

(1) When the wagon wheel runs on the standard frog, the contact positions are the wing rail - the wing and nose rail - the nose rail. While on the worn frog, the wheel contacts the wing rail again after transiting to the nose rail. The wheel jumping between the wing rail and the nose rail makes the frog wear seriously.

(2) The equivalent stress of the wheel and the frog under the 25 t axle load exceeds the material yield limit, which makes the wheel and the frog enter the plastic deformation stage. When the wheel contact the worn frog, the contact patch is on the edge of the wing and nose rail which makes the wing and nose rail “flash”.

(3) The wheel displacement has an effect on the equivalent stress of the wheel and the frog, so it is necessary to take the effect of the displacement into consideration when the wheel and the frog are proceeded the contact calculation.

Acknowledgement

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References

Fan Q. A. (1999). “The laying and the maintenance of the speed rail.” *China Railway Publishing House.*

Kassa E. and Nielsen J. (2008). “Dynamic interaction between train and railway turnout:full-scale field test and validation of simulation models.” *Wagon System Dynamics*, 46:521-534.

Chen R. and Wang P. (2009). “The finite element analysis of No. 12 high manganese steel frog with 75 kg/m rail.” *Subgrade Engineering*, (4): 26-28.

M. Wiest, W. Daves, F. D. Fischer, et al (2008). “Deformation and damage of a crossing nose due to wheel passage.” *Wear,* 265: 1431-1438.

Martin P. Werner D. and Heinz O. (2008). “A wheel passing a crossing nose: Dynamic analysis under high axle loads using finite element modeling.”

Journal of Rail and Rapid Transit, 226(6):603-611.
Zhao H. Y. (2010). "The discussion of the technical index of Daqin heavy haul railway." *Railway Engineering,* (4):89-91.

Monitoring and Simulation Analysis of Composite Foundations on Bearing Characteristics for a High-Speed Railway

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Abstract: The methods of geogrid reinforced and CFG pile-supported foundation is a new technique for foundation treatment developed in recent years. It is the first time to be applied in high-speed railway whose design speed is 350 km/h. It consists of rigid piles, geogrids, cushion and soft soil foundation. The unity of pile, geogrid and soil bear the load together. Because of the soil arching effect, tensioned membrane effect and stress concentration. The composite foundation can not only restrict the side deformation of soft soil, but also give full play to the strength an the deformation properties of the soil, in order to effectively improve the strength of the soft soil foundation, reduce settlement of the soft foundation after reinforcement, short construction period and lower construction costs. In this paper, based on the test section of a high-speed railway line, experimental analysis and numerical simulation were used to study the action mechanism, the deformation rules and the stress distribution rules of the pile-net composite foundation.

Keywords: Composite plie-net foundation; Foundation settlement; Pile and soil stress; Geogrid tension.

1 Introduction

With the rapid development of high-speed railway in soft foundation, foundation treatment technology has become mature, the most outstanding is CFG pile composite foundation technique. CFG pile composite foundation is made of cement fly ash gravel pile (CFG pile), pile of soil and sandstone, between sand and gravel several problems such as the medium material composition together constitute layer. It has high bearing of capacity, convenient, low costing, strong adaptability and quality control easier. So it is widely applied and promoted. Under static and dynamic loads, the relations of the high-speed railway CFG pile composite foundation is very complex. Figure 1 shows the Traditional CFG pile composite foundation.

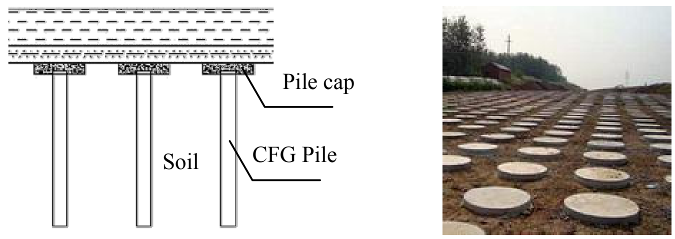


Figure 1. Traditional CFG pile composite foundation

For a high speed railway line in China therefore three different construction methods for a better and safe load transfer, distribution and concentration were carried out: ① Reinforced concrete slab on top of the piles; ② Horizontal geogrid reinforcement on top of the piles (so-called "geosynthetic-reinforced pile-supported embankment"); ③ Cement stabilization of the embankment material.

2 Project and Horizontal Geogrid Reinforcement on Top of the Piles

Between cities the high speed railway are being built. With a design speed of 350 km/h. About 70% of the railway line will run on a structure consisting of single-span and multi-span bridges. The remaining length of the track will run on an embankment. Composite Foundation: Cement Fly-ash Gravel (CFG) Pile + High Strength Geogrids (Ultimate Tensile Strength ≥ 300 kN/m) + Cement Grade Macadam. Figure 2 shows the test geological profile of the high speed railway.

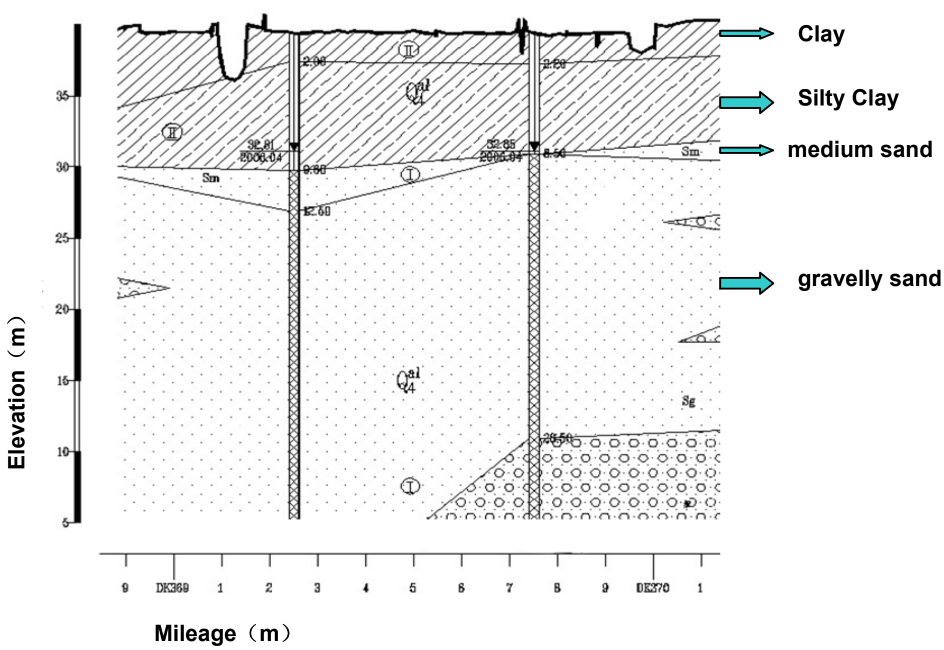


Figure 2. test geological profile

The reinforced method is geosynthetic-reinforced and pile-supported embankment. Normally the Cement Grade Macadam filled with a thickness of about

70 cm on top of the piles for a safe load transfer, distribution and concentration was used. In the Cement Grade Macadam fill, two layers horizontal geogrid reinforcement (300 kN/m) are placed. The diameter of CFG pile is 0.5 meter, and the space between of CFG piles is 1.5 meter. A schematic view of the pile supported embankment is shown in Figure 3 and a picture is given in Figure 4.

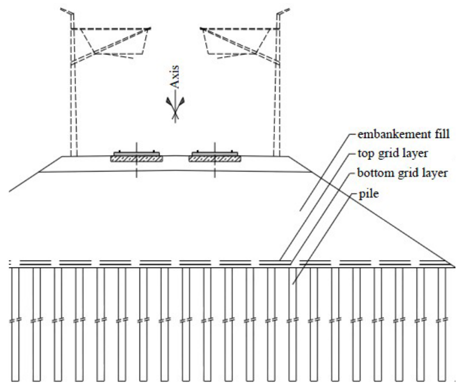


Figure 3. Geosynthetic-reinforced and pile-supported embankment

Figure 4. CFG pile reinforced soft subsoil embankment

The stress relief from the soft soil results from an arching effect in the reinforced embankment over the pile heads and a membrane effect of the geosynthetic reinforcement. Figure 5 shows In the Cement Grade Macadam filled with two layers horizontal geogrid reinforcement on top of the piles. The height of embankment is 8.16 meter (Figure 6).

Figure 5. In the Cement Grade Macadam filled with two layers horizontal geogrid reinforcement on top of the piles

Figure 6. Embankment fill

In order to further understand the intensity of pile-net structure subgrade stability and deformation, pile, requirements of the high-speed railway track bed, it needs to do pile-net structure parameter sensitivity analysis. According to high-speed railway CFG pile composite foundation, the numerical analysis can well solve the coupling effect of piles and soil.

Considering the roadbed symmetry, take half range foundation and embankment structure is analyzed. Calculation scope: vertical take 20 m, transverse take 41 m and longitudinal take a single pile distance. Because of the lower boundary of foundation soil, load has little effect, as no displacement of fixed boundary, the center of each node symmetry and lateral horizontal displacement, the surface is restricted free boundary. Figure 7 shows the finite element calculation model.

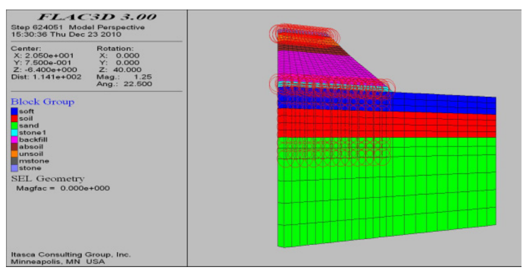


Figure 7. The finite element calculation model

3 Monitoring and Measurement results

3.1 Monitoring of foundation settlement

3.1.1 Monitoring Scheme

The five monitored cross sections, DK369+345、DK369+420、DK369+520、DK369+620、DK369+720, are selected. The different monitored cross sections have distances between 100 m. In the vicinity of K369 +345 section the bridge and embankment are connected, and in the vicinity of K369 +720 section the embankment is connected with the culvert. A large quantity of vertical and horizontal inclinometers and geophones were installed. Additionally, the settlements of the rails were measured. Figure 8 shows the five monitored cross sections.

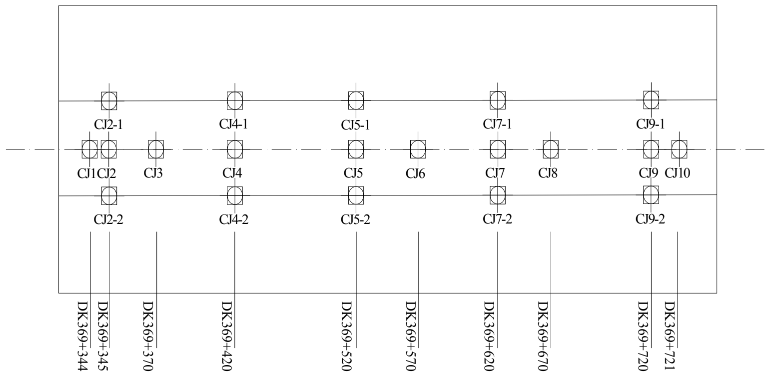


Figure 8. monitored cross sections

In a typical measurement cross section one horizontal inclinometer and up to three settlement plates are used for the examination of the deformation behaviour, see Figure 9. Figure 10 is pictures of the measurement of the settlements.

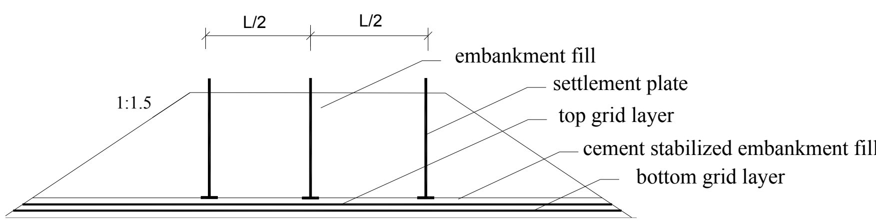


Figure 9. Typical measurement cross section

Figure 10. the measurement of the settlements

3.1.2 Simulation Analysis

This paper has calculated by finite difference FLAC3D program simulated and analyzed. The basic idea is with a differential grid discrete solving domain, difference formula will be ordinary differential equation or partial differential equations turn into difference equation, then combines initial and boundary condition, to solve the linear algebra equations.

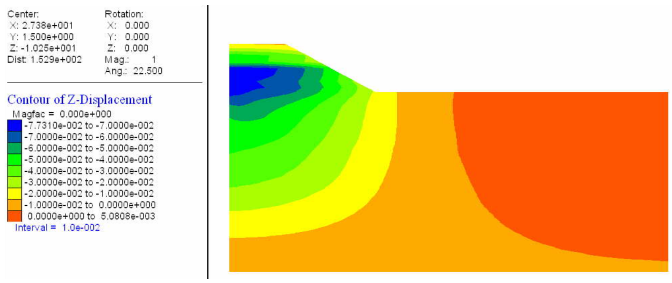


Figure 11. The calculation results

Figure 11 shows that the road embankment foundation surface subsidence center place, reach a maximum. As the center of the distance from the embankment settlement increases gradually reduce, maximum settlement is occurred in the positions shown in figure, the maximum displacement for 30.838 mm on the piles.

3.1.3 Measurement results

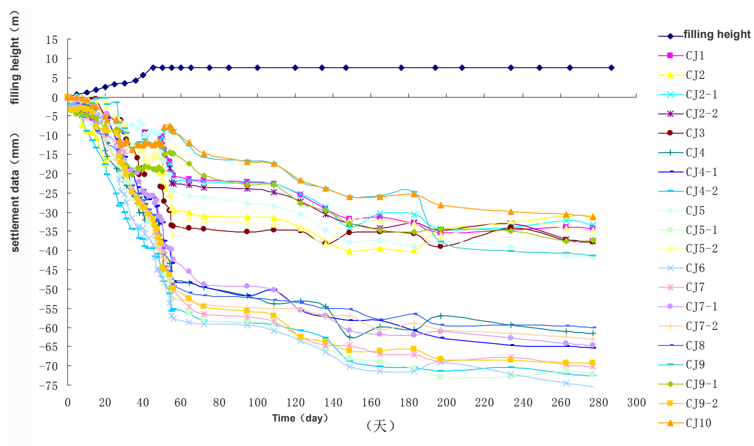


Figure 12. The measurement results

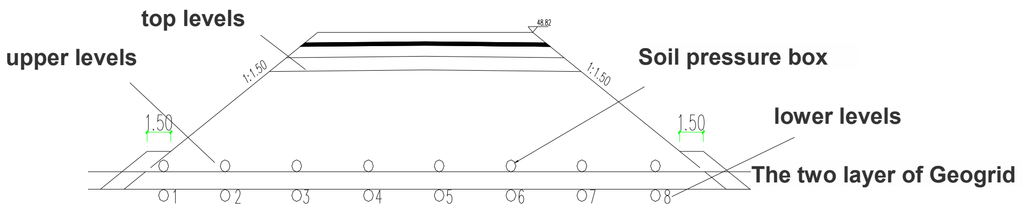
As shown in Figure 12, with the increase of the filling height, roadbed settlement is increasing. The difference between the settlement of pile top and the ones of soil between piles is increasing. Settlement of pile top and soil between piles settlement are obvious stratification. And the settlement of soil between piles is bigger than the settlement of pile top.

During the period of the embankment filling (0～48 days), settlement increase sharply. Foundation settlement rate is proportional to the embankment filling rate, when the filling rate is bigger, the settlement growth rate is larger. When filling to the top of the embankment, settlement curve is an obvious turning point, subsidence increment decreases, and the subsidence rate decreases, the sedimentation stabilized.

3.2 Testing of pile and soil stress

3.2.1 Monitoring Scheme

Test point arrangement is as shown in Figure 13 and the measurement of compressive stress is shown in Figure 14.



1、3、5、7 ： the position between piles; 2、4、6、8 ： the position on piles

Figure 13. test point arrangement

Figure 14. the measurement of compressive stress (Soil pressure box)

3.2.2 Simulation Analysis

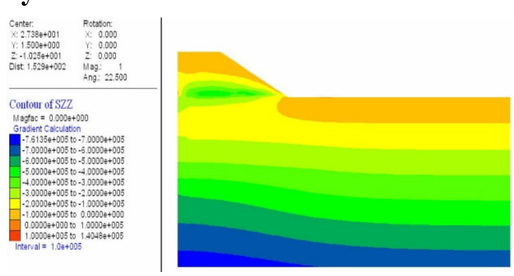
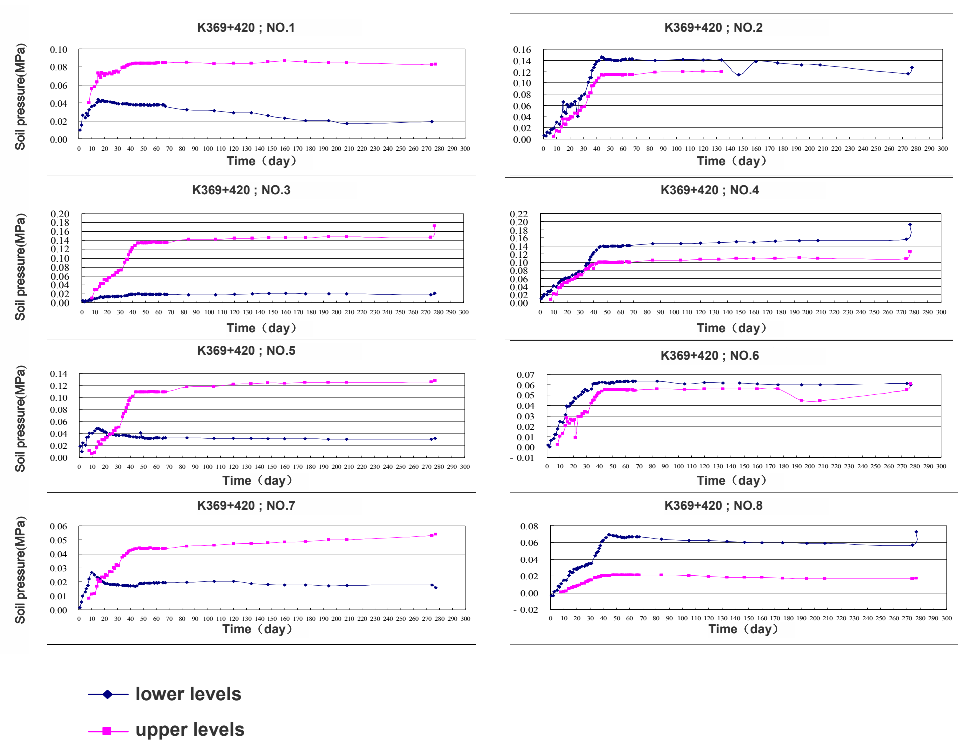


Figure 15. Composite Foundation vertical stress cloud map

From Figure 15 we can see, there are not centralized stress phenomenon in the foundation. Along with the increase of the depth of foundation, vertical uniform stress increases, the more obvious stratification. This shows that the pile and soil between piles have formed a whole of the pile net composite foundation. Also verified the pile net composite foundation treatment has a good effect. When produced differential settlement between pile and soil, geogrid tension produced, forming a "net" to hold the upper embankment soil body, and makes the its under the vertical stress increase. Reinforced cushion of high strength geogrid due to tensile action, "the film effect" to produce more stress to the CFG pile load sharing.

3.2.3 Measurement results

The arrangement position of soil pressure box is that No.2, No.4, No.6, No.8 locate on the top of CFG pile, contrarily the No.1, No.3, No.5, No.7 locate on the soil between the piles. By analyzing the measured data, the following conclusions are obtained: with the filling height of soil increased, soil pressure curve rise. On the top of the pile, soil pressure at the lower greater than that of the upper. On the contrary, on the soil between piles, upper data of earth pressure is greater than the lower. This shows that the geogrid and cushion layer can be a very good uniform distribution of soil pressure on the top of pile and the between of them. As shown in Figure 16.



(a) the position between piles (b) the position on piles

Figure 16. The test data of soil pressure

3.3 Measuring of geogrid tension

3.3.1 Monitoring Scheme

Test point arrangement is as shown in Figure 17 and the measuring instrument is shown in Figure 18.

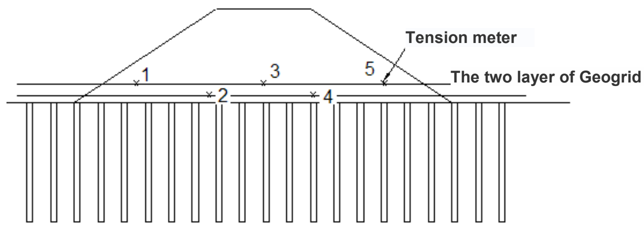


Figure 17. Test point arrangement of geogrid tension

Figure 18. measuring instrument of geogrid tension

3.3.2 Simulation Analysis

It can be seen from Figure 19, on the surface of composite foundation the level stress is minimum, and at the cushion position appeared larger horizontal stress. Because of the existence of the cushion layer of geogrid, under the load function, with the composite foundation pile, soil settlement difference, geogrid tensile stress caused by tensile, constraints of the lateral deformation of the foundation, makes the foundation level of stress redistribution. Pile net composite foundation joined the geogrid in the cushion, geogrid tensile properties can play a very good effect, effectively constraint the lateral displacement of embankment foundation. On the other hand, it makes the surface of compound foundation, namely the top of pile, much less horizontal stress and then protects the piles.

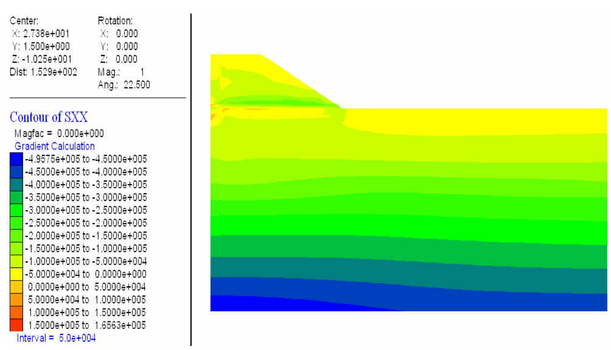
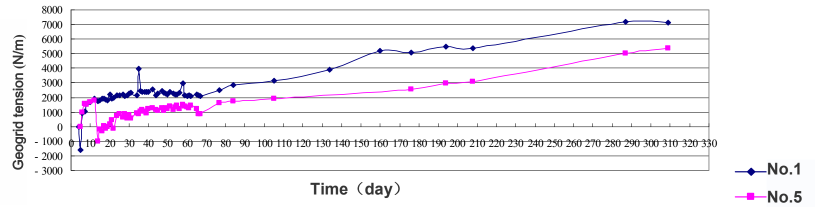


Figure 19. Composite Foundation level stress cloud map

3.3.3 Measurement results



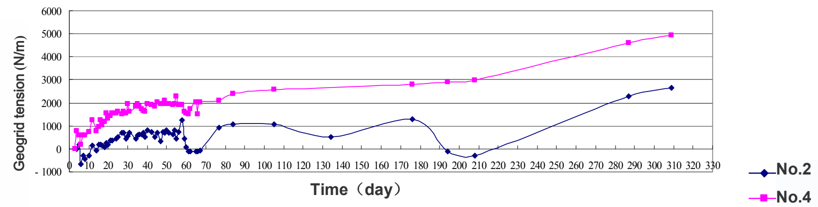


Figure 20. geogrid tension on the section of DK369+520

With the increase of the height of the embankment, geogrid tension increases. After the completion of filling, geogrid tension still rise. Geogrid tension continued to increase after preloading. This shows that the geogrid strength have a time effect.

4 Conclusions

Settlement occurs mainly in embankment construction phase, later, the settlement is lesser and embankment is stabilized. Along the mileage direction differential settlement of embankment is too large, it is necessary to add the temporary load about half a year in order to eliminate eventually the uneven settlement.

The characteristic of High Strength Geogrids is “tensioned membrane effect”. The composite foundation can not only restrict the lateral deformation of soft soil, but also give full play to the strength an the deformation properties of the soil, in order to effectively improve the strength of the soft soil foundation, reduce settlement of the soft foundation after reinforcement, short construction period and lower construction costs.

The pile-net composite foundation deformation rules and stress distribution rules of Mohr - Coulomb model were studied using the numerical simulation software. Studies have shown that: the Reinforced cushion reduced the level of stress and deformation to protect the pile and homogenized vertical stress to reduce the differential settlement. The unity of pile, geogrids and soil bear the load together.

References

Faheem, H. (2004). “Dimensional base stability of rectangular excavations in soft soils using FEM. ” *Computers and Geotechnics*, 31, 67-74

Rowe, R. (2001). “Skinner-Numerical analysis of geosynthetic reinforced retaining wall constructed on a layered soil foundation.” Geo textiles and Geo mem branes, 19, 387. 412

Widening Methods of Existing Cast-in-Situ Continuous Curved Beams

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Abstract: An existing cast-in-situ continuous curved bridge was located at the acceleration lane of a new Interchange, widening was needed to meet the width requirements. The original lateral bump walls of the bridge were removed, cantilever sections of beam were cut off about 50cm, and medial bump walls were replaced with corrugated guardrails for balance. With the help of the finite element modeling, conditions of limit and normal state with different load combinations were analyzed. The results, numerical simulations of ultimate flexural capacity and stress of both the top and bottom sides under normal state, showed that the widening project was practicable. On the basis of numerical simulations, vertical deformations between exiting and new beams under using stage were calculated，and by comparison on advantages and disadvantages of different splicing scheme, Polyurethane elastic expansion joint was finally recommended to treat Joints between new and old beams.
Keywords: Existing cast-in-situ continuous curved beams; Numerical analysis; Vertical deformation; Polyurethane elastic expansion joint.

1 Introduction

A new interchange located on the transfer joint of National Expressway No. G94 and No. G45, which was showed in Fig. 1 By the interchange, collinear between G94 and G45 were complied. In 2036, according to the traffic volume forecast, one-way traffic volume on mainstream direction was 34384 pcu/d, while the peak hour traffic volume was 2476 pcu/h, compared with 1942 pcu/d（140 pcu/h, one-way）on the minor direction.

Fig.1 Planar graph of the interchange

In G45 expressway, the bridge was in horizontal curve (R=2500m), intersecting angle was 65°between bridge and local road. Span Arrangement of existing bridge was asymmetric and no bridge pier ([left: 30+(30.676+3×41.5+30.676)+4×30+3×30] and [right:30+(30.676+2×41.5+43.5+28.676)+4×30+3×30]m). The width of (30.676+3×41.5+30.676) and (30.676+2×41.5+43.5+28.676) in upper structure that made up of cast-in-situ continuous beam was 2×20.25m, which the height of beam gradually changed from 2.2 to 2.4m. While the other part, whose girder was 1.7m, was build up by precast box girder. The substructure was partly supported by rectangular pier of 1.4×3.5m,which consisted of a pile cap and 4 pile foundations of φ1.2m,skewed with Tour-Road at its both bump wall and two sides, while the rest was supported by double-column bridge piers of pile foundations (D=1.3~1.5m).

Therefore, the bridge of G45 in the new interchange should be widen, whose piers had to be disposed in the median strip of local road, the method and new or old expansion joint (NEJ or OEJ) were showed in Fig. 2.

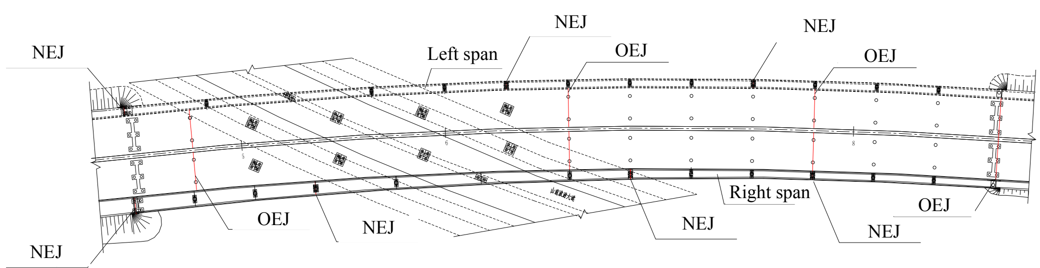
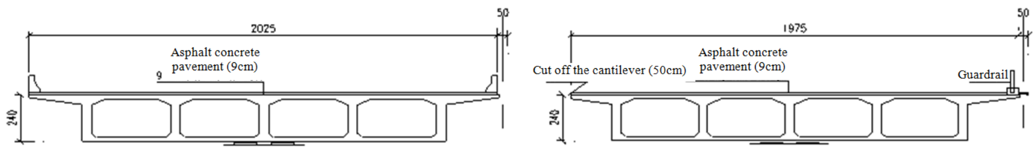


Fig.2 Planar graph of the widen bridge

Widen scheme was showed in Fig. 3 The original lateral bump walls of the bridge were removed, cantilever sections of beam were cut off about 50cm, and medial bump walls were replaced with W-typed Beam barriers for balance. Global stress of upper beams was calculated under the scheme.



（a）Original cross-section （b）cross-section after widening

Fig.3 Widening scheme

2 Calculation Parameters

(1)Permanent Load

structure weight:

concrete capacity: 26kN/m3;

bridge deck pavement: 0.09×19.25×26=45kN/m;

W-typed Beam barriers on one side: 4kN/m;

shrinkage and creep: calculated based on JTJ 023-85.

(2) variable load

Basic variable loads:

Vehicle : Super -20t, 5 lane;

Checking load: trailers -120t, 1 lane ;

Vehicle impact: the impact coefficient μ = 0.1.

other variable loads:

changes of global temperature:±25℃

(3) Load combinations

Combination I: Constant load + Vehicle ;

Combination II: Constant load + Vehicle +other variable load;

Combination III: Constant load +trailers

3 Finite Element Model

The whole bridge was divided into 143 Nodes and 117 Space beam elements in MIDAS. Boundary conditions were simulated towards actual structure situation.

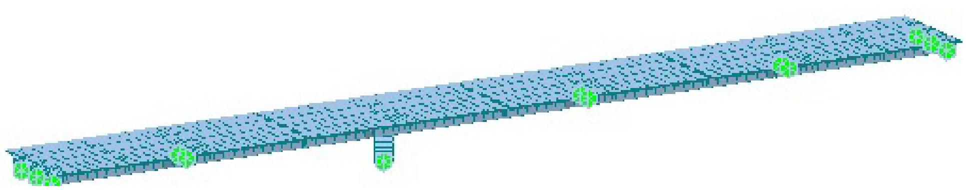


Fig.4 Finite Element Model

In order to analysis the feasibility of widen methods at the same time provide data support for splicing mode, different load combinations as well as their normal and limit state were analyzed(ZHANG Lifang, 2001), deformation value on the vertical direction at joints of bridges were calculated.

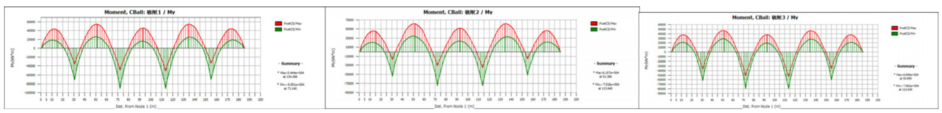
Boundary conditions: Vertical deformation was 0 at the piers, the other boundary are all free.

4 Calculation Results

4.1 Bearing capacity

(1) Limit state

Calculation results of bending moment after widen under limit state were shown in Fig. 5 and Table.1.



I II III

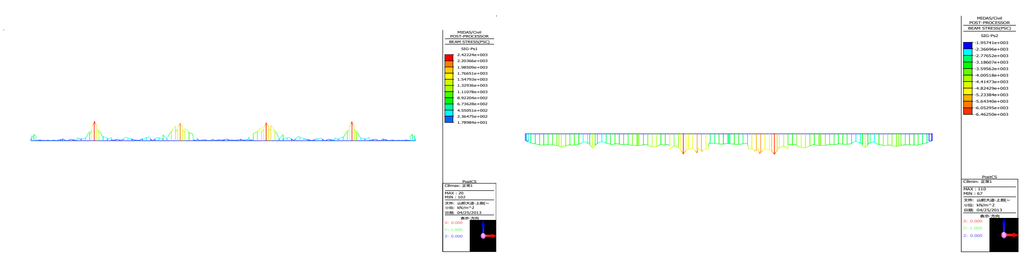
Fig.5 Envelope diagram of bending moment

Table.1 Calculation results of bearing capacity of bending

structure position	bearing capacity of bending(kN • m)				
	internal force			structural resistance	surplus
	I	II	III		
middle of side span	43359	45084	37595	75001	66%
top of secondary middle-pier	-71167	-54089	-61445	73891	4%
middle of secondary side span	53931	61207	46851	81352	33%
top of middle-pier	-90509	-74788	-78998	109113	21%
middle of midspan	-45368	51576	37761	67902	32%

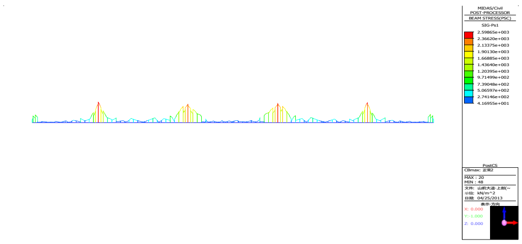
(2) Normal state

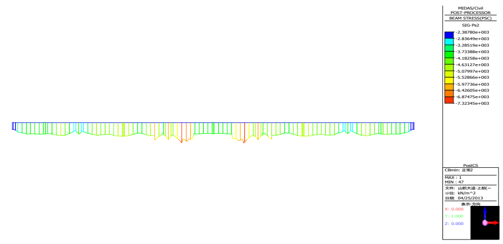
Simulated results of principal tensile stress on the top and compressive stress at the bottom of the bridge under different load combination were shown in Fig. 6, normal stress shown in Table 2 and principal stress shown in Table 3.



Principal tensile stress Principal compressive stress

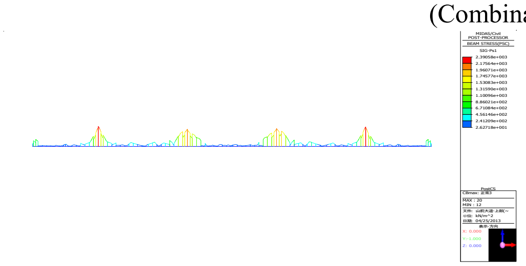
(Combination I)

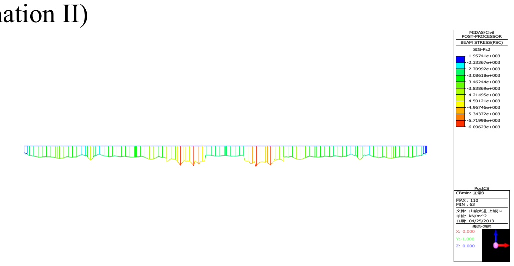




Principal tensile stress Principal compressive stress

(Combination II)





Principal tensile stress Principal compressive stress

(Combination III)

Fig. 6 Results of Principal tensile stress and compressive stress with different load combination (I, II, III)

Table 2. calculation result from aspect of normal stress

Type	Compressive stress (MPa)				Tensile stress (MPa)			
	Calculation results		standard value	content or not	Calculation results		standard value	content or not
	top	bottom			top	bottom		
I	6.06	6.37	17.5	OK	0.485	0.585	2.4	OK
II	7.197	6.132	21	OK	-0.844	0.077	2.7	OK
III	5.795	5.87	21	OK	-0.053	-0.569	2.7	OK

Table 3. calculation result of principal stress

Type	principle shear compressive stress (MPa)			principle shear tensile stress (MPa)		
	Calculation results	standard value	content or not	Calculation results	standard value	content or not
I	6.462	21	OK	2.422	2.4	NO
II	7.323	22.75	OK	2.598	2.7	OK
III	6.096	22.75	OK	2.39	2.7	OK

(3) Result Analysis

Calculation result showed that all the index content standard value except for that of principle shear tensile stress of Combination I, which proved that the widening methods were feasible.

4.2 vertical deformation after widen

Since deflection of the bridge was basically stable when expansion joint was installed, only vertical displacement at the flange plate of both sides of expansion joint under vehicle load was taken into account(WANG Zonghua,2009; LIN Jing, LIN Guohui,etc,2011; ZOU Zhiping, ZHU Runtian,2013), which was able to provide data support for splicing plan. Calculating result were showed in Table.4, Table.5 and Table.6.

(1) deflection of （30.676+41.5+41.5+43.5+28.676）m continuous box girder in G45under Vehicle load was showed in table 4.

Table 4. Deflection of mid-span in old bridge under vehicle load

Deflection results of mid-span (mm)				
First span	Second span	Third span	Fourth span	Fifth span
-2.94	-5.17	-5.37	-5.41	-2.98

(2) Deformation value of flange plate from inbuilt bridge under vehicle load was 0.68mm.

(3) Deflection of widen bridge under vehicle load

Deflection of (40+40.352+35.5+30) m continuous box girder from right range of widen bridge under vehicle load was showed in table 5.

Table 5. Deflection of mid-span (right) under vehicle load

Deflection results of mid-span (mm)			
First span	Second span	Second span	Second span
−10. 5	−9. 9	−11. 8	−5. 3

Deflection of (40+42+40.352+35.5+30) m continuous box girder from left range of widen bridge under vehicle load was showed in table 6.

Table 6. Deflection of mid-span (left) under vehicle load

Deflection results of mid-span (mm)				
First span	Second span	Third span	Fourth span	Fifth span
−8. 1	−6. 3	−6. 2	−4. 2	−3. 2

(4)As cantilever of flange plate from widen bridge was only 0.75m long under vehicle load that could be neglected.

4.3 Summary

As cantilever of flange plate from widen bridge under vehicle load was so tiny that could be neglected, the maximum vertical displacement of both sides of expansion joint was 11.8+0.68=12.5mm,which meant that expansion joint that could afford 20mm of vertical displacement was optional.

5 Linking measures of vertical expansion joint between the bridges

Based on the experiences(MA Chunsheng, SONG Shenyou,2003), three kinds of expansion joint-which was made of TST elastic broken stone, seamless polymer elastomer and section steel-were chosen in comparison mainly on the aspect of construction difficulties, construction cost and durability. Detailed comparison of upper three kinds of expansion joint on relate aspects were showed in table 7:

Table.7 Comparison of expansion joint

	TST elastic broken stone(asphalt stuff)	Seamless polymeric elastomer Joints	Steel joints
Construction difficulty	technical maturity, convenient construction	technical maturity, convenient construction	technical maturity, convenient construction and higher installation requirement
cost	low （RMB800.00/m）	high （RMB1600.00/m）	moderate （RMB1200.00/m）
performance	Smooth, comfortable	Smooth, comfortable	noisy and low driving comfort because of visible joint
durability	poor fatigue resistance, dustproofing and waterproofing, short life	High fatigue resistance, dustproofing and waterproofing, long life	General fatigue resistance, dustproofing and waterproofing, long life
maintenance	low difficulty but high frequency of replacement, low maintenance cost	low difficulty and frequency of replacement, high maintenance cost	high difficulty but low frequency of replacement, moderate maintenance cost
operation safety	less security threat in virtue of seamless and modified asphalt stuff	less security threat in virtue of seamless and polymer elastomer-polyurethane stuff	more security threat in virtue of visible joint, exposed section steel and cast-in-situ concrete

Though TST elastic broken stone joints had less security threat and low cost, its poor performance of waterproofing and anti-cracking as well as short life span-which was only about two years-lead to regularly maintenance that road traffic was affected. The third one had high technical maturity and long life span, of which it was widely used. However, its strict installation requirement and high difficulty of replacement that brought about more security threat, which did great harm to highway safety. The second one had the highest cost, notwithstanding. Firstly, it had longer life span compared with the first one; secondary, driving become smoother and more comfortable compared with the third one due to no visible joint; what's more, for its low difficulty of installation, replacement as well as designation of joint width and thickness according to deformation, it had great advantages towards the other two kind. So the second one was recommended for designation of connection scheme for the new and the old bridge.

6 Conclusions and suggestions

(1)Results of numerical analysis of working condition corresponding to different load combinations under limit state and normal state proved that widening methods, by which cantilever sections of beam was cut off about 50cm,lateral bump wall was replaced by corrugated guardrails for balance, was feasible.

(2) Analyzed results shown that maximum vertical deformation of using emerged bridge was 20cm, providing data support for selection of expansion device.

(3)By detailed comparison of upper three kinds of expansion joint on relate aspects such as construction difficulty, cost, performance, durability etc., combined with upper analyzed results, expansion made of seamless polymer elastomer was recommended for connection scheme.

(4)Since expansion joint made of seamless polymer elastomer was applied few at home, it was advisable to strengthen construction management for quality ensuring while keep an eye on the service situation during operation, which was of great help to accumulate experience for using.

Acknowledgment

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References

ZHANG Lifang, GUO Tao, WU Wenqing, YE Jianshu (2006). Analysis of the influence of connecting method on old bridge performance in widening bridge, *Journal of highway and transportation research and development*, 23(2),102-105.

XIANG Haifan (2001). Advanced bridge structure theory. Beingjing.

WANG Zonghua(2009). Study on bridge widening splicing technology in expressway, Master Thesis, Xi'an.

Lin Jing, LIN Guohui, ZHOU Xinping, YE Jianshu (2011). Highway bridge widening project design ,JOURNAL OF CHINA & FOREIGN HIGHWAY, 31（1），119-122.

ZOU Zhiping, ZHU Runtian(2013). Comparison of Bridge Broadening Splicing Technology Scheme in Highway Reconstruction and Extension Project, *Bridge& Tunnel Engineering*, No.11,96-100.

MA Chunsheng, SONG Shenyou(2003). Design of Connection between New Bean and Old One of Huzhou Bridge on Guangfo Expressway, *Highway*, No.8, 63-66.

A Decision-Making Sequencing Model of a Mixed-Model Assembly Line Considering the Leveling of Material and Assembly Switch Cost

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Abstract: Sequence model is one of the most important decision of production plan and control for mixed-model assembly line. This paper firstly according to customs' demand and lead time divides the products into four categories: core strategic products I, customer-oriented products II, time-oriented products III, ordinary products IV. And then two principles (customers' demand and material balance) are proposed for every category of product. By using the principle of MPS, two-objective with minimum variations of part usage rate and minimum assembly switch cost sequencing model is given. Finally, the optimal solution set of every categories in a MPS are solved with genetic algorithm (GA), so that decision-making method is clear offered on mixed-model assembly line sequencing problem when with different preference and in structure characteristics of demand. The results show that two-objectives sequencing model above outperforms good shown as four parameters with work-in-process inventory, rate of material balance, assembly switch cost, lead time, etc.

Keywords: Mixed-model assembly line; Sequencing; Material balance; Assembly switch cost.

1 Introduction

To adapt the variation of customer demand, Mass customization gradually replaced the Make-to-Stock mode, and Assembly line also changed from single into mixed. Mixed-Model Assembly Line (MMAL) is known to be a special case of production lines where various and different models of the same product are inter-mixed to be assembled on the same line (Monden, 1983). So, MMAL improve enterprises' ability to response the market changing, and realize the production target: Just-in-Time。

Mixed-model assembly line with multi-product and small batch is of operation characteristics as below: small quantities, complex manufacturing process, high conversion frequency, high-flexibility of the production plan, etc. Sequence model is the one of most important decision of production plan and control for this kind of assembly line. Production plan is influenced by those factors: customer demand changes, material supply reliability, capacity balancing, load balancing of assembly line etc. Sequencing method and model are very important decisions of production planning and control of MMAL.

By existed method of sequencing, major customer demand are given priority to sequencing, then other customs' orders are inserted randomly if there is still spare capacity. This method is conclude the rule of material balance, thereby causes many problems: hardly to implement production plan, inventory excess coexisted with shortage, high assembly switch cost, unguaranteed delivery date and so on.

2 Research Status

Since 1961, Kilbridge and Wester put forward the concept and types of mixed-model assembly line, they began study sequencing problem of MMAL as early as 1963.Sequencing problem firstly need to determine the decision-objective. Monden(1983) defined two goals for the sequencing problem, after then, decision-making target changed at any time. Just like the study of Miltenburg(1990)、Sumichrast(1992)、McMullen（2000). Multi-objective (such as constant rate of usage of resources, maximum efficiency, minimum cost) envoled from single objective.

Some scholars converted above-mentioned goals into other quantifiable objective functions. Bard(1994) developed a model involving two objectives. Chul(1998) addressed three objectives minimizing total utility work, keeping a constant rate of part usage, and minimizing total setup cost. The scholar Yi Dongbo(2003) solved a double- objectives model by Toyota Goal Chasing Algorithm(GCA).Zhang Pengjun(2009) established multi-objective mathematical model considering two objectives: minimize the workstation overload time and idle time, minimize the production cycle.

Leveling of Material derived from Monden(1983),it present as the rate of usage of material, which means the ingredients of production line maintain systematic equilibrium, not only volume of production, but also variety, working time and production load. Song Huaming (2002) discussed the problem of material flow leveling in terms of supply chain, and applied SAA to solve the problem. Liu Wenping(2004) minimizing material consumption variation, switch time incurred by adjustment for model changing, utility work necessitated by overload of workstations, and total assembly cost are formulated. Yang Lin(2013) compared two single objectives: material consumption and the optimization of production time. As a result, GA were proved to be effective in solving sequencing problems.

Mixed-model assembly line sequencing problems have been proved to be a kind of NP-hard by many experts and scholars, besides the selection and optimization of decision-making objectives, they also actively explored in algorithm. There are three kinds of commonly used algorithms : optimal solution algorithm represented by branch and bound method, such as Zhao Xiaobo(1994); heuristic algorithm represented by GCA and variance algorithm, for instance, Yi Dongbo(2003),Jin MZ

& Wu SD(2003); loop improved algorithm including simulated annealing algorithm(SAA), genetic algorithm(GA), tabu search algorithm(TSA),such as Liu Zhaohui(2004) applied SAA in solving the sequencing problem, Mansouri(2005) solved the same problem with improved genetic algorithms，in which elite strategy and niche cubicle was introduced. Dong Jianhua(2003) used GA and hybrid genetic-tabu search algorithm(HGTSA) to solve the problem, result showed that HGTSA is better than GA in global search ability and convergence performance.

In conclusion，manufacturing enterprises should not only meet the customers demand of varieties, quantity, and leading time, but also the improve the internal performance of MMAL.As customization becoming more popular, the leveling of material still has some room for improvement on production plan and control, meanwhile, the influence of switch cost are more sensitive to enterprises benefits. This article divides the products into four categories in chapter 3.And then in chapter 4, two principles (customers' demand and material balance) are proposed for every category of product. By using the principle of Minimal Production Set (MPS), two--objective with minimum variations of part usage rate and minimum assembly switch cost sequencing model is given. The optimal solution set of every categories in a MPS are solved with genetic algorithm (GA). Finally, evaluate the effect of sequencing model proposed before by observing index, which can offer valuable references for determining the ultimate optimal sequencing solution.

3 Products Classification

If it is multi-item small sized production, sequencing of MMAL need to strike a balance between customer requirements and enterprise capacity, Not only the importance of big customer (high demand) and small customer(small demand) , and lead time, but also capacity matching relationship and constraints of material supply.

According to customs' demand and lead time, we divides the products into four categories: core strategic products I, customer-oriented products II, time-oriented products III, ordinary products IV, as shown in figure 1 .

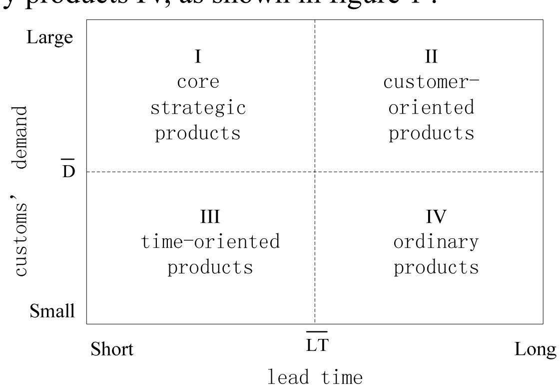

Figure 1. Four categories products

Total customer demand $\overline{D}$, average of maximum and minimum lead time $\overline{LT}$, are the fundamental basis of dividing categories, which need to determined by the actual situation of production line. The details of four categories products as below: Core strategic products (CSP) I: $\mathrm{D} > \overline{\mathrm{D}}$, and $\mathrm{LT} < \overline{\mathrm{LT}}$; Customer-oriented products (COP) II: $\mathrm{D} > \overline{\mathrm{D}}$, and $\mathrm{LT} > \overline{\mathrm{LT}}$;Time-oriented products (TOP) III: $\mathrm{D} < \overline{\mathrm{D}}$, and $\mathrm{LT} < \overline{\mathrm{LT}}$;Ordinary products (OP) IV: $\mathrm{D} < \overline{\mathrm{D}}$, and $\mathrm{LT} > \overline{\mathrm{LT}}$.

The purpose is managing the important products. Therefore, we develop sequencing solutions of I, II, III, IV one by one. It should be pointed out that, in practice, category II and category III are difficult to determine which one should firstly be sequenced, we usually determine it by actual situation with the aid of other indicators.

4 Decision-making Sequencing Model with Two Objectives

Sequencing of MMAL is based on four categories products, solve this problem of every category, two-objective sequencing model is given, namely, The objective function F_1, minimum variations of part usage rate, and objective function F_2, minimum assembly switch cost.

Specifically, we determine production structure by using the principle of Minimal Production Set (MPS), and solve sequencing problem with genetic algorithm (GA) . Sequencing solutions of every category are S_I、S_{II}、S_{III}、S_{IV}.

The superiority of MPS is embodied in determining the production structure of every category quickly, by determining the minimum cycle, finally realize the equalization and synchronization in mixed-model assembly line.

MPS is a vector representing a product mix, such that $(b_1, b_2, \ldots, b_m)$=$(B_1/\omega, B_2/\omega, \ldots, B_m/\omega)$; where m is the total number of product series, B_m is the number of products of series type m that need to be assembled during the entire planning horizon, and ω is the greatest common divisor of $B_1, B_2, \ldots, B_m$. This strategy operates in a cyclical manner. Obviously, ω times the repetition of producing the MPS products can meet the total demand in the planning horizon.

Decision-making sequencing model with two objectives in this paper are as follows:

F_1: Minimum variations of part usage rate. That is to say, at any stage in the production, no matter what the value of k is, the variance of ideal consumption and actual consumption of material is minimal.

F_2: Minimum assembly switch cost. Namely, Multiply switching frequency of different series by single switch cost get F_2.

$$F_1 = min \sum_{h=1}^{r} \sum_{k=1}^{E} (I'_{kh} - I_{kh})^2 \tag{1}$$

$$F_2 = min \sum_{k=1}^{E} \sum_{j=1}^{m} \partial_{jk} C \tag{2}$$

$$I'_{kh} = kN_h/E \tag{3}$$

$$I_{kh} = \sum_{j=1}^{m} n_{jh} * \partial_{jk} \tag{4}$$

$$N_h = \sum_{j=1}^{m} n_{jh} b_j \tag{5}$$

$S.T.$

$$\sum_{j=1}^{m} \partial_{jk} = 1 \tag{6}$$

$$\sum_{k=1}^{E} \partial_{jk} = b_j \tag{7}$$

$$\sum_{j=1}^{m} \partial_{jk} = \sum_{x=1}^{m} \partial_{x(k+1)} \quad k = 1，\cdots\cdots，E-1 \tag{8}$$

$$\sum_{j=1}^{m} \partial_{Ej} = \sum_{x=1}^{m} \partial_{1x} \tag{9}$$

Constraints as follows：

(1) Position constraints: Equation (6) ensures that exactly one product is assigned to each position in a sequence. Equations (8) and (9) ensure that the sequence of products be maintained while repeating the cyclic production.

(2) Demand constraints: Equation (7) guarantees that demand for each series is satisfied.

The parameters of above models and constraints are as follows:

i， the serial number of enterprise's customers, i =1,2,…,n

j， the serial number of the products series, j=1,2,…,m

h， the serial number of varieties of parts, h =1,2,…,r

k， the serial number of production sequencing, k=1,2,…,E

d_{ij}， the demand of m series products of ith customer

D， total demand of m series products

E， in a MPS, the demand of m series products

B_j， the demand of jth series products

b_j， $b_j = B_j/\omega$, in a MPS, the demand of *j*th series products

ω， the greatest common divisor of $B_1, B_2, \ldots, B_m$

n_{jh}， the demand of *h*th parts of *j* series products, n_{jh} is a matrix

N_{h}， the total demand of *h*th parts of *m* series products

∂_{jk}， $\partial_{jk} = 1$， indicate that the *k*th product in a sequence is series *j*; Otherwise, $\partial_{jk} = 0$.

I_{kh}， the actual consumption of *h*th parts after finish the *k*th product

I'_{kh}， the ideal consumption of *h*th parts after finish the *k*th product

C， the switch cost required when series type is changed (Constant)

5 Solution and Results

5.1 Basic Data

The research object of this example is a mixed-model assembly line system of a production enterprise Z in Changchun. This system's production organization pattern is Pull Production. That is to say, monthly production plan is made by customers' monthly order. We assume that takt time and workstations in MMAL are known, four customers A, B, C, D of enterprise need 10000 products which contains four series. Classification based on demand is as shown in Table 1. According to the classification standard in figure 1. we present the demand of every category in Table 2, which devotes B_j of formula(2).

Table 1. The demand for each series of products of each customer

Series / Customer	Lead time	A		B		C		D		sum
Customer1	short	500	300	2500	2000	1000	700	1000	600	5000
	long		200		500		300		700	
Customer2	short	300	200	800	500	500	300	1000	400	2600
	long		100		300		200		300	
Customer3	short	100	50	400	200	300	200	500	300	1300
	long		50		200		100		200	
Customer4	short	100	50	300	200	200	100	500	300	1100
	long		50		100		100		200	
sum		1000		4000		2000		3000		10000

Table 2. The demand of category I to IV, B_j

Series / Category	A	B	C	D	Sum
I CSP	500	2500	1000	1000	5000
II COP	300	800	500	1000	2600
III TOP	100	400	300	600	1400
IV OP	100	300	200	400	1000
Sum	1000	4000	2000	3000	10000

Core components of one product include 11 kinds. The specific demand for all kinds of parts of series A-D product is shown in Table 3., which is the matrix n_{jh}(4*11) in section 4.1, as basis data of MMAL.

Table 3. The demand of components of one product

Series	Quantity	The demand of components										
		n_1	n_2	n_3	n_4	n_5	n_6	n_7	n_8	n_9	n_{10}	n_{11}
A	1	1	1	2	2	2	2	2	2	2	2	1
B	1	1	1	2	0	0	2	2	0	0	2	1
C	1	1	1	2	0	0	2	2	0	0	2	1
D	1	1	1	2	0	0	2	2	0	0	2	1

5.2 Computed Result

Chul(1998), Mansouri(2005), Dong Jianhua(2003), Cao Zhenxin (2005)etc. are using Genetic Algorithm(GA) to solve sequencing problem of MMAL. To solve the above examples, MATLAB 2013a is used to write code to get the model solution, the result show as below.

(1)Situation 1 ： before subdivision

Input the total demand of A, B, C, D series products before subdivided, is $B_1 = 1000$，$B_2 = 4000$，$B_3 = 2000$，$B_4 = 3000$。Run at least 300 times, choose 10 group single optimal solutions, whose $F_2 < 30000$, we get suboptimal solution set S={S_1，S_2，…，S_{10}} of sequencing, just as Table 4.

Table 3. Sequencing solutions before subdivision

Number	Sequencing solutions S	Objective function	
		F_1	F_2
1	Solution =1 2 2 2 2 3 3 4 4 4	2430.4	4500
2	Solution =1 2 2 3 3 2 2 4 4 4	2278.4	6000
3	Solution =1 2 2 2 3 2 3 4 4 4	2316.4	7500
4	Solution =1 2 2 2 3 2 4 3 4 4	2354.4	9000
5	Solution =1 2 2 2 2 3 3 4 4 4	2278.4	10500

6	Solution =1 2 2 2 2 3 4 3 4 4	2316.4	12000
7	Solution =1 3 2 2 2 2 3 4 4 4	2430.4	13500
8	Solution =1 2 2 2 2 4 3 4 4 3	2430.4	15000
9	Solution =1 2 2 2 3 2 4 3 4 4	2354.4	16500
10	Solution =1 2 2 2 2 3 4 4 4 3	2392.4	18000

(2)Situation 1 ： after subdivision

Input four row data of Table 2. successively. We get suboptimal solution sets of four categories are SI={S_{I1}, S_{I2}, …S_{I10}}, SII={ S_{II1}， S_{II2}, ……, S_{II10}}, SIII={ S_{III1}, S_{III2}， ……， S_{III10}}， SIV={ S_{IV1}， S_{IV2}， ……， S_{IV10}}， as Table 5-8.

Table 5. Sequencing solutions of I category product S_I

Number	Sequencing solutions S_I	Objective function	
		F_1	F_2
1	Solution=1 2 2 2 2 2 3 3 4 4	2582.4	4500
2	Solution=1 3 2 2 2 2 2 3 4 4	2772.4	6000
3	Solution=2 1 2 2 2 2 4 3 3 4	2693.2	7500
4	Solution=1 2 2 2 2 4 3 2 3 4	2772.4	9000
5	Solution=1 2 2 2 3 2 4 2 3 4	2772.4	10500
6	Solution=1 3 2 2 2 2 2 3 4 4	2772.4	12000
7	Solution=1 2 2 2 2 2 3 3 4 4	2582.4	13500
8	Solution=1 2 2 2 2 3 2 3 4 4	2620.4	15000
9	Solution=1 2 2 2 3 2 3 2 4 4	2696.4	16500
10	Solution=1 2 2 2 2 3 2 4 3 4	2658.4	18000

Table 6. Sequencing solutions of II category product S_{II}

Number	Sequencing solutions S_{II}	Objective function	
		F_1	F_2
1	Solution=1 1 1 2 2 3 2 2 2 2 3 2 2 3 3 3 4 4 4 4 4 4 4 4 4 4	78581.8	10500
2	Solution=1 1 2 2 2 2 2 3 2 3 3 4 2 2 1 3 3 4 4 4 4 4 4 4 4 4	79373.5	13500
3	Solution=1 1 2 1 3 2 3 2 2 2 3 2 2 2 3 3 4 4 4 4 4 4 4 4 4 4	78920.1	15000
4	Solution=2 1 1 4 2 2 2 1 2 2 3 3 2 3 2 3 3 4 4 4 4 4 4 4 4 4	79505.9	16500
5	Solution=2 2 1 1 1 4 2 2 3 2 3 3 2 2 3 4 4 4 4 4 4 4 4 3 4 2	80573.6	18000
6	Solution=2 1 2 2 2 2 1 2 3 2 3 1 3 3 4 4 3 2 4 4 4 4 4 4 4 4	79324.4	19500

7	Solution=2 1 1 2 2 2 3 3 2 4 1 3 2 4 4 4 3 2 3 2 4 4 4 4 4 4	80330.8	21000
8	Solution=1 4 1 2 1 2 2 3 3 2 2 2 3 3 4 2 4 4 2 4 4 4 4 4 3 4	80470.7	22500
9	Solution=2 2 2 1 2 1 2 3 2 1 2 3 3 4 3 4 4 2 4 4 4 4 3 4 4 4	79556.1	24000
10	Solution=1 1 2 2 3 2 2 2 2 4 4 1 4 3 4 2 4 3 4 3 2 4 3 4 4 4	80714.5	25500

Table 7. Sequencing solutions of III category product S_{III}

Number	Sequencing solutions S_{III}	Objective function	
		F_1	F_2
1	Solution=2 2 1 2 2 3 3 3 4 4 4 4 4 4	8129	6000
2	Solution=1 3 2 2 2 3 3 2 4 4 4 4 4 4	8285.6	7500
3	Solution=2 1 2 2 2 3 3 4 4 4 3 4 4 4	8207.3	9000
4	Solution=2 1 4 2 2 2 3 3 4 4 4 3 4 4	8549.3	10500
5	Solution=1 2 2 2 2 4 3 3 3 4 4 4 4 4	8171.6	12000
6	Solution=2 3 2 1 2 4 3 3 4 2 4 4 4 4	8620.7	13500
7	Solution=1 2 2 2 2 3 3 4 3 4 4 4 4 4	8095.6	15000
8	Solution=3 2 1 2 2 2 3 3 4 4 4 4 4 4	8319.0	16500
9	Solution=1 2 2 2 2 3 3 3 4 4 4 4 4 4	8057.6	18000
10	Solution=2 2 2 3 1 4 3 2 4 3 4 4 4 4	8504.4	19500

Table 8. Sequencing solutions of IV category product S_{IV}

Number	Sequencing solutions S_{IV}	Objective function	
		F_1	F_2
1	Solution=2 2 2 1 3 3 4 4 4 4	2154.8	4500
2	Solution=1 2 2 2 3 4 4 4 4 3	2202.4	6000
3	Solution=1 3 2 2 2 4 4 3 4 4	2240.4	7500
4	Solution=1 2 2 3 2 4 3 4 4 4	2126.4	9000
5	Solution=1 2 4 2 3 2 3 4 4 4	2316.4	10500
6	Solution=1 2 2 2 3 3 4 4 4 4	2050.4	12000
7	Solution=1 3 2 2 2 3 4 4 4 4	2164.4	13500
8	Solution=1 2 2 3 3 4 2 4 4 4	2202.4	15000
9	Solution=1 2 2 2 4 3 4 4 4 3	2240.4	16500
10	Solution=1 2 2 2 3 4 4 4 3 4	2164.4	18000

5.3 Observing Index

(1)Equipment Activation α

Divide the actual operation time by schedule time, and we get equipment activation α, to measure work time utilization. The higher α is, the greater the efficiency of equipment operation are.

$$\alpha = \frac{T-t}{T} = \frac{T-\frac{F_2}{C}\times\omega}{T} = \frac{CT*M}{T} \quad (10)$$

α——Equipment activation.

T——Schedule time. It refers to working time that except the interval, break, and extra work time.

t——Unplanned stoppage time. It is caused by equipment failure, switching operations, and abnormal personnel & materials. In this article, we only consider line stoppage time caused by switching operation, and ignore the rest of the reasons.

CT——Production takt.

M——The total output within schedule time.

(2)Production Capacity Rate β

Production capacity rate is calculated with the ratio of ideal working time and actual operation time, or refers to the operating personnel's capacity in the actual operation time. It is used to measure the time efficiency in operation time, the greater, the better.

$$\beta = \frac{\text{ideal working time}}{\text{actual operation time}}\times 100\% = \frac{CT\times D}{T-\frac{F_2}{C}\times\omega}\times 100\% \quad (11)$$

D——total demand of products.

(3)Leveling Exponent of Material Consumption γ

γ is an index that can measure discrete degree of material consumption in assembly line. The less the value, the better the sequencing solution.

$$\gamma = \sqrt{\frac{\sum_{h=1}^{r}\sum_{k=1}^{E}(I'_{kh}-I_{kh})^2}{E}} = \sqrt{\frac{F_1}{E}} \quad (12)$$

(4) Order Fill Rate б

Order Fill Rate is equal to the ratio of actual finished product and product demand, б expressed as follow.

$$\delta = \frac{\varphi b_j}{B_j} \quad (13)$$

φ——the times that have cycled.

5.4 Example Analysis

This example apply the decision-making sequencing model established before, and get suboptimal solution set with GA, then determine the best sequencing solution by calculate the above indexes and evaluate the effect.

According to section 6.2, two situations' indexes are shown in Table 9. and Table 10. We compare them in following paragraphs.

Table 9. The value of objective function & observing index in situation 1

Sequencing solutions S										ω	Objective function		Observing index		
											F_1	F_2	α	β	γ
1	2	2	2	2	3	3	4	4	4	500	2430.4	4500	93.06%	74.63%	15.59
1	2	2	3	3	2	2	4	4	4		2278.4	6000	90.74%	76.53%	15.09
1	2	2	2	3	2	3	4	4	4		2316.4	7500	88.43%	78.54%	15.22
1	2	2	2	3	2	4	3	4	4		2354.4	9000	86.11%	80.64%	15.34
1	2	2	2	2	3	3	4	4	4		2278.4	10500	83.80%	82.88%	15.09
1	2	2	2	2	3	4	3	4	4		2316.4	12000	81.48%	85.23%	15.22
1	3	2	2	2	2	3	4	4	4		2430.4	13500	79.17%	87.72%	15.59
1	2	2	2	2	4	3	4	4	3		2430.4	15000	76.85%	90.36%	15.59
1	2	2	2	3	2	4	3	4	4		2354.4	16500	74.54%	93.17%	15.34
1	2	2	2	2	3	4	4	4	3		2392.4	18000	72.22%	96.15%	15.47

Table 10. The value of objective function & observing index in situation 2

Sequencing solutions S'								Objective function		Observing index		
I 类		II 类		III 类		IV 类		F_1'	F_2'	α'	β'	γ'
S_I	ω	S_{II}	ω	S_{III}	ω	S_{IV}	ω					
S_{I1}	500	S_{II1}	100	S_{III1}	100	S_{IV1}	100	10182.52	4350	93.29%	74.44%	14.27
S_{I2}		S_{II2}		S_{III2}		S_{IV2}		10357.15	5700	91.20%	76.14%	14.39
S_{I3}		S_{II3}		S_{III3}		S_{IV3}		10283.38	6900	89.35%	77.72%	14.34
S_{I4}		S_{II4}		S_{III4}		S_{IV4}		10404.36	8100	87.50%	79.37%	14.43
S_{I5}		S_{II5}		S_{III5}		S_{IV5}		10492.36	9300	85.65%	81.08%	14.49
S_{I6}		S_{II6}		S_{III6}		S_{IV6}		10385.75	10500	83.80%	82.87%	14.41
S_{I7}		S_{II7}		S_{III7}		S_{IV7}		10350.28	11700	81.94%	84.75%	14.39
S_{I8}		S_{II8}		S_{III8}		S_{IV8}		10409.41	12900	80.09%	86.71%	14.43
S_{I9}		S_{II9}		S_{III9}		S_{IV9}		10333.61	14100	78.24%	88.76%	14.38
S_{I10}		S_{II10}		S_{III10}		S_{IV10}		10467.53	15300	76.39%	90.91%	14.47

S of situation 1 and S' of situation 2 represent different sequencing solutions. For the purposes of drawing expression, we set the number of S and S' as abscissa. Here is the trend graph on observing index α, β, γ (Figure 3).

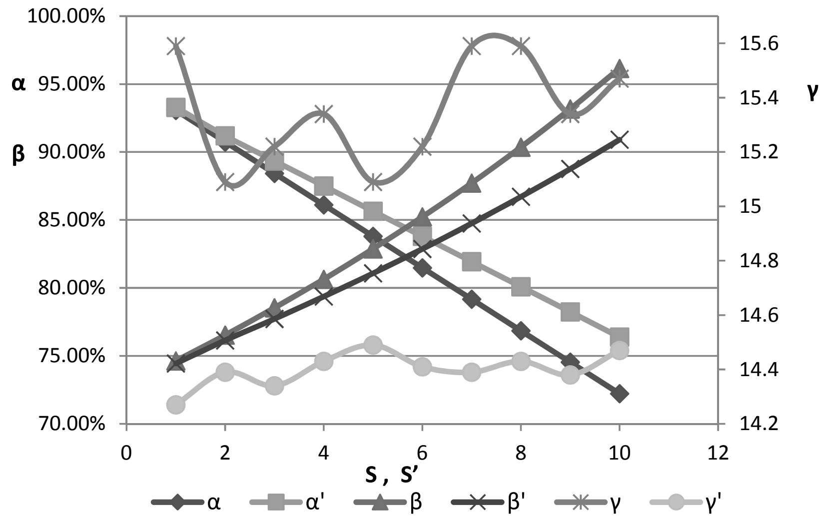

Figure 3. The trend graph on observing index α, β, γ

(1) Equipment Activation α' > α, α of situation 2 after subdivision is more than situation 1, so time utilization and equipment operation efficiency of situation 2 are higher, gross production is more.

(2) Production Capacity Rate β' < β, in the view of β, situation 2 reduce the production capacity rate of assembly line, situation 1 is better.

(3) Leveling Exponent of Material Consumption γ' < γ, γ in two situations both undulate slightly, and meet the demand of the leveling of material. But in comparison, γ of situation 2 is smaller, so we can see by this index that sequencing solutions of situation 2 is superior to situation 1.

(4) For category I product, order fill rate б of different series product are presented in Table 11.

Table 11. Order fill rate б of different series product of category I

the times that have cycled	Situation 1 δ				Situation 2 δ'			
φ	A1	B1	C1	D1	A2	B2	C2	D2
50	10%	8%	10%	15%	10%	10%	10%	10%
100	20%	16%	20%	30%	20%	20%	20%	20%
150	30%	24%	30%	45%	30%	30%	30%	30%
200	40%	32%	40%	60%	40%	40%	40%	40%
250	50%	40%	50%	75%	50%	50%	50%	50%
300	60%	48%	60%	90%	60%	60%	60%	60%
350	70%	56%	70%	105%	70%	70%	70%	70%
400	80%	64%	80%	120%	80%	80%	80%	80%
450	90%	72%	90%	135%	90%	90%	90%	90%
500	100%	80%	100%	150%	100%	100%	100%	100%

After cycled 500 times, order fill rate б of two series product A, C are constant.For instance, in situation 2, after repeating a MPS 500 times, б of series products A, B, C, D are all 100%; however in situation 1, series B is 80%, though series D also meet the demand, it's output beyond 50% than actual demand. So, from the analysis of order fill rate, situation 2 is better than situation 1.

6 Conclusion

In this paper, we sovle the sequencing problem of mixed-model assembly line, two principles (customers' demand and material balance) are proposed for every category of product. And according to customs' importance degree and lead time , we divides the products into four categories. By using the principle of Minimal Production Set (MPS), two--objective with minimum variations of part usage rate and minimum assembly switch cost sequencing model is given. Then get the solution sets of subdivided and un-subdivided, finally, establish the evaluation index system, in order to evaluate the proposed decision-making model, and provide a reference basis for determining the optimal sequencing solution.

(1) Product category reflect the requests of customer order quantity and lead time. Subdivision of series product has remarkable effect for both external demand and internal balance on assembly line. After subdividing product, situation 2 have an advantage over situation 1 considering three indicators α, γ, б.

(2) On the basis of ensuring leveling of material, organizing products' variety, quantity reasonably, can eliminate the workstations' "logistics bottleneck", keep lower work in process(WIP) inventory, and realize smoothly and timely material supply at the assembly line, make product, time, quality, equipment load become comprehensive balanced.

(3) Minimum assembly switch cost is the goal, at the same time, we ensure a constant rate of material consumption, total assembly switch cost of situation 2 decrease an average of 9.5% than situation 1. obviously, it not only reduce the switch time between series, but also improve the efficiency of assembly line, thus the total cost become lower.

(4) How to use suboptimal solution set to determine the optimal sequencing solution. On the one hand, after solving the mathematical model, we choose it with the aid of the system output index of MMAL; on the other hand, we can design indexes on four aspects: equipment efficiency, output capacity, leveling of material, and customer satisfaction, to determine the optimal sequencing solution that meeting demand of operation characteristics of MMAL.

Reference

Bard JF, Stub A, Joshi S B(1994).Sequencing mixed-model assembly lines to level parts usage and minimize line length. *International Journal of Production*

Research, 32:2431-2454.

CAO Zhenxin, ZHU Yunlong(2005). Application of Multiple Objective Genetic Algorithms in Sequencing Mixed Model Assembly Lines. *Computer Engineering*, 31(22): 138-142.

Chul JH, Kim Y(1998). A genetic algorithm for multiple objective sequencing problems in mixed model assembly lines[J].*Computers and Operations Research*, 25(7):675-690.

DONG Jianhua, XIAO Tianyuan, etc(2003). Application of Genetic-Tabu Search Algorithm in Sequencing Mixed-Model Assembly lines. *Industrial Engineering and Management*, 12(2):14-17.

G. Morel, H. Panetto, M.B. Zaremba, etc(2003). "Manufacturing enterprise control and management system engineering".*rationales and open issues*, 11(3):65-76.

HUANG Gang(2007). A Dissertation Submitted in Partial Fulfillment of the equirements for the Degree of Doctor of Philosophy in Engineering. *Huazhong University of Science and Technology*.

Kilbridge M D, Wester L. A(1961). A heuristic method of assembly line balancing. *Journal of industry engineering*, 7(4):292-298.

Jin M Z,Wu S D(2003). A new heuristic method for mixed model assembly line balancing problem.*Computers and industrial engineering*, 44(l):159-169.

Joaquin Bautista, Ramon Companys, Albert Corominas(2000). Note on cyclic sequences in the product rate variation problem[J]. *European Journal of Operational Research*, 124 : 468～477.

LIU Wenping(2004). A Study of Balancing and Sequeneing Problems of Mixed-model Automobile Assembly Lines. *Shandong University.*

LIU Zhaohui(2004). Study for Production Sequencing of Mixed-Model Assembly Lines in Just-In-Time Production Mode. *Jillin University.*

Mansouri S A(2005). A Muti-objective genetic algorithm for mixed-model sequencing on JIT assembly lines. *European Journal of Operational Research*, 167:696-716.

Monden Y(1983). "Toyota Production system ".*Atlanta: Institute of Industrial Engineering Press, Institute of Industrial Engineers*.

Miltenburg J(1990). Steiner G. *Yeomans* S. A dynamic programming algorithm for scheduling mixed-model just-in-time production systems. *Mathematical Computation Modeling*, 13,57-66.

McMullan P R, Frazier G V(2000).A simulated annealing approach to mixed-model sequencing with multiple objectives on a just-in-time line, *HE Transactions*, 32:679-686.

SONG Huaming(2002), HAN Yuqi. Leveling the Material Supply on Mixed-Model Assembly Line [J]. *systems engineering*, 20(3):15-19.

Sumichrast R T, Russel R S(1990). Evaluating mixed-model assembly line sequencing heuristics for just-in-time production systems. *Journal of*

Operations Management, 9:371-390.

YANG Lin(2013). Research on the Sequencing Problem of Engine Producing Mixed Model Assembly Line. *Kunming University of Science and Technology.*

YI Dongbo(2003). Analysis and Application of Mixed Input Sequencing Method for Multi-Products Based on Production Balancing. *Journal of nanchang ShuiZhuan*, 2003,22(3):19-21.

ZHANG Pengjun(2009). Planning and Simulation of the Mixed Engine Assembly Line , *Henan University of Science and Technology.*

ZHAO Xiaobo, ZHOU Zhaoying(1998). Sequencing Problems for Mixed Model Assembly Lines in Automotive Industry. *Chinese Journal of Mechanical Engineering,* 9(3):28-31.

Nonparametric Approach to Analyze the Effects of Heterogeneity on Travel Duration

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Abstract: Activity-based travel demand forecasting has got great concern in the past decade. In this paper, a nonparametric regression method is presented which can model travel durations by identifying heterogeneity patters that may undermine duration modeling if not detected. The technique utilizes a kernel estimate of the probability density function (PDF) of daily travel durations to compare different activity pattern. The advantage of this method is that it's free of any distributional assumption. The results show that the more complex activity pattern, time spent in travel is more. And it is also found that the distribution of travel duration for the standard-working group and the long-term maintenance group cannot be modeled by a linear or a linearized function. It is indicated that the approach is effective in evaluating covariate effects.
Keywords: Activity; Kernel estimate; Nonparametric regression; Travel duration.

1 Introduction

Activity-based travel demand forecasting approaches have been proposed as an effective method in travel behavior analysis because of their ability to model the derived nature of travel demand (Kuppam and Pendyala, 2001). The timing of activities and travel is an important aspect of activity-travel behavior. Hence, models of activity and/or travel timing are at the core of several activity-based systems that are designed for travel forecasting and evaluating travel demand management policies. The point of activity-based models is to analyzing the activity participation behavior of individuals or households so that travel demand can be predicted. Activity models can be classified into two classes, utility maximization based and micro-simulating method, while the former is complex to find solutions especially when there are many choice branches. Because of improved investigation technology and statistic methodology, simulating activity with probability distribution is more attractive and feasible.

Two broad categories of activity-based travel timing models are simultaneous regression-based models and hazard duration based models (Srinivasan and Guo, 2003). Histogram density estimator and parametric regression are most used methods to simulate the activity pattern. But histogram method is not possible to estimate the probability of unobserved data. The relationship between the dependent variable and its covariates should be pre-assumed to be either linear or a form that may be linearization. Certain distribution features, such as bimodality often cannot be modeled by a theoretical distribution. But the nonparametric approach can leave functional form and distributional assumptions unspecified. And nonparametric density estimation seeks to allow the data to stand on its own by using alternative methods to determine the form of the density function. The major nonparametric approach is the kernel density estimator (KDE).

This paper is to apply nonparametric techniques to model activity pattern and at the same time able to describe the data well. Previous applications of nonparametric techniques in transport contexts include using nonparametrics to specify a model to measure the value of time and using semiparametric to estimate a work trip mode choice model (Fosgerau, 2007; Horowitz, 1993). Relationships between travel time and activity duration are investigated by the bi-variate KDE using travel diary survey data in Seoul, Korea (BAE et al., 2010). A particular strength of some of these techniques is that they allow one to visually inspect various distributions and relationships prior to the imposition of any specific functional form. This paper uses this approach to study the various activity durations distributions of full-time commuters segmented into five individual groups.

2 A Review of Non-Parametric Kernel Density Estimation

2.1 Kernel density estimator (KDE)

The KDE is a completely nonparametric approach for estimating the density function of a continuous random variable. Let $X_i(i=1, 2, \ldots, n)$ denote n independent, identically distributed observations of the random variable X. The PDF for X can be defined as

$$f(x) = \lim_{h\to 0} \frac{\Pr\{x-h < X < x+h\}}{2h}. \tag{1}$$

An approximation for the density function given above may be attained by allowing h to be very small and using the relative frequency proportion at this particular point's neighborhood. A kernel K which is a general function used to weight observations and a bandwidth h which determines the size of the average neighborhood are used here to define the neighborhood. Now by summing the "influence" of each observation placed a kernel, the kernel estimate is defined as

$$\hat{f}(x) = \frac{1}{nh}\sum_{i=1}^{n} K(\frac{x-X_i}{h}). \tag{2}$$

In contrast to the histogram estimator which requires specification of the origin and bin width, the kernel density estimate requires only specification of the bandwidth, h (Kharoufeh and Goulias, 2002).

2.2 Bandwidth selection

The choice of kernel is generally less important as results will not be much affected. Selecting an appropriate bandwidth is, however, an important issue with no easy solution. If the bandwidth is too large then it is over-smoothing. Too much detail disappears and there will be bias. If the bandwidth is too small, then there will be under-smoothing: that is, over-fitting to random fluctuations in data. Thus the choice of bandwidth is about balancing the trade-off between bias and variance. A significant part of the nonparametric literature is devoted to the issue of bandwidth selection but without any single method emerging as a clear winner. More automatic approach is to use cross-validation (Ye, 2003). This is performed using the estimated prediction error $EPE(h) = N^{-1}\sum_n (y_n - m_n(x_n, h))^2$, where the estimate $m_n(x_n, h)$ is computed with bandwidth *h*, unconsidering *n*'th observation. A bandwidth can then be selected by minimizing *EPE*(*h*).

Another approach is to determine an optimal bandwidth from convergence properties of the estimator. This approach relates the bandwidth to the sample size. Thus according to the most used Gaussian kernel which is given by

$$K(t) = (2\pi)^{-1/2} \exp\{-t^2/2\}, \quad -\infty \le t \le \infty, \tag{3}$$

its optimal bandwidth was found to be proportional to $n^{-1/5}$. It will be used throughout this work because it is a unimodal, symmetric distribution, which allows for automatic selection of the smoothing parameter.

3 The activity duration problem

It has been increasingly realized that travel is a derived demand determined by the way how individuals and households organize their time and when and where they go and which travel modes they will use. Past years travel behavior analysis has evolved from being trip-based to activity-based. Researchers have paid considerable attention to the notion of time use while they believe that understanding the mechanisms of activity choice and time allocation will lead to increase reliability in forecasting travel demand and evaluating transportation planning options. Previous theoretical studies emphasized the importance of activity duration as a determinant of activity patterns by suggesting that the value of an activity is positively correlated with the frequency of participation and its duration (Sharman et al., 2012). So activity duration can describe the "intensity" of participation in different activities. That is the reason why activity duration should be measured to find commonalities across various groups of individuals.

The standard activity duration analysis is to use parametric hazard-based models because it regards the duration dependence which means the time at which an activity will be completed depends on the time already spent in the activity (Srinivasan et al., 2003). The hazard function essentially describes the probability that an event will terminate given that it has lasted until time *t*. The hazard function also called failure rate is denoted by $h(t)$ and calculated from

$$h(t) = f(t) \big/ \big(1 - F(t)\big), \tag{4}$$

as $f(t)$ represents the probability density function of a duration, and $F(t)$ represents the corresponding cumulative distribution function. Many existing duration model applications are based on the assumption of proportional hazard functions as follows:

$$h(t) = h_0(t)\exp(-\beta' X + w), \tag{5}$$

where $h_0(t)$ denotes the baseline hazard function, β the vector of parameters to be estimated, X the covariate vector and w represents heterogeneity of individuals. In this approach, it is assumed that hazard rates vary systematically across individuals. The effect of these covariates is modeled by scaling the baseline hazard rate up or down by a multiplicative factor (Srinivasan et al., 2003). Consequently, all individuals have the same hazard situation, although the intensity of hazard function can vary. So it is necessary to propose a more suitable method to describe the distribution of baseline hazard function and take consider of the unobserved heterogeneity.

Define T_{ij} as the continuous random variable denoting the amount of time that individuals in the group $j \in J$ spend on activity $i \in I$. We seek to estimate the probability distribution of T_{ij}. Kernel density estimate of the true pdf for T_{ij} is denoted by $\hat{f}_{ij}$, so the density estimate is given by

$$\hat{f}_{ij}(t) = \frac{1}{n_{ij}h_{ij}} \sum_{k=1}^{n_{ij}} K\left(\frac{t - T_{ijk}}{h_{ij}}\right) \tag{6}$$

where n_{ij} is the number of independent, identically distributed observations for T_{ij}, h_{ij} is the optimal smoothing parameter and T_{ijk} is the kth duration observation for an individual in group j participating in activity i.

Although activity duration times are naturally continuous random variables, we choose to estimate their distributions by discrete approximations. One reason is that in practice we need to obtain the estimation of the density over a finite grid of points to achieve this visualization. Another reason is that most activity duration times are reported in multiples of 5 min. And people in the survey also are intuitive to approximate the times as such. Let $Q_{ij} = \{t : t = 5k, k = 0, 1, \cdots, M\}$ be a finite support for the distribution of T_{ij}, where M is a positive integer chosen large enough so as to contain the sample space of the random variable. Using the kernel density estimates by Eq.(4), a probability mass may be calculated for each $t \in Q_{ij}$. Let $p_{ij}(t)$ denotes the probability given by

$$p_{ij}(t) = pr\{T_{ij} = t\} = \delta^{-1}\hat{f}_{ij}(t), \tag{7}$$

where $\delta = \sum_{t \in Q_{ij}} \hat{f}_{ij}(t)$ normalizes the density so that the massed sum to unity over the finite support. In essence, Eq.(7) constructs a histogram estimator of the duration times in which each cell width is equal to zero. Jones (1989) demonstrates that even when the kernel estimate is discretized, the appropriate optimal bandwidth is still proportional to $n^{-1/5}$. Thus, the effect of discretization is minimal when we use the appropriate smoothing parameter.

4 Data and Results

Data used in this study to estimate the activity duration with nonparametric approach originated from the Shenyang city residents travel survey in 2004. As most travel surveys, the survey typically gathered information on the socio-economic and demographic characteristics of the commuters. The survey collected very detailed revealed preference information on all out-of-home and in-home activities over a 24-hour period. This type of intense data can be used as a basis for exploring trade-offs people may make various activities. Due to article length limitations, the main focus is the full-time commuters' travel duration characteristic of various activity.

With regard to demographic and socio-economic characteristics, the average household size of the sample is about 3.11 persons per household and the average age is close to 40-years-old. Based on a preliminary analysis of the distributions of various activity categories, segmentation of people to five mutually exclusive and exhaustive groups allows for a comparison of the estimated duration densities by means of goodness-of-fit tests. Those are standard-working group (denoted as Q1), high-intensity working group (Q2), low-intensity working group (Q3), short-term maintenance group (Q4) and long-term maintenance group (Q5) (Shao, 2006). The probability distribution of each group contains much more information about the behavior of the qualitative assessment of covariate effects and heterogeneity attained through the shape of the distributions. Table 1 shows the variables and grouping included in the study in addition to the number of individuals (n) in each group.

Table 1. Summary of full-time commuters' segmentation

Group	Description	n
Q1	Main activity is working; working time is less than 9 hours with only 1 travel for working.	8328
Q2	Main activity is working; working time is more than 9 hours with only 1 travel for working.	7916
Q3	Main activity is working; the frequency of travel for working is more than once.	2022
Q4	Main activity is entertainment or maintenance; out-of-home time is not more than 9 hours.	3440
Q5	Main activity is entertainment or maintenance; out-of-home time is more than 9 hours.	686

The data were not segmented and the nonparametric approach mentioned above was used to test for each of the five activity duration variables: subsistence, maintenance, entertainment, staying-at-home, and travel. Travel is the total time spent traveling for any reason during a day. Throughout this work, distribution functions were compared at 60 points (t=0, 5, 10,…300) for which the true distribution is approximated. The distribution of commuters' activity patterns by duration is shown in Table 2.

Table 2. Summary of activity and travel characteristics

Activity type	Average for entire sample (N=22392)	Non-zero observations
Subsistence	7 hr 35 min	17266
Maintenance	3 hr 24 min	4012
Entertainment	3 hr 31 min	3741
Staying-at-home	6 hr 15 min	21365
Travel	2 hr 23 min	20479

Fig. 1 provids sample PDFs generated by the kernel method for travel duration for various groups. Q2, Q3 and Q4 are similarities. Surprisingly, Q5 has the features of the bimodality. The results show that not all commute travels are taken by starting from home and arriving at office. The maintenance and entertainment activities may spend more time on traveling on road. It is important to improve the accessibility especially for the entertainment or leisure activities.

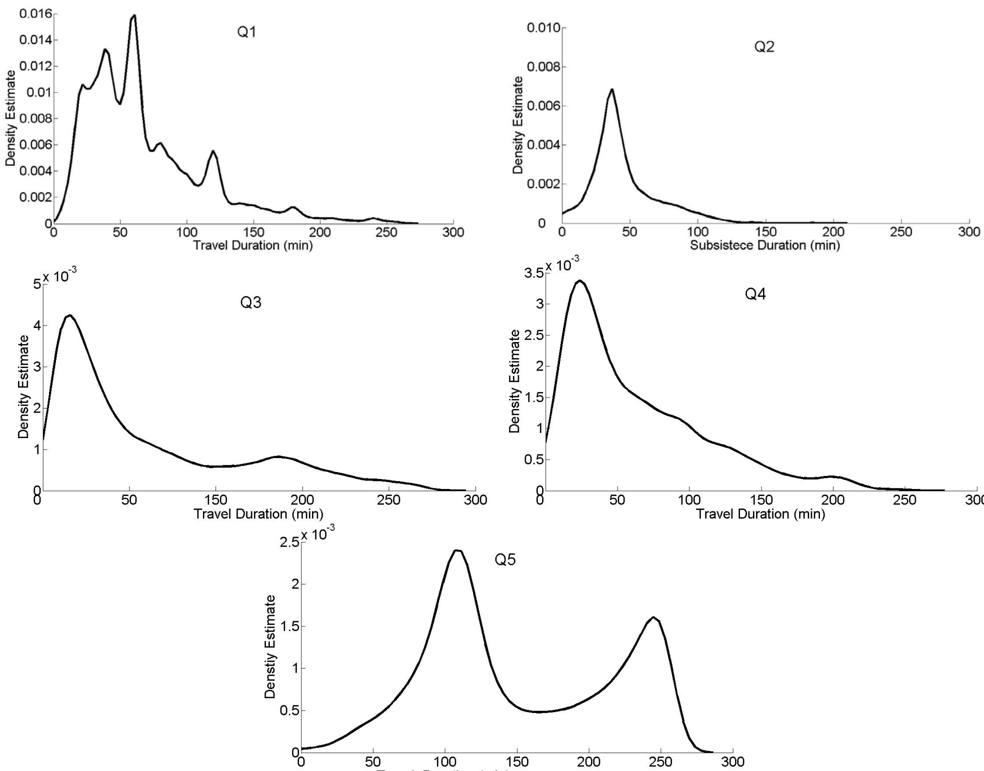

Figure 1. Sample travel density estimates for various groups.

5 Conclusions

This paper presents how to use a nonparametric pattern tool to investigate covariate effects and heterogeneity. A kernel estimate of the PDF is used and distribution functions of groups of individuals are compared. It is not necessary to make a presumption about the distribution of activity duration. And the kernel method is unaffected by potential bimodality in distributions. The kernel technique was tested on five activity durations and contributes to observe the relationship in behavioral visually. So this technique can be an alternative to regression models. This work can be extended in many potential research areas of activity-based travel demand forecasting.

Acknowledgement

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References

BAE, Y., Lee, J. Y., Chung, J. H., & Kim, H. (2010). "A bi-variate Kernel Estimation Model for Travel Time and Activity Duration." *Journal of the Eastern Asia Society for Transportation Studies*, *8*, 615-629.

Fosgerau M. (2007). "Using nonparametrics to specify a model to measure the value of travel time." Transportation Research Part B, (41), 842–856.

Horowitz J. (1993). "Semiparametric estimation of a work trip mode choice model." Journal of Econometrics, (58), 49–70.

Jones P.M. (1989). "Discretized and interpolated kernel density estimates." Journal of the American Statistical Association, 84(407), 733-741.

Kharoufeh J.P., Goulias K.G. (2002). "Nonparametric identification of daily activity durations using kernel density estimators." Transportation Research Part B, 36 (1), 58–82.

Kuppam A., and Pendyala R. (2001). "A structural equations analysis of commuters' activity and travel patterns." Transportation, 28(1), 33-54.

Shao Y. H. (2006). "Study on the activity-based travel demand model and the effect of information." PhD Dissertation, Southeast University.

Sharman, B. W., Roorda, M. J., & Habib, K. M. N. (2012). "Comparison of parametric and nonparametric hazard models for stop durations on urban tours with commercial vehicles." Transportation Research Record: Journal of the Transportation Research Board, 2269(1), 117-126.

Srinivasan K.K., Guo Z. (2003). "Analysis of trip and stop duration for shopping activities: a simultaneous hazard duration model system." Transportation Research Record, 2003

Ye A. Z. (2003). "Nonparametric Econometrics." Nankai University Press. China.

Simulation and Analysis of a Crowd Evacuation in a Subway Station

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Abstract: Taken Shenyang North subway station as an example, the simulation method of successive event was used to analyze the influence of traffic congestion in subway internal environment. First, the crowd evacuation simulation model in subway station was built. Second, the bottleneck positions and blocking reasons in the process of subway evacuation was analyzed based on the simulation model. At last, the potential safety hazard was eliminated by optimizing the service level and changing the number of service facilities, which can reduce travel time-cost to improve the service quality for passengers.
Keywords: The subway station; Crowd evacuation; The social force model; Pedestrian simulation.

1 Introduction

Subway station is a densely populated place especially at rush hour. Although the interior space of subway is bigger enough, it’s poor connectivity with outside. Particularly in case of an emergency, it’s easier to increase passengers’ psychological panic, which will lead to a large number of casualties and serious economic losses if there are no effective ways to evacuate the passenger flow.

Nowadays, some researchers have been achieved some remarkable results. Dikr Helbing’d (2000) quantified pedestrian behavior reaction into the social force, and reappeared the classic pedestrian evacuation behavior successfully, such as the group effect, he also had explained the phenomenon of "fast is slow" during evacuation. Carl Adam Petri (2000) put forward the concept of Petri nets, which can describe the system structure and the dynamic behavior of the system. American HCM (Fruin, 1985) mainly engaged in the pedestrian movement simulation and macro technology analysis of road capacity. Blue and Adler (1998) had established a series of cellular automaton traffic model. Wang Lida (2006) took Beijing subway line 2 as an example, had researched the aspect of evacuation system、evacuation bottlenecks and evacuation plans.

2 The Analysis of Passenger Flow Organization in Subway Station

2.1 Properties of subway passengers

Personnel evacuation behavior is a kind of group behaviors. Due to the restricted by environment, different positions of evacuation and interaction between individuals, there are many differences between individuals in crowd evacuation. Therefore, we need to separate crowd into independent individuals when building an evacuation model. Subway station passenger process diagram is shown in Figure 1.

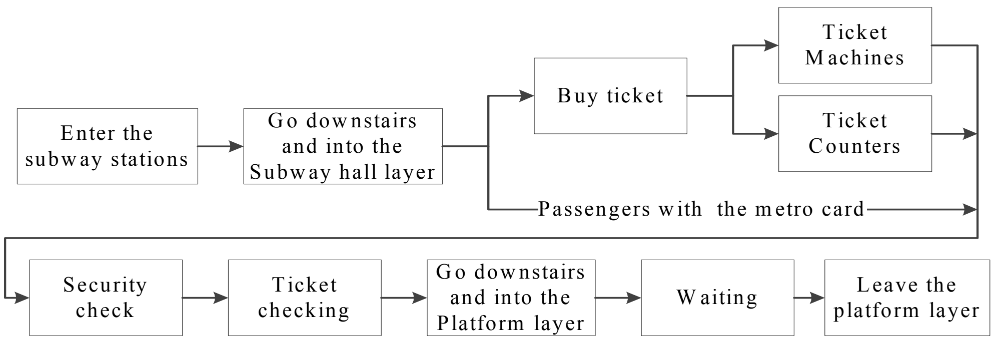

Figure 1. Subway station passenger process diagram

2.2 The subway passenger evacuation modeling method

According to basic theory and research method, the evacuation model can be classified into macroscopic, mesoscopic and microscopic (LIU Zhenyu,2009). The pedestrian movement mode is continuous in the macroscopic model, but it ignores the differences between evacuation individuals, so this kind of method is quite limited.

Pedestrian movement in the microscopic model both interaction and independent, every pedestrian is regarded as a microscopic particle, the particle's social psychological behavior feature is described as the social force. This kind of model makes the pedestrians more like real subway passengers whom can react readily to surroundings. This method is more accurate and widely suitable for most of the evacuation problems.

General mesoscopic method has already detail the units of analysis to the individual. But it haven't considering the interaction between individuals. It's coarser than the Social Force Model.

2.3 The spatial distribution of passenger flow

2.3.1 Passengers queuing phenomenon

When a large number of passengers entered subway station, the through ability would dropped fast and lead to serious crowd congestion. It's necessary to analyze the passengers queuing phenomenon to solve this problem: queue length (the number of passengers in queue); queue time (wait time at service facilities); queue discipline (first come first served); queue system (the number of passengers in station system); queue area (active area of passengers before accepting service).

2.3.2 Passenger traffic conflict

The mechanism of traffic conflict (ZHANG Jianxun,2007) is shown in Figure 2.

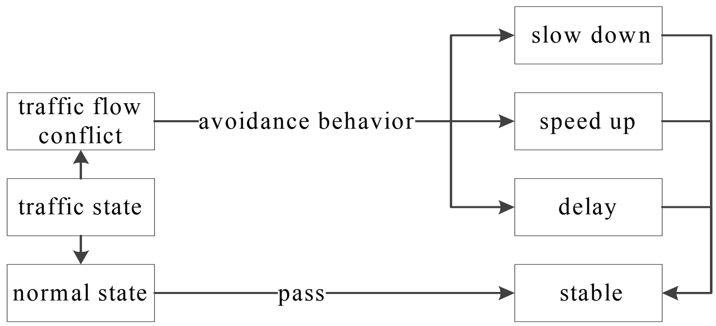

Figure 2. The mechanism of traffic conflict

Firstly, analyze the space structure of the station adequately to determine the direction of passenger flow, and try to find out the potential conflicts spot and the causes of bottlenecks. Then, analyze the influencing factors and put forward an assumption to design the simulation experiment of reducing traffic conflict. Finally, give some reasonable evacuation plans for this problem.

3 Modeling and Simulation of Crowd Evacuation in Subway Station

3.1 Data of the pedestrian traffic characteristics

Shenyang North subway station is located in a heavy traffic urban area, which has the structure of three-tier in the whole Shenyang Metro Line 2. Here are two main kinds of ticketing systems in the station: ticket machines and ticket counters. The service time in ticket machines is around 25.6 seconds, which is longer than ticket counters, 7.5 seconds. The proportion of these two systems is 3:2. The proportion of passengers whether with luggage is 7:3(with luggage: no luggage). Calibration of desired speed in station (WANG Zijia,2013) is shown in Table1.

Table 1. Calibration of desired speed in station(m/s)

Value	Gender		Up Stair	Down Stair
	Male	Female	（Horizontal Direction）	
Max	1.956	1.733	1.194	1.236
Min	0.828	0.697	0.306	0.547
Mean	1.391	1.180	0.700	0.728

3.2 The subway simulation model

The model consists of three layers in total: the ground floor, the subway hall and the platform layer. Considering the complexity of this model, assuming the number of the entrances and the exits of the station as shown in Figure 3.

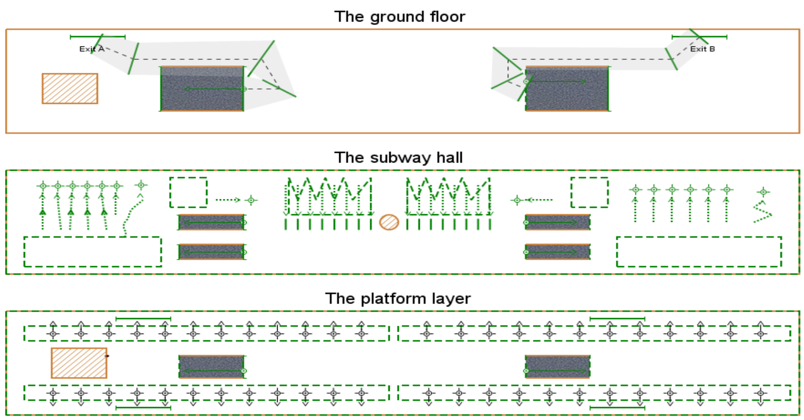

Figure 3. The simulation model plan

Passengers in the system of agent-based have their own thoughts and keep a distance from each other automatically. Diameter of the people obeys uniform (0.4, 0.5) meters. Firstly, passengers enter the ground floor and go downstairs to the subway hall, they have two choices to buy tickets (ticket machines and ticket counters), and the service time obey uniform (20.0, 30.0) seconds and uniform (6.0, 9.0) seconds. Secondly, passengers begin waiting for security checking, the service time obey uniform (4.0, 5.0) seconds. Then, they walk to another waiting area to check tickets, the service time obey uniform (2.0, 3.0) seconds. Finally, passengers go downstairs to wait for subway in the platform layer. About 1-3minutes later, the train draw in and all the passengers get on.

3.3 Model validation

According to the survey data of Shenyang North subway station platform, I had validated the model which established in this paper, the results are shown in table 2.

Table 2. The estimated and actual value of subway station

Test Type	Estimated	Actual Value	Relative Error
Wait Time at TVM (s)	24.5	25.6	-3.52%
Passengers in System (min)	5.6	5.8	-3.45%

The results of the model validation show that both the actual value of "Wait Time at TVM" and "Passengers in System" are higher than the estimated slightly, but the relative errors are in the acceptable range, proving that the pedestrian evacuation model established in this paper is effective.

4 Analysis of Subway Crowd Evacuation Experimental Results

4.1 Analysis of simulation results

Using the computer simulation method can observes the evacuation process and distribution of population intuitively, so as to find out the bottlenecks of the crowd and would also be a reference for optimizing design of the station's layout. Density threshold for platform in the station serve to crowds gathering event (Keith Still,2000) is shown in Table 3.

Table 3. Density threshold for platform in the station serve to crowds gathering event

Danger level	3.59 pedestrians /m^2	
Crowded level	2.15 pedestrians /m^2	
acceptable level	1.08 pedestrians /m^2	

In the simulation, the density map is commonly used to detect the areas with critical densities. Red color indicates the critical density. But in order to make the simulation effect more obvious, the red color is defined as 1.5 pedestrians/m^2, the orange color is 1 pedestrians/m^2, and the green color is 0.5 pedestrians/m^2.

Figure 4 is the simulation result of the ground floor. The densities of entrance and the corner of stairway sometimes were orange during running the model, which means these two places would be easy to form bottlenecks when a large number of passengers coming. In the process of going downstairs, some factors can also lead to traffic congestion such as limited stair capacity、velocity difference and huge flow of people etc.

Figure 5 is the simulation result of the subway hall. Both sides of the stairs and the corner are serious bottlenecks. Both areas of ticket machines and ticket counters are also easily gather lots of passengers and lead to congestion. Meanwhile, it's prone to gather a large crowd when the passengers are waiting in line for security checking. At present, the through capacity of automatic ticket gate is in good condition because of the sufficient number of the gates.

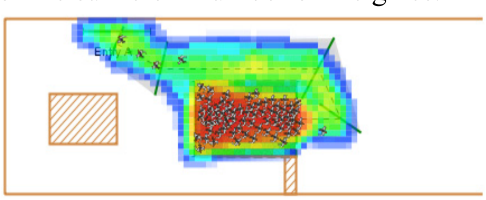

Figure 4. The ground floor

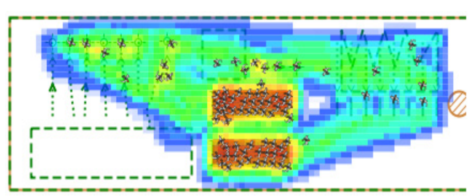

Figure 5. The subway hall

Figure 6 is the simulation result of the platform layer. Stairs are still the most populated areas. Owing to the obvious signs, there is little cross when the passengers select waiting areas. However, it's easily gather a large number of passengers in the waiting areas sometimes, especially at rush hour.

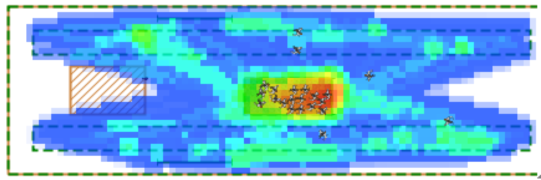

Figure 6. The platform layer

4.2 Optimization program and rationalization proposals

In above，increasing the through capacity of stairs is a good way to solve the potential threat of congestion in both the ground floor and the platform layer. However, the subway hall have the largest number of service facilities、the largest passenger volume and the most complicated structure etc. The passengers stay for a long time in this layer. If there are no effective ways to disperse the crowd when the traffic density is approaching the limit or occur some emergency accidents, the subway hall is more likely to causes congestion and stampede accidents compared with the other two layers.

When the number of passengers increased from 600 pedestrians per hour to 700 pedestrians per hour, there are serious intersection conflict points between the area of ticket counters and the line of security check, as shown in Figure 7. In order to prevent crowd congestion, the station need to reduce the passengers' staying time by opening more ticket machines, setting up some temporary ticket windows, and simplifying the machines' system to improve the efficiency of buying tickets. When the number of passengers increased to 800 pedestrians per hour, lots of passengers gathered in the ground floor, which would causes the pedestrians cannot go downstairs as before and the whole station system would be crashed. So, as long as the passenger arrival rate exceed 700 pedestrians per hour, and station would be ready for avoiding potential danger by opening the mode of early-warning to control the inbound numbers, arranging some professional subway staffs to channel the crowd orderly. At this point, the evacuation signs and emergency broadcasting system can effectively help passengers make the right decision quickly to reduce the time-cost of evacuating, and realize the safety evacuation.

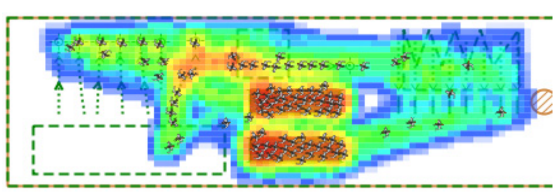

Figure 7. Jam of the subway hall

5 Conclusions

The passenger evacuation model with three-tier structure breaks through the past models with two-tier structure, which has the effectiveness and reference value.

Simulation results show that there is an upper limit for the service ability of subway station. When the inbound pedestrian density exceeds more than 700 pedestrians per hour of each entry would lead to serious congestion even stampede accidents. In order to optimize the quality of the subway service, it's necessary to simplify the ticketing system to reduce pedestrian ticketing time, increase the number of serve machines during the peak time and set some emergency evacuation signs to guide passengers choose the right directions quickly etc. Meanwhile, subway staffs should come to organize passengers to evacuate rapidly if somewhere congestion seriously.

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References

Blue V J, Adler J L. (1998). "Emergent fundamental pedestrian flows from cellular automata micro simulation". *Transportation Research Record*, 1644: 29-36.

Fruin, et al. (1985). "Highway Capacity Manual". Washington D C. Transportation Research Board, *National Research Council.*

G_Keith Still. (2000). "Crowd Dynamics". PhD dissertation of University of Warwick.

Helbing D.T, Platkowski. (2000). "Self-organization in space and induced by fluctuations". *Internet. J. Chaos Theory*, 525-39.

Helbing D, I Farks I, T V icsek T. (2000). "Simulating dynamical features of escape panic". *Nature*, 407: 487- 490.

Highway Capacity Manual. (2000). *Washington D C: National Research Council*. 637-670.

Liu Zhenyu, Bing Xiaoping. (2009). "Research of subway emergency evacuation model". *Railway Computer Application.*

Wang Lida. (2006). "The simulation research of crowd evacuation behavior in subway station". *Master's degree thesis of Beijing Jiaotong University.*

Wang Zijia, Chen Feng, Shi Zhongheng. (2013). "Agent-based realization of social force model and simulation of pedestrians in subway passageway". *Journal of south china university of technology.*

Zhang Jianxun, Han Baoming, Li Dewei. (2007). "VISSIM in the passenger flow microscopic simulation of subway hub". *Computer Simulation*. 24(6):55- 58.

Analysis on Cluster Dispatching Resources in a Marshalling Yard

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Abstract: The resources of marshalling yard can be divided into physical resources and information resources. For the resources could be used reasonably in marshalling yard, the physical resources and information resources' characteristics were summarized by analyzing the operation process of wagon-flows based on the background of the fact that the integrated automation of marshalling station advances progressively. Moreover, the resources were analyzed by clustering analysis method which is first used in the field of computer. The result shows that it is reliable to use the classify solution to avoid marshalling resources wasting. Compared to the traditional resource, the cluster resource are much wider in space and much longer in time. The foundation can be built for controlling cluster resources based on this research.
Keywords: Marshalling yard; Dispatching system; Cluster resources; Analysis.

1 Introduction

Marshalling station has a series of different types, but it consists of the same multiple subsystems according to the technical process of wagons, like arriving operation subsystem, disintegration subsystem, marshalling subsystem, starting operation subsystem and departure system (There are two sets of such kind system with relative independence and similarity in the Two-way layout of network marshalling station). They connect with each other as a queuing system and they are regarded as a random service system which contains some influence factors. In the random service system, each subsystem has their input streams and service systems which all follow the queuing rule. The queuing system is a waiting system that is serial and insurmountable in the five subsystems. There are different operations and services for different nature of the freight trains which requires different kinds of resources on the station (Wang Ciguang, 2004). So the advantage of all resources should be used fully.

2 Complexity of the Operation in marshalling yard

Because there are so many kinds of work in marshalling yards, we can image how complexly and indeterminacy the station work is.

On one hand, the different station work requires some same resources and facilities. Further, we should take the station work time and operation order into account. The main performance of that is the interaction of the arriving subsystem, break-up subsystem, marshalling subsystem, and departure subsystem. The simulation of the auto-mechanical marshalling yards work process gives us the chance to understand the interaction and the corporation principle of the different station work.

On the other hand, the performance of the indeterminacy includes arriving late trains, fluctuation of working time, equipment bug, running accident.

In conclusion, on the background of automatic marshaling yards, we do research on the optimization of dispatching to dig the dispatching information and the mechanic of integrated control, so that improve the effective of the station work. As a result then make the dispatching system scientific and intelligent. That also can help the railway transportation meet their need, optimizing resource allocation and relieve the bottleneck. In one word, there are many theory and practical meanings on railway transportation (Xue Feng and Luo Jian, 2012).

3 Using of Resources

3.1 Using of physical resources

(1) The different shunting locomotive has different tasks in partitioning in marshalling yards. Each shunting locomotive has specific provision. For example, the duty of shunting locomotive on the hump is to disintegrate trains. The duty of shunting locomotive on the lead tracks is responsible for marshalling. The duty of shunting locomotive on the freight yards is responsible for picking up and delivering wagons (REN Guangwei, 2009). We can see that different locomotive serve different trains' task. The effective use of the locomotive has benefit for the stations.

(2) The locomotive order need to arrange based on the train need. Avoiding mutual interference between the disintegrated and marshalling work is our purpose. When arranging hump operation sequence, the disintegration order of the trains needs to be arranged according to the collocation of wagon-flows situation. For the trains which are in emergency, they should be disintegrated first. The marshalling sequences should be designed according to the train departure time. In one words, the station work should be arranged property. Only in this way can we improve the efficiency of the station work.

(3) The corporation of shunting locomotives. If there are free lines on the lead tracks, marshalling work should be timely arranged for leaving the shunting lines. As a result the wagons have spaces on the shunting lines after their disintegration work on the hump. The locomotives should be arranged separately for the different wagons'

resources. Two locomotives can be arranged to do two kinds of separate work, for example, one for disintegrating the arriving trains, and the other for picking up the local wagons. It means the two shunting locomotives work together at the same time to guarantee the effective of station work. That also can make sure the trains departure in time.

(4) For the stations which have two sets of independent operation of hump, we should use the two independent operation of hump properly. It must be known that the two independent operation of hump can finish work independently in different directions. For the special wagons which need twice work, the hump should be used carefully.

(5) For the arriving and departure lines, their taking up time should be considered. Through analyzing the features of taking up time on the departure lines of different trains, we can take balance advantage of departure lines. Sometime the objective of the use of departure lines is to take them up as least as possible and so on.

Train disintegration sequence and the arrangement of marshalling sequence are similar to the machine scheduling problems. They both have very high requires to scheduling plan, but the machine scheduling problem is relatively simple which only has one goal, so that is to reduce work time. However, sequence problem on marshaling yards is not only to consider to reduce working time, but also to consider the matching between resources and tasks (CHEN Dong, WU Baiqing and GAO Siwei, 2008). Marshalling yard work is much complicated, which involves the time-space problems and so on. Therefore, the disintegration and marshalling sequence problem in marshaling yards have a great difference with the machine scheduling problems in nature.

3.2 Using of information resources

There are many information resources in marshaling yards. Every station work has many information resources. By managing different information in the yard can improve the efficiency and corporation of the station works. Integrated information resources management is the trend of automatic marshalling yards. Through the use and the check of information, dispatchers can cooperate with each other, which can make sure the safety of all station work.

It is important that we should try to collect more and more information. The more we get from the information the better use of the information we can. All the work or task in marshalling yard have relations with each other, so the information resources can help the workers who are responsible for different task know the state of ever station work, for example, shunting. Not only the dispatchers of the shunting can know the process of the work but also others like dispatchers for marshalling can know that. That means all the dispatchers and workers can adjust and do the work very well according the information resources (XUE Feng and WANG Ciguang, 2008).

In one words, all resources should be used and shared reasonably.

4 Integrated Resources in Marshalling Yards

4.1 Purpose of integrated resources

The effective dispatching system is the condition of the better use of the resources and the corporation of locomotive-trains-tracks. Dispatching system makes decisions according to the collecting and analyzing of the information. So the better use of the information the better decisions the dispatching system can make. Also, that can help to improve the efficient and ability of marshalling yards.

Based on the comprehensive point and aim to guarantee the trains running on timetable, the resources are collected as wide as possible. Through effective management and dispatching approach, we can control and use the resources initiatively. Our purpose is to arrange the resource to different work reasonable.

4.2 Classification of integrated resources

Integrated resources in marshalling yards can be classified into four parts based on their statues of being used.

(1) Free resources

Its meaning is that some reality resources can be used now and then. Resource in free means we can use them no limit. Their supply is more than their demand. For example, there are many free dispatching locomotives on the stations waiting for doing work such as for dispatching in marshalling yard. These locomotives can be used free now and then.

(2) Shortage resources

It means they are less than free resources, and we just can use those resources to do limited task in limited time. We know that phase plan is to plan what are the wagons and where are they come from. That plan also develop locomotives plans and tracks plans. As a result the state of all the resources can be predicted and be determined. Shortage resources show that they are used partly or they will be used soon. We also can know how the resources are being used now and how they will be used soon through information resources and phrase plan. So the future state of the resource will be changed because of the change of the phase plan.

(3) Saturation resources

It means the resources (both physical and information resources) are all being used at the moment or because of some rules they cannot be used by any other task. For example, the being used hump which is used for dispatching. They cannot be used by other station work. Saturation resources are very sensitive. If the resources in the saturation state have any emergency problems, they can easily impact the process of station work. There are not any alternative resources in marshalling yard.

(4) Breakdown resources

It means those resources cannot serve for any station work before they are fixed well. The difference between Breakdown resources and Saturation resources are the later one can serve for station and their objects which the resources will serve can change as the result of the change of phase plan.

4.3 Effect of resources classification

We choose cluster analysis to classify the resources in marshalling yard, this approach classify the resources into different classification based on their property. Resources with similar property can be classified into the same class. So we can classify the resources by analyzing their state during a proper time.

Through classifying the resources into different class, we can use them more efficient. That also can help to improve the efficiency of station work. Because all station work need many kinds of resources and the same resource can be used for different station work which can make the resource disorder with each other.

The reasonable using of the resources is the primary condition of effective work on stations. As a result, we can use the resources flexible. The classification of the resources can help us to cope with all them quickly and accuracy. For instance, we can change the phase plan or even change the plan ahead according to the state of the resources. Those can prevent the deadlock of marshalling yards, on the other words, works stop because of the disorder of the resources. It is also a good way to improve the efficiency of station work.

5 Conclusions

(1) Classifying resources can improve the efficiency and corporation of the stations work in marshalling yards. It can make us know the state of the resources quickly and accuracy.

(2) Through the classification, the ability of the marshalling yards can be estimated and predicted. That helps us organize the work efficient and adjust our phase plan in time.

(3) This approach of classification is just a try to analysis resources, and the research on this problem will go on.

Acknowledgement

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Reference

Chen Dong, Wu Baiqing, Gao Siwei. (2008). "Establishment and Realization of Intelligent Shunting Control System in Marshalling Station." *Journal of*

Railway Transport and Economy, 30(4), 34-37.

Ren Guangwei. (2009). “Intelligent management of dispatching system in marshalling yards. ”*Chinese railway*, (11), 61-64

Wang Ciguang. (2004). “Transportation models and optimization.” *China Railway Publishing House*, Beijing.

Xue Feng, Wang Ciguang. (2008). “Analysis on the Correlated Problems of Wagon-flow Allocation in Marshalling Station.” *Journal of the Transportation Engineering and Information*, 6(4), 29-33.

Xue Feng, Luo Jian. (2012). “Study on dispatching IDSS for railway marshalling yard.” *World Automation Congress 2012*, Puerto Vallarta, Mexico, 1882-1885

Analysis of the Main Influence Factors of the Capacity Coordination Problem between Freight Stations and Marshalling Yards under the "Real-Freight System"

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Abstract: With the high-speed railways have been put into use in our country, railway transportation capacity achieved liberation. And it make possible of further optimizing program organization and improving the quality of service. Freight demand accepted online began to effect on September 1, 2012, to actively carry out the real-freight system requirement of "open the acceptance of goods, loaded as soon as picked" and to take the customer as the center concept to meet the maximum loading needs of the clients, which put forward higher request for the accuracy and flexibility of the collocation of the transport capacity. Therefore, the capacity coordination of freight stations and railway stations has become a vital and urgent problem. This paper take the freight stations and marshalling yards in railway terminal as main research subjects, through analyzing their working relationship, to summary the capacity coordination connotation of freight stations and railway stations under "real-freight system" and to explore the main factors influencing their capacity coordination. In order to provide feasible and effective theory to improve the capacity coordination situation of freight stations and railway stations as well as to enhance the integrated efficiency of railway.
Keywords: Real-freight system; Capacity coordination; Freight stations; Marshalling yards.

1 Introduction

Depending on the freight of e-commerce system, our country pursues the "real-freight system". This Changes of railway transportation environment, requiring railway transportation system of self-adjustment, to improve the adaptability of the external environment, but also put forward new requirements on the transport capacity of railway hub. The ability of railway transportation hub as a multi-link system capacity, transport capacity will not only restrict any weak links of the system, and will cause the other areas of investment and the ability of the waste, so each link in the system must be coordinated ability. Among them, freight stations and marshalling stations are of railway freight transportation main and basic production unit (DENG Yuncheng,2014). The achievement of capacity coordination of freight station and marshalling yards is closely related to the survival and development of transportation, and meet the needs of railway transport enterprises.

2 The Capacity Coordination Connotation of Freight Station and Marshalling Yards Under "Real-Freight System"

"Coordination" in different areas of the meaning is not the same, but the basic meaning is the same, namely, correct processing system of various internal and external relations, create good conditions and environment for the system to work, promote the system goal. In general, the need for coordination system often contains several contradictory and conflict. Between freight stations and marshalling stations operation mainly includes: the marshalling yard with functions of freight business and freight business in area of marshalling station (LUO Anquan,2009).

2.1 Marshalling yard with functions of freight business

Figure 1 shows the operation flow of marshalling yard with functions of freight business. Shipper with the delivery of goods to the freight car to the freight station Ⅰ, then transported by transship trains to the receiving departure of the marshalling yard Ⅰ. According to the whereabouts of cargo each freight station yard in the disintegration of trucks, trains same fate compiled to form a new train departure, transport, arrived marshalling yard Ⅱ to carry out the same job in the marshalling yard Ⅰ process again. Finally, a small operation will be grouped by train transporting goods to the freight station Ⅱ, Ⅱ freight station pick notify the consignee, the consignee with their own car after unloading the goods shipped to its warehouses or factories.

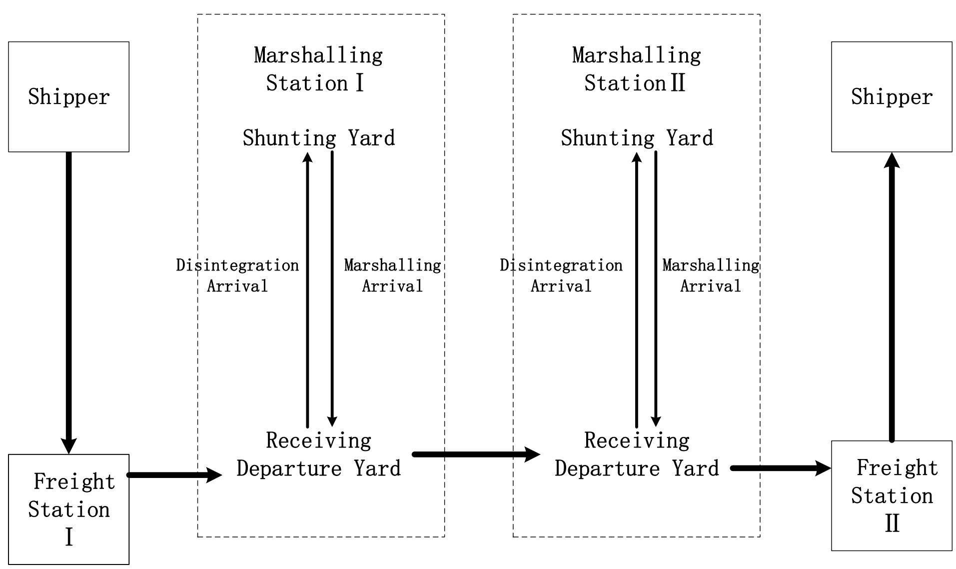

Figure 1. Operation flow of marshalling yard with functions of freight business

2.2 Freight business in area of the marshalling station

Figure 2 shows the operation flow of freight business in area of the marshalling station. Generally in accordance with the freight station nearest freight forwarders, freight station nearby, and then run through transship trains sent goods to disintegration and grouping in marshalling station, the goods will be transported to other places. A choice of direction cargo freight station shown Ⅰ, Ⅱ freight station for loading point, and then sent to the marshalling yard run by small train. Finally disintegrated by the marshalling yard marshalling to arrive to the user.

Similarly, goods from other marshalling yard hubs should also enter the marshalling yard, and then disintegrated by marshalling yard. The marshalling yard put the region's goods to the nearest freight station. And each freight station give the goods to their owner. Self-delivery by the owner and the owner is also responsible for the goods transported by freight station to the demand of the goods.

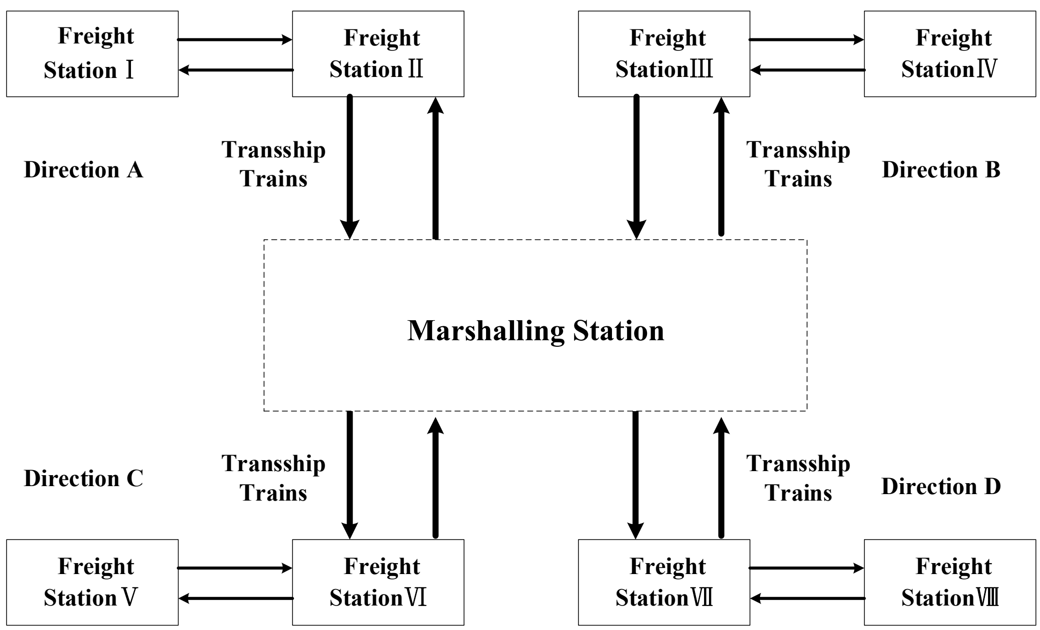

Figure 2. Operation flow of freight business in area of the marshalling station

By operating contact between the two, from different levels and angles , analyze and summarize the meaning of railway freight stations and marshalling yards capacity to coordinate, sum up includes the following four aspects: (1) cargo terminal and Marshalling load capacity on reasonable, balanced (SUN Qi,2010); a reasonable match between (2) freight station and marshalling yard equipment and technology operational capability; (3) the freight station and marshalling yard production order is relatively stable, continue a short time.

3 The Main Influence Factors of the Capacity Coordination Problem Between Freight Station and Marshalling Yards Under "Real-freight System"

(1)Wagon flow organization

Among all the freight stations and marshalling stations in the hub, can form a plurality of traffic flow path (*i.e. transship trains section*), a freight station on the general several each one (LIANG Wangrong,1995). Therefore, a traffic flow on each path independently of wagon flow organization, which can be divided into marshalling station to freight station and freight station to marshalling station, two organizational scheme. And the preparation of freight station and marshalling station organization scheme is more complex. In order to achieve full play in the hub of technical equipment potential, reduce hub station vehicle reorganization work and reduce vehicle maximum repetition adaptation and angle operation. And also make it possible to improve transport efficiency, accelerate the cargo delivery, shorten the residence time of the locomotive and vehicle in the hub and ensure smooth and good transport order.

(2)Handling time

Freight cars loading and unloading part of the residence time of about one-third freight car turnaround time(Cao Xueming,2007), loading and unloading cargo terminal part is finished in the freight station, this part-time compression mainly involves taking reasonable wagons. Cargo operations in vehicle technology job, taking delivery of the car is the most important part of the job. It improves the efficiency of cargo and has a major impact on the compression wagon staying time and wagon transit time.

Through plan to organize delivery in wagon flow organization, tissue material equilibrium arrival station can avoid sending concentrated, but cause blockage of library field. The delivery vehicle in the organization, strengthen the wagon's placing –in and taking-out, directly affect the vacated pick up car line timely and floor smooth. The freight station placing-in a car timely make it possible to the timely completion of cargo handling operation. The freight station taking-out a car timely make it possible to freight cars promptly into the train starting. At the same time, reasonable loading and unloading point of delivery vehicles in order, can effectively use the locomotive and compression wagon staying time.

Therefore the freight station open or not, have a major effect on marshalling station capacity. Freight stations handling equipment capacity tension, causing vehicles cannot be unloaded, which make this part of the vehicle be detained in the marshalling station. As a consequence, it will shunt marshalling station lines and affect the marshalling stations to pick up car and break-up operation of the hump.

(3) Empty car distribution

Shunting yard and special line of empty wagon distribution is mainly realized in a certain shift plan with empty time. According to the specific distribution of empty cargo and effective coordination, and in the condition of considering the dual task, the marshalling yard reasonably determine the flow's directions and flow of the available empty car of the empty station supply point. In order to realize the residence time in the station compression wagon staying time and reduce the empty total transfer cost. China's productivity distribution and regional social and economic development is not balanced, resulting in railway traffic structure presents obvious characteristics. Loaded cars' structure appear in distribution from north to south and from west to East. Otherwise the empty cars and heavy traffic, on the contrary, appear in distribution from south to north and from east to west, and this is the main vehicle evacuation direction. It is because of the need to empty imbalance distribution of the spatial and temporal that provides the need of distribution of empty wagons. The reasonable distribution scheme of the empty wagon, can not only to meet the greater demand for transportation, but also contribute to reducing the empty cars running kilometers, and compression of wagon turnround time.

4 Suggestions

(1)Optimize the organization scheme of car flow. The reasonable organization nonstop of loaded and empty trains, and no adaptation by marshalling stations, which will reduce the reorganization work and save the vehicle hour. The small operation train of the freight station operation section can be a single or a few organized, and marshalling yards excluded nonstop of loaded and empty trains. Then we discuss the organization schemes of the remaining traffic again which include operated on direct and picking and hanging train. Should not only consider the transship trains on the way to run, the residence time of province, and it is more important in marshalling stations short switching time. With the small operation matched with the transit flow, it will realize the train formation plan of the marshalling station according to the provision of cars, create conditions according to the train diagram of crane and shorten the " transit time" scheme.

Therefore, it must reflect the local to the global, to operate a transship train to obey the principle of organization run train. The specific method should be according to the need of the marshalling station transit traffic aggregation, connection and cooperation, to determine the marshalling content of transship train. At the time, according to the railway marshaling stations line train departure time requirements, marshaling stations organize "dispatching a vehicle". It should combine with marshalling station to operate a small freight station train organization schemes, a transship train of locomotive operation scheme and each line, each station, to determine the realization of comprehensive load capacity.

(2)During the wagon staying time, to be delivered in time, to be installed, and other non-production time occupies a large proportion of. In order to shorten the residence time of these nonproduction, collaboration must strengthen the factory, mine, port and railway, forestenterprise department. Combined with labor departments within the organization way, improvement of goods vehicles operating organizations, to avoid disconnection between the working link technology. Therefore, we should combine the characteristics of traffic station and special line of the cargo operation site equipment with operation conditions and the traffic to the law, take the principle of vehicle delivery, cargo handling, train to cooperate closely, to determine a reasonable number of delivery, delivery order and delivery time to each of the work place. The key to shorten cargo stay time, lies in the railway and enterprises can cooperate closely and strongly compressed to be sent, to be installed, to be unloaded and standby and other non-production and residence time of loading and handling time.

(3) Be based on the analysis of factors of empty wagon kilometers influence, we can draw the following basic method for compression of wagon kilometers. ① Adjust the layout of productivity, reducing the imbalance of the empty wagon flow in all directions. ②The optimization of railway empty wagon adjustment plan and empty train formation plan, and making plan of empty wagon distribution reasonable and empty place of transit operation. ③The optimization of wagon flow path. When empty by truck to the loading, the general should be through the shortest path,it must eliminate the same empty at the same radial road and a parallel path of convection. ④Improve the dual task coefficient, the reasonable organization of circulation through train, using empty haul back loading, but to ensure the loading station stop time not exceeding. ⑤Increase the axle load of freight cars, thereby increasing static load, reduce the direction of heavy vehicle number; ⑥Improve the versatility of the truck, and create conditions for the empty substitution of car types. ⑦Strengthen the empty car adjustment plan, and make the distribution of the use of vehicles sensible.

Railway transportation "real-freight system" revolution is an important initiatives by railway transportation administration to face the increasingly potential market competition and under the business philosophy that develop the market by good service. The transportation revolution stress that take the customer as the center concept to meet the maximum loading needs of the clients ,which put forward higher request for the accuracy and flexibility of the collocation of the transport capacity. Therefore, the capacity coordination of freight stations and railway stations has become a vital and urgent problem .This paper explore the main factors influencing their capacity coordination, and to provide the theoretical basis for their optimization method.

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References

Cao Xueming.(2007)"Railway Transportation Organzation Model and Method for Accelerating Railcar Cycling" *Journal of Southwest Jiaotong University.*

DENG Yuncheng,Li Ming-zhou,ZHANG Ying-gui.(2014). "Analysis and Countermeasures about the Adaptability of Railway Freight Station"*Logistics technology* (12),13-16

LUO Anquan.ZHANG Guohua.FANG Zhi-jun.(2009). "How to Build a Logistcs Center Based on a Marshalling Yard with Founction of Freigent Buisiness." *Logis*, 28(3), 26-29

LIANG Wangrong.(1995)"Study on Organization of Wagon Flow in Railway Terminals" *Journal of Southwest Jiaotong University,* 30(2), 140-144

SUN Qi.(2010). "Research on Capacity Coordination of Station and Line Based on Railway Freight Transportation Operation Process" *Beijing Jiaotong University.*

Optimizing System Design for Departure Time Domains of Passenger Trains

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Abstract: The departure time domain of passenger trains is mainly to solve the overall layout problem of the passenger trains running line. A reasonable departure time domain of passenger trains can not only construct the skeleton and the core issue of the passenger train working diagram, but also improve the feasibility of the working diagram. The system for optimizing departure time domain and arrival time domain of passenger trains is developed based on the genetic algorithm constraints of the receiving and dispatching trains capacity of railway passenger transportation nodes model in the paper. The goal and function of the system are detailed description. Then the corresponding actual simulation is proposed to validate the effectiveness of the system.
Keywords: Departure time domain; Passenger trains; Genetic algorithm; Optimizing system.

1 Introduction

The originating scheme of passenger trains is mainly to solve the overall layout problem of the passenger trains running line, which is an important prerequisite of the preparation of passenger train working diagram. And as the skeleton and the core issue of the passenger train working diagram, the originating scheme directly affects the feasibility and quality of passenger train working diagram. At the same time, a reasonable originating scheme of passenger trains can not only meet the passenger's requirements of travel time and service quality and enhance the market competitiveness of railway transportation enterprise, but also take full use of existing passenger station facilities and the equipment of passenger car servicing depot, improve the quality and efficiency of operation organization in passenger stations. Meanwhile, with the improvement of transportation efficiency, the railway operating income can be increased and the operating cost be reduced.

As an important part of the passenger train operating organization, the originating scheme establishment of passenger trains is affected by many factors, such as the passenger train plan, passenger station equipment capacity, servicing capacity of passenger car servicing depot, passenger locomotive and rolling number, train safe driving requirements, passenger travel time, etc.. Meanwhile, the originating scheme establishment of passenger trains is a multi-objective, multi-constrained and large-scale combinatorial optimization problem. Taking the maximum degree of passenger travel convenience as the objective function and considering some constraint conditions such as the carrying capacity of arrival and departure tracks and passenger trains must departure and arrive in rational time intervals, an objective programming model for optimizing the departure and arrival time intervals of passenger trains was established (Chen Tuansheng,2006). The departure time domain of passenger trains optimization models for a single node and optimization model for multi-node are established respectively based on the constraints of the receiving and sending capacity of railway passenger transportation nodes. Moreover, the genetic algorithm combined with conflict detection strategy is proposed to solve the problem of the passenger trains' departure time domain for a single node, and a heuristic priority strategy algorithm was put forward for the same problem too(Ni, Shaoquan,2012). Furthermore, the heuristic algorithm combined with conflict detection strategy is designed to solve the problem of the passenger trains' originating scheme for multi-node(Chen Dingjun,2012). There are also many scholars have discussed the scheme of passenger trains from different perspectives.

In the paper, the system for optimizing departure time domain and arrival time domain of passenger trains will be developed based on the genetic algorithm constraints of the receiving and dispatching trains capacity of railway passenger transportation nodes model, and the detailed function of the system will be introduced.

2 Optimization Model and algorithm for Departure Time Domain of Passenger Trains

2.1 Optimization Model for Departure Time Domain of Passenger Trains

We can get the Model of Departure Time Domain of Passenger Trains in paper (Chen Dingjun, 2012), which gives the heuristic priority strategy algorithm.

$$\max f(t) = \alpha \sum_{d=1}^{\sum_{i=1}^{m} f_{0i}} \sum_{t \in T} \delta(d)\mu(x_d(t \oplus w)) + \beta \sum_{a=1}^{\sum_{i=1}^{m} f_{0i}} \sum_{t \in T} \delta(a)\mu(y_a(t \otimes w)) \quad (1)$$

S.t.

$$\sum_{d \in D} x_d(t) \le N_{0t}^{\text{dispatch}} \quad (2)$$

$$\sum_{a\in A} y_a(t) \le N_{0t}^{\text{receive}} \quad (3)$$

$$\sum_{t\in T} x_d(t) = 1 \quad (4)$$

$$\sum_{t\in T} y_a(t) = 1 \quad (5)$$

Where formula (1) expresses let the trains the maximize convenience to passengers; formula (2) expresses the number of trains departure from node at any time can not exceed the dispatching capacity at the period t; formula (3) expresses the number of trains arrival at node at any time t can not exceed the receiving capacity at the period t; formula (4) expresses every train departs from node at only one period of time; formula (5) expresses every train arrives at node at only one period of time.

2.2 Algorithm for Departure Time Domain of Passenger Trains

In the paper (Chen Dingjun,2012), thorough analysis the complexity of the problem, the improved elite group genetic algorithm combined optimization departure time domain of passenger trains and conflicts detecting strategy was designed. Now we developed the optimization system based on the algorithm and combined with the actual application needs.

3 optimizing system for departure time domain of passenger trains

3.1 System Target

Departure time domain of passenger trains is based on the train operation plans which have been draw up ,then the time resources can be preliminary allocated to trains by meeting the travel time and the constraints of the receiving and dispatching trains capacity of railway passenger transportation nodes .

Currently, the method of passenger train departure time domain is a uniform distribution, which can not provide t powerful assist to rain working diagram. With the depth development of transportation products to meet the market demand, the working mode lacking of information means can not help lighten the labor intensity of plan engineering and improve the working efficiency, which has not been able to adapt to the demands of railway development. Therefore, the goal for researching and developing the optimizing system for departure time domain of passenger trains is to improve the intelligent level of train working diagram, achieve plan intelligent generating, and provide the necessary decision-support tools for the working diagram.

The performance of the system have to meet the reliability, practicability, advanced ability to avoid data loss or errors under a long time run. In addition, the system must be simple, practical and simple operation to convenient for the user to master the use of the system.

3.2 System development environment for optimizing departure time domain of passenger trains

In this paper, genetic algorithm based on conflicts detecting is realized by Visual C + +, optimizing system for departure time domain and arrival time domain of passenger trains is developed, and by the computer with Intel Core 2.26GHz and 2GB memory.

3.3 System functions for optimizing departure time domain of passenger trains

(1) Parameters setting function for GA

In the software, parameters such as the size of the population, crossover probability, mutation probability, maximum genetic algebraic can be set and modified (Fig.1).

Figure 1. Software interface for setting GA parameters

(2) Capacity of arrival-departure lines in unit time setting function

According to the actual situation of passenger transportation node, capacity of arrival-departure lines in unit time can be set (Fig. 2.).

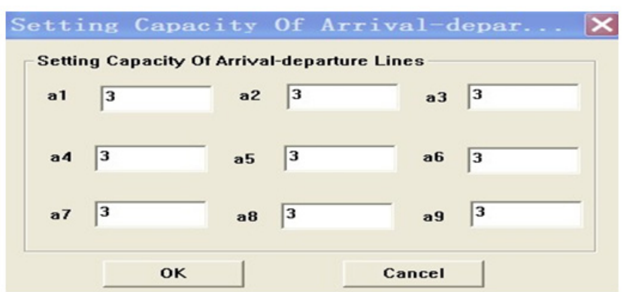

Figure 2. Software interface for setting capacity of arrival-departure lines.

(3) Data management function

Travel time data of passenger trains can be managed, including data reading, data storage, data modification.

(4) Results output function

Results, including fitness value of each generation, optimal solution, fitness value of optimal solution, etc, can be output (Fig.3.).

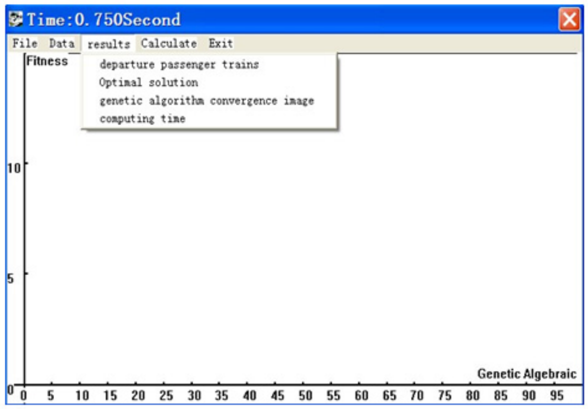

Figure3. Interface for results output

(5) Result statistics function

Statistical results, including the number of departure passenger trains, genetic algorithm convergence image, computing time, etc.

4 Simulation analyses

Parts of passenger departure trains data of Chengdu station are adopted to validate the effectiveness of the model and the algorithm. There are 12 arrival-departure lines, 6 up going available lines and 6 down going available lines, 4 platforms, 2 tunnels, one bridge. According to the station capacity and departure and arrival trains situation, time domain [6,24]can be divided into 9 time periods by 2 hours, and, suppose, maximum number of trains departure from the station at each time period is 9.

(1) Genetic algorithm parameters setting

TABLE 1

GENETIC ALGORITHM PARAMETERS SETTING BASED ON CONFLICTS DETECTING

Parameters	size of the population	crossover probability	mutation probability	maximum genetic generation
Value	30	0.8	0.1	200

(2) Computing Results

The computing results are listed in the TABLE 2, in which only partial results are given because of space constraints.

TABLE 2

Computing Results

Train number	Departure Time Domain								
	[6,8]	[8,10]	[10,12]	[12,14]	[14,16]	[16,18]	[18,20]	[20,22]	[22,24]
T8904			1						
T8906	1								

T8910				1					
T8902								1	
T8912							1		
T8908			1						
K9506			1						
5615	1								
K9458				1					
K9445					1				
...									

5 Conclusions

In this paper, the system for optimizing departure time domain and arrival time domain of passenger trains is developed based on the genetic algorithm constraints of the receiving and dispatching trains capacity of railway passenger transportation nodes model in the paper. The goal and function of the system are detailed description. Then the corresponding actual simulation is proposed to validate the effectiveness of the system. The detailed timetable of the trains in the whole railway net will be research in our future work.

Acknowledgement

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References

Chen T.S., Mao B.H., He Y.Q.. (2006). "Study on Optimization of the Departure Time Domain of Passenger Trains. " Journal of the China Railway Society, 28(4):12-16.

Ni S.Q, Lu M.M., Chen, D.J., Lu H.X.. (2012), Departure time domain optimization model of passenger trains based on heuristic algorithm. International Review on Computers and Software. 7(4):1755-1759.

Chen D.J.. (2012). Study on the model and algorithm of the originating scheme of passenger trains. Southwest Jiaotong University of PhD thesis..

Models and Heuristics for the Split Delivery Vehicle Routing Problem

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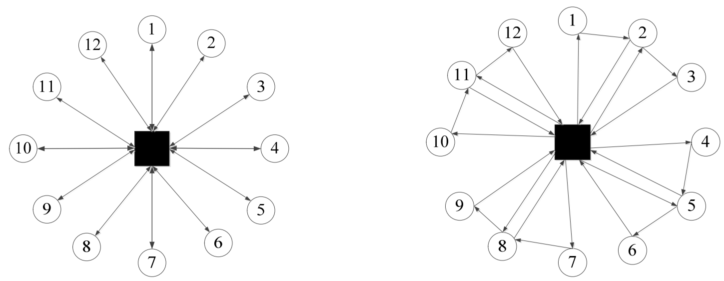
Abstract: Split delivery vehicle routing problem (SDVRP) is a variation of vehicle routing problem, where some customers may be served by more than one vehicle. This paper is a survey on the models and solution approaches for SDVRP. Some models is reviewed. Heuristic and exact solution approaches for the SDVRP are presented. Finally, future work about SDVRP are given.

Keywords: Split delivery; Vehicle routing problem; Heuristic; Exact solution approaches.

1 Introduction

The split delivery vehicle routing problem (SDVRP) (Dror, 1989), is an variation of vehicle routing problem. The difference between SDVRP and VRP is that, the demand of some customers may be larger than the capacity of a vehicle, and can be serviced by more than one vehicle. At this time, the amount deliveried by a vehicle to a split customer becomes a variable. Fig.1 shows the difference between the solutions of VRP and SDVRP.



(a) (b)

Fig.1 the difference between the solutions of VRP and SDVRP(a for solution of VRP, b for solution of SDVRP; capacity of vehicle 6, customer demand 4)

More recently, the literature addresses more complicated problems, such as SDVRP with time windows, SDVRP with pickup and delivery, SDVRP with inventory and production, SDVRP with minimum fraction served, and SDVRP under stochastic environment, SDVRP motivated by applications etc. There are also papers such as (Dror, 1989; Archetti, 2005) etc., which consider the properties of SDVRP and the maximum saving that can be achieved by split deliveries. Most studies develop heuristic and exact algorithms to solve the proposed models.

This paper is a survey on the models and heuristic/exact algorithms to solve SDVRP. In section 2, the mathematical programming formulation of SDVRP is presented. Sections 3 and 4 review the heuristics and the exact approaches proposed for the SDVRP. Finally, Section 5 provides further research on SDVRP.

2 Formulation of SDVRP

The formulation of Dror's is a basic model for SDVRP, which is a mixed-integer program model.

SDVRP is defined over an undirected graph $G=(N,A)$, where $N=\{0,1,\cdots,n\}$ is the vertex set with the depot 0. $A=\{(i,j):i,j\in A,i\neq j\}$ is the set of edge. The cost of an edge $(i,j)\in A$, c_{ij}, is non-negative. There are m vehicles in the depot, each with capacity Q_v, which is different from each other. The demand of customer i is given by q_i, which satisfies $q_i\leq \max_v\{Q_v\}$ 。

x_{ijv} ($i\neq j$) is a binary variable that takes value 1 if vehicle v travels directly from i to j, and 0 otherwise;

y_{iv} is the percent of the demand of i delivered by the vehicle v.

The SDVRP can be formulated as follows:

$$\min\sum_{i=0}^{n}\sum_{j=0}^{n}\sum_{v=1}^{m}c_{ij}x_{ijv} \tag{1}$$

S.T.

$$\sum_{i=0}^{n}x_{ikv}-\sum_{j=0}^{n}x_{kjv}=0 \quad (k=0,1,\cdots,n;v=1,\cdots,m) \tag{2}$$

$$\sum_{v=1}^{m}y_{iv}=1 \quad (i=0,1,\cdots,n) \tag{3}$$

$$\sum_{i=1}^{n}q_iy_{iv}\leq Q_v \quad (v=1,\cdots,m) \tag{4}$$

$$\sum_{j=0}^{n}x_{ijv}\geq y_{iv} \quad (i=1,\cdots,n;v=1,\cdots,m) \tag{5}$$

$$x_{ijv}\in\{0,1\} \quad (i,j=0,\cdots,n;v=1,\cdots,m) \tag{6}$$

$$0\leq y_{iv}\leq 1 \quad (i=1,\cdots,n;v=1,\cdots,m) \tag{7}$$

$$\sum_{v=1}^{m}\sum_{j=0}^{n}x_{ijv}\geq 1 \quad (i=1,\cdots,n) \tag{8}$$

$$\sum_{v=1}^{m}\sum_{i\in S,j\in\bar{S}}x_{ijv}\geq V(S) \quad (S\subseteq N\setminus\{0\};|S|\geq 2) \quad \text{or}$$

$$\sum_{v=1}^{m}\sum_{i,j\in S} x_{ijv} \le |S|-1 \quad (S \subseteq N\setminus\{0\}; |S|\ge 2) \tag{9}$$

Constraints (2) are flow conservation conditions. Constraints (3) specify that the demand of any customers is entirely satisfied. Constraints (4) ensure that vehicle capacities are never exceeded, while constraints (5) guarantee that if some customer is visited by some vehicle, then the same vehicle leaves that customer. Constraints (8) impose that each vertex is visited at least once. Constraints (9) are subtour elimination constraints. The former is for the situation in which the total demand of all customers is larger than the vehicle capacity; the last is for the situation in which the edge satisfies the triangle inequality.

The varieties and extended models are all based on (Dror's,1989), and the most important one is SDVRP with time windows and with homogeneous fleet. The main results are shown in Tab1.

Tab 1 papers on variety and extended models for SDVRP

papers	model type	Remark
Frizzell(1995)	mixed-integer program	SDVRP with hard time windows, heterogeneous fleet
Belfiore(2009)	mixed-integer program	SDVRP with time windows, heterogeneous/unlimited fleet
Ho(2004)	mixed-integer program	SDVRP with time windows, homogeneous fleet
Belenguer(2010)	mixed-integer program	Split delivery capacitated arc routing problem, homogeneous fleet
Lei(2012)	stochastic programming model	SDVRP with stochastic demands, homogeneous fleet
Desaulniers(2010)	mixed-integer program	SDVRP, homogeneous fleet
Archetti(2014)	flow formulation	SDVRP with time windows, homogeneous fleet
Huang(2012)	integer program	SDVRP, homogeneous fleet

3 Heuristics

Heuristics can solve large-scale problem, and are widely applied on VRP. Most of the heuristics for solving VRP can be used to solving SDVRP, including tabu search, genetic algorithm, memetic algorithm, scatter search, simulated annealing method etc., and hybrid heuristic algorithms. The key point of solving SDVRP by heuristics is how to deal with the split customers. Several ways have been proposed to deal with split delivery, such as splitting the last customer of a route, whose demand can't be satisfied fully; delivering part of all customers' demand firstly, then servicing the remainder etc. The main results researching on heuristics for solving SDVRP are shown in table2.

Tab 2 papers on solving SDVRP using heuristics

papers	Algorithm	Remark
Dror(1989,1990)	Local search algorithm	consider only the case with each demand less than the capacity of the vehicle
Archetti(2006)	Tabu search	proved to be much more effective than Dror and Trudeau's(1989) algorithm
Boudia(2007)	Memetic algorithm with population management	proved to beat the tabu search(Archetti, 2006)in many cases
Archetti(2008)	hybrid heuristic based on tabu search	results improve the ones produced by the tabu search (Archetti, 2006) in many cases
Jin(2008)	limited-search-with-bounds algorithm	tested on the set of 12 instances proposed by Belenguer (2000), improve the lower bound on 10 instances and the upper bound on six instances.
Xie(2012)	ant algorithm	Stable results, difference between the best and the worst solution is small
Tan(2008)	ant algorithm	Split delivery result to the reduction of the number of vehicle used and the total route length
Xie(2006)	tabu search/genetic algorithm	put forward an operator to solve the tendency of over-split
Liu(2011,2012)	Two-stage algorithm Clustering algorithm	effective than tabu search(Xie, 2006)
Mota(2007)	Scatter search	minimum possible number of vehicles
Belfiore(2009)	Scatter search	SDVRP with time windows
Aleman(2010a)	adaptive memory algorithm	minimum possible number of vehicles is imposed
Aleman(2010b)	Tabu search with vocabulary building approach	minimum possible number of vehicles; remarkably improve the results of the previous adaptive memory algorithm(Aleman, 2009)
Huang(2012)	greedy randomized adaptive search procedure	delivering part of all customers' demand firstly, then servicing the remainder
Derigs(2009)	local search-based metaheuristic	minimum possible number of vehicles
Lei(2012)	Adaptive large neighborhood search	SDVRP with stochastic demands
Berbotto(2013)	tabu search with granular neighborhood	minimum possible number of vehicles; most results are better than ever results
Wilck IV(2012)	Genetic algorithm	minimum possible number of vehicles; faster than the column generation approach and two-stage algorithm

Summarizing form the literatures listed above, most approach for solving SDVRP are constructive heuristics, such as local search, tabu search, adaptive large neighborhood search algorithm, greedy randomized adaptive search procedure etc. But researches on heuristics based on population is rare. This kind of algorithm, such as particle swarm optimization, genetic algorithm etc. has been proved very effective to solve many difficult problem, specially for VRP, and whether these algorithms can be applied well to SDVRP need to be verified further. And literature of this kind in Chinese is rare.

4 Exact Algorithms

Like the heuristics, the exact algorithms for solving VRP all can be used to solve SDVRP, including column generation approach, cut plane algorithm, branch-price-cut algorithm, branch and bound algorithm, dynamic programming etc. The main results on exact algorithms for solving SDVRP are shown in table 3.

Tab 3 papers on solving SDVRP using exact algorithms

papers	Algorithm	number of customer	remark
Dror(1994)	Local search	20	improve previous lower bounds
Belenguer(2000)	Cut plane algorithm	51	a new family of valid inequalitie
Lee(2006)	labeling algorithm	7	minimum possible number of vehicles
Yu(2007)	Lagrangian relaxation approach	200	inventory routing problem
Jin(2008)	column generation	22	minimum possible number of vehicles
Archetti(2009)	branch-and-price-and-cut algorithm	144	in most cases, improve previous lower bounds and found some new best feasible solutions.
Desaulniers(2010)	branch-and-price-and-cut algorithm	100	SDVRP with time windows
Moreno(2010)	lower bounding procedure based on column and cut generation	100	in most cases, improve the previous lower bounds
Archetti(2011b)	Improved branch-and-price-and -cut algorithm	100	SDVRP with time windows
Archetti(2014)	Branch and cut algorithm	100	present two exact branch-and-cut algorithms

Summarizing form the literatures listed above, researches on dynamic programming to solve SDVRP is rare.

5 Results And Further Research

Since SDVRP has been introduced, it has received increasing attention over time. Heuristic and exact solution algorithms have been proposed. But there are many other issues in SDVRP that need to be considered, including more complicated SDVRP and designing more effective algorithm. In terms of more complicated SDVRP, it is clearly important to consider the situation close to practical application, such as SDVRP in stochastic environment, SDVRP in urban distribution, SDVRP combined with urban transportation etc. Another area of further research is to design more effective algorithm for SDVRP. One way is to present improved algorithm based on the heuristics and the exact algorithms; another way is to apply some existing algorithms to SDVRP, such as particle swarm optimization, dynamic programming etc., which has been verified very effective for VRP. And also, one can design hybrid algorithms to solve SDVRP

Reference

Aleman R.E.(2009). “A guided neighborhood search applied to the split delivery vehicle routing problem”, Thesis, Wright State University.

Aleman R.E.(2010a). “An adaptive memory algorithm for the split delivery routing problem”. Journal of Heuristics, 16: 441–473.

Aleman R.E.(2010b). “A tabu search with vocabulary building approach for the vehicle routing problem with split demands”. International Journal of Metaheuristics, 1: 55–80.

Archetti C.(2005). “Complexity and reducibility of the skip delivery problem”. Transportation Science, 39: 182–187

Archetti C.(2006). “A tabu search algorithm for the split delivery vehicle routing problem”. Transportation Science, 40: 64–73

Archetti C.(2008). “An optimization-based heuristic for the split delivery vehicle routing problem”. Transportation Science , 42: 22–31.

Archetti C.(2009). “A column generation approach for the split delivery vehicle routing problem”. Networks, 58(4): 241-254

Archetti C.(2011a). “Complexity of the VRP and SDVRP”. Transportation Research Part C, 19 : 741–750

Archetti C.(2011b). “Enhanced branch-and-price-and-cut for vehicle routing with split deliveries and time windows”. Transportation Science,45(3): 285–298.

Archetti C.(2014). “Branch-and-Cut Algorithms for the Split Delivery Vehicle Routing Problem”, European Journal of Operational Research. 228(3): 685-698.

Baldacci R.(2009). “The split delivery vehicle routing problem”. AIRO the fortieth

Annual Conference of the Italian Operational Research Societ.
Belenguer J.M.(2000). "A lower bound for the split delivery vehicle routing problem". Operations Research, 48: 801–810.
Belenguer J.M.(2010). "Split delivery capacitated arc routing problem: Lower bound and metaheuristic". Transportation Science, 44: 206–220.
Belfiore P.(2009). "Scatter search for a real-life heterogeneous fleet vehicle routing problem with time windows and split deliveries in Brazil". European Journal of Operational Research, 199: 750–758.
Berbotto L.(2013). "A Randomized Granular Tabu Search heuristic for the split delivery vehicle routing problem". Annals of Operations Research, 1-21.
Boudia M.(2007). "An effective memetic algorithm with population management for the split delivery vehicle routing problem". Hybrid Metaheuristics, 4771: 16–30.
Desaulniers G.(2010). "Branch-and-price-and-cut for the split delivery vehicle routing problem with time windows". Operations Research, 58: 179–192.
Derigs U.(2009). "Local search-based metaheuristics for the split delivery vehicle routing problem". Journal of the Operational Research Society, 61: 1356–1364.
Dror M.(1989). "Savings by split delivery routing". Transportation Science, 23: 141–145
Dror M.(1990). "Split delivery routing". Naval Research Logistics, 37:383–402
Frizzell PW(1995). "The split delivery vehicle scheduling problem with time windows and grid network distances". Computers & Operational Research 22(6):655–67.
Ho S.C.(2004). "A tabu search heuristic for the vehicle routing problem with time windows and split deliveries". Computers and Operations Research, 31:1947–1964
Huang M.(2012). "Models for relief routing: Equity, efficiency and efficacy". Transportation Research Part E, 48(1): 2-18.
Jin M.(2008). "A column generation approach for the split delivery vehicle routing problem". Operations Research Letters, 36: 265–270.
Lee C.G.(2006). "A shortest path approach to the multiple-vehicle routing problem with split pick-ups". Transportation Research B, 40: 265–284.
Lei H.T.(2012). "the Vehicle Routing Problem with Stochastic Demands and Split Deliveries". Information Systems and Operational Research, 52(2): 57-71
Liu Wangsheng(2011). "Two stage algorithm for split delivery vehicle routing problem". Journal of Jimei University(Natural Science). 16(1): 38-44.
Liu Wangsheng (2012). "Clustering algorithm for split delivery vehicle routing problem". Control and Decision, 27(4): 535-541.
Moreno L.(2010). "Improved lower bounds for the split delivery vehicle routing problem". Operations Research Letters, 38: 302–306.

Mota E.(2007). “A new metaheuristic for the vehicle routing problem with split demands”. Evolutionary Computation in Combinatorial Optimization, 4446: 121-129.

TAN Jiamei(2008). “Solution to Vehicle Routing Problem with Split Deliveries”. Journal of Systems & Management. 2：43-46.

Wilck IV J.H.(2012). “A Genetic Algorithm for the Split Delivery Vehicle Routing Problem”. American Journal of Operations Research, 2:207-216.

XIE Binglei(2012). “A model and algorithm to solve vehicle routing problem with split delivery”. Operations research and management science. 6: 72-76.

XIE Yi(2006). “The study of logistics vehicle routing problem with split demand”. Tongji University.

Yu Y.(2006). “Large scale inventory routing problem with split delivery: A new model and Lagrangian relaxation approach”. International Journal of Services Operations and Informatics1, 304–320.

Genetic Optimization of an Operation Scheme for the Flow Assignment Method Based on Level Classification

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Abstract: The main difference between optimization model of train operation plan under the condition which grading passengers and trains level and traditional optimization model is: the mismatch between the passengers level and the trains level will generate additional time consumption, passengers at different levels trains need to transfer. On the basis of existing research, it constructs the hierarchical transfer network; the analysis of the characteristics of a single network showed that there is no transfer arc and network cost in this network, traffic assignment problem is equivalent to the minimum stops problem. This reasearch construct a complete network flow assignment process which is considering the complexity of hybrid network, combined with the passenger travel characteristics and a single network characteristics, using layered flow assignment method to simplify the process of flow assignment. Finally, taking the Beijing-Shanghai high-speed railway as an example, calculate forecasting passenger flow and operation plan in 2015 respectively by traffic assignment method before and after simplification.

Keywords: Passenger railway line; Level classification of passengers and trains; Operation plan; Network flow assignment.

1 Introduction

The transportation organization mode for the high-speed dedicated passenger railway in our country is trains with several speed levels running on the same line. In order to meet different kinds of passenger's transportation demands, high-speed dedicated passenger railway usually designs at least two kinds of passenger transportation product to get more social benefit and enterprise benefit. The existing research did not consider passenger's demand level, for reasons of refining market, it is necessary to study transportation products and optimization problems of train operation plan in the high-speed dedicated passenger railway under the situation of classifying passenger demands.

2 Optimization Model of Train Operation Plan

A complete optimization process of train operation plan in the high-speed dedicated passenger railway can be described as a bi-level programming problem. the upper level programming is to solve the benefit maximization problem in operation plan , the lower level programming is to assign specific operation plan of passenger flow.

The existing research can reach a typical optimization model of train operation plan in the high-speed dedicated passenger railway. the passengers are divided into two levels: high demand level and middle demand level,the trains are also divided into two grades: high grade and middle grade. After grading,the difference of the optimization model is mainly reflected in that for the same OD travel, conversion of high, mid-range passenger hour consumption are different, it can be described as:

$$\min T = \sum_{i,j,k} (x_{ijk}^1 t_{ijk}^1 + x_{ijk}^0 t_{ijk}^0) \tag{i}$$

S.t.

$$\sum_{i,j,k} x_{ijk} = N \tag{1}$$

$$\sum_{k} x_{ijk} = N_{ij} \tag{2}$$

$$n_h \le C_h \tag{3}$$

$$n_h A_0 S \le \sum_{i,j,k} x_{ijk} w_{kh} \le n_h A_0 \tag{4}$$

$$x_{ijk}^0, x_{ijk}^1 \in \overline{z^-} \tag{5}$$

$$w_{kh} \in \{0,1\} \tag{6}$$

From formula (i): $\min T$ is the objective function; x_{ijk}^1, x_{ijk}^0 is the number of passengers in high and middle grade who select travel scheme *k* (origin -destination is station *i,station j*); t_{ijk}^1, t_{ijk}^0 is equated hour consumption in high and middle grade passengers who select travel scheme *k*(origin -destination is station *i,station j*); N is the total number of passengers to send; N_{ij} is the amount of passengers in origin -destination; n_h is the number of trains in interval *h*; C_h is the carrying capacity in interval *h*; A_0 is rated carrying passengers number; S is break-even attendance; w_{kh} is 0-1 variable(when the Kth operation plan include interval h, w_{kh}=1,or w_{kh}=0)

After grading passengers and trains level,the key influence factor is the mismatch between the passengers level and the trains level generating additional time consumption, it can be simply describe as αt_{ijk}^0 or βt_{ijk}^1, the number of α and β is determined on the basis of the condition of the line.

3 Transfer Network And Traffic Assignment Process

3.1 Construction of transfer network

For the specific operation scheme, it can be constructed as a single source and single sink, non-node-cost transfer network and assign flow by minimum path algorithm. After grading passengers and trains level, changes in the network are as follows:

(1)Trains at different levels run in the same interval can not be combined, it will largely increase the number of transfer arc;

(2)Consumption parameter at running arc is a two dimensional vector, its component correspond to the equated hours that high, mid-range passenger spend in taking trains.

Obviously, after grading passengers and trains level, the scale of transfer network greatly increase. Considering the the problem of computational efficiency, it is necessary to deal with a simplified flow assignment process.

3.2 Simplify the design of the whole process of the flow assignment

It is difficult to accept the extra expense from the mismatch of trains and passengers,so the first step should come to the single network construction, then put the passengers into the corresponding level network by assigning flow.

In a complex network consisting of two levels trains, high-grade passenger's travel behavior is divided into four cases: using high-grade trains to transport derectly, using high-grade trains to interchange, coordinating high-grade and low-grade trains to transport, using high-grade trains to transport derectly or interchange. From high-grade passengers' properties, scheme of using high-grade trains to transport derectly is clearly superior to other schemes, so the high-level passengers can assign priority to high-grade network, the high-level passengers can also assign priority to low-grade network.

Giving priority to assign a certain level of passenger flow to the corresponding level of traffic in a single network greatly simplifies the problem:

(1)In a single network, for the same OD flow, passengers need not consider the transfer, there is no transfer arc.

(2)All kinds of direct transportation schemes have the same origin build-up time, it can not be considered.

(3)If the trains are at the same levels, it means the passengers' travel time and the fare are same, the fare on the running arc can also no be considered.

In summary, when carried out directly with the flow in a single network, the shortest path corresponds to the minimum stoppings and the problem is greatly simplified.

The multi-level flow assignment process is as follows:

(1)Construct a high-level trains' single operation network and carry on through flow assignment to high-level passengers;

(2)Construct a low-level trains' single operation network and carry on through flow assignment to low-level passengers;

(3)Delete the through passenger and full loading trains,modify the trains' corresponding capacity which is failure to meet the requirements of train capacity.

(4)Construct a complex transfer network to assign remaining passengers again.

Sequencing problem should be considered in the network flow assignment.

Long-distance passengers flow should be given priority in allocation, it can reduce train loss and allocate passenger flow into trains as much as possible. After it, trains or operation schemes can be adjusted according to the presence situation of the loss section. then it comes to re-assign flow. Thus, during the whole flow assignment process, it need to carry on human external control to flow assignment progress to prevent it entry into the "dead cycle".

In the network flow assignment, specific flow assignment process as shown in Figure 1.

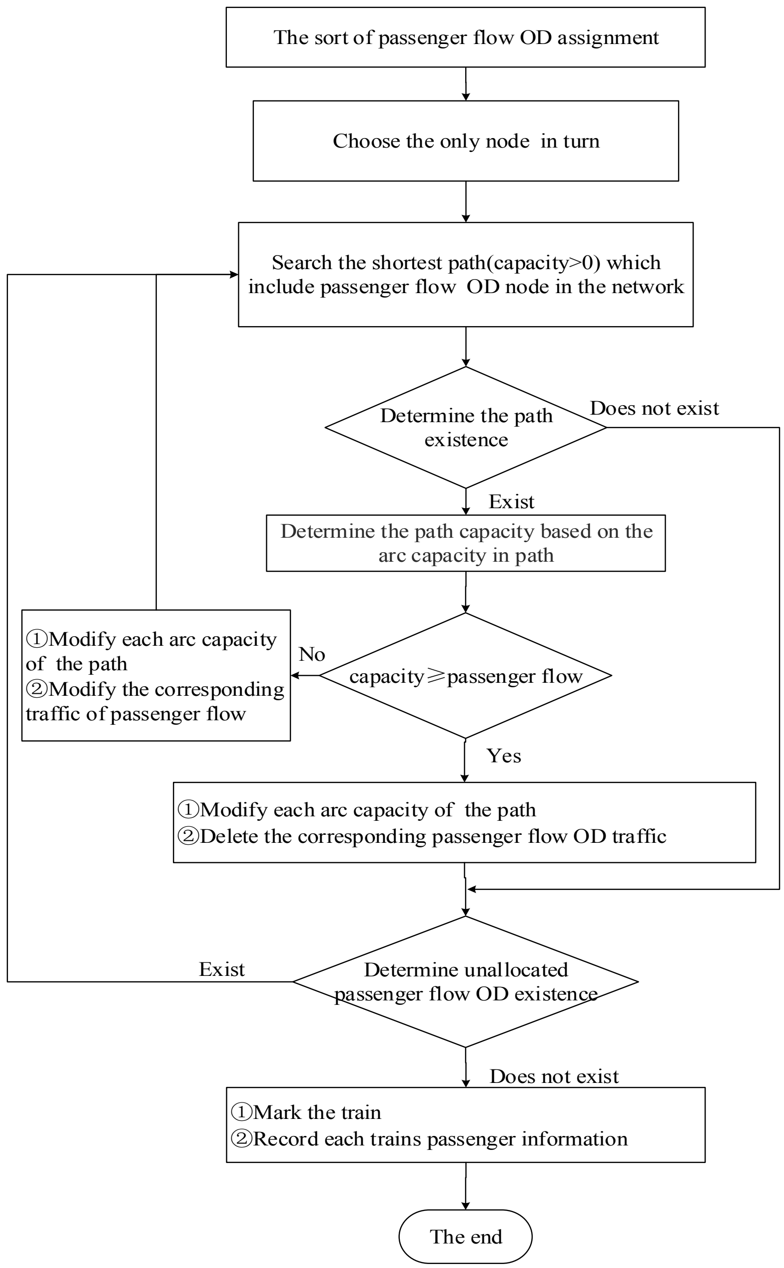

Figure 1. Network traffic assignment process diagram

4 Calculation Of Actual Case

Taking the Beijing-Shanghai high-speed railway as an example, the predicted passenger flow and operation scheme are shown in table 1.

Use self-developed software to carry on the distribution of passenger flow respectively through the non-simplified complex network and simplified transfer network(α=β=1.2), the main indicators are shown in table 2.

Table 1 The Beijing-Shanghai high-speed railway predicted passenger flow and operation scheme in 2015

Predicted passenger flow volume		Operation scheme	
300km/h	200km/h	High speed train	Middle speed train
3982 million/Single direction	742 million/Single direction	94 pairs	20 pairs

Table 2 The main indicators comparison of the flow assignment simplification before and after

	Flow assignment time	Seat utilization	Passengers' time consumption per day
Before flow assignment	7min30s	86.56%	685384.81h
After flow assignment	1min25s	85.7%	673126.83h

Table 2 shows that, the simplified flow assignment results did not produce significant changes, while greatly reducing the computation time.

5 Conclusion

This research had put forward the discussion and the example verification for the flow assignment after classifying the level of passengers and trains, but it didn't carry on the thorough analysis and exploration to optimization and adjustment of trains or operation plan after producing waste section during flow assignment, human external control method in flow assignment process. These two aspects is very important for the flow assignment and the optimization's effect, and it is the focused research direction for the next phase.

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References

Deng Lianbo, Shi Feng, and Qin Jin. (2004). "Passenger Assignment on the Base of Passenger Train Plan." *China Railway Publishing House*, Beijing, 47-51.

Deng Lianbo. (2007). "Study on the Optimal Problems of Passenger Train Plan for Dedicated Passenger Traffic Line." Central South University.

Dong Shouqing, Yan Haifeng, and Li Qunren. (2012). "Research on Genetic Optimization of Operation Scheme For PDL Trains Based on Network Flow Distribution ." *China Railway Science*, 2012, 33(4):105-111.

Jing Nan, and Shi Feng. (2007). "The Study on Optimization Decision Making Model of Passenger Traveling Plan by Train." *Journal of Railway*, 29(3), 13-18.

Shi Feng, and Deng Lianbo. (2004). "Optimal design of passenger transfer network." *Journal of Railway Science and Engineering*, 1(1), 78-82.

Zhang Yiying. (2009). "Optimal design of passenger transfer network." *Journal of Southwest Jiaotong University* , 44(4), 517-522.

Effects of a Single Price Coefficient Change on the Test Number in a Transportation Problem

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Abstract: Price coefficient changes will affect optimal solution of transportation problem. This paper regards using potential method to solve balanced transportation problem as the research target, focusing on the study of the effects on the optimal solution in the case of single price coefficient change. The study found that the change of non-base variable and base variable price coefficient will cause the change rule of potential and test number, and proved a series of theorems and corollaries. On this basis, the paper gives a simple algorithm to count new test number aimed at single price coefficient change. At the same time provided mathematical analysis.
Keywords: Transportation problem; Price coefficient; Potential method; Test number.

1 Introduction

The transportation problem (Wang Guangmin, 2011) is described below. Yield of each production sites $A_i (i = 1,2,\cdots,m)$ is a_i, and sales volume of each sales locations $B_j (j = 1,2,\cdots,n)$ is b_j. The unit price from A_i to B_j comes to c_{ij}. Then how can we get the scheduling scheme $X^* = \{x_{ij}^*\}_{m\times n}$ to minimize the total freight. It can be described as

$$z = \min\left\{\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij} \middle| \left(\sum_{j=1}^{n} x_{ij} = a_i\right) \cap \left(\sum_{i=1}^{m} x_{ij} = b_j\right) \cap (x_{ij} \geq 0)\right\} \quad (1)$$

After we get optimum solution of the transportation problem, because of the change of c_{ij}, we need to recalculate the optimal solution. It will take a lot of time if the order of price coefficient matrix is large. When c_{ij} changes little, it will greatly simplify the calculation if we can using the characteristics of original optimal solution to quickly judge the change in the optimal solution.

Through the virtual place of origin or sell, all the transportation problem can be turned into balanced transportation problem. This paper focused on the study of the effects on the optimal solution in the case of single c_{ij} change when using potential method to solve balanced transportation problem. For the linear programming problem (Zeng Meiqing, 2010), we have got a mature theory (Le Xiaoyang, 1990 Wang Huanxiong, 1984). Transportation exhibits a special problem of linear programming. When this occurs, we can get a similar theory.

2 Analysis on change of non-base variable price coefficient

When using the potential method to solve the balanced transportation problem, we can get u_i, v_j according to $\sigma_{ij}^B = c_{ij}^B - (u_i^B + v_j^B) = 0$ (Li Weizheng, 2005), when c_{ij}^N corresponding to the non-base variable changes, because c_{ij}^B is invariant, all the u_i and v_j will not change. Then

Property **1:** In balanced transportation problem, if price coefficient c_{st} of non-base variable changes into c'_{st}, test number σ_{st} will change into $\sigma'_{st} = c'_{st} - (u_s + v_t)$, the rest test number stay unchanged.

So, when a certain c_{ij}^N changes, we can use property 1 to recalculate the corresponding test number of non-base variable. If the test number is still not negative, the optimal solution is unchanged, otherwise, we can use closed-loop method take the non-base variable as in-variable to adjust.

3 Analysis on change of base variable price coefficient

In order to describe convenience, definite as follows:

Definition: For A and B, if A changes into A±a, and B also changes into B±a, then call A is the same change with B. If A changes into A±a, but B changes into B∓a, then call A is the opposite change with B.

Through the research of price coefficient change, we can get the following theorem and corollary:

Theorem **1**: When using potential method to solve standard transportation problem, only if the price coefficient c_{pq} of base variable changes, then

(1)If there is only one base variable x_{pq} in the *q* column and $u_p = 0$, then v_q is the same change with c_{pq}, the rest u_i and v_j are unchanged.

(2)If there is only one base variable x_{pq} in the *p* line and $v_q = 0$, then u_p is the same change with c_{pq}, the rest u_i and v_j are unchanged.

Proof: Because x_{pq} is a base variable, $\sigma_{pq} = 0 = c_{pq} - (u_p + v_q) \Rightarrow c_{pq} = u_p + v_q$ and $u_p = 0 \Rightarrow c_{pq} = v_q$.Based on $\sigma_{ij}^B = c_{ij}^B - (u_i^B + v_j^B) = 0$, we get (*m*+*n*-1) equations. Only one base variable x_{pq} in the *q* column means except $c_{pq} = v_q$ the rest (*m*+*n*-2) equations exclude v_q.Then according to the (*m*+*n*-2) equations and $u_p = 0$,we can get the unique solution of (*m*+*n*-1) potentials exclude v_q.The solution is nothing about v_q. So, theorem 1(1) is proofed. Similarly to theorem 1(2).

Corollary **1:** When using potential method to solve standard transportation problem, in the table of optimal solution, if there is only one base variable x_{pq} in the *q* column and its price coefficient c_{pq} changes into $c'_{pq} = c_{pq} + a_1$, only test number of non-base variable in the *q* column will change and be the opposite change with c_{pq}.

Proof: Make $u_p = 0$.According to the theorem 1 we find that when $c'_{pq} = c_{pq} + a_1$, then $v'_q = v_q + a_1$, the rest potentials will be unaltered. According to the equation $\sigma_{ij} = c_{ij} - \left(u_i + v_j\right)$, we find that $\sigma'_{ij} = c_{ij} - (u_i + v'_j) = c_{ij} - (u_i + v_j) = \sigma_{ij}(j \neq q)$ and $\sigma'_{iq} = c_{iq} - (u_i + v'_q) = c_{iq} - (u_i + v_q + a_1) = \sigma_{iq} - a_1$. So, corollary 1 is proofed.

***Theorem* 2**: When using potential method to solve standard transportation problem, only if the price coefficient c_{pq} of base variable changes, then

(1)Let $u_p = 0$, then v_q is the same change with c_{pq}. If there are (*b*+1) base variables in the *q* column respectively in the line $p, p_1, p_2, \cdots, p_b$, then u_{p_i} are the opposite change with c_{pq}. And if there is only one base variable in the $p_i (i = 1, 2, \cdots, b)$ line, then the rest potentials will be unaltered except u_{p_i} and v_q.

(2)Let $v_q = 0$, then u_p is the same change with c_{pq}. If there are (*b*+1) base variables in the *p* line respectively in the column $q, q_1, q_2, \cdots, q_b$, then v_{q_j} are the opposite change with c_{pq}. And if there is only one base variable in the $q_j (j = 1, 2, \cdots, b)$ column, then the rest potentials will be unaltered except u_p and v_{q_j}.

Proof: Because x_{pq} is a base variable, $\sigma_{pq} = 0 = c_{pq} - (u_p + v_q) \Rightarrow c_{pq} = u_p + v_q$ and $u_p = 0 \Rightarrow c_{pq} = v_q$. If c_{pq} changes into $c'_{pq} = c_{pq} + a_1$, $v'_q = v_q + a_1$, According to $c'_{p_i,q} - (u'_{p_i} + v'_q) = 0$, then $u'_{p_i} = c'_{p_i,q} - v'_q = c_{p_i,q} - v_q - a_1 = u_{p_i} - a_1$ .So u_{p_i} is the opposite change with c_{pq}. Based on $\sigma^B_{ij} = c^B_{ij} - (u^B_i + v^B_j) = 0$, we get (*m*+*n*-1) equations. Only one base variable in the $p_i (i = 1, 2, \cdots, b)$ line means among the (*m*+*n*-1) equations there will be (*m*+*n*-*b*-2) equations exclude u_{p_i} and v_q .Then according to the (*m*+*n*-*b*-2) equations and $u_p = 0$,we can get the unique solution of (*m*+*n*-*b*-1) potentials exclude u_{p_i} and v_q .The solution is nothing about u_{p_i} and v_q. So, theorem 2(1) is proofed. Similarly to theorem 2(2).

***Corollary* 2**: When using potential method to solve standard transportation problem, in the table of optimal solution, if there are (*b*+1) base variables in the *q* column respectively in the line $p, p_1, p_2, \cdots, p_b$ and only one base variable in the $p_i (i = 1, 2, \cdots, b)$ line, only c_{pq} changes, then only test number of non-base variable in the *q* column and the $p_i (i = 1, 2, \cdots, b)$ line will change, ones in the *q* column is the opposite change with c_{pq},and others in the p_i line is the same change with c_{pq}.

Proof: Make $u_p = 0$.According to the theorem 2(1) we find that when $c'_{pq} = c_{pq} + a_1$, then $v'_q = v_q + a_1$, $u'_{p_i} = u_{p_i} - a_1$ and the rest potentials will be unaltered. According to the equation $\sigma_{ij} = c_{ij} - \left(u_i + v_j\right)$, we find that $\sigma'_{ij} = c_{ij} - (u_i + v'_j) = c_{ij} - (u_i + v_j) = \sigma_{ij}$ ($i \neq p_i, j \neq q$), $\sigma'_{iq} = c_{iq} - (u_i + v'_q) = c_{iq} - (u_i + v_q + a_1) = \sigma_{iq} - a_1 (i \neq p_i)$,

$\sigma'_{p_i,j} = c_{p_i,j} - (u'_{p_i} + v_j) = c_{p_i,j} - (u_{p_i} - a_1 + v_j) = \sigma_{p_i,j} + a_1 (j \neq q)$.So, corollary 2 is proofed.

4 Simple algorithm

Using the above theorem, under the enlightenment of Hungarian Algorithm in assignment problem, we get a simple algorithm to calculate new test number when a single price coefficient changes.

Suppose x_{pq} is a variable and its price coefficient c_{pq} changes, make $u_p = 0$.Based on the original table of test number, take x_{pq} as the starting point and take the steps as follows:

STEP-1: Marking

① Mark √ at v_q, mark out the q column;

② In the lined column, if there are variables without marking out the rows , mark Δ at u_i in the rows for the base variables, mark out the rows, turn into③. If not, come to the end.

③ In the lined rows, if there are variables without marking out the columns, mark √ at v_j in the columns for the base variables, mark out the columns, turn back to ②. If not, come to the end.

STEP-2: Calculating new potential

All the v_j marked √ are the same change with c_{pq}, and all the u_i marked Δ are the opposite change with c_{pq}.

STEP-3: Calculating the test number of non-base variable

All the test number of non-base variable just marked out by vertical line are the opposite change with c_{pq}. All the test number of non-base variable just marked out by horizontal line are the same change with c_{pq}.The rest test number remain the same.

Usually when using potential method to solve transportation problem, we will suppose $u_1 = 0$. In order to facilitate the use of the above algorithm, it provides property 2.

***Property* 2:** When using the potential method to solve the balanced transportation problem, in the same group of base variable, sign the potential as u_i, v_j when making $u_1 = 0$, u'_i, v'_j when making $u_p = 0 (p \neq 1)$, u''_i, v''_j when making $v_q = 0$,then

(1)If $u_p = a_1$ when making $u_1 = 0$, then there will be $u'_i = u_i - a_1$ and $v'_j = v_j + a_1 (\forall i, j)$ when making $u_p = 0$;

(2)If $v_q = a_1$ when making $u_1 = 0$, then there will be $u''_i = u_i + a_1$ and $v''_j = v_j - a_1 (\forall i, j)$ when making $v_q = 0$.

5 Example

A transportation problem is showed as follows in table 1, using table working method we get the table of test number and optimal solution as in table 2. Suppose price coefficient of base variable x_{43} changes into $c'_{43} = 5$.

Table 1.production and sales volume and unit tariff

Terminal / Origin	B_1	B_2	B_3	B_4	B_5	B_6	Sales Volume
A_1	10	20	5	9	10	0	6
A_2	2	10	8	30	6	0	5
A_3	1	20	7	10	4	0	2
A_4	8	6	3	7	5	0	9
Yield	4	4	6	2	4	2	22

Table 2.table of test number and optimal solution

Terminal / Origin	B_1	B_2	B_3	B_4	B_5	B_6	u_i
A_1	7	12	0 ④	0	3	0	0
A_2	0 ④	3	4	22	0 ①	1	-1
A_3	1	15	5	4	0 ②	3	-3
A_4	7	0 ④	0 ②	0 ②	0 ①	2	-2
v_j	3	8	5	9	7	0	—

Note: The circle number at the upright means optimal solution

(1)According to the property 2, we can calculate the change of test number in table 2 when making $u_4 = 0$, then we get table 3.

Table 3. table of test number making $u_4 = 0$

Terminal / Origin	B_1	B_2	B_3	B_4	B_5	B_6	u_i
A_1	7	12	0	0	3	0	2
A_2	0	3	4	22	0	1	1
A_3	1	15	5	4	0	3	-1
A_4	7	0	0	0	0	2	0
v_j	1	6	3	7	5	-2	—

(2)Circle x_{43} means taking this as the starting point for marking, then we get table 4.

Table 4. table of optimal solution after marking

Terminal / Origin	B_1	B_2	B_3	B_4	B_5	B_6	u_i
A_1	-	-	4	-	-	2	Δ
A_2	4	-	-	-	1	-	-
A_3	-	-	-	-	2	-	-
A_4	-	4	②	2	1	-	-
v_j	-	-	√	-	-	√	—

(3)According to the simple algorithm, u_1 which marked Δ should reduce 2 and v_3, v_6 which marked √ should add 2.Then test number $\sigma_{23}, \sigma_{33}, \sigma_{26}, \sigma_{36}, \sigma_{46}$ should reduce 2 and $\sigma_{11}, \sigma_{12}, \sigma_{14}, \sigma_{15}$ should add 2.The table of new test number as in table 5.

Table 5. table of new test number

Origin \ Terminal	B_1	B_2	B_3	B_4	B_5	B_6	u_i
A_1	9	14	0	2	5	0	0
A_2	0	3	2	22	0	-1	1
A_3	1	15	3	4	0	1	-1
A_4	7	0	0	0	0	0	0
v_j	1	6	5	7	5	0	—

(4)Because table 5 exists a negative σ_{26} , the optimal solution will change.

(5)Take x_{26} as in-variable, using closed-loop method to continue calculating until get the optimal solution.

6 Conclusions

In real life, the scale of transportation problem is large, and price coefficient changes frequently. If we already get optimum solution, we can use simple algorithm easily get the table of new test number in the new price coefficient, then judge whether the optimal solution is changed or not.

However, the simple algorithm in this paper is aimed at single price coefficient, and it does not consider the condition that several price coefficients change together. So this will be the future research direction.

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References

Li Weizheng, Guo Yaohuang. (2005). *Operation Research*. Tsinghua University press. Beijing, 83-86

Le Xiaoyang, Li Songren, Jia Chunlin, (1990). "Sensitivity analysis models of linear programming." *Central South Institute of mining and metallurgy,* 21(6), 602-609

Wang Huanxiong, (1984). "Sensitivity analysis and application of linear programming." *Jilin Institute of Chemical Technology.* 3, 54-68

Wang Guangmin, Ma Linmao, Li Lanlan, (2011). "The algorithm and broader research for solving transportation problems in operation research." *Yangtze University (Nat Sci Edit),* 8(10), 1-4

Zeng Meiqing, Tian Dagang, (2010). "The algorithm overview of linear programming." *Science Technology and Engineering,* 10(1), 152-159

Optimal Algorithm of the M_3 Scheduling Problem

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Abstract: M_3 scheduling problem is one of the most difficult problems in the world in the field of operational research. Analysis of the problem suggests that all the processing time is equal to both the processing time of all parts and floor time on the third sets of machine tools. Correspondingly the minor floor time on the third machine tools matches the fewest total time. According to such thoughts to reduce the floor time of the third machine as much as possible, we design a general algorithm for M_3 scheduling problem, and give the algorithm steps. Finally, through examples we tested and verified the feasibility of the algorithm.
Keywords: Scheduling problem; 3 sets of machine tools; Algorithm; Example.

1 Problem Description

The issue of job-shop scheduling can be simply described as: n workpieces (J_1,J_2,…,J_n) are operated on m machine tools(M_1,M_2,…M_m)at the same time,each workpiece(J_i) has n operations O_{i1},O_{i2},…,O_{in}, and the processing time is v_{ij} when the operation O_{ij} comes; workstages should operate at row and work out once where one machine tool can only processs one product and one product cannot be processed on two or more machines at the same time. In the condition that mentioned above, how can shorten the time when the last workpiece completed?

2 Literature review

General, the subclass of this issue---having the same workstages among the workpieces, which be called scheduling problem. The complexity about this problem is NP-Hard, because if n or m is bigger, it cannot be solved by Exhaustive Method[1]. In 1954 Johnson solved the problem of M_2 scheduling problem by putting forward the optimal algorithm of two machines(m=2) processing n of workpieces[2]. However, the problem of scheduling problem when M_k(k≥3) hasn't be reached, which is the puzzle in the world in the field of operational research.

This paper tries to take Matrices Method to explore optimal algorithm of M_3 scheduling problem.

3 Algorithm Steps

In order to conveniently research, hypothetically n of workpieces are processed on the machine tools A,B,C at row. And the processing time needed on the A respectively are a_1,a_2,…,a_n, and that needed on the B respectively are b_1,b_2,…,b_n, and that needed on the C respectively are c_1,c_2,…,c_n. We define the matrix operation time as $V=\{v_{ij}\}_{n\times 3}$, and $v_{i1}=a_i$, $v_{i2}=b_i$, $v_{i3}=c_i$.

Analyzing this problem can get : all the processing time needed to finish all parts is equal to sum of the time spended on the machine tool C to process all parts and the floor time on it; the less floor time on machine C , the less time needed in whole stages. Therefore, the whole time can be cut to the least if we take the method to reduce the floor time on the machine C.

Following the idea, the arithmetic of M3 scheduling problem can be described as below.

STEP1: Initialization,let p=0.

Define set $T^p = \phi$,express none workpiece has been selected; $P^p = \{1,2,\cdots,n\}$, express n workpieces hasn't been selected. Computing matrix $M^p = \{m_{ij}^p\}_{n\times 6}$,line i express workpiece J_i; column 1(2) express start(end) time when J_i is operated on machine tool A, column 3(4) express start(end) time when J_i is operated on machine tool B, column 5(6) express start(end) time when J_i is operated on machine tool C;and $\forall i = 0 \bigcup \forall j = 0 \Rightarrow m_{ij}^p = 0$,

$$m_{ij}^p = \begin{cases} m_{i,j-1}^p & (j=1, 3, 5) \\ m_{i,j\text{-}1}^p + v_{i,j/2} & (j=2, 4, 6) \end{cases} \tag{1}$$

STEP2: Determine the state variables.

Define the state variables $r_p = y_{p\text{-}1}$,and $y_{\text{-}1}=0$;waiting time $\min\{m_{i5}^p - m_{r6}^p\} = t_{y_p}$,if t_{y_p} not only, determined in accordance with the following rules:

(1) $\min\{|m_{i4}^p - m_{r6}^p|\} = t_{y_p}$,if t_{y_p} still not only,turn to (2);

(2) $\max\{m_{i6}^p\} = t_{y_p}$, if t_{y_p} still not only,choose anyone of them.

STEP3: Matrix calculation,let $p= p+1$.

$T^p = T^{p-1} \bigcup \{r_p\}$, $P^p = P^{p-1} \wedge \{r_p\}$, element of M^p

$$m_{ij}^p = \begin{cases} m_{ij}^{p-1} & (i \in T^p) \\ \max\{m_{i,j-1}^p,\ \ m_{r,j+1}^p\} & (i \notin T^p) \bigcap (j=1, 3, 5) \\ m_{i,j\text{-}1}^p + \mathrm{v}_{i,j/2} & (i \notin T^p) \bigcap (j=2, 4, 6) \end{cases} \tag{2}$$

STEP4: Matrix iterative.

Judge ?$(P^p = \phi)$;yes, turn to STEP5;no,turn to STEP2.

STEP5: Output result.

Output the optimal processing sequence： $(J_{y_0}, J_{y_1}, J_{y_2}, \cdots, J_{y_{n-1}})$,the total time: $\sum_{i=1}^{n} \mathrm{c}_i + \sum_{p=0}^{n\text{-}1} t_{y_p} = m_{y_{n\text{-}1}6}^{n\text{-}1}$.

The computational steps of M_3 scheduling problem is shown in Figure 1.

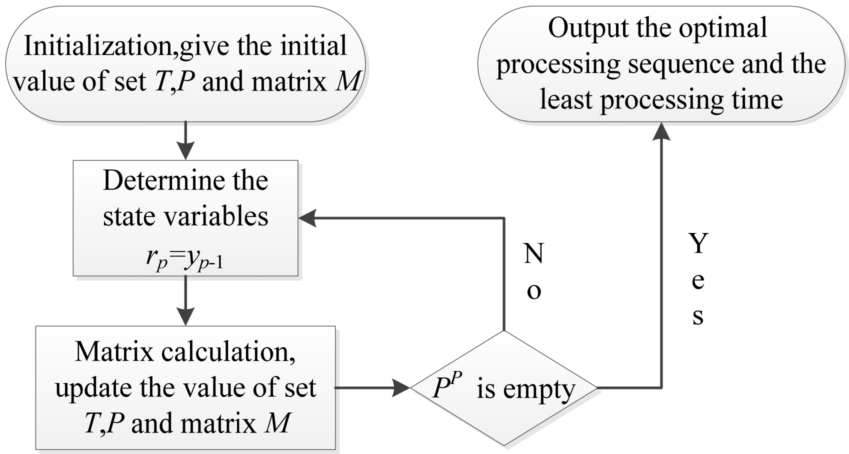

Figure 1. computational steps of M₃ scheduling problem

4 Example

The processing time of workpieces J_1,J_2, J_3, J_4, J_5, J_6 on machine tools A,B,C can form a time matrix as

$$V=\begin{pmatrix}3&7&6\\6&7&3\\6&5&9\\2&6&2\\8&3&5\\9&4&4\end{pmatrix}。$$

(7) p=0, $r_0=y_{-1}=0$, $T^0=\phi$, $P^0=\{1,2,3,4,5,6\}$,

$$M^0=\begin{pmatrix}0&3&3&10&10&16\\0&6&6&13&13&16\\0&6&6&11&11&20\\0&2&2&8&8&10\\0&8&8&11&11&16\\0&9&9&13&13&17\end{pmatrix},\quad \min\{m_{i5}^0-m_{06}^0\}=t_{y_0}=t_4=8;$$

(2) p=1, $r_1=y_0=4$, $T^1=T^0\bigcup\{r_1\}=\{4\}$, $P^1=P^0\wedge\{r_1\}=\{1,2,3,5,6\}$,

$$M^1=\begin{pmatrix}2&5&8&15&15&21\\2&8&8&15&15&18\\2&8&8&13&13&22\\0&2&2&8&8&10\\2&10&10&13&13&18\\2&11&11&15&15&19\end{pmatrix},\quad \min\{m_{i5}^1-m_{46}^1\}=t_{y_1}=t_3=5;$$

(3) p=2, $r_2=y_1=3$, $T^2=T^1\bigcup\{r_2\}=\{4,3\}$, $P^2=P^1\wedge\{r_2\}=\{1,2,5,6\}$,

$$M^2=\begin{pmatrix}8&11&13&20&22&28\\8&14&14&21&22&25\\2&8&8&13&13&22\\0&2&2&8&8&10\\8&16&16&19&22&27\\8&17&17&21&22&25\end{pmatrix},\quad \min\{m_{i5}^2-m_{36}^2\}=t_{y_2}=t_2=0;$$

(4) p=3, $r_3=y_2=2$, $T^3=T^2\cup\{r_3\}=\{4,3,2\}$, $P^3=P^2\wedge\{r_3\}=\{1,5,6\}$,

$$M^3=\begin{pmatrix}14&17&21&28&28&34\\8&14&14&21&22&25\\2&8&8&13&13&22\\0&2&2&8&8&10\\14&22&22&25&25&30\\14&23&23&27&27&31\end{pmatrix},\quad \min\{m_{i5}^3-m_{26}^3\}=t_{y_3}=t_5=0;$$

(5) p=4, $r_4=y_3=5$, $T^4=T^3\cup\{r_4\}=\{4,3,2,5\}$, $P^4=P^3\wedge\{r_4\}=\{1,6\}$,

$$M^4=\begin{pmatrix}22&25&25&32&32&38\\8&14&14&21&22&25\\2&8&8&13&13&22\\0&2&2&8&8&10\\14&22&22&25&25&30\\22&31&31&35&35&39\end{pmatrix},\quad \min\{m_{i5}^4-m_{56}^4\}=t_{y_4}=t_1=2;$$

(6) p=5, $r_5=y_4=1$, $T^5=T^4\cup\{r_5\}=\{4,3,2,5,1\}$, $P^5=P^4\wedge\{r_5\}=\{6\}$,

$$M^5=\begin{pmatrix}22&25&25&32&32&38\\8&14&14&21&22&25\\2&8&8&13&13&22\\0&2&2&8&8&10\\14&22&22&25&25&30\\25&34&34&38&38&42\end{pmatrix},\quad \min\{m_{i5}^5-m_{16}^5\}=t_{y_5}=t_6=0;$$

(7) p=6, $r_6=y_5=6$, $T^6=T^5\cup\{r_6\}=\{4,3,2,5,1,6\}$, $P^6=P^5\wedge\{r_6\}=\phi$, algorithm finished. Output the optimal processing sequence:(J_4,J_3,J_2,J_5,J_1,J_6) ,the total time: $\sum_{i=1}^{6}c_i+\sum_{p=0}^{5}t_{y_p}=m_{66}^5=42$.

5 Conclusion

Although in this paper the example get an optimal solution, the strict proof about this cannot be offered, so this arithmetic is not the optimal algorithm technically. Through the steps of algorithm, it can be seen that this algorithm is able to apply to the job-shop scheduling problem of M_k（k>3）. Compared with the traditional critical path, the effectiveness of this algorithm remains to be improve.

Reference

Xing Wenxun, Xie Jinxing. (1999). Modern optimization methods. *Tsinghua University Press,* Beijing, 80-88.

Wang Ciguang. (2010). “Transportation system optimization theory and method Handouts.” *Southwest Jiaotong University,* Chengdu.

Huang Xiyue. (2005). Modern intelligent algorithm theory and application. *Science Press,* Beijing

Qian Songdi. (2005). Operations research. *Tsinghua University Press*, Beijing, 80-88.

Train Combination Model of a Passenger Train Plan for a High-Speed Railway

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Abstract: According to the idea of combined train plan, this paper optimizes the train plan through the mathematic modeling. It aims to adjusting the sub problems of the problem, which transforms the problem of how to make the qualified trains combine to reduce the number of train and improve the train attendance into a solution problem for bi-objective programming model. Finally, an example is given to prove the feasibility and validity of the model and the algorithm, providing effective support for intelligent development of train scheme optimization for high-speed railway.
Keywords: High-speed railway; Train plan; Plan optimization; Train combination.

1 Introduction

The operation scheme of high-speed railway station is directly related to the level of high-speed railway transport services and the obtained economic benefits, reflecting the railway passenger transportation management strategy and service strategy. The reasonable train operation scheme helps to improve the economic benefit of transportation enterprises, but also facilitate passenger travel, and enhance the competitiveness of the high-speed railway market, so it is necessary to make the in-depth study on the problem of optimizing scheme of high-speed railway train.

According to the Japanese Shinkansen high-speed train plan, they propose the idea of merging-type passenger train plan, and deeply analyze the impact of high-speed railway transportation organization. It is concluded that the combined train scheme has obvious advantage, also the negative influence can be controlled by taking the relevant measures. Therefore, along this idea, enriching the merging connotation of trains at the same time, and further researching on the train combination problem in the process of optimizing train scheme of high-speed railway, this paper puts forward to the mathematical model of solving the problem and designs the special algorithm which is easy to realize on a computer.

2 Assumptions and related definitions

2.1 Assumptions

(1)The assumption on initial train scheme

This paper studies only the combined problems in the process of optimizing train scheme of high-speed railway, so the initial plan of needing be optimized high-speed railway train has been completed by other means, including train species number contained in the proposal, various types of train route, stop scheme, number of the train and direction, which all have been informed.

(2) An uncertainty hypothesis on passenger assignment result

This hypothesis on the initial train operation scheme as the optimization object has completed the passenger flow distribution link and detailed information of each passenger train services needed are known, including the branch number of service passenger flow, OD and the number of passengers etc.

(3)Train personnel quota assumption

Following the "thought of simplified", the train in the assumptions uses unified train personnel, and train personnel value has been informed through other means.

(4) Deterministic hypothesisof passenger choice

This assumption of all the passengers travel choice have been determined by the passenger flow assignment results, and the merger would not cause any train passenger selection changes.

(5) Closed system hypothesis

This paper's studies are not related to the macro effects of the high-speed railway passenger train plan, so the system formed by the research problem is closed, namely the state change of the system will not have any influence on the environment, especially not to attract outside passenger flow and not cause passenger flowing from the system to the outside world.

2.2 Parameter description

N representsthe train number of initial operation scheme of high-speed railway train; n_i represents the number of stationon the train running path, the collection $S_i = \{1, 2, \cdots, n_i\}$ shows the collection of the station on the train running path, among which, the element of 1 corresponds to the start station of the train, n_i corresponds to the end station of the train,other elements stand for intermediate station the train pass by; L_m^{ij} represents the line length between m station and m+1station on the operation path after train i and train j are merged. P represents unified train personnel quota; f_{OD}^i shows the passengers number of riding the train i starting from the O station and arriving at the D station; h_m^i shows the number of carried passengers that the train i runs between m station and m+1 station.

2.3 Variable definition

Definite0-1 variables,the meaning is as follows:

$$x_{ij} = \begin{cases} 1 & combine\ train\ i\ and\ j \\ 0 & other \end{cases} \tag{1}$$

Among which, $i, j = 1, 2, \cdots, \mathrm{N}$, and $i \neq j$, respectively corresponding to initial train scheme in a column that contains detailed information of the train flow.

2.4 Operator definition

(1)First, definite a unary operator $\left| \bullet \right|$,calculate the number of elements of collection S, such as $|S|$.

(2)Second,denifite two unary operator,the algorithm is as follows:

$$S_i \oplus S_j = \begin{cases} 1 & \text{The direction of the train is consistent with the other train} \\ 0 & other \end{cases} \quad (2)$$

Among which, i *and* j are respectively the ordered set of the train path station, $i, j = 1, 2, \cdots, \mathrm{N}$.

In general, the related station on the high-speed railwayis only. The arrangement of station on the line can determine a sequence and form S of a totally ordered station set. The train operation cannot be divorced from the high-speed railway line, so the elements of the collection S_i or S_j must be the elements of S. According to the sequence of elements in S_i and S_j, in contrast with the sequence of elements in S, we can determine whether the array direction of elements is consistent, and then determine whether the running direction of train i and j is consistent.

3 The establishment of the model

3.1 Determination of the target function

1.With the aim of maximizing number of combined train

By merging all the train which meet the combination condition,the result is get that maximizes reducing the number of high-speed line train,reducing the daily operation organization difficulty, improving the efficiency of the high speed train of hanging line at the same time, and indirectly creating favorable conditions for reducing the number of train. Otherwise the idea of combined type passenger train plan will bemeaningless.So the target function is as follows:

$$\max Z_1 = \sum_{i=1}^{\mathrm{N}-1} \sum_{j=i+1}^{\mathrm{N}} x_{ij} \quad (3)$$

2. With the target of minimizing empty train degree

The degree of emptiness to train directly corresponds to the train attendance, reflecting the use ofmobile equipment transportation capacity and the rationality of trainoperation, its value can directly reflect the degree of passenger flow demand on train operation section. With the imaginary degree minimum as the objective to merge the trains, the transport capacity of mobile devices can be made full use, in the premise of completing the same transport task, the trains can more reasonably operate, minimizing the use of quantity and train running kilometers, thus minimizing the daily operating costs of transportation enterprises of high-speed railway and increasing the economic benefit of enterprises.So the target function is as follows:

$$\min Z_2 = \sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\sum_{m,m+1\in\left(S_i\cup S_j\right)} x_{ij}\left(\mathrm{P}-h_m^i-h_m^j\right)L_m^{ij} \tag{4}$$

3.2 Determination of the constraint conditions

1.The constraints of passengers carried between train station

The change of the number of train passengers would only occur at the station, but the number of train passengers is a fixed value in the process of running between stations.Its value should satisfy the following constraint:

$$h_m^i = \sum_{O=1}^{m}\sum_{D=m+1}^{n_i} f_{OD}^i \qquad \left(m=1,2,\cdots,n_i-1; i=1,2,\cdots,\mathrm{N}\right) \tag{5}$$

2. The constraint of train continuity

The running path of two short haul trains must overlap or connect,otherwise it may cause the merged train idling running between part of stations.

$$x_{ij} \le \left|S_i \cap S_j\right| \left(i,j=1,2,\cdots,\mathrm{N} \text{ and } i\neq j\right) \tag{6}$$

3. The directional constraints of train combining

The running direction of two row short haul trains must be consistent, otherwise it is unable to determine the direction of train operation after merging.

$$x_{ij} \le S_i \oplus S_j \left(i,j=1,2,\cdots,\mathrm{N} \text{ and } i\neq j\right) \tag{7}$$

4. Constraints of the capacity of combined trains

The sum of carried passenger between station on overlapping path of the two short haul train cannot be more than the train personnel quota, otherwise the combined train won’t be able to complete all the transportation of the two short haul train.

$$\left(h_m^i+h_m^j\right)x_{ij} \le \mathrm{P} \left(i,j=1,2,\cdots,\mathrm{N} \text{ and } \mathrm{i}\neq\mathrm{j}; m,m+1\in\left(S_i\cap S_j\right)\right) \tag{8}$$

4 Algorithm Design

The combined train model proposed in this article belongs to the double objective programming model category. The traditional approach to solve a double objective programming problem starts off by converting it to a single objective programming problem. We usually consider the calculation of satisfaction value as a single objective programming model by ignoring objective 1, since objective function 2 contains objective function 1 and is more practical to a certain degree. Due to the existence of constraint condition 3, we still cannot solve this problem using currently existing algorithms. Here we propose a newly developed quick and easy solution for satisfaction value calculation as follows, (1)Calculate and store the number of passengers of each adjacent stations for all the trains according to the passenger assignment information in the initial train operation scheme.

(2)Calculate the ordered set (***S***) for all trains according to the direction of study, then sort all the trains according to the departure station and the sequence of the elements in set ***S***.

(3)Take out No. ***l*** *trains* by order If there are trains without tag *; the algorithm ends if all trains are tagged with *.

(4)Determine if there are trains without tag**after train No. ***l+1***. If such trains exist, take out train No. ***k (k>l)*** for feasibility test of combination; if not, tag the No. ***l*** train with *and cancel out all the ** tags, then switch back to step 3.

(5)If the initial station of train No. ***k*** is ahead of or the same as the terminals of train No. ***l***, switch to step 7 for volume check; if not, then tag train No. ***k*** with ** and move on to the next step.

(6)Carry out feasibility test of combination in step 5 with the train without ** tag after train No. ***k***; if no such train exist, tag the train No. ***l*** with * and cancel out all the train tagged with **, then switch to step 3.

(7)Replace train No. ***l*** (no * tag) with the combination train No. ***k*** and train No. ***l*** if the passengers carried between the initial station of train No. ***k*** and the terminal station of train No. ***l*** do not exceed the train seating capacity, then delete train No. k, cancel out all ** tags and switch to step 3; otherwise tag the train No. ***k*** with ** then switch to step 6.

5 Application Examples

In this paper, the high speed railway train as an important part of the research of optimization scheme. By combining with other related research results, we can complete the adjustment and optimization of the specified initial scheme.

The author used the computer programming technology to achieve a complete program for high speed railway train operation plan optimization adjustment. Selecting the 2005 Beijing Shanghai High-speed Railway train plan as the initial scheme, the relevant parameters are as follows: Train staff (1060), attendance (75%), high class passenger time value (0.7) and the corresponding price coefficient(0.3), Intermediate passenger time value (0.3) and the corresponding price coefficient(0.7). after simulating, create a new train plan which contains some data as shown in Fig.1. Some parts index numbers as shown in table 1.

After comparison and optimization of methodology and index, we observed statistical significant improvement of efficiency with the reduction of 7 pairs of trains in operation, in which 6 less pairs of trains required in operation distance between 200 and 500 km, 4 less pairs of trains required in operation distance between 500 and 1000 km, 2 less pairs of trains required in operation distance between 1000 and 1500 km, however 5 more pairs of trains required if the operation distance exceeds 1500 km, On the other hand, the overall efficiency of seats utilization increases from 72.25%to 87.06%, in which the efficiency increases from 71.63% to 89.77% in high-speed trains while the efficiency increases from 73.13% to 75.81% in low-speed trains. We demonstrated that the new model proposed can significantly improve the efficiency of train operation by reducing the void time which leads to increase revenue of railway companies, it works even better on those with high speed trains with higher ticket price.

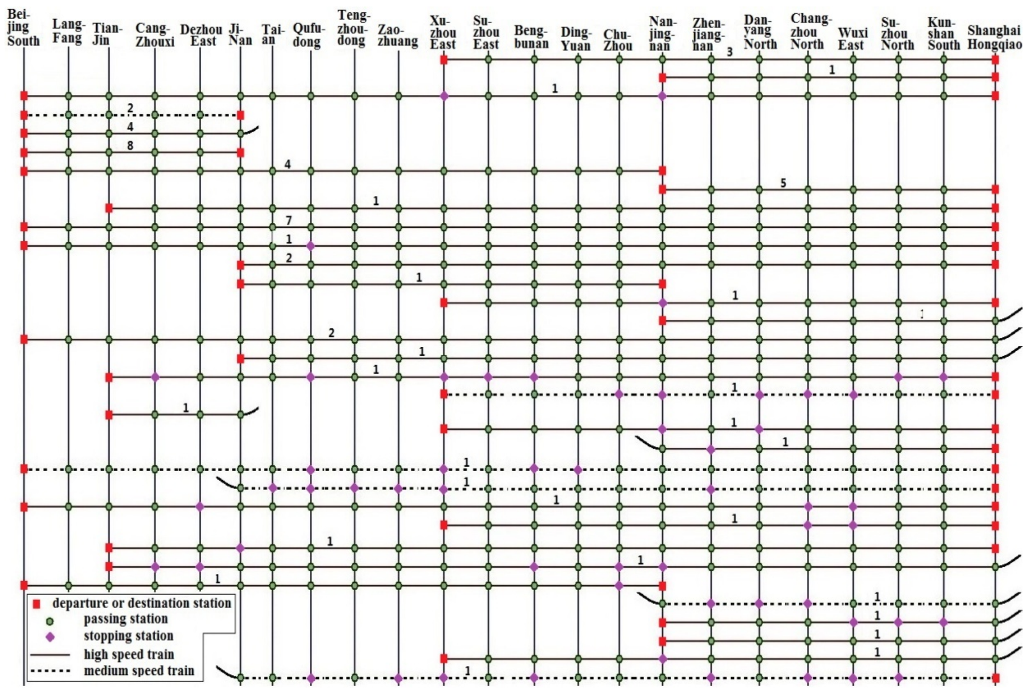

Figure 1. Part of the new train plan

Table 1. The index of operation scheme

The number of trains in operation		
	Before optimization	After optimization
Medium speed train	20	21
High speed train	102	92
The train operation in high speed railway line	102	90
Running distance		
200~500km	25	19
500~1000km	36	31
1000~1500km	53	50
more than 1500km	8	13

6 Conclusions

In this paper, by creating a model and algorithm, using the computer programming to realize the optimization and adjustment of a operation plan. Through the example of calculation, it almost certainly that the model and algorithm are feasible and easy to implement, basically achieve the consolidation purposes.So it improving the high-speed railway train operation plan optimization theory and Promoting the development of intelligent transportation organization.

Acknowledgement

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References

YAN Haifeng(2007). " Study on the optimal problems of passenger train plan for dedicated passenger traffic line." *China Academy of Railway Sciences Press. Beijing.*

YAN Haifeng, DONG Shouqing and LI Qunren(2008). " Comprehensive review on optimization of train running scheme of dedicated passenger railways."Railway Transport and Economy, 30(5): 69-72.

YAN Haifeng(2012). "The optimizationof passenger train plan for dedicated passenger traffic line." Southwest Jiaotong University press. Chengdu.

Passenger Transfer Volume Prediction Method of an Urban Comprehensive Passenger Transport Hub

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Abstract: Passenger transfer volume size determines the construction scale and transfer mode of urban comprehensive hub. From the factors which influence passengers to transfer to analysis the transfer requirements of large-scale comprehensive passenger transport hub, the main factors influencing the passenger transfer mode selection characteristics can be summarized as traffic modes, the traveler characteristics and travel characteristics from three aspects. This paper compares the traditional urban comprehensive passenger transport hub with a new mode of urban comprehensive passenger transport hub in transfer type, concluded the transfer mode of comprehensive passenger transport hub and function are more diverse. The transfer between the internal and external transportation hub is actually the choice of transportation problem, it's the key point of hub transfer volume prediction. This paper considers the transfer influence factors of different people and present a simple prediction function.
Keywords: Comprehensive passenger transport hub; Transfer volume; Prediction method.

1 Introduction

Comprehensive passenger transport hub is treated as a hub which collecting a variety of passenger transport and transfer ways, the passenger transfer flow among transfer ways determines the scale and transfer mode of the hub in the very great degree. In the regard of planning and choosing a large passenger transportation hub construction scale and transfer model, not only needs to meet the needs of recent passenger distribution and transfer, but also needs to meet the development requirements of the future passenger transport. Therefore, based on analyzing the current scale of passenger transport hub passenger flow and the way of transfer characteristics to choose the reasonable method to change to the passenger volume prediction has an important guiding significance to the operation of the passenger transport hub.

At present, there are usually two kinds of transfer volume prediction at home and abroad: the four stages predict disaggregate models based on traditional; The disaggregate models based on utility theory (Wu, et al., 2013). Disaggregate models, such as Li et al. (2002) established gravity model by introducing traffic distribution principle; Tan (2013), Sun et al. (2008) established the maximum entropy model, etc. For the disaggregate model, such as Luo (2009) used Logit model calculates the trip distribution hub for passengers; Ou et al. (2010) take Hainan station transport hub as an example, using the Logit model to predict large passenger inside hub transfer behavior; Jia et al. (2009) used the disaggregate Logit model to set up and calibration transfer impedance function and set up the comprehensive passenger transport hub transfer quantity prediction model which based on the double restraint gravitational model.

Although many scholars at home and abroad had studied to comprehensive passenger transport hub transfer volume prediction method deeply, but some problems still exist. Such as the model adaptability is not strong, the transfer ways of cross transfer prediction research are not comprehensive, prediction method is complex, etc. On the basis of combining the reality of comprehensive passenger transport hub, considering the transportation need among varieties of transfer ways comprehensively, this paper proposes a simple change to the amount of prediction method.

2 Influence Factors of Passenger Transfer Mode Selection

It is actually a multi-objective decision-making process when passengers choose their mode of transportation in the center transfer. And it considers a combination of factors like rapid, convenient, economic, safe, comfortable and reliable. These factors can be divided into three aspects: transport characteristics, traveler characteristics and travel characteristics (Luo,2009). *M* expresses the final results that transfer passengers choose. And x, y, z respectively express three aspects of factors influencing transfer passengers' selection. The following function shows the factors influencing passenger transfer.

$$M(x,y,z)=\left\{(x_1,x_2\cdots,x_i),(y_1,y_2\cdots,y_j),(z_1,z_2\cdots,z_k)\right\} \tag{1}$$

Type, x_i express the factors relating to transport characteristics, such as timeliness, service level, transportation security, price, etc. y_j represents the subjective factors of travel choice, such as economic conditions, preference for travel mode, age, gender, etc. z_k represents the objective factors of travel choice, such as travel purpose, travel distance, etc.

In general, in the above factors, speed and ticket price are the two aspects that passengers mainly consider. But sometimes other factors also play a decisive role, such as passengers on official business or business travel generally do not consider fares, but more concerned with fast, convenient and comfortable. Passengers have very time requirements often consider the difference between expected arrival time and actual arrival time, so as to choose the minimum differential mode of transportation, it involves many factors such as speed, service frequency, reliability (Zhai, 2005; Feng, 2006).

Different people choose different travel ways. For some areas have poor transportation, passengers often consider accessibility and safety at first. Passengers have strong economic ability tend to first consider convenience, safety and comfort, and for low-income passengers, economy often comes to the first consideration.

3 Urban Comprehensive Passenger Transport Hub Transfer Type

Urban comprehensive passenger transport hub is a transfer node which assembled the external transport, urban public transport , private transport mode and many other mode of transport (as shown in figure 1), the transfer form is more diverse than traditional external passenger transport hub, the city public transport hub and so on. In order to get the transfer volume prediction which consistent with actual situation and scientific, we must have a fully correct understanding about transfer mode.

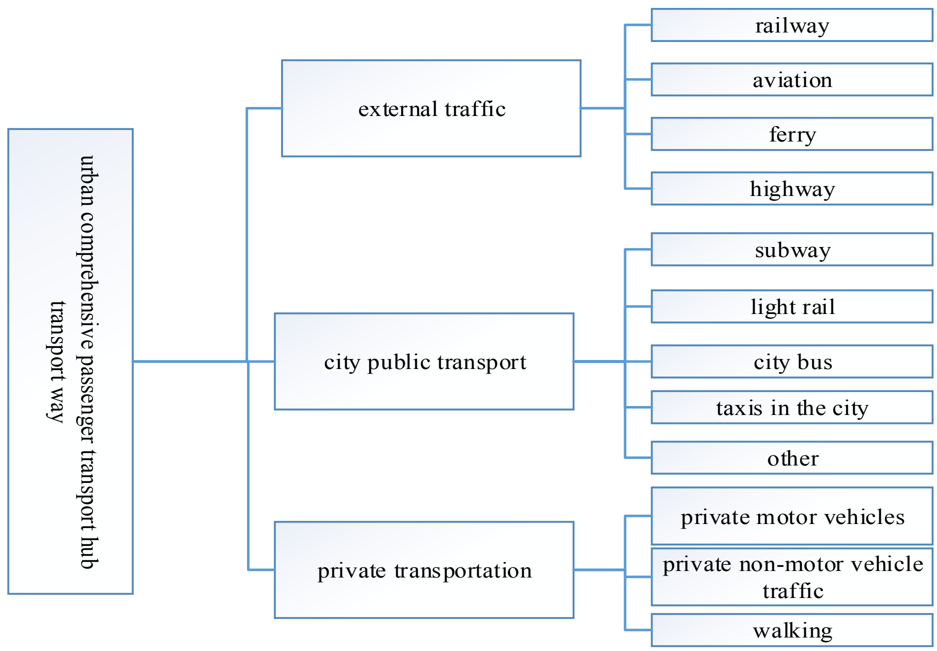

Figure 1. Transportation Mode of Urban Comprehensive Passenger Transport Hub

Table 1 compares urban comprehensive passenger transport hub with traditional passenger transport hub in the transfer form. Traditional passenger transport hub achieves the internal transfer between urban external traffic mainly in transfer function, transfer mode is relatively single. And new type comprehensive passenger transport hub not only contains the transfer which between city and outside of city, the transfer between inner cities, but also requires to achieve two or more external transfer modes.

Table 1 Comparison in Major Transfer Forms of Urban Passenger Hub

Hub	Major Transfer Mode	Diversity of Function
Traditional Passenger Hub	traffic transfer between inside and outside of city	single
Comprehensive Passenger Transport Hub	traffic transfer between inside and outside of city Transfer between external traffic Transfer between internal traffic of city	diverse

4 Transfer Volume Prediction Model

4.1 Description of Problem

Transfers between internal and external traffic in hub is a convergence problem between urban traffic and external traffic, it actually is a problem of transportation choice. According to distributed traffic of the outbound traffic in hub, by predicting various traffic sharing rates to get the transfer volume between the various transportation modes. Because of the passenger traffic within the city is relatively stable, according to a large number of daily passenger transfer passenger data and analyzing the date to get its recent transfer volume. We can know that the transfer forecast of internal and external traffic is the key issues of transfer volume prediction in hub.

4.2 Creation of Model

To passenger volume of one transportation, it can be obtained by classified and counted passenger ticketing system of hub; To the share rate of one transportation, it can also be analyzed by a lot of actual data, but this kind of data tend to lack in our country, so when we analyze transfer volume prediction of the passenger hub, methods of establish transfer model between the various transportation modes are often adopted.

According to the division principle of urban comprehensive passenger transportation hub's transportation modes, using the disaggregate Logit model[10] of transportation mode selection to establish transfer volume prediction model. For comprehensive passenger transport hub, passengers can choose a variety transportation modes when they enter and go out hub, this is a multiple choice question.

Assume that passenger travel mode choice suitable their travel characteristics; all certainty factors which influence passenger change transportation by i to transportation mode j are expressed by X_{ij}, and uncertainty factors are expressed by β, then the reliability which passenger change transportation mode i to transportation mode j can be represented as:

$$K = X_{ij} + \beta \qquad (2)$$

Assume that β obeys double exponential distribution (Gumbel Distribution), use p_{ij} to express the apportion rate of passenger change transportation mode i to transportation mod j , the mathematical expressions of multiple selection probabilities model can be pushed to as follows:

$$p_{ij} = p(K) = \frac{exp(X_j + \beta)}{\sum_{j=1}^{n} exp(X_{ij} + \beta)} = \frac{1}{1 + \sum_{i \neq j}^{n} exp(X_{ij} - X_j)} \quad (3)$$

On the basis of the type (3), assuming that S_i is expressed to be the passenger volume of transportation mode i, the passenger volume of different transportation modes can be predicted by the following function:

$$Q_{ij} = \sum_{i=1}^{m} \sum_{j=1}^{n} S_i \cdot p_{ij} \quad (4)$$

Type, Q_{ij} means the transfer volume of transportation mode i transfer to transportation mode j .

The total transfer volume of all kinds of transportation mode is as follows:

$$Q = \sum_{i=1}^{m} \sum_{j=1}^{n} Q_{ij} \quad (5)$$

5 Adaptability Analysis of Model

Urban comprehensive passenger transport hub is a complex including a variety of modes of transportation and a variety of transportation equipment, it is very important to coordinate its internal subsystems each other. Based on using the disaggregate Logit model to calculate the transfer assessment rate, the transfer volume prediction model is established by fully considering the cross transfer of various transfer ways and predicted the transfer volume of various transfer ways, it also covered the passenger transfer characteristics between various transfer ways.

By analyzing the characteristics of the model parameters, we can obtain the mechanism which all influence factors influence passengers to make the travel decision of choice. By analysis the calculation of transfer modes assessment rate, travelers can be analyzed the difference and the influence on the decision-making behavior with the difference in travel purpose, the different requirements in timeliness, comfort, security, etc, the results can provide scientific basis for all kinds of traffic operation scheduling and improve the connection between transportation coordination.

6 Conclusions

It is a complex work for large comprehensive passenger transport center to forecast the transfer demand. It involves in many fields, such as social, human, economic and system analysis. At present, though there are many scholars and experts studied systematically, there is no mature prediction method for reference. On the basis of above theoretical analysis, this paper proposes a simple and feasible method for transfer demand predicting, providing reference for the demand predicting in the domestic similar comprehensive passenger transport center transfer.

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References：

Wu Wenjing, Jin Xiaotong and Ma Tianyu. (2013). "Transfer Volume Forecasting Method and Application for Passenger Terminal." *Journal of Transport Information and Safety.*

Li Dong, Shan Jingtao, Ye Yuanchun. (2002). "Study on Urban Transport Hub Transport Analysis and Evaluation of the Passenger Flow Organization." *The Seventh Time City Road and Traffic Engineering Academic Conference Proceedings*, China Civil Engineering Society, Beijing.

Tan Mingjun (2013). "Application of Maximum Entropy Model in Transfer Volume Distribution Forecast for Futian Hub." *Technology of Highway and Transport.*

Sun Lishan, Yao Liya, Rong Jian and Ren Futian. (2008). "Application of Entropy-maximizing Model in Transfer Distribution Forecast of Urban Public Transportation Terminal." J*ournal of Highway and Transportation Research and Development* , 25(9), 140-144.

Luo Xia. (2009). "Study on Transfer Demand Forecasting of Large Comprehensive Passenger Transport Hub." *Railway Transport and Economy*, 31(8).

Ou Dongxiu, Ye Pufei, Zhang Wei. (2010). "Passengers Selection Model on Transport Mode at Transport Hubs Based on Disaggregate Model." *Transport Standardization*, (230), 30-34.

Jia Hongfei, Zong Fang, Qiao Lu (2009). "Transfer Volume Forecasting Method in Comprehensive Passenger Transport Hub." *Systems Engineering*, 27(1), 15-18.

Zhai Na. (2005). "Analysis on Transfer Organization Pattern of Urban Comprehensive Passenger Transport Hub." *Southwest jiaotong university*, (13), 18-22.

Feng Xiangming (2006). "Construction of Integrated Hub：The Key to Promote the Development of Integrated Transportation." *Comprehensive Transportation*, 13(15), 13-15.

Liu Canqi. (2001). "Modern Transportation Planning." *China Communications Press.*

System Design for Express Freight Train Diagraming Programming

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Abstract: Nowadays, as one of the most important procedures of the organization of express freight transportation, the traditional manual programming can not keep up with the change of the transportation market. Therefore, it's important to design the express freight train diagram programming system. Firstly, the background of the research is explained. Then, the system requirements are analyzed .Furthermore, the system functions are designed. Finally, the significance and strength of the system are summarized.
Keywords: Express freight train; Train diagram; System design.

1 Introduction

It is well-known that the express freight transportation is a kind of freight organization form, which is with simple procedure, high loading efficiency and high transportation speed (Lan 2009). It's conducive to the realization of multimodal transport, "door to door" transportation and bulk cargo direct transportation, high value added goods are the main objects of express freight transportation(Peng etal.2011,Yang 2000). Express freight transportation has become one of the development trend of railway transportation because of its necessity and the feasibility reasons (Dai etal. 2013, Zhang etal. 1999).

2 Analysis of Express freight train diagram programming system requirements

2.1 The influence factors of express freight train diagram programming

Before the part of system design, the influence factors of express freight train diagram programming have been analyzed according to the features of express freight train. By analyzing, it mainly includes these factors: train diagram elements, application and capacity of equipment, coordinated operation and transport demand.

2.2 Transport demand

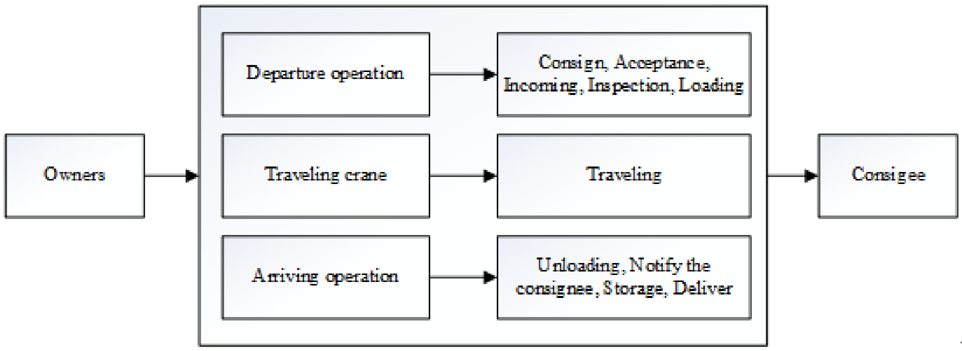

Figure 1. The express freight transportation process

From the express freight transportation process (Figure 1.), the demands of express freight trains' transport could be embodied in the following four aspects: quickness, accuracy, convenience and safety.

The transportation demand of through freight train could be embodied in three levels: the transport business facilitation needs, the whole time demand and the personalized needs of transport service.

2.3 The definition of user agent and service provider

2.3.1 User agent

The user agent is the main service object of a system, which describes and understands that the systems are the bases of system requirements analysis and system design (Hao etal. 2001).The user agent of express freight train diagram programming system mainly includes: external users (the owners and other coordination departments) and inside users (the operations department, transport security department and information service department).

2.3.2 Service provider

Service provider of system means inside users, and mainly includes the operations department, transport security department and the information service department. All of these departments cooperate with each other meet external users' demands.

The service providers mainly include: transportation management, transport security and information service management.

2.4 Requirement analysis of users of the system

2.4.1 Requirement analysis of user agent

From the express freight transportation process, the system satisfies the following demands:

(1) Information service and express freight transport real-time schedule;

(2) Real-time position of express freight trains;

(3) The owners' proposed and evaluation to system as one of the improved data;

(4) Demands of fast freight train and through freight train;

(5) Demands for convenience, which mainly includes convenient delivery (Table 1.). The owners can choose a variety of express freight train to finish transportation flexibly;

Table 1. Express freight handing ways

Delivery type	Handing ways
Telephone	Call the phone number of the freight stations
	Call the phone number of China railway customer service center
Internet	www.12306.cn
	the freight stations
The scene	The railway workers door-to-door service

(6) Demands for accuracy;

(7) Safety requirements. The system shall ensure both safety in train running and the quality of goods;

(8) When freight trains go through technical stations without being marshalled, minimize the stopping time; system should prevent mutual interference between train paths.

2.4.2 Requirement analysis of service provider

(1) Transportation management department

Freight management department: Collecting freight data, analyzing the information of supplied goods, trying to simplify the procedures of fast freight transportation, determine a reasonable plan of cargo transport and express freight train scheme, and provide express freight transport supply ability to the society.

Fixed equipment management department: Providing the information sharing platform for the system.

Mobile device management department: It is responsible for allocating locomotives rationally, reducing waiting time, improving cargo delivery speed.

(2) Dispatching centre

Train diagram programming

Express freight train diagram programming management

(3) Transport security department

Ensuring the coordination between the various departments, the rational allocation of locomotives; the reduction of waiting time, the improvement of cargo delivery speed.

(4) Information service

It mainly includes: data collection, data sharing, data analysis management and maintenance.

3 Express freight train diagram programming system functions design

3.1 Brief introduction to the main functions of the system

According to the analysis of the previous four chapters, system functions could be divided into six parts: online enquiry, data collection and processing, diagram programming, information query, information publishing, information feedback.

3.2 The online query function for express freight trains

This part of function mainly provides services for the external users. Users could search all of the express freight trains in operation at present, as well as information displayed in tabular form, such as the train loading station, frequency, transfer station, marshalling content and so on.

3.3 Data collection and processing function

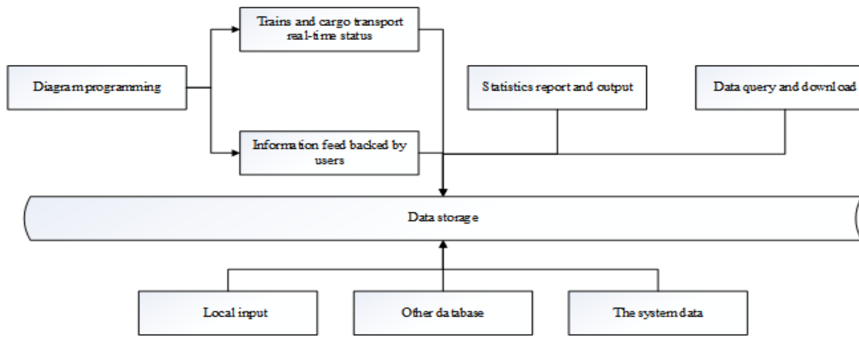

Figure 2. Data processing function

As is shown in Figure 2, the express freight train diagram programming system should have the functions of data collection, processing and management, including data operation, data inspection and storage, statistical data output, data report, search and download etc.

3.4 Diagram programming function

Express freight train diagram programming system includes the following three subsystems: input function of passenger trains' running line; initial point scheme of express freight train diagram; diagram programming and output. The three subsystems coordinate with each other to accomplish the programming of express freight train diagram. The specific process is illustrated in Figure 3.

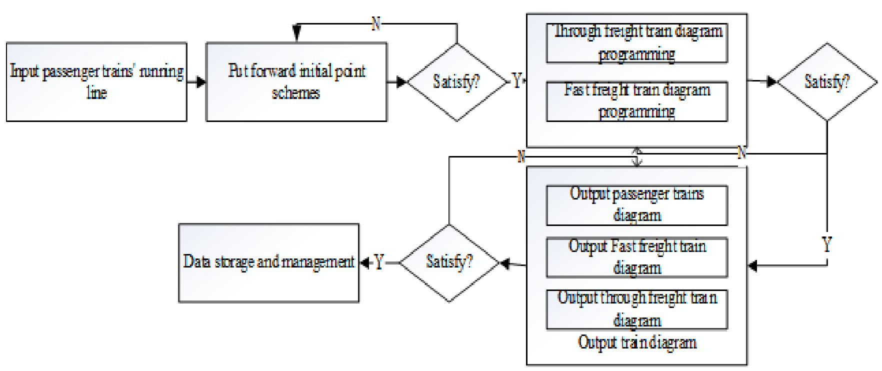

Figure 3. Diagram programming and output

3.5 Information publishing and query functions

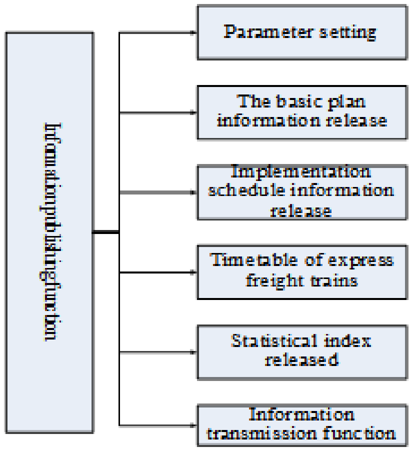

Figure 4. Information publishing

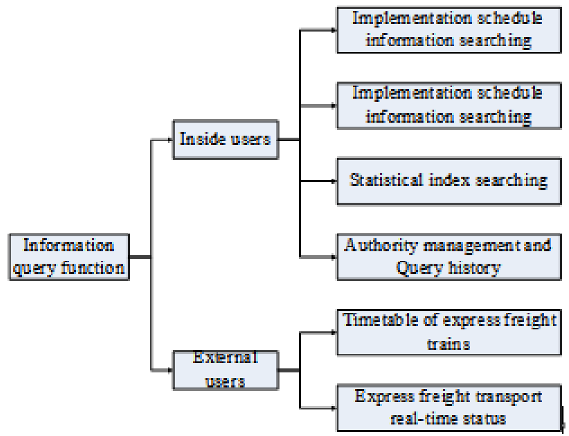

Figure 5. Information query

As is shown in Figure 4 and 5, the system has information publishing function and query function. All kinds of data are released by the system automatically, which could be inquired by users.

3.6 Information feedback function

The system has an information feedback platform, which can collect and deal with the feedback information of users, and establish optimization models.

4 Conclusions

Based on the research background and research situation of express freight train diagram programming system, the paper gives a detailed analysis of factors influencing factors of express freight train diagram programming, then it discusses about all aspects of system requirements and system functions. First of all, the background is introduced. Then, the system requirements are analyzed. Then it design the system functions , such as the data collecting and processing, diagram programming, information query and feedback functions, which embody the humanization and intelligent of the system, and is in line with the requirements of human-computer interaction.

Acknowledgement

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References

DAI Xinliu, and MA Botao. (2013), "Strategic thinking of China Railway Express freight transport", Railway Economic Research，（2/3）:1-5.

HAO Jianqing, and ZHANG Zhongyi. (2001) “Research on the method of requirement analysis of information system”, Journal of Industrial Engineering and Engineering Management, 15(2):35-39.

LAN Jingzong. (2009), “Discussion of China Railway Express Freight Transportation Development”, Railway Transport and Economy, 31（7）:18-20+46.

PENG Qiyuan, and WANG Ciguang. (2011), “Train operation and organization”, Beijing: CHINA RAILWAY PUBLISHING HOUSE.

YANG Hao. (2000), “Present situation and Prospect of the development of Chinese railway express freight transport” , *Journal of Northern Jiaotong University*，24（6）:20-24.

Discussion about the Product Structure of Bulk and Direct Freight Based on Transport Benefits

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Abstract: This paper summarizes the product development of domestic bulk and direct freight. Based on the needs of goods category, the bulk and direct freight demand is divided into upper, center and lower three levels. From two angles of economic and social benefits analyzes the transport benefit of bulk and direct freight. Based on the maximization of business income, establishing bulk and direct freight optimization model, and by adjusting the freight volume, designing different levels of freight product structure to achieve optimal transport benefit.
Keywords: Bulk and direct freight; Transport benefit; Freight volume; Product structure.

1 General situation about Chinese through bulk and direct freight product

For a long time, Railway freight transportation as the backbone of the transportation has made a contribution to the national economic development. With the development of economy, the demand of coal and steel is getting smaller, and the competition of transportation market is changing fiercer. 2004-2013, the growth of volume of railway freight is 6.6%, but the volume of rail freight traffic and tonnage mileage in the whole transportation market is changing less as the average speed of 0.55% and 1.1%. Through freight product is the main constituent part of rail freight, in 2012 the proportion of the through freight product in the whole road is about 30%. In order to meet the market demand better, China has taken a series of measures to improve the development of through bulk and direct freight product as following:

Table 1. The event list of Chinese through bulk and direct freight product

Year	Event
2002	Quondam railway ministry designed 54 point to point crossing board through lines in order to guarantee the electricity-coal transportation.
2004	Using the fifth speeding-up, designed 181 point to point originating direct operating lines, and optimized railway freight product project.
2005	Improved the quality of through project by standardizing through line's project etc. methods.
2006	Brought the supply of goods that annual shipments are over 40 tons with the same departure and arrival station into.
2011	The number of through bulk freight lines has grown to 723, and the scope of

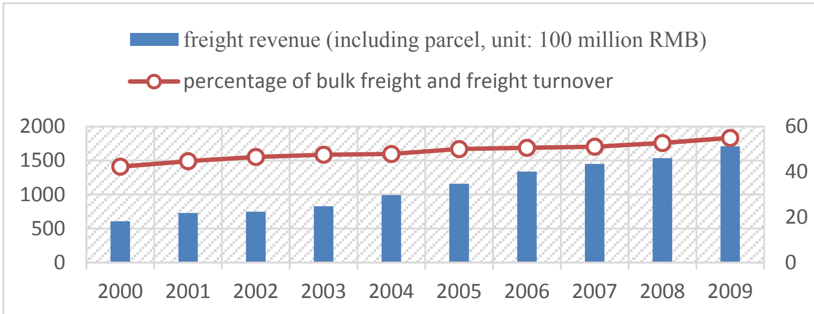
	operation has also been extended.
2012	Pay attention to the big channel and block, design the bulk and direct freight product by different level.

At present, the bulk and direct freight product (the Transport Bureau of Railways Ministry, 2006) is based on coal, oil, ore, steel, coke, grain and other bulk materials category, According to the characteristics of these products, we can design different product based on the category of goods, operation mode, handling mode, timeliness, and transportation organization (Wang Jiankuang, 2014). Many scholars from freight marketing, product structure, capacity allocation, freight organization point of view, for the bulk and direct freight product depth research, has made some achievements in scientific research. In this paper, based on the needs of the different categories of goods, the bulk of through freight demand is divided into three levels: the upper, middle and lower. Upper freight demand products mainly refers to key materials related to people's livelihood, such as coal, mining, petroleum, food, etc., and the needs of the military transport, emergency relief supplies, mainly playing an important manifestation of railway public property and safeguard the basic needs of society; the middle Freight transport demand is for the quality of timeliness, safety and other services required for high value-added products; lower freight product demand mainly contain some low value-added products, and actively tap the market in easing the situation to start marketing capacity, which is in order to better adapt to market competition performance. But when the railway capacity is short and the product under the premise of freight is limited, freight product structure design should in order of meeting the upper, middle, lower transportation needs. Combine with freight demand to design freight product, and with the goal of maximum of enterprise income, establish the bulk and direct freight structure optimization model. Through different levels of demand for freight cargo adjusts freight product to achieve the best overall transport efficiency.

2 The analysis of transport benefit for bulk and direct freight

2.1 Economic benefit

The key to improve transport revenue is the addition of economic benefit and the reduction of transportation costs. Bulk and direct freight advantages of scale to reduce production costs. Construction of large trucks point sources to achieve centralized, organizational focus, is to create efficient, safe conditions for direct freight. By reducing the sorting and marshalling operation, shortening the turnaround time of goods, bulk and direct freight relieves the capacity of technical station and interval, and increases production efficiency. As shown in Figure 1. Accounting to the railway freight revenue and bulk cargo for rail cargo turnover percentage point, some of the bulk cargo turnover always account for about 50% in railway freight transport, and with the increase of bulk cargo turnover, the rail freight revenue increased significantly.

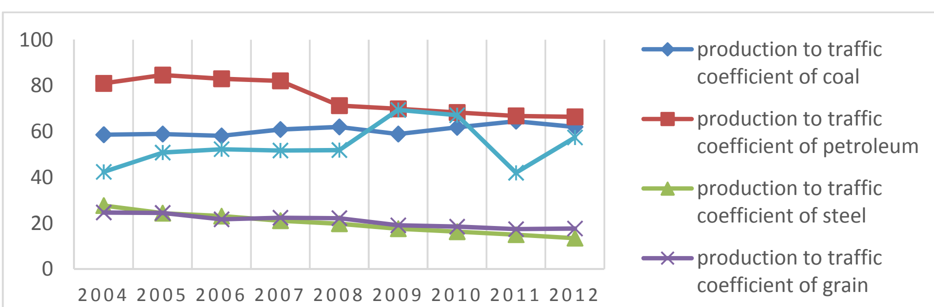


Note: Data from the 2001-2010 "China Statistical Yearbook"

Figure 1. Percentage of railway freight revenue and bulk cargo turnover

2.2 Social benefit

Direct transport bulk cargo object mostly is the key materials in petroleum, likes coal, grain, agricultural and other livelihood. In order to meet the community needs and ensure the state's key materials transportation, railway organizes bulk and direct freight for oil, ore, coal and others, which provides strong guarantee for social and economic development. As shown in Figure 2, China's railway transport of goods in bulk is always dominant from the variation of main product's produced and transported coefficient. In addition, the direct goods transport not only to reduce the total time and save the transit time, but also compress corresponding amount of enterprise stock and production cost, accelerate cash flow. The service, which includes an entrustment, once paid, a vote in the end, responsible for the whole process, is provided from bulk and direct freight to shipper, can decrease the number of intermediate links and improve convenience. Compared with other modes of transport, railway direct transport in bulk goods also has a strong competitive and advantage on scale, security, reliability and all-weather transport (Zong Yan, 2014).



Note: Data from 2005-2013, "China Railway Yearbook"

Figure 2. China produced and transported coefficient of main products

3 The structure optimization model of bulk and direct freight products based on transport benefit

The benefits of bulk and direct freight products include economic benefits and social benefits. On the premise of maximizing bulk and direct freight product revenue, the public property in the social development and national stability should be considered more. So the structure optimization of bulk and direct freight products must be based on meeting social demand, calculating the sum of the product freight revenue after the distribution of bulk and direct freight products by the difference of origin-destination (OD), freight transport demand and product categories. Optimizing the structure of bulk and direct freight products and realizing the optimal transportation benefits by solving the number of different product volume.

3.1 The assumptions of the model

Structure optimization of bulk and direct freight products based on transport benefit affected by many factors, so it is a complex problem. In order to achieve structure optimization of transportation products only taking on freight volume as variable, model assumption is as follows:

Hypothesis Ⅰ: Each freight rate of bulk and direct freight products that operated by railway are known; **Hypothesis Ⅱ**: The wagon flow paths of bulk and direct freight are known; **Hypothesis Ⅲ**: Because of market volatility, assuming different levels of rail freight demand is determined in a certain period. **Hypothesis Ⅳ**: Ignoring the influence of locomotive and car application and passenger organizations on freight products.

3.2 The establishment of the model

$$\max Z = \sum_{O=1}^{X} \sum_{D=1}^{Y} \sum_{s=1}^{S} \sum_{l=1}^{L} (P_1^{ls} + P_2^{ls} * D_{OD}^{ls})\ Q_{OD}^{ls}$$

$s.t.$

$$\begin{cases} \sum_{O=1}^{X} \sum_{D=1}^{Y} \sum_{s=1}^{S} \sum_{l=1}^{L} Q_{OD}^{ls} \le \omega_a & (1) \\ \sum_{D=1}^{Y} \sum_{s=1}^{S} \sum_{l=1}^{L} Q_{OD}^{ls} \le F_X & (2) \\ \sum_{O=1}^{X} \sum_{s=1}^{S} \sum_{l=1}^{L} Q_{OD}^{ls} \le D_Y & (3) \\ \sum_{s=1}^{S} \delta_{OD}^{ls} Q_{OD}^{ls} = R_{OD}^{l} & (4) \end{cases}$$

In the formula:

OD expresses the beginning and the end of the train in network, $O=1,2,\ldots,X$, $O \in X$; $D=1,2,\ldots,Y$, $D \in Y$; l expresses demand level, $l \in L$; s

expresses species of freight products, $s \in S$; P_1^{ls} 、 P_2^{ls} express the base price of the l-layer and s-kind freight product; D_{OD}^{ls} expresses the transport price distance of the l-layer and s-kind freight product between any OD; Q_{OD}^{ls} expresses the freight volume of the l-layer and s-kind freight product between any OD; ω_a expresses the carrying capacity of the line in limit section a, $a = 1, 2, \ldots, A$; R_{OD}^{l} expresses the freight demand of the l-layer between any OD; F_X expresses the capacity constraints of starting station; D_Y expresses the capacity constraints of ending station; δ_{OD}^{ls} expresses the coefficients of satisfaction of the l-layer and s-kind freight product between any OD, $\delta_{OD}^{ls} \in [0,1]$; If l_1、l_2、l_3 express the upper, middle and lower demand, then $\delta_{OD}^{l_1 s} > \delta_{OD}^{l_2 s} > \delta_{OD}^{l_3 s}$.

The objective function is the product of price and freight volume of bulk and direct freight products in different OD and demand level. In the situation of a fixed price, as different freight products volume according to the distribution of constraints, achieving the enterprise income maximization, which reflects the best enterprise economic benefit.

The constraints condition (1) is the capacity constraint in the section, for freight products in several origin-destination of the road network may pass through the same section, which lead to insufficient capacity; The constraints condition (2), (3) represent capacity constraint of starting station and ending station respectively, in case of insufficient capacity caused by different freight product concentrating in freight station. The constraint condition (4) is the satisfaction constraint of different levels of freight transport product. When distribute amount of freight products, upper, middle, lower demand are considering, so the best social benefits is reflected.

3.3 Algorithm design

The railway freight product structure design model using capacity constraint and satisfaction constraint of freight transport product to combine and screen freight volume of different demand levels, getting a series of freight volume conforms to the basic requirements, to which the structure optimization of bulk and direct freight products is according. Algorithm process is as follows:

Step1: Setting the volume initial value of each freight product from freight product portfolio to 0, namely not running train, turn step2; **Step2**: Increasing the volume of each freight product from freight product portfolio in turn, turn to step 3; **Step3**: Checking whether each freight product volume combination satisfies capacity constraint of the interval or the station, if satisfied, turn step4, otherwise, turn step5;

Step4: Checking whether each freight product volume combination satisfies demand satisfaction constraint of different levels of freight volume, if satisfied, keeping the freight product portfolio, otherwise, deleting it, turn step2; **Step5**: Calculating the economic benefits of the current freight volume of different levels demand, to get the optimal combination.

4 Conclusions

Due to the lack of actual data, failed to verify the feasibility of the model and algorithms by examples, this is worthy of further study beyond. Through model analysis, the Q_{OD}^{ls} , ω_a , F_X , and D_Y are positive correlation. There is a relationship between Q_{OD}^{ls} and δ_{OD}^{ls} . The larger the market demand，the more freight product is, so as social benefit. Combined with the above conclusions, the suggestion following is summarized on freight product design.

(1) When passenger and freight run separately, railway companies should vigorously develop the middle and lower freight products, and increase product proportion of high added value, high quality requirements goods before releasing of transport capacity and meeting the needs of the upper products. Through combinations of transport, design intercity and fast freight, high speed rail freight to attract potential sources. (2) Based on improvement of the rolling stock technology, increases heavy haul train proportion in the product of bulk and direct freight on busy road. (3) Model only through different demand levels of freight volume as variable to optimize the product structure. After the railway into the market competition, considering the freight and freight volume is the key to achieve business benefit. Therefore, freight floating should be coordinated to the product structure optimizing.

Acknowledgement

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References

The Transport Bureau of Railways Ministry. (2006). "management measures about rail transport heavily coming and backing and transport organization of bulk and direct freight." *Journal of Railway Freight Transport.*

Wang Jiankuang. (2014). "Research on Railway Mass and Direct Freight Transport Product." *Central South University master degree thesis.*

Zong Yan. (2014). "Study on Design and Development of Railway Freight Transport Products in China." *Journal of Railway Freight Transport.*

Design for Cooperation between the Locomotive Scheduling System and the Train Scheduling System

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Abstract: Locomotive scheduling and train scheduling are important parts of the railway operation planning, locomotive scheduling should be cooperated with train scheduling, which could be benefit railroad operation efficiency and make railroad operation be more productive. This paper discuss the Cooperation design for locomotive scheduling and train scheduling based on Train Working Diagram System (TWDS). First, analyzing the business work flow between locomotive scheduling and train scheduling, and coordination process in TWDS. Then, according to the data flow and business requirements, design the mode of data sharing and data synchronizing. Finally, cooperation function and cooperation mode were designed for functions cooperation between locomotive scheduling and train scheduling.
Keywords: Locomotive scheduling; Train scheduling; Train working diagram system; Cooperation.

1 Introduction

Locomotive scheduling and train scheduling are both important railroad operation plan, they should be formulated together, and their cooperation could make the scheduling to be more feasible and close to real. Traditionally, the locomotive operation planner and train operation planner worked separately, but now with the development of information technology, locomotive scheduling system and train scheduling system were developed for railroad industry, which were general used by almost all railroad company. Then, the cooperation between Locomotive Scheduling System and Train Scheduling System become available.

In China, there is a integrated decision support system that both locomotive scheduling system and train scheduling system included, which is named as Train Working Diagram System (TWDS). Besides the two system, TWDS include railroad infrastructure data system, passenger transportation plan system, train tractive effort calculating system, train operation simulation system, train GIS etc. The system structure of TWDS could be shown as Fig.1.

In TWDS, all the subsystem share the railroad infrastructure data, included rail line data, station data, section data, track data etc, and with the share data, all of subsystem would be consistency while data transfer, further more the data manage would be more easier. As parts of TWDS, the locomotive scheduling system and train scheduling system could be cooperated more convenience and closely combined, also, with the C/S network platform of TWDS, the two system could exchange information immediately. This paper will discuss the cooperation model for locomotive scheduling system working with train scheduling system based on the system introduced above.

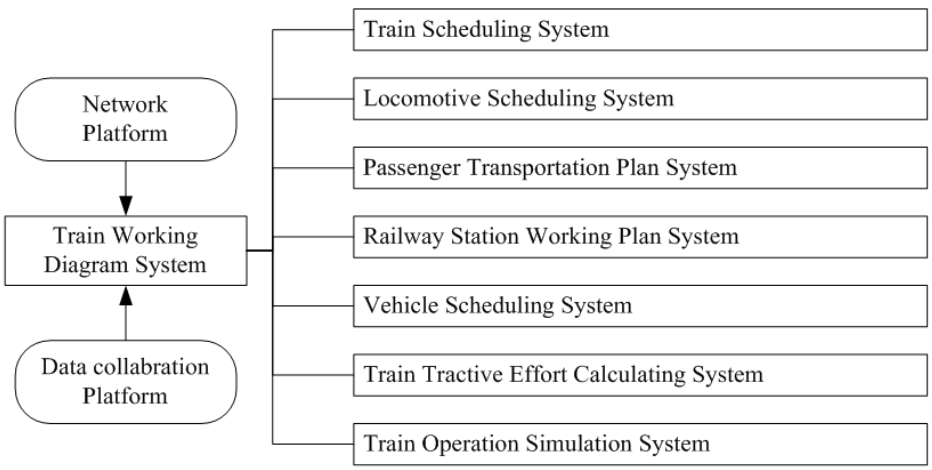

Figure 1. System structure of Train Working Diagram System

2 Cooperation Process Description

Locomotive scheduling should be built in company with train scheduling, they are depend on each other mutually and restrain each other. Train scheduling is a comprehensive transportation resource allocation plan, so much factors should be considered, moreover, locomotive diagram is prepared in accordance with the train line, therefore, it is a coordinated feedback relationship between Locomotive Diagram and train diagram: In the train scheduling preparing stage, some locomotive turn-round factors should be considered, such as locomotive hanging dwell time, locomotive turn-around time standard. Furthermore, In train scheduling sketching stage, locomotive diagram sketch should be formulated, then locomotive indicators should be checked, if locomotive technical working time and crew working time standard were not meet, or certain locomotive efficiency indicators were unreasonable, by analyzing the structure of train diagram, a workable regulatory timetable adjustment feedback plan should be programmed. Therefore, the cooperation process between locomotive scheduling and train scheduling can be expressed as shown in Fig.2.

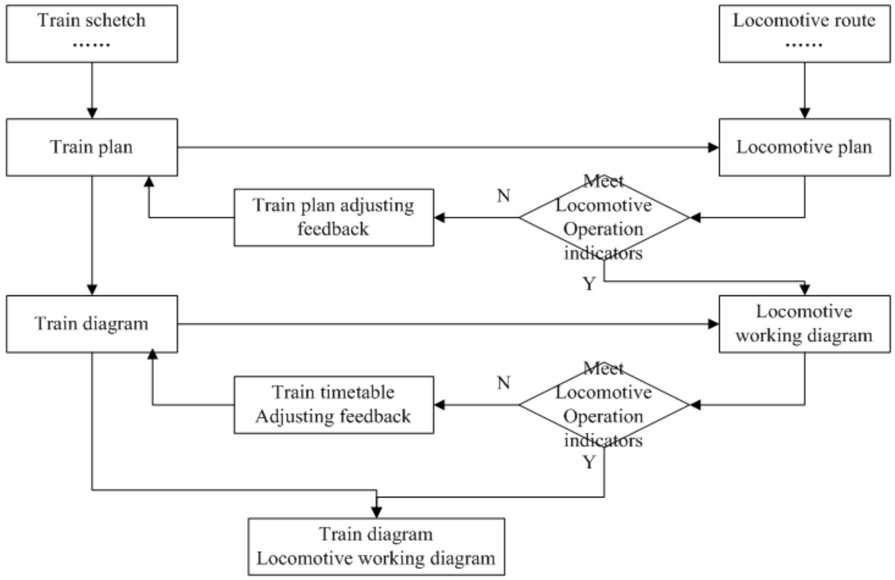

Figure 2. Locomotive scheduling and train scheduling cooperation flow chart

As shown in the locomotive scheduling and train scheduling cooperation process, the locomotive scheduling is carried out after train scheduling, and then train timetable rescheduled after locomotive scheduling for timetable adjustment plan, that is a circular process. which including the cooperation about data, business functions, and the time and space aspect of cooperation involved.

In TWDS, all the subsystem share public data and work on the network platform, so the model for cooperation between locomotive scheduling and train scheduling could be discuss in the aspect of data cooperation, function cooperation and user interface.

3 Data Cooperation Design

In TWDS, according to the data flow and business requirements, the data can be divided into public infrastructure data and business data. The public infrastructure data include railroad network data, infrastructure data, organizations and other basic data, regulations and standards. business data include a lot of different types of data supported for independent business functions of each department. In TWDS, data associated with train scheduling and locomotive scheduling could be listed as follows:

Table 1 Locomotive scheduling and train scheduling data systematization

Data Type	Business Type	Data Description
Public Data	Railroad Network	Rail lines, Stations, Sections, Tracks
	Infrastructure and Equipment	Locomotive type, Train type
	Business Management	Railway corporations, Departments
Business Data	Train Scheduling	Trains, Routes, Maintenance time, Train plan
	Locomotive Scheduling	Locomotive route, Locomotive routing connection, Crew turn-around route

In TWDS, there are cooperation on different departments and different majors, and cooperation on different clients, business cooperation is in cooperated with data transfer and data synchronization. Then, by data sharing and data synchronizing, all subsystem could avoid repeating operation and data inconsistent. Finally, all the data in TWDS were integral and consistent, which make the system be more efficient than separated subsystem. In this section, data sharing and data synchronizing would be discussed.

3.1 Data synchronizing requirement analyze

(1) Public data synchronizing requirement analyze

Public data are the key data of TWDS, it is the basis of data transfer and data interface for all the subsystem, and it is also the standards data. Once the public data modified, all the data refer to the public data should be renewed. The public data included: railroad network data (rail line data, station data, section data), business data (railway company data, department data, train type data).

(2) Business data synchronizing requirement analyze

Business data are the data depend on the subsystem, the business data synchronization between locomotive scheduling system and train scheduling system are their data transfer on work flow process. For business data, some data are the basis or reference of other business, and some data are only for inner business process. For the first situation, refer data should be renewed immediately. For the second situation, no synchronization process should be carried out. The business data should be synchronized included: train data and train timetable in train scheduling system, locomotive route data, trains on routes in locomotive scheduling system.

3.2 Data synchronization mode

The common data synchronization mode could be list as follows:

(1) Message droved mode

(2) Timer droved mode

(3) Request mode

(4) Real time interface mode

Above is the data synchronization mode, and implement mode also should be considered, there are synchronization implement mode and a synchronization implement mode, which depends on data requirement, data flow and data transfer frequency.

3.3 Data synchronization design.

For TWDS, there are desktop mode and network mode. For desktop mode, data synchronization is implemented by data logistic consistent functions which based on integrated data platform for all subsystem. For network mode, based on network platform and message droved mode, all clients of locomotive scheduling system and train scheduling system could implement data synchronization. The whole data synchronization process could be designed as follows:

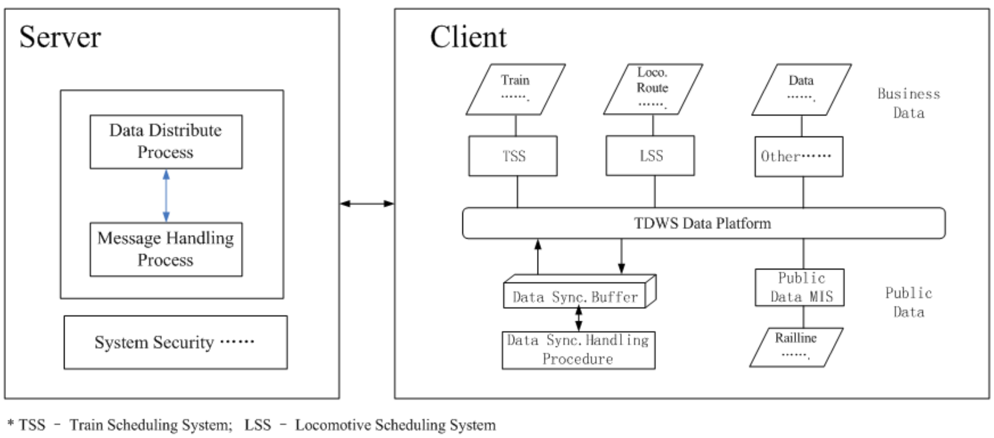

Figure 3. Locomotive scheduling and train scheduling data synchronization process

4 Business Cooperation Design

As shown in section 2, cooperation between locomotive scheduling and train scheduling is a cyclic process, in TWDS, supported by the networking platform, the business functions could be designed for the cooperation, and the cooperation work flow could be expressed as follows.

For functions cooperation between locomotive scheduling and train scheduling, it could be discuss from the aspect of cooperation function design and cooperation mode design.

4.1 Cooperation functions design

Train scheduling involves more departments, which is restricted by more operation rules, and it is the basis of locomotive scheduling, therefore, the cooperation design should be focus on how locomotive scheduling system provide related functions for train scheduling system to dispatch. According to the cooperative process, functions could be designed as follows:

(1) Automatic locomotive scheduling

Automatic Locomotive scheduling function should be designed parameterized to meet all kinds of facilities and complex locomotive operation rules, such as locomotive route, train type, hanging dwell time standards, and whether locomotive running across multiple railway bureau. Moreover, optimized algorithms should be designed, the locomotive indicator could be calculated. The function could be used for not only one locomotive turn-around station, but also whole section, or whole locomotive working diagram.

(2) Technical working time checking

In the process of locomotive scheduling, sometimes locomotive operation changed such as the locomotive hang station changed or crew shift station changed, the technical working time at the working station maybe changed, so the train dwell time and locomotive turn-around time should be checked. This function should be designed to check whether the locomotive turn-around time at turn-around station and train dwell time at crew shift station meet standards according to locomotive routing and crew routing.

(3) Working overtime check

According crew mode and crew route, the function should be designed to check whether the crew working time is over working time standard.

(4) Locomotive indicators setup

Before locomotive scheduling, design a function setting up designated locomotive indicators to check the quality of locomotive working diagram and train diagram, indicators including locomotive numbers, train travel time etc.

(5) Train timetable adjustment feedback plan

With the setting up indicators, design a function to formulate train timetable adjustment feedback plan which base on optimized locomotive operation.

4.2 Cooperation mode design

There are two mode for the function cooperation between locomotive scheduling and train scheduling. The first mode is the user interface mode by commands from planner, which could make use of the knowledge and professional experience of planners, in TWDS, the function should use this mode including: technical working time check, working overtime checking, automatic locomotive scheduling. The second mode is the integrated dispatch mode by inner function call from system, which could make the cooperating process be more simplified, according the business rules and presetting arguments, system could carry out the cooperation automatically, then the scheduling efficiency improved, in TWDS, the function should use this mode including: locomotive indicators setup, train timetable adjustment feedback planning.

5 Conclusions

Based on Train Working Diagram System, this paper discuss the cooperation design for locomotive scheduling and train scheduling, data synchronization and business function cooperation were mainly considered, the resolution would be benefit for the system development and other cooperation system. However, cooperation between two system is more complicated, the other aspect such as system security, interface structure should be involved, it is worth further study on these topics for cooperation design.

Acknowledgement

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References

NI Shaoquan，LU Hongxia，ZHANG Jie，CHEN Tao. Research on concurrency control method of train working diagram compilation system based on group coordination. Sciencepaper Online. 2009(10): 738-741.

XIA Ming. Research on key problems of high speed railway networked cooperative train scheduling . Beijing Jiaotong University. 2011.

ZHU Jianping, ZHOU Leishan, YUE Yixiang. Network based multi-user cooperative train working diagram system.China Railway Science.2010(1): 139-144.

Selection and Application of Organization Modes of Container Drop-and-Pull Transport Based on Different Service Objects

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Abstract: As an advanced way of transport organization, container transport with dumping trailers should be considered as a kind of low-carbon and energy-saving mode for the popularization with Green logistics developing vigorously in our country. Since container transport is implemented later in China, and its organizational mode is simply between two points. Therefore its radiation range is often limited by the selected business routes. As a result of the simple organization mode, the efficiency of container drop-and-pull transport has been greatly limited. In order to solve the problems above, this paper analyzes the selection and application of organization modes of container drop-and-pull transport, according to different application objects and circumstances. The results from the thesis are of great practical value and can be used as a guide for transportation enterprise to choose an efficient and scientific organization mode of container drop-and-pull transport.
Keywords: Drop-and-pull transport; Organization modes; Selection; Application.

Container drop-and-pull transport is mainly used in the situation of point to point transportation within large enterprises or factories, fixed-point container transport on trunk lines, interregional transportation and multimodal transport in port area. Because of the difference of transport mileage, arrangement of loading and unloading working points and transportation cost, varied organization modes are required. Furthermore, new types of multi-mode drop-and-pull transport group are needed.

1 Fixed-point container drop-and-pull transport on trunk lines

Trunk line transport is a vital important form of transportation, which transferred goods in long distance with using of large-capacity trunk road transport. Container transport on trunk lines between fixed points, such as logistics transport on intercity direct lines and transport between interregional logistics parks, is definitely suitable for container drop-and-pull transport in the organization mode of “Two Point One Line”, for the character of steady transportation task, sufficient supplies and fixed freight location.

According to statistics, actual loading rate of fixed-point container drop-and-pull transport on trunk lines can reach to 80%. In practice, transport enterprises should build a solid, long-term cooperation between consignor and consignee, or even set business points in separated cities, to ensure the condition of supply organization steady, and to delivery and management turnover trailers effectively. Depending on freight traffic and load distance, turnover trailers can be equipped in delivery point and receiving point. And drop-and-pull transport is arranged in the way of "Two Points One Line, drop-and-pull transport in terminal(s)", which is shown in Figure 1.

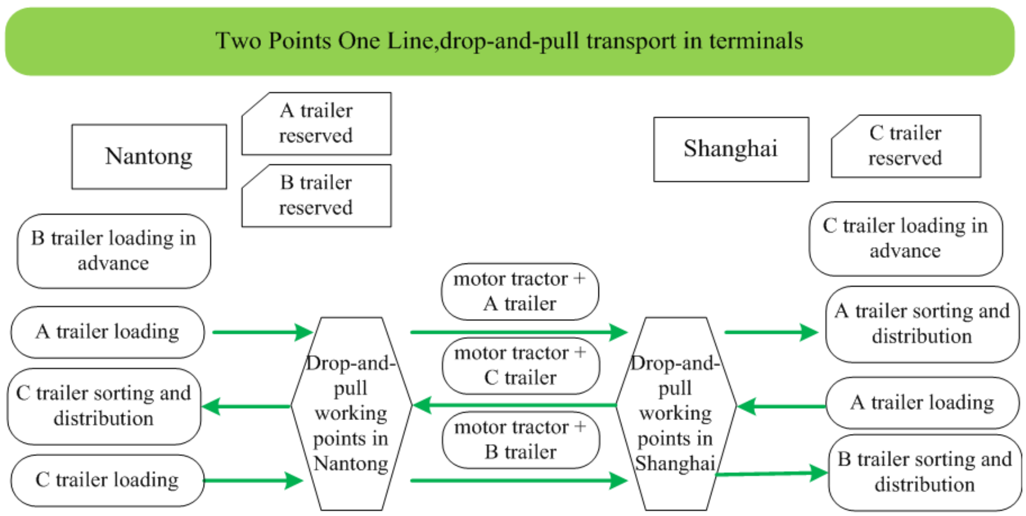

Figure.1. Illustrated of "Two Points One Line" drop-and-pull transport on trunk lines

Figure 2 illustrates a practical case that a logistics enterprise runs a drop-and-pull transport assignment on trunk lines between Guangzhou and Qingdao. The organization mode of "Two Points One Line, drop-and-pull transport in terminals" is selected, for sufficient supplies of container freight traffic and fixed freight location in these two cities. Load distance between two cities is 2250 kilometers, and transit time needs 30 hours. In circumstances of the traditional regular transportation, motor tractor takes 72-76 hours to fulfill a round-trip task, while loading and unloading time needs almost 12-16 hours. That means loading and unloading time accounts for about 20% of total time. It just costs 60 hours to complete a round-trip task by using drop-and-pull transport. It is obviously that efficiency of the tractor organization and operation has improved significantly.

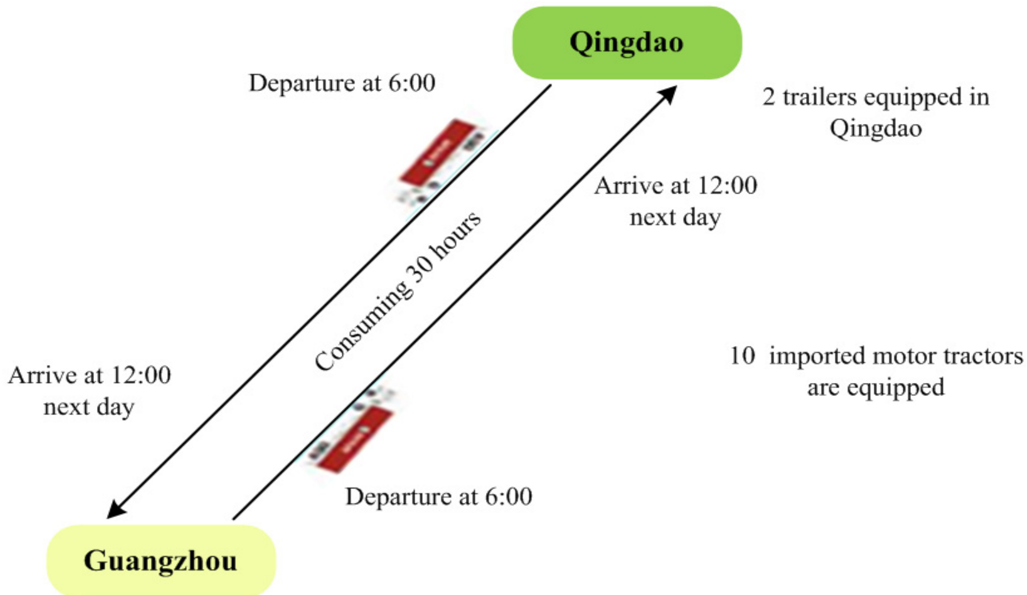

Figure.2. Map for the organization mode of
"Two Points One Line, drop-and-pull transport in terminals"

2 Interregional container drop-and-pull transport

Container drop-and-pull transport are now making great efforts to broaden the operation network, expand the scope of the market, strengthen the business cooperation between enterprises, and it is a general trend. Depending on "Two Points One Line" and advantages of the networked sufficient supplies, source of trailer, station and goods can be shared by building drop-and-pull transport coalition with other enterprises. As shown in Figure 3, the organization mode of "Circle Drop and Pull" or "Several Points One Line, Drop and Pull in Turn" should be selected between transport enterprises and manufacturing enterprises, so as to the ports, harbors and storage yards in the certain related regions. As a result, it can take full advantage of motor tractors and trailers. Therefore drop-and-pull transport can expand from inner-enterprise operation to outer-enterprise operation, from the mode of "Two Points One Line" to "Circle Drop and Pull", thereby efficiency of regional transport operation and level of the organization are raising and promoting.

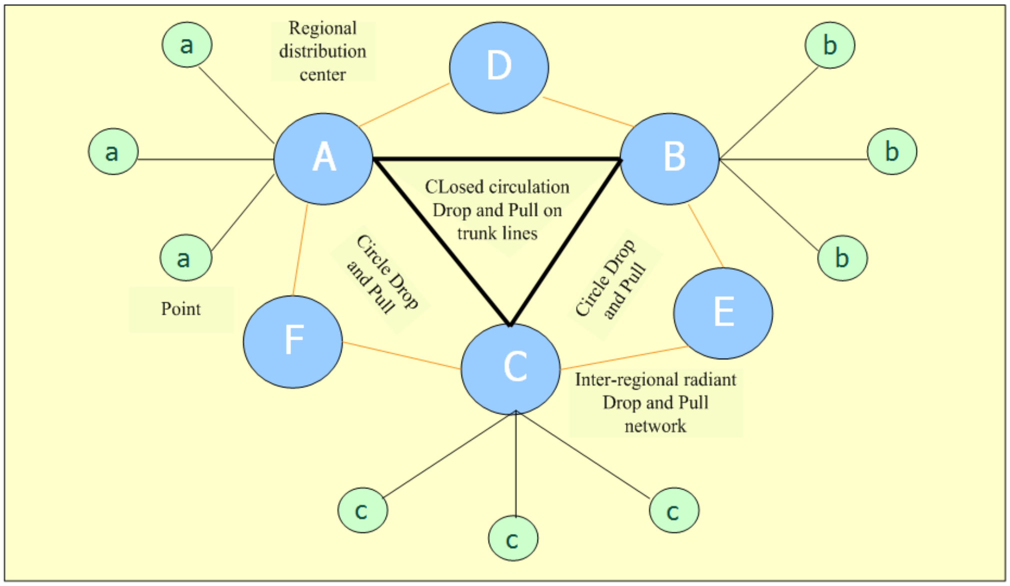

Figure.3. Interregional Container "Circle Drop and Pull"

In reality, each fixed loading and unloading point on closed circulation loop should equip a set number of trailers and turnover containers. When a motor tractor reach to a fixed point, it drops all the containers and trailers, and then keep on traveling after pulling all prepared containers and trailers. As we can see, interregional container transport in the way of "Circle Drop and Pull" can reduce the average cost of one-way freight effectively, raise actual loading rate of round-trip transport infinitely. Besides container drop-and-pull transport in the mode of "Circle Drop and Pull" calls for a fully configured system of inter-regional loading and unloading points and large transportation enterprises. Furthermore, objectively speaking, freight transport promotes from traditional point and linear transport lines to network transport routes. At the same time, regional drop-and-pull transport requires the enterprise the ability of organization of freight source, and to be organized and informationalized. Thus the company keeps on technological innovation, to be intensification, large-scale, networking, and normalization.

Seven provinces, including Shandong, Heilongjiang, Liaoning, Jilin, Neimenggu, Hebei and Tianjin, build the Around Bohai bay drop-and-pull transport coalition, with the advantage of the location around Bohai bay. Drop-and-pull transport can cooperate at a regional scale, the benefits of drop-and-pull transport can be highlighted, and container drop-and-pull transport can be promoted. A company in Shandong shows a good example for it. Initially the traditional operation mode was used. Vehicles reached the operating points for unloading and loading, then went back to distributing center. The return time for vehicles back to distributing center is limited, to ensure the loading and unloading of freight in distribution center. Otherwise the goods cannot be delivered to the receiving point on time in the next day. It is obviously that working hours in the point is very tense, when the load distance and travel time is long. What is more, if delay occurs, the whole system will break down. After equipping motor tractors and trailers as 1:2, drop-and-pull transport can be implemented smoothly all along the working points. Working time of motor tractors in working station is significantly shorter. Organizational problems of system operation caused by the time of operating procedures in working point, can be solved effectively. In consequence, on-time rate of operation is increasing, service time is reducing, and the stability and reliability of the whole system is enhancing, as shown in Table 1 and Table 2.

Table 1.Operation Timetable in Traditional Way

Motor Tractor	Beijing	Tianjin	Jinan	Tianjin	Beijing
Departure Time	12:30	18:30	04:00	13:30	
Arrival Time		15:30	01:00	10:30	16:30

Table 2.Operation Timetable in the Way of Drop-and-Pull

Motor Tractor	Beijing	Tianjin	Jinan	Tianjin	Beijing
Departure Time	12:30	17:00	01:00	09:00	
Arrival Time		15:30	23:30	07:30	12:00

3 Container drop-and-pull transport in port area

3.1 Multimodal drop-and-pull transport for collecting and distributing

Transport enterprises, relying on port, carry out multimodal drop-and-pull transport for collecting and distributing on freight rolling transport, in order to improve transport efficiency and save the cost. Motor tractors take trailers carried containers to the harbor, then trailers take a long-distance transport by ship. After arriving the destination, motor tractors take trailers again to the enterprise or storage yard. As shown in Figure 4, multimodal drop-and-pull transport for collecting and distributing reduces the waiting time of motor tractor, saves the capacity of transport resource, improves the capacity of utilization and ship handling efficiency.

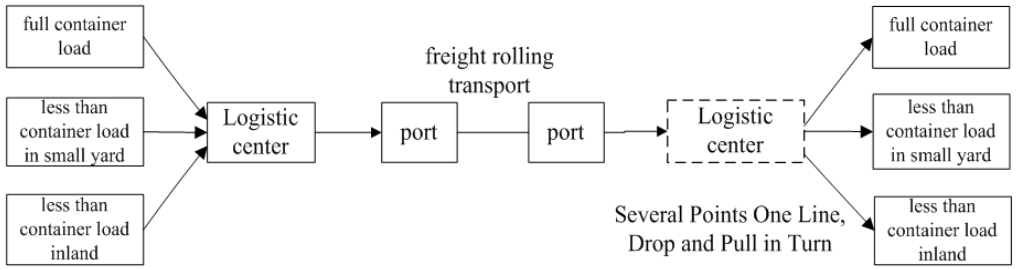

Figure 4.Rolling Shipment Container Drop-and-Pull Transport

Multimodal transport is radially distributed about a port as central part in the view of network configuration of drop-and-pull transport. Due to the containers concentrated in port, a large number of containers will pile up. So we need to build a logistics center between harbor and enterprise, which will become a transit point by selecting an organization mode of "Several Points One Line, Drop and Pull in Turn". All the goods are delivered from enterprises to the logistics center rapidly, and then transported to the port rapidly in form of container by motor tractors in the harbor according to the schedule. The application of logistics center can make the containers deliver from enterprises to harbor rapidly come true, settle the problem such as small footprint of storage yard and lack of handling capacity effectively, improve the responsiveness of port services chain links, maximize the efficiency of port and enhance the service ability of port.

3.2 Container double drop-and-pull transport in dry port

Dry port is a logistics center built in the inland country, with service function of harbor such as customs declaration, applying for inspection and signing and issuing bills of lading, with the purpose of enhancing radiation intensity of port to the inland hinterland. Container double drop-and-pull transport makes container return to operating points of dry port from enterprises and factories import nearby, and transport the containers needed to export from client nearby to storage yard in the harbor.

As double drop-and-pull transport services more outlets, there are round-trip transportation needs and sufficient supplies between customer base and port. For selection of the mode of "Circle Drop and Pull" between harbor and factories, dry port and storage yard, its profit is triple of traditional mode. For high efficiency of this transport organization mode, it has been widely used in foreign countries. What is more, it has been promoted in our country in recent years.

Conclusion

As a kind of low-carbon and energy-saving mode of transport organization, container transport with dumping trailers should be promoted with Green logistics developing vigorously in our country. While container drop-and-pull transport requires the conditions of a higher degree of organization in order to carry out better. So selection of container drop-and-pull transport discussed in this paper must think about type of sources, layout of loading and unloading points, form of transportation management, type of operation lines, form of transportation network in practice. After analyzing the right to choose the prefect container transport organization mode, drop-and-pull transport can get the best economic benefits

References

DONG Q.L. (2008). "Transportation histology." *Renmin transportation Press*.

GAO H.T. (2012). "Techniques and Approaches of Drop-and-Pull Transport." *China Material Press*, 53-66.

QI H.X. (2012). "The study of Low-carbon transport Organization Mode based on Drop-and-Pull Transport" [J]. *Logistics Engineering and Management*, 34(4).

GAO H.T. (2011). "Organization Technique and Application Practice of Drop-and-Pull Transport." *Renmin Fortune Press.*

ZHU X.N. (2010). "Container Transport and Multimodal Transport." *China Railway Press.*

Research on Urban Rail Train Routing Optimization

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Abstract: In order to solve the key issues of urban rail train routing problem, which were considered as to determine running section and turn-back stations, combined with practice experience, a multi-objective 0-1 mixed integer programming model about urban rail train routing problem is established in this paper. This model manages to pursue best matching between train routing strategy and space distribution characteristics of passenger flow demand, when considering capacity limitation of the railway lines and stations as well as facility transportation organization and passenger convenience. Then, the model was simplified according to its features aiming to be solvable by optimizing soft wares directly. Finally, taking Chongqing urban rail line 1 as an example, the practical application of the model has proved its feasibility and efficiency.
Keywords: Urban rail transit; Train routing plan; Multi-objective 0-1 mixed integer programming.

1 Introduction

Urban rail train routing plan fixed the operation section and turn-back station of the trains based on line section of passenger flow distribution and the train makeup. In a more common way, it also includes train interval solutions, diurnal time section and car configuration plan. Better train routing scheme can improve the efficiency of vehicle utilization, make full use of limited resources, and convenient passengers. Therefore, starting from the characteristics of time and space distribution of traffic demand, to seek the best match of train routing and traffic demand space and time characteristics by making the rain routing scheme was a common interests of both passenger and operation partners.

GUO Kai (2005) analyzed routing comparison respectively in Shanghai, Chongqing, Nanjing, Guangzhou and other cities. ZHOU Gang, LU Jing.(2010) used analytic hierarchy process (AHP) to construct a more general operating path optimization model. XU Ruihua, CHEN Jingjing, DU Shimin (2005) is putting forward lower rail capacity and car configuration mathematical model by "running cycle analysis calculation", then choose routing scheme for the operating unit. SUN Yan,SHI Qizhou,ZHAO Yuan(2004) and TIAN Fu-sheng, LU Hong-xia, LI Zhi-hong(2006) also are given from the aspect of transportation enterprise as several car use lower bounds, and established mathematical optimization model formula of the maximum load rate and diurnal time section at the same time. a number of decision variables: makeup length, operation frequency and operation period was defined, from the aspect of transportation efficiency and the traffic demand at the same time in DENG Lianbo，ZENG Qiang，GAO Wei，BIN Song.(2010), established a multi-objective model of urban rail transit train plan. And according to the model, based on the experience of the operation plan formulation method, a three stage method was designed.

In conclusion, the existing literature used pattern comparison or optimization of train operation plan. However, there is a lack of unified and clear rules, the latter have not deeply involved in a variety of special combination of the route collections. While Urban development brings the change of population distribution, however, that a single delivery way already cannot adapt to the passenger flow distribution characteristics of continuous change. Match the space-time characteristics of passenger flow with a complex train routing scheme of urban rail transit is one of the breakthrough point to solve the problem of traffic demand in a long period. This paper will based on traffic demand characteristics of space and time, in order to reach the best match between train route and traffic demand characteristics of space and time as the goal, at the same time considering transportation enterprise benefit and passenger convenience, to solve the routing scheme.

2 Problem description

Urban rail transit train routing can be classified as single route、long-short route、section nested route, cross route and combination in several forms. Combination route is the combination of more than the other two styles, operating organization is very complicated. At present, the vast majority of rail transit operation organization using simple single route mode. However, with the updating of urban development concept, some cities began to show obvious characteristics of multicenter, in turn, affects the population distribution and travel demand, only a single rail route cannot handed well to adapt to the continuous change of passenger flow distribution. more flexible train routing scheme should be adopted in urban rail transit only can it match the passenger flow characteristics of time and space, and undertake the mission of public transport backbone.

The influencing factors of urban rail transit train routing scheme mainly from the perspective of long-term planning, include: passenger section flow distribution characteristics, characteristics of passenger flow between OD, train makeup plan and the station conditions, etc.

The establishment of Routing scheme should be first based on the section passenger flow distribution of time and space. According to the flow amount, time distribution can be divided into two categories: peak and flat period, two periods can be regarded as independent of each other according to the traffic optimization respectively in making Routing scheme. And spatial distribution of passenger flow in a single line without transfer can be reflected by the OD passenger demand. At the same time, the station line conditions, combined with train plan determines the supply capacity, of which the train makeup plan make the most direct way to develop relationship with routing scheme. Based on the following two assumptions, this paper constructs the train operation section and turn-back station mathematical programming model:

(1)the urban rail transit lines use one form of the train makeup, fixed and unified;

(2)this paper builds the model of downside direction only;

3 Train routing model

3.1 parameters

There is a urban rail straight line of n stations, n-1 sections. The Routes set is J, $J=\{ J(i) | i=1 \cdots m\}$, with m routes, each route has its turn-back station and running sections. Thus the *ith* route can be described as：$J(i)=\{A(i), B(i), S(i), L(i)\}$。

In which, $A(i), B(i)$ are the turn-back stations of the *ith* route. $S(i)$ is the station sets the ith route contains. L (i) is the sections the ith route contains.

0-1decision variables are defined as:

$x_{ij} = \begin{cases} 1, j \in L(i) \\ 0, j \notin L(i) \end{cases}, y_{ik} = \begin{cases} 1, k \in S(i) \\ 0, k \notin S(i) \end{cases}$,

x_{ij} equals to 1 if route *i* contains section *j*, or else equals to 0. y_{ik} equals to 1 if route *i* contains station *k*, or else equals to 0.

3.2objective function

The primary goals of urban rail transportation organization from the point of view of system optimization for the routing scheme is to determine the spatial characteristics of transport capacity and traffic demand the best match, but as routing plan is made before the frequency of train services, the difference between uneven coefficient of passenger and coverage rate of route in section is taken to measure the matching between spatial characteristics of demand and the route.

The uneven coefficient of passenger is the ratio of passenger flow in each section j and the minimum one. Let passenger follow of section j be pj, j∈[1,n-1], in which the minimum one is minjpj，then the uneven coefficient of passenger is pj/minjpj。the coverage rate of route is ratio of the amount of routes that contains section j and the lowest bound., let the amount of routes that contains section j be $\sum_i^m x_{ij}$, the lowest bound be minJ, then the coverage rate of route is $\sum_i^m x_{ij}$ /minJ .

Objective function one can be presented as:

$$\min z_1 = \sum_j^{n-1} \left| p_j/\min_j p_j - \sum_i^m x_{ij}/\text{minJ} \right| \quad (1)$$

The second objective function considered the least transfer flow. Let passenger flow between station *o* to *d* be p_{od}, *o,d*∈[*1,n*], a function was designed to describe if station *o* and *d* be connected by one route, in other words, if the passenger flow between station *o* and *d* need transfer or not. That is $\sum_i^m y_{io}\, y_{id} > 0$, $\partial(\sum_i^m y_{io}\, y_{id}) = 1$; or$\sum_i^m y_{io}\, y_{id} = 0$, $\partial(\sum_i^m y_{io}\, y_{id}) = 0$。

Objective function two can be presented as:

$$\min z_2 = \sum_o^{n-1} \sum_{d=o+1}^{n} p_{od} (1 - \partial(\sum_i^m y_{io}\, y_{id})) \quad (2)$$

Taking the operating enterprise efficiency into consideration, income depends on ticket prices and operation cost which is directly related to the car configuration. The shorter the length of route, the faster the car turnover, so as to complete the same transport task takes fewer cars. As a result, the length of route can be taken to measure the cost in routing scheme. The distance between station *f* and *k* is ω_{fk}, *f,*∈[*1,n*]; Then $\omega_{fk} \sum_i^m y_{if}\, y_{ik}$ are the lengths of routes between station *f* and *k*.

Another Objective function can be presented as:

$$\min z_3 = \sum_f^n \sum_k^n \omega_{fk} \sum_i^m y_{if}\, y_{ik} \quad (3)$$

3.3 constrains

As a result of the limitation of urban rail transit lines, station capacity and the requirements of convenience transport organization, several constraint conditions should be satisfied.

(1)any turn-back station on both ends of the route must be the station has turn-back capacity.

$$A(i), B(i) \in \{S_r\},\ S_r \text{ is set of stations has turn-back capacity}, \quad (4)$$

(2)the routes contain all the sections between turn-back station on both ends.

$$xij=1,\quad j\in[A(i),B(i)-1] \quad (5)$$

(3)the routes contain all the stations between turn-back station on both ends.

$$y_{ik}=1,\ k\in[A(i), B(i)] \quad (6)$$

(4)the upper bound of route amounts be satisfied

$$m\leq M,\ \text{M is the upper bound of route amounts} \quad (7)$$

(5) any section coveraged by at least lower bound.

$$\min j \leq \sum_i^m x_{ij},\ j \in [1, \mathrm{n}-1], \quad (8)$$

(6) any station coveraged by at least lower bound.

$$\min j \leq \sum_i^m y_{ik},\ k \in [1, \mathrm{n}], \quad (9)$$

In addition, decision variables still need to meet the station-line connection, namely:

$$x_{ij}= y_{ij}\ y_{i(j+1)},\ i\in[1,m],\ j\in[1,n-1], \quad (10)$$

4 Model simplification

Urban rail transit train routing planning model is confirmed by (1) - (10). The Model has two sets of 0-1 decision variables x_{ij}, y_{ik} and integer variables m, $A(i), B(i)$. The Model has three optimization objectives, the objective function (1) has an absolute value, (2) has nonlinear term partial $\partial(\sum_i^m y_{io}\, y_{id})$. In conclusion, the upper model of urban rail transit train routing planning is a multi-objective nonlinear 0-1 mixed integer programming model, which must be simplified in order to facilitate solving.

4.1 simplifications of the decision variables

The relationship between the decision variables are represented by constraint (5), (6) and (10). The key to determine the routing scheme is to determine each route turn-back station on both ends. Therefore, after the turn-back station set is given, with two turn-back station a and b to mark each route, new 0-1 variables c_{ab} and constant e_{jab}, t_{kab} are defined to replace the original decision variables. c_{ab} value 1 if route J of turn-back station a and b on both ends be selected, otherwise 0, $a,b\in[1,|S_r|]$,$|S_r|$ is turn-back station number. e_{jab} value 1 if section j belong to a and b, otherwise 0, $j\in[1,n-1]$, t_{kab} value 1 if station k belong to a and b, otherwise 0, $k\in[1,n]$. So $x_{ij}=c_{ab}e_{jab}$, $y_{ik}=c_{ab}t_{kab}$.

4.2 simplifications of objective function

Replace xij, yik with cab ,then objective function one turn into:

$$\min z_1 = \sum_j^{n-1} \left| p_j/\min_j p_j - \sum_a^{|S_r|} \sum_b^{|S_r|} c_{ab} \mathrm{e}_{jab} \right| \quad (11)$$

Objective function two turn into:

$$\min z_2 = \sum_o^{n-1} \sum_{d=o+1}^{n} p_{od} (1 - \partial (\sum_i^m c_{ab} t_{oab} t_{dab})) \tag{12}$$

Objective function three turn into:

$$\min z_3 = \sum_a^{|S_r|} \sum_b^{|S_r|} c_{ab} \omega_{ab} \tag{13}$$

There are a lot of methods to solve the multi-objective programming. Almost all of them are turning the problem of multiple objectives into single objective programming problem. In this paper, the first target is to optimizing transport organization system which is the main objective. There is contradiction in the relationship between the other two objectives. Goal two is seeking route length to be considerably long while objective three target at minimum the total route length. Therefore, in order to satisfy the two goals at the same time, optimal routing length should be limited in a reasonable range. Here measured it through passenger average travel length. With $\bar{l}$ as passenger average travel length, the objective function two and three are combined to be:

$$\min z_{2,3} = \sum_a^{|S_r|} \sum_b^{|S_r|} \left| c_{ab} \omega_{ab} - \bar{l} \right| \tag{14}$$

the finally objective function represented as:

$$\min z = \gamma_1 \sum_j^{n-1} \left| p_j / \min_j p_j - \sum_a^{|S_r|} \sum_b^{|S_r|} c_{ab} e_{jab} \right| + \gamma_2 \sum_a^{|S_r|} \sum_b^{|S_r|} \left| c_{ab} \omega_{ab} - \bar{l} \right| \tag{15}$$

In which, γ_1, γ_2 are the Weight coefficients.

4.3 simplifications of constrains

only constrains(8)、(9)are needed after Replace x_{ij}, y_{ik} with c_{ab} ,then constrains(8)、(9)turn into:

$$1 \le \sum_a^{|S_r|} \sum_b^{|S_r|} c_{ab} e_{jab} \le \min j, j \in [1, n-1] \tag{16}$$

$$1 \le \sum_a^{|S_r|} \sum_b^{|S_r|} c_{ab} t_{kab} \le \min j, k \in [1, n] \tag{17}$$

After the simplification, the urban rail transit train routing planning model is made by (7), (15) - (17), which greatly simplifies the decision variable in type and amount, reduced the number of constraints, made the mixed 0-1 integer programming to be 0-1 programming.

Considering the capacity constraints of general urban rail transit station turn-back equipment, more than one train are not allowed to operate at the same time, or it will influence each other and enlarge the turn back time, as shown in the literature [8]. At the same time too many routes will increase the complexity of passengers. At present, RER line - B in Paris, for example have four routes at flat peak period, five at the peak period. Therefore, take total maximum routes amount M for 2-5. After simplification processing, the model can be solved in the optimization software LINGO11.0 programming, when using LINGO default branch and bound method to solve.

5 Case study

Taking train routing scheme of chongqing rail line 1 for example to validate the effectiveness of the model. chongqing rail line 1 opened 27 stations (ChaoTianMen - wall mount), 49 km line length in Long-term operating. Turn-back station set {1,2,14,19,27}. different routes Can be chosen between turn-back station is $C_5^2 = 10$. predict passenger flow in the peak hour of each section is shown in table 1, OD flow forecast data is also needed.

Table 1. prediction of section passenger flow during peak hour for line 1

section	1	2	3	4	5	6	7	8	9	10	11	12	13
p_j	4384	13448	20467	23651	27639	29395	35791	34806	34347	30015	28252	26527	23169
section	14	15	16	17	18	19	20	21	22	23	24	25	26
p_j	17487	15003	13002	11833	10454	7902	7270	8673	7835	6968	4730	4303	2781

The calculation results are shown in table 2 and figure1-4.

Table 2. calculation results

M	minj	γ_1	γ_2	iterations	time(s)	Z	Z_1	$Z_{2,3}$	Z_2	Z_3
2	2	0.5	0.5	47	2	62.41861	114.3635	10.47368	0	51
3	3	0.5	0.5	104	2	53.63167	97.21072	10.05263	0	69
4	4	0.5	0.5	71	2	45.11821	80.69256	9.543860	0	86
5	5	0.5	0.5	68	2	39.17948	70.46422	7.894737	0	106

(1) M=2, minj =2, c=(0, 0, 0, 1, 0, 0, 1, 0, 0, 0)

(2) M=3, minj =3, c=(0, 0, 1, 1, 0, 0, 0, 1, 0, 0)

(3) M=4, minj =4, c =(0, 0, 1, 1, 0, 1, 1, 0, 0, 0)

(4) M=5, minj =5, c=(0, 0, 1, 1, 1, 1, 1, 0, 0, 0)

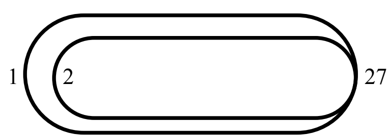

Fig. 1 train routing plan 1

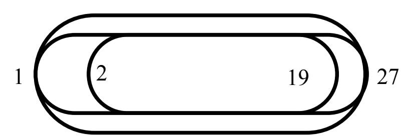

Fig. 2 train routing plan 2

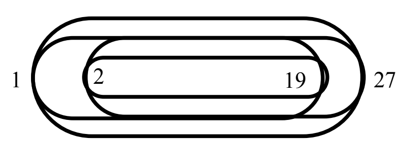

Fig. 3 train routing plan 3

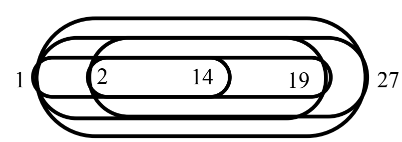

Fig. 4 train routing plan 4

When M=2-5, a throughout route has grew up in the final plan, no passenger need to transfer, so the z2=0. The equivalent of z2 is preferred to be satisfied. With the increase of upper limit M, the objective function z1 and z2,3 continues to decline, show that the total objective function decreases with the increase of route number. But as z3 increases with the larger M, because it will make total route length increased.

6 Conclusions

Taking the core problem in urban rail transit train routing scheme as the decision variables, considering the reasonable demand, transport capacity, transportation organization then the mathematical programming model was established. And the model is simplified based on the characteristics of train routing scheme. The simplified model is integer programming and can be solved quickly through optimization software with high efficiency and quality of solution.

Application of chongqing urban rail transit line 1 and the analysis of calculation results show that satisfy section passenger flow distribution is the primary goal of the routing scheme and transfer flow can be solved throughout route. Train running section and turn-back station is the foundation of the urban rail transit transport organization plan, providing the basis for the establishment of for train operation interval solutions, configuration plan and train stops. Although the research object defined as a single straight line, it also laid the foundation for urban network level rail routing scheme more of complex and practical value in further research.

References

DENG Lianbo，ZENG Qiang，GAO Wei，BIN Song. Optimization method for train plan of urban rail transit. SCIENCEPAPER ONLINE, 2010.5(10):767-772.

GUO Kai. Study on train running solutions for Shanghai-Nanjing inter-city rail transit.Modern Urban Transit,2005.2 (2):121-124.

LI Suying, CHEN Guanghua, CHE Yongbin. Shanghai urban rail line 1 routing plan practice . Urban Transit research, 2007.7(1):27-30.

LU Jingsheng, YANG Pujie, LIANG Qingsheng. Guangzhou metro line 3 Y type routing plan practice . technical innovation paper, 2008.9 (1): 29.

SHAN Ning, SONG Jian. Chongqing urban rail line 3 capacity and routing plan research .metro,2005. 3(1):8-13

SUN Yan,SHI Qizhou,ZHAO Yuan.Method on making train running-plan for urban railway traffic.Journal of Tongji University,2004.32(8):47-49.

TIAN Fu-sheng, LU Hong-xia, LI Zhi-hong. The Design of Metro Train Routing based on Optimized Train Set Configuration. railway transport and economy,2006.28(1):26-28.

XU Ruihua, CHEN Jingjing, DU Shimin. Study on Carrying Capacity and Use of Rolling Stock with Multi-routing in Urban Rail Transit. Journal of the china railway society,2005.27(4):6-10.

ZHOU Gang, LU Jing. Application of Analytic Hierarchy Process on Optimal Locomotive Routing Schemes in Subway Operation. Urban Transit research, 2010.6 (1):52-54.

Business Process Reengineering of Railway Freight Transport by Petri-Net Based on Supply Chains

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Abstract: A method of business process reengineering of railway freight transport based on supply chain was discussed. The disadvantage and development of business process reengineering of railway freight transport based on supply chain were introduced. Based on Petri Net and the characters of supply chain, the method model of business process reengineering of railway freight transport was proposed. Every step of the model as a whole was studied. Two steps of the business process reengineering of railway freight based on supply chain were proposed. Lastly, the optimized freight service process was given.
Keywords: Business process reengineering; Supply chain; Petri Net; Railway freight transport.

1 Introduction

As the artery of national economy, railway undertakes the main procurement of people's livelihood supplies and capacity is extremely tense. The goal of Chinese railway cargo transport organization optimization only consider from inside the railway which obeys the principles of economy and benefit maximization while ignore the interests of the cargo owner. Railway cargo business process optimization is based on supply chain, the railway cargo business process as the organic composition of logistics system, pay more attention to cooperate with other logistics service function implement effective connection, thus and logistics systems in the upstream and downstream enterprises established stable cooperative partnership (KONG, 2006).

2 Analysis of railway freight business process based on supply train

2.1 Main problems in business process of railway freight transport

(1) Using tandem mode in business processes, which is time consuming and inefficiency.

Most of business process in railway system is tandem which is time consuming for customers. In addition, several apartments are in low condition thus inhibiting the increasing of overall efficiency.

(2) Lacking in consideration from customer's perspective with tedious procedure and single business.

In the consideration of pursuing high efficiency, railway department could not meet customers' variant need because of its single business and service which do not conform to requirement of outer service-oriented enterprise.

(3) Coordination degree of each operation link is insufficient, and the waiting time during middle processes is too long.

Each department of freight stations is uncoordinated though connected in the procedure of business in some degree due to the distribution of department functions.

2.2 Effects of supply chain thought on business process reengineering of railway freight transport

Railway freight is no longer facing on the original transport market, but a integral supply chain network with all kinds of logistical function including multimodal transport, warehouse management, distribution management, etc. Customers' requirements on transportation and distribution are effected by mercurial market which means transport service provider should keep high efficiency to make sure the procedure more quickly, accurate and stable from place an order to get cargo. However, traditional railway transportation mode could not handle this contradiction. In order to meet customers' need effectively, we should optimize railway freight transport process based on the whole supply train management (ZHANG, 2008).

3 The modeling method of business process reengineering based on Petri Net

Extend the analysis on railway freight transport process before based on Petri Net theory, abstract the flow diagram, and draw a business process model.

Define a four dimensional array $\sum$ as follow:

$$\sum = \left(P, T; A, M_{ij}\right)$$

The transforming relationship between railway freight transport processes and elements in Petri Net was showed in table 1.

Table 1. Correspondence between rail freight transport processes and Petri Net

Railway freight transport process	Petri Net
Processes or tasks of transport demand	P
Implement of processes	T
Resource constraints or capacity	M_0
Time or cost index in processes	A

First of all, main links of freight transport process is modeling on the whole. Each link is represented symbolically by P, T from the register on e-commerce platform to delivery cargos through a series of operations including freight submission, cargo loading, payment of charges, transportation, etc. And finally build a main process network model as chart 1 shows. Submission of transport requirement in sending end and delivery in receiving end are complex which need a more detailed description thus regarding them as sub-procedure symbolized as detailing and modeling submission sub-procedures of freight transport and logistic needs as chart 2and3. Meanings of P and T in model charts are showed in table 2, 3 and 4.

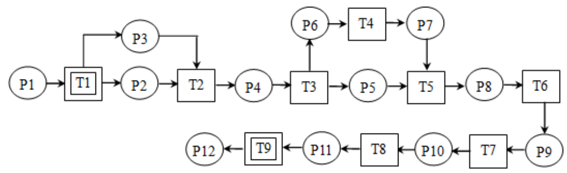

Figure 1. Petri Net model of railway freight transport business process

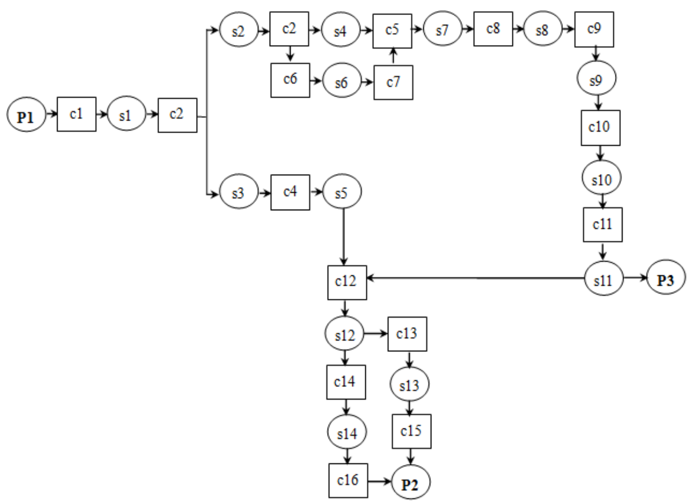

Figure 2. Petri Net model of T1

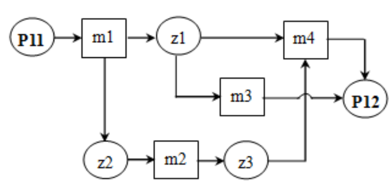

Figure 3. Petri Net model of T9

Table 2. Meanings of P and T in Petri Net model of railway freight transport business process

P	The content of P	T	The task of T
$P1$	Register and prepare for submission	$T1$	submission subprocedures of freight

			transport and logistic needs
$P2$	Receive cargos from customers	$T2$	Cargos loading
$P3$	Empties arrive for cargos loading	$T3$	Account expense and inform customers of payment
$P4$	Cargos loading	$T4$	Customers check expense and pay
$P5$	Inform customers of payment	$T5$	waybill-making
$P6$	Customers receive messages	$T6$	Trains sending out
$P7$	Payment finished	$T7$	Inform stations of trains information
$P8$	waybill-making finished	$T8$	Trains arrive
$P9$	Transportation	$T9$	Cargos delivery subprocedure
$P10$	Stations receive trains information		
$P11$	Trains arrive		
$P12$	Customers receive cargos, deals done		

Table 3. Meanings of T1 in Petri Net model of rail freight transport business process

S The content of P	C The task of T
S1 Customers on the system, ready to deal with business	C1 Customers enter the account password, login electronic commerce system
S2 The order of freight transport is on checking	C2 Customers fill out and submit demand of freight transportation and logistics demand
S3 Railway Bureau received orders to logistics	C3 System automatically review the freight orders
S4 The order of freight transport finish checking	C4 Railway Bureau approval logistics orders
S5 Logistics services ready to be executed	C5 Automatic check qualified orders, reported to the Railway Bureau
S6 The order of freight transport is on checking by people	C6 Automatic check unqualified orders, reported to the station
S7 The order of freight transport is on checking by the Railway Bureau	C7 The order of freight transport is on checking by worker of freight transport
S8 Customer receive the result of checking and ready to booking empty vehicle	C8 Railway Bureau examine the plan of freight transport, and issued the results of the examination
S9 The information of customer demand vehicle reported to the Railway Bureau and waiting for authorization	C9 Customer fill the information of booking empty vehicle
S10 The Railway Bureau deal with the customer booking empty vehicle, to be issued	C10 The Railway Bureau make the plan of using the empty vehicle
S11 The customer received the notice of loading and ready to loading the goods	C11 The station shuttle the empty vehicle and inform the customer of loading the goods
S12 Customers choose independent delivery or	C12Inform the customer of the determination

logistics services	results
S12 Customers ready for delivery goods	C13 Customers arrange the goods
S14 Customers waiting to the service of pick up goods	C14 Customers view of the results of logistics
	C15 customer delivery to the station, finished goods delivery
	C16 Finished goods delivery

Table 4. Meanings of T1 in Petri Net model of railway freight transport business process

Z content of P	M task of T
Z1 Completion of the unloading, storage of goods	M1 Reminding customer to pay fees and giving receive notification
Z2 Customer receive a notification and ready to receive the goods	M2 Customer pay fees
Z3 Customer ready to delivery verification and receive the goods	M3 Customer go to station to receive the goods and completion delivery verification
	M4 Delivering goods to customer

4 Railway freight business process reengineering of the vehicle

4.1 Design ideas and solutions of rail freight business process optimization

(1) To shorten the time of each part is consumed, on the basis of without changing the business process

Through the full use of electronic commerce platform has been shortened documents, delivery time, to make the Railway Bureau, railway freight station and customer can be shared information in time. On the basis of this measure, reasonable arrangement the connection of different modes of transport, to make different business department can be coordination and cooperation and finally to realize seamless connection.

(2) Optimization the process from the structure of business process

Series behavior as much as possible instead of parallel behavior, in this way it can save some time. Then it is a good way to reduce the process which can not bring profit. At last it should consider the relationship of customer and the Railway Bureau.

4.2 The design and optimization in the first phase of the business process

(1) The optimization of railway freight vehicle business process

① Make the tickets and shipping processes in parallel, that is to amend of p4 to p8 process, to improve the efficiency of process make the series structure to parallel.

② in the T6 send train forecast to the customer, notice customers ready to take goods in advance to improve the efficiency of station.

(2)Optimization of the process for T1, T9 process

① improve the efficiency of the system automatically audit order accuracy and remove artificial audit order process, eliminate subnet 1 and 2 in the conflict;

② after the shuttle bus schedule on that day, in advance to remind customers to pay the cost of freight and logistics, namely to modify c11.

③ calculated through actual investigation and take delivery way, resolve the conflict c13 / c14.

④ through actual investigation and calculation way, solve the z1 / z3 conflict.

4.3 The second phase of the business process design and optimization

The second phase of the business process design and optimization under e-commerce environment is mainly focused on the logistic need submission, acceptance and implementation in sending end and receiving end with the goal of synchronous submission, acceptance and implementation of freight transport and logistic need (ZHANG, 2013).

(1)Optimization of logistic demand submission

①Service type: Dividing railway freight transport service into five types according to customers' requirement: Through agent service, door to door service, door to station service, station to door service and station to station service. Customers in sending end fill in logistic demand information and report logistic service demand according to their own needs. Customers in receiving end directly report detailed logistic service after receive the delivery message.

②Service content: Railway logistics value-added services is compared with traditional freight, stretch around freight service chain, promoting the value of freight products and provides all the logistics services.

(2)Optimization of logistic demand acceptance

In terms of how to distribute logistic orders to companies, this article puts forward a method which introduces a score of service area and content (MA, 2008).

(3)Optimization of logistic service implementation and logistic cost payment

Logistic service implementation under e-commerce environment is no longer dispersedly operated, but complete together by railway departments use the way such as strategic cooperative joint operators, with the aid of e-commerce platform, integration of logistics enterprise resources.

In conclusion, we can reach the freight logistic service process in sending end and receiving end based on full logistic thought, supply chain theory and Petri Net model as chart4 and 5(XU, 2002).

The operations of rail freight develop logistics value-added services are on the basis of railway logistics resources integration of the railway corporation, the railway administration and railway logistics companies. As a system, railway logistics are in the influence of the internal and external motivation and resistance. However, from the study of mechanism of railway logistics resources integration we know, whatever motivation or resistance, the overall efficiency and competitiveness will continually increase when integrate all kinds of resource.

5 Conclusion

This article expounded the emergence and development of business process reengineering under supply chain environment, raised a reengineering model and optimized current railway freight service process in two phases. However, this article only generally introduced the business process reengineering model based on supply chain, and lacked a detailed description which should be completed in next phase. Due to the limited level, the proposed model is not perfect enough. It should be modified according to specific situations.

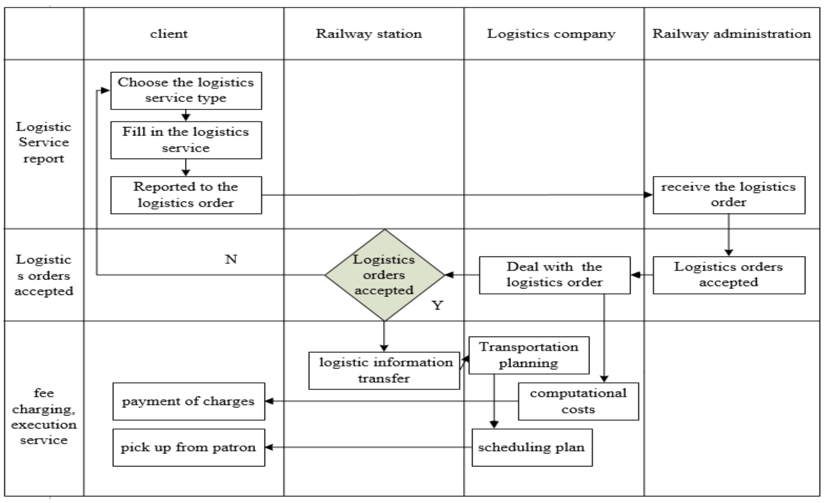

Figure 4. Logistic service flow diagram of sending end after optimization

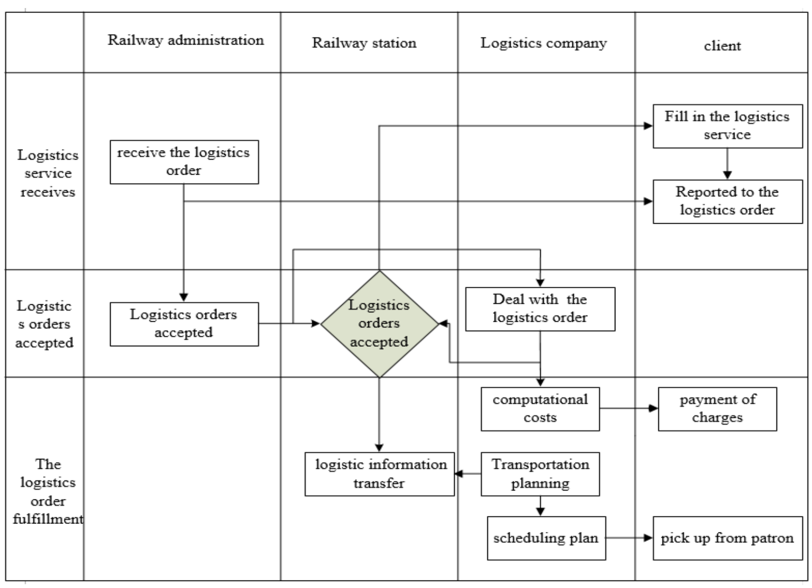

Figure 5. Logistic service flow diagram of receiving end after optimization

Acknowledgement

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References

KONG Zao-jie, DONG Rui-guo. (2006). "Study for method of BPR based on supply chain."Journal of Hebei University of Technology, 35(4), 14-19.

MA She-jiang. (2008). "Railway logistics business process reengineering based on information technology." Logistics Technology, 27(4), 208-210.

XU Wei-xiang, YANG Zhao-xia.(2002). "A study on business process reengineering for the program of railway freight." Journal of Industrial Engineering and Engineering Management, 16(4), 46-50.

ZHANG Dan-yu, WANG Yan-yan.(2008). "Research on BRP based on supply chain." Supply Chain Management, 27(12), 93-112.

ZHANG Xiao-jiang, HU Fang-jie.(2013). "Research on business process of railway freight vehicle under the E-commerce mode." Journal of Transportation Engineering and Information, (3), 24-30.

Design for the Production Organization and Safety Management System of a Railway Passenger Transportation Depot

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Abstract: This paper intends to establish a production control and safety management system for the passenger transportation depot to improve the level of information. First of all this paper analyzes the necessity and significance of the system. On the bases, describes the design objectives and design range of the system. And then this paper designs the overall structure of the system, proposes the logical architecture and technical architecture program of the system, and then designs the system network solution. Finally this paper carries out a detailed functional design of the system, and the system is divided into two subsystems, the command center subsystems and safety management subsystem, and both of the two subsystems' functional modules are designed in detail.
Keywords: Passenger transportation depot; Production organization; Safety management; System design; Functional analysis.

1 Introduction

The production organization and safety management system of railway passenger transportation depot plays a role of platform for information exchanging between the various departments and types of work within the railway passenger depot, and it is also an information system for leaders of various level to implement dispatch and safety management to various basic units uniformly.

The production organization and safety management system, as one of the internal systems of railway bureau's passenger transportation depot, and an important part of quick response system, its information construction level plays a decisive role in the realization of transportation production of "Efficient command, exchange information and scientific decision-making". And the construction of the system plays a significant role in railway safety production. The main role of the system includes the following aspects.

(1)The system is the main channel of information collection. It provides information support for the production management of the passenger transportation depot to ensure the timely and accurate transmission of information.

(2)The system helps to achieve the production planning management of the passenger transportation depot.

(3) The system is able to implement emergency dispatching disposal facing the sudden events. And it can make a rapid response to ensure the smooth flow of rail transport.

(4) Assistant decision-making.

(5)Coordinate various departments of the passenger transportation depot, achieving smooth communication between the upper and lower levels.

The production organization and safety management system of railway passenger transportation depot should meet the needs of the daily dispatching and production management of the passenger transportation depot, and it should establish a networking, information, intelligence safety management systems to realize sources sharing and to meet the demand for the innovation development of production arrangement and safeguards in the new period. The system plays a positive role in the safety management of railway field, optimization of transportation organization as well as the improvement of work efficiency under this new situation.

2 Research status at home and abroad

2.1 Relevant foreign research

The relevant foreign research mainly focus on the automatic establishment of the crew routing plan, but there are less research on the overall production control and security management system.

The scholar Dennis Huisman studied the implementing procedure of the crew routine plan and the crew dispatching plan of the Nederlandse Spoorwegen in detail. The scholar Alberto Caprara described the development of a new crew planning system set up by Ferrovie dello Stato SpA (the Italian railway company) in cooperation with the University of Bologna. The system divided the procedure into three phases, namely pairing generation, pairing optimization and rostering optimization. The scholar Ernst A.T proposed an integrated optimization model to solve both crew scheduling and crew rostering. The integrated optimization model can adapt to the actual situation of railway operations in Australia.

2.2 Relevant domestic research

The scholar Qu Zhiheng developed the “management system for the passenger train in transit” to strengthen the security monitoring and management for the operations of the passenger train in transit. Including the conductor inspection tour subsystem, vehicle terminal subsystem and data processing center subsystem.

On the basis of the existing “management system for the passenger train in transit”, the scholar Qu Zhiheng integrated the functions and upgraded the hardware configurations of the existing system, and developed the “integrated management system of dispatching of the passenger depot". The system consisted of six subsystems, including the train in transit subsystem, management of cadres' plan of participation in crew work, production scheduling subsystem, video management subsystem, safety information subsystem and train office subsystem.

Xi'an railway bureau completed tasks of constructing the two-level production safety command center of railway administration and the station segment. The command center can realize daily production plan online approval, real-time online monitoring of key aspects of the operation, emergency command online, implementation of operating standards inquiry and efficiency and effectiveness index analysis.

A conclusion can be drawn from analysis of the research status home and abroa d that the current research mainly concentrate on one or a few aspects and lack the comprehensive information architecture. This paper covers comprehensively the entire process of production organization and safety management of passenger depot. And the overall system has been divided into the command center subsystem and safety management subsystem, and its functional architecture has been designed clearly and comprehensively.

3 System design objectives and design range

3.1 System design objectives

Adopt advanced GPS global positioning technology, video surveillance technology, fingerprint recognition technology, computer network technology, information processing and integration technology, building a unified production organization and safety management system which covering the entire process of transportation production within the railway passenger transportation depot.

The system will be in the crew organization, safety monitoring, production safety risk management, railway morale quality assessment as the core, combining computer science, and give full play to the posts initiative of the staff. Control and monitor the production situation and the service quality of the passenger transportation depot accurately and real-timely, raising the level of decision-making management, comprehensively promoting the informatization management of passenger transportation depot.

The design objectives of the system including the following aspects:

(1) Control of real-time information of safety in production and service quality

(2) Implement emergency command processing

(3) Realize the routing of the safety risk management

(4) Improve the efficiency of production scheduling dispatch

(5) Realize the dynamic management of passenger transportation depot personnel

(6) Full and accurate statistical analysis

3.2 System design range

The construction scope of the system covers the management of the passenger transportation depot and its subordinate units, including the departments directly under the passenger transportation depot, team dispatching departments, car team, passenger service workshop, and carriage servicing workshop located around, also including the management of the train on the way, and the construction of the team dispatching video monitoring. The construction range of the system as is shown in the figure 1.

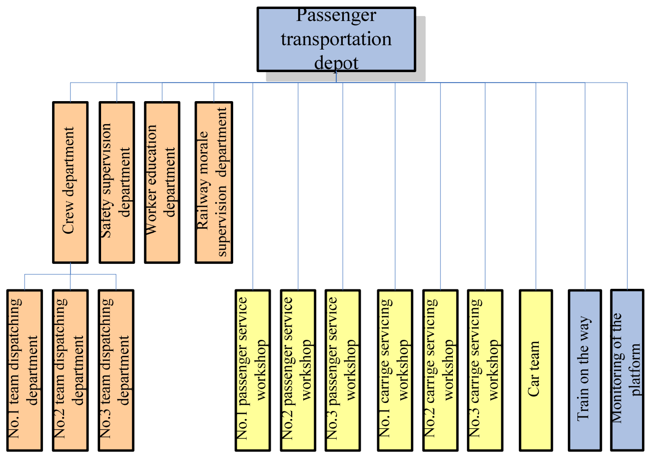

Figure 1.The design range of the system

4 System general designs

4.1 Logical architectural of the system

The logical architectural of the system mainly oriented to the users including the managers of the passenger transportation depot, each team dispatching department, the train on the way, and the train attendants, to provide them a set of convenient and comfortable operating environment, which can realize the real-time organization management, monitoring, and query of the transportation production of the passenger transportation depot. The whole system is divided into user layer, service layer and basic information layer. The logical architectural of the system as is shown in the figure 2.

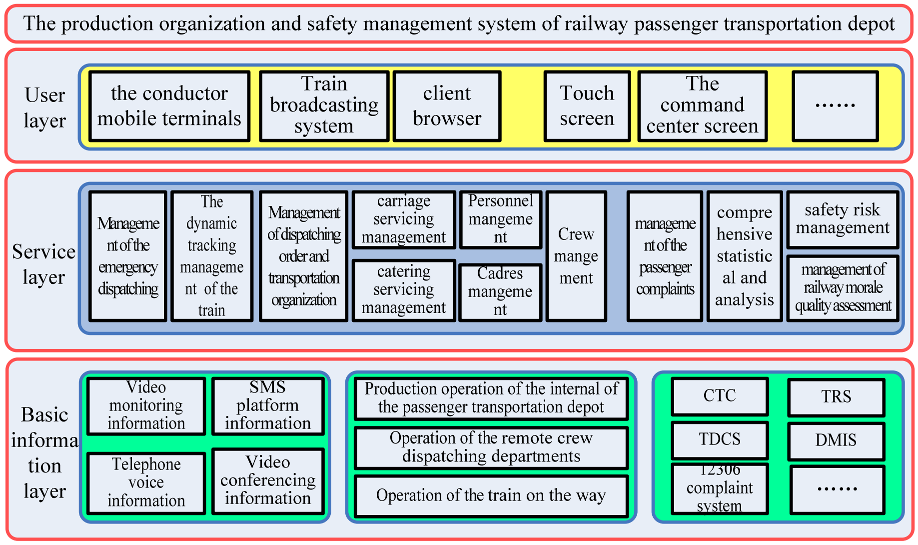

Figure 2.The logical architectural of the production organization and safety management system of railway passenger transportation depot

(1)User layer

User layer provides the users of the system with operation interface, preliminary check the integrity of the user input information, verify the identity of the users. Different users such as the railway bureau, passenger transportation depot, team dispatching departments, and the train on the way can access the production organization and safety management system of railway passenger transportation depot via by devices such as the client browser, the conductor mobile terminals, touch screen, and the command center screen to implement different types of related work and decision analysis of the passenger transportation depot management.

(2) Service layer

Service layer act as the bridge between the user layer and the basic information layer, concentrated the business logic processing of the system. The service layer respond to the requests conveyed from the user interface layer. And perform the corresponding tasks. The service layer extracts relevant data from the data layer, and transmits the necessary data to the user interface layer.

System service layer complete business processes through the unified basic information, and maintain the consistency and integrity of the basic data in the information processing. Business layer contains multiple business services and functional modules. Realize business functions such as statistical, analysis, decision-making, publishing, monitoring, supervision and sharing and exchange data and other business functions. And address the different needs of users directly.

(3) Basic information layer

Basic information layer integrated the operating data of the internal of the passenger transportation, remote crew dispatching departments and the train on the way. And the basic information layer introduces various types of video and audio information. And share the related information from existing systems such as KMIS, TDCS, CTC, TRS, DMIS and 12306. The basic information layer provides basic data and information support to achieve the requests of the service layer.

4.2 Technology structure of the system

Taking into account of the high reliability, scalability, availability, integrity and manageability, the technology structure of the system adopt the Browser/Server structure. Server is responsible for data management; users transact business through the client browser, guarantee the security, integrity of the system data. The system is designed as the typical three-tier architecture, including the presentation layer, business logic layer, and data access layer.

The system separates different business logic and application, and provides the service program that allows the underlying data access, data encapsulation, data transmission, to achieve the application that in accord with the customer application logic. The system accesses between every layer through interfaces to avoid that one layer logic leads to business changes have an impact on other layers.

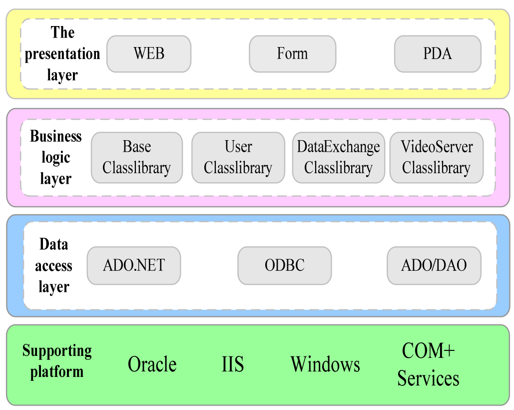

Figure 3.The technology structure of the production organization and safety management system of railway passenger transportation depot

5 Network structure design of the system

The system based on the existing railway network environment, on the premise of reliable, safe and efficient, guarantee the fluency of the network between the system and other related railway production management systems.

The network of the system needs to cover the railway bureau, passenger transportation depot, remote crew dispatching departments, and the train on the way. The network structure of the system as is shown in the figure 4.

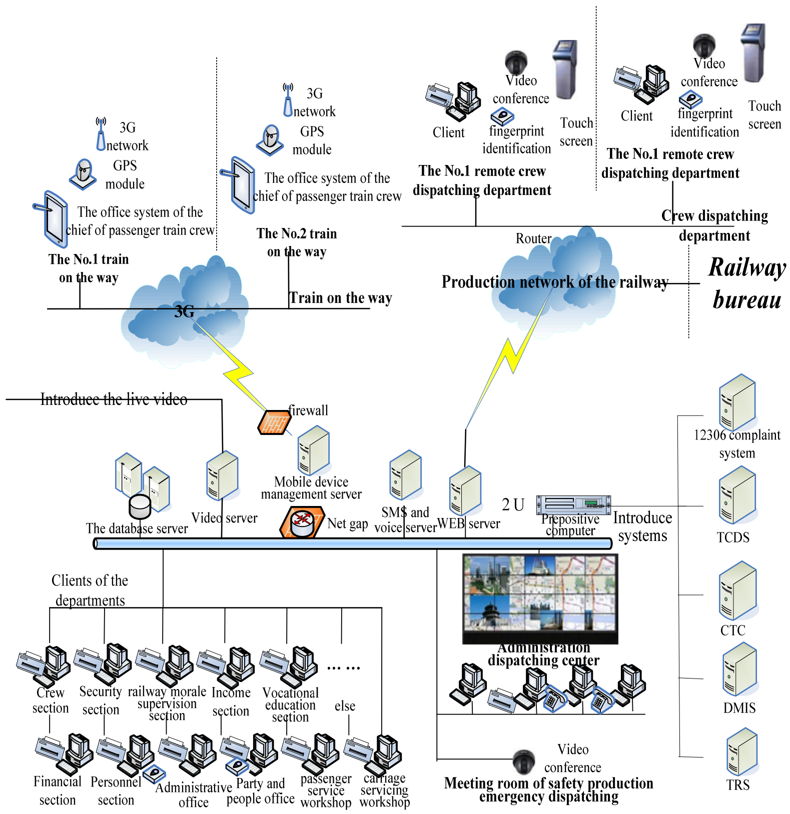

Figure 4.The network structure of the production organization and safety management system of railway passenger transportation depot

6 Functional structure design of the system

6.1 Overall functional structure design of the system

The production organization and safety management system of railway passenger transportation depot is designed based on the modularization. And it integrates production command and safety management these two aspects to design the function. The system consists of two subsystems, the command center subsystem and safety management subsystem. The overall functional structure as is shown in the figure 5.

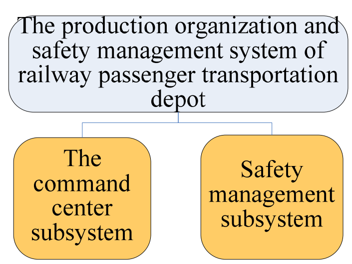

Figure 5.Overall functional structure design of the system

The command center subsystem mainly realizes the commanding and coordinating of the production business and urgent incident. And the safety management subsystem mainly realizes the management of the passenger transportation depot's production management information. Two subsystems complement each other; meet the demands of production organization and safety management of the passenger transportation depot in common. Design function of these two subsystems respectively in the following.

6.2 The command center subsystem

The command center subsystem supposed to have five functions including production scheduling, security monitoring, integrated query, emergency handling and dynamic management of cadres. To realize the function of the command center subsystem, we need to start from hardware and software both of the two aspects for construction. And strengthen the construction in terms of personnel, institutions and systems in order to guarantee the normal operation of the system function.

The command center subsystem focuses on the organization of production, and it via the tracking technology including video conferencing, telephone voice, SMS, and GPS to fully grasp the situation of the train on the road. And the subsystem dispatches the crew team real-timely by taking the form of video commanding and multi part call. And communication and collaboration with the higher authorities through video conferencing, teleconferencing. And implement the treatment of the emergency events.

The main functional modules of the command center subsystem include:

The dynamic tracking management and monitoring of the chief of passenger train crew, management of crew routine, management of the dispatching command and production organization, construction of video surveillance, platform of the SMS sending and receiving, telephone voice call center, management of the emergency dispatching, video conference of the emergency dispatching, and mobile terminals of the chief of passenger train crew. Each modules perform different functions, and combine with each other, formed a perfect platform for production organization which is informatization, networking, real-time and efficient.

The functional structure of the command center subsystem as is shown in the figure 6.

6.3 Safety management subsystem of the passenger transportation depot

The safety management subsystem mainly realizes the management of the passenger transportation depot's production safety information.

The main functional modules of the safety management subsystem include:

Personnel management, crew management, management of railway morale quality assessment, management of cadres, safety risk management, management of the passenger complaints, carriage servicing management, touching screen management, and comprehensive statistical and inquiry. Each modules perform different functions, and combine with each other, formed a perfect informatization, networking, real-time and efficient safety production information management subsystem.

The functional structure of the safety management subsystem as is shown in the figure 6.

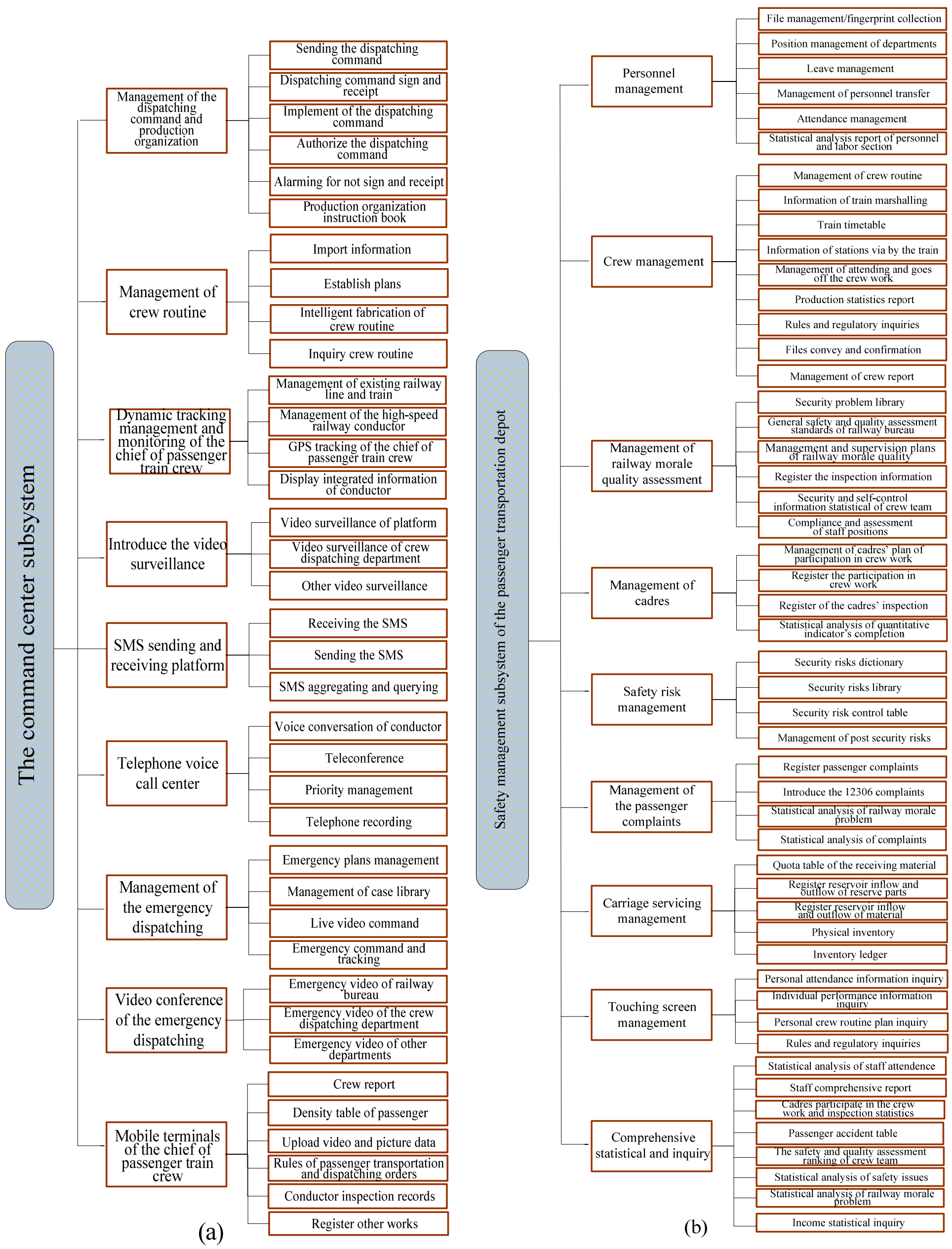

Figure 6. Functional structure design of the command center subsystem and the Safety management subsystem

7 Conclusions

The organization management of the passenger transportation depot relate to the efficiency and patency of the whole transportation organization. Because there are lots of complex links inside the passenger transportation depot, shall make plenty of information. In order to meet the requirement of the development, we need to improve the informatization level of the passenger transportation depot.

The paper designs the production organization and safety management system of railway passenger transportation depot in detail, and puts forward the design scheme of the key parts. The system has reasonable structure and complete functions, has a certain practical value for the organization management. And the system will play a positive role in promoting information construction of the passenger transportation depot.

Acknowledgement

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References

Alberto Caprara. (1998). Modeling and Solving the Crew Rostering Problem. *Operations Research.* 1998.46(6).820-830.

Caprara A, Fischetti M, Guida P L, et al. (1999). Solution of large-scale railway crew planning problems: The Italian experience.Computer-aided transit scheduling. 1999: 1-18.

Ernst A T. (2001). An Integrated Optimization Model for Train Crew Management. Annals of Operations Research. 2001.108.211—224

Huisman D, Kroon L G, Lentink R M, et al. (2005). Operations research in passenger railway transportation. Statistica Neerlandica. 2005, 59(4): 467-497.

LI Huikang. (2010). Xi'an railway built-up the two-level production safety command center of railway administration and the station segment. Xi'an Railway Technology. 2010 (001).

QU Zhiheng. (2011). Establishment and management of management system for the passenger train in transit. China Railway. 2011,03: 009.

QU Zhiheng. (2012). Establishment and management of integrated management system of dispatching of the passenger depot. China Railway. 2012(10):29-33.

Schedule Design for Liner Shipping Based on Wave Optimization

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Abstract: This paper focuses on the schedule design problem for liner shipping to hedge against uncertainties. As a complement of Robust Optimization, a new optimization method – Wave Optimization (WO) is proposed, which is more suitable for socioeconomic systems. Then a mixed-integer nonlinear programming model based on WO is presented to solve the vessel schedule design problem. A real-life case study is investigated and proves that the proposed model could be solved effectively and efficiently for the realistic scale problem.
Keywords: Liner shipping; Schedule design; Wave optimization; Mixed-integer nonlinear programming.

1 Introduction

Not like tramp shipping, liner shipping services have fixed sequences of ports of call and fixed schedules for a period of time (usually 3 to 6 months), mainly involves the transportation of containers (Karlaftis et al., 2009; Norstad et al., 2011; Rakke et al., 2011; Øvstebø et al., 2011). However, there are many uncertainties (disruptions) in liner shipping services, such as bad weather, strike in ports, congestions in passageways and ports, and mechanical failures (Brouer et al., 2013). The various disruptions could make a decrease in schedule reliability. According to Notteboom (2006) approximately 70-80% of vessel round trips experience delays in at least one port. Furthermore, schedule unreliability would have a negative effect on many actors in the supply chain. E.g., Vernimmen et al. (2007) present a case study to illustrate the impact of schedule unreliability on the level of safety stock that should be kept by a manufacturer who sources spare parts from overseas, and it is concluded that an improvement in schedule reliability can lead to significant cost savings for the company under consideration.

There are mainly two ways to handle disruptions in liner shipping services. One is through reactive scheduling (disruption management), and the other one through proactive scheduling (design robust schedules). Only one published journal paper is found in literature devoted to disruption management in liner shipping. Brouer et al. (2013) proposed a vessel schedule recovery problem to evaluate a given disruption scenario and to select a recovery action balancing the trade-off between increased bunker consumption and the impact on cargo in the remaining network and the customer service level.

The literature on schedule design problem in liner shipping is also limited however a trend of increasing. One category of the studies addresses the schedule design problem in a deterministic environment. Mourão et al. (2001) examined two possible schedules for the feeder route in the model they proposed. Ting and Tzeng (2003) presented a dynamic programming model for scheduling a single ship route under berth time-window constraints. Wang et al. (2014) and Alharbi et al. (2014) also proposed the schedule design problem with port time windows, what different is, Wang et al. (2014) focused on a single ship route but Alharbi et al. (2014) focused on a liner shipping network with many ship routes. Wang and Meng (2011) investigated the schedule design problem and the container-routing problem simultaneously which objective is to minimize the sum of the total transshipment cost and penalty cost associated with longer transit time than the market-level transit time, minus the bonus for shorter transit time. The second category of the studies considers uncertain factors when designing the schedules of liner services. In the work of Wang and Meng (2012a), the uncertain port time and sea time contingencies were captured when designing the optimal schedules. They formulated a stochastic MINLP and proposed a cutting-plane based algorithm. Qi and Song (2012) designed an optimal vessel schedule in the liner shipping route to minimize the total expected fuel consumption considering uncertain port times (treated as a random variable). Wang and Meng (2012b) designed robust schedules that can hedge against the uncertainties in port operations, including the uncertain wait time and uncertain container handling time.

This paper focuses on the schedule design problem for liner shipping to hedge against uncertainties whatever occurred on sea or at ports, based on a new optimization theory we proposed – Wave Optimization (WO), which would be introduced in the next section.

2 Wave Optimization

As is known, robust optimization (RO) is one of the most common methods to handle uncertainties in a system and have made great development in the last decade (see Gabrel et al., 2014, for reviews). However, there are some inherent drawbacks of RO, such as: (1) Seeks to obtain a solution that will be feasible for the realization of the worst-case, however, complete protection from adverse realizations often comes at the expense of a severe deterioration in the objective (Gabrel et al., 2014); (2) Usually uses a finite number of scenarios to compute the worst case, but cases beyond the set could happen in real-life which would make the solution not effective anymore; (3) No consideration of resilience in case of the deterioration of the system state. These shortcomings above mentioned limit the application scope of RO in socioeconomic system, though it is fit for some engineering applications of robustness, such as robust control theory, as the engineering failures would produce high-profile repercussions (Gabrel et al., 2014). To remedy the disadvantages of RO, we propose a new optimization method – WO, which is more suitable for the socioeconomic system. Firstly, we introduce the related concepts of WO, see in subsection 2.1.

2.1 Concepts

Wave is the basic representation form of the world, such as mechanical wave, electromagnetic wave and so on and the state curve of something also can be seen as wave (e.g. one's mood, the performance of a basketball player, et al.). The former wave category can be called substantial wave, and the later one virtual wave. We often use the word volatility to describe the bad effect of wave, but few to notice the good side of it. Actually, there is great wisdom in the pattern of wave which is illustrated below with the help of a graph, see Figure 1.

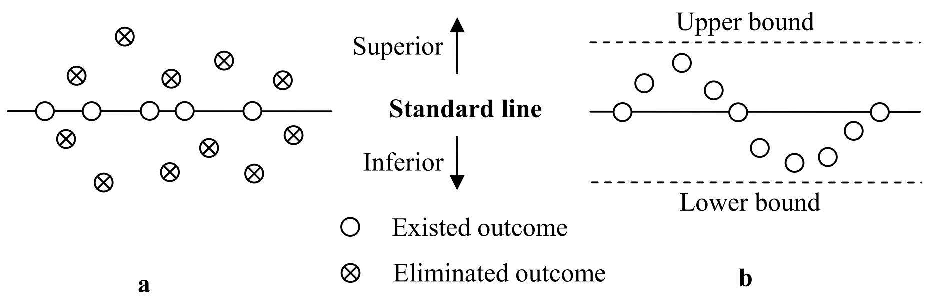

Figure 1. Two different survival modes

In Figure 1a (line form), it only allows of existence of the outcomes which accord with the standard line rigidly, while others would be eliminated. However, in Figure 1b (wave form), it allows the outcomes to fluctuate around the standard line within a certain limit, so more outcomes could be survived than those in Figure 1a. It is obvious that in the form of wave, there's a property of inclusivity which supply the space for various possibility and diversity (uncertainties). Besides, if it reach the crest of the wave, there's always a fall towards the balancing status in the following period of time, and if it get the trough, there would be a rise towards the balancing status as well. This property of wave can be called as recoverability. In this paper, we define the good properties, i.e. *inclusivity* and *recoverability*, as "**waviness**" as integrity of which the adjective form is "**wavy**". Further, in the basic framework of WO, we come up with two index systems to measure waviness: *tolerance* and *resilience*, refers to *inclusivity* and *recoverability* respectively. Then we present the general model of WO consists of the two main index systems, see in subsection 2.2.

2.2 General model

The general model of WO is inspired by the mathematical expression of simple harmonic wave in physics, which can be described by sine function (or cosine function), see Eq. (1).

$$y = A\sin(\omega x + \varphi) \quad (1)$$

In Eq. (1), A is amplitude, ω is angular frequency, and φ is initial phase. In the theory of WO, the parameter φ makes no difference and therefore is set as 0; and the parameter B which is the displacement of equilibrium position in the y direction is needed. So Eq. (1) is converted to Eq. (2).

$$y = A\sin(\omega x) + B \quad (2)$$

The sketch map of Eq. (2) is shown in Figure 2.

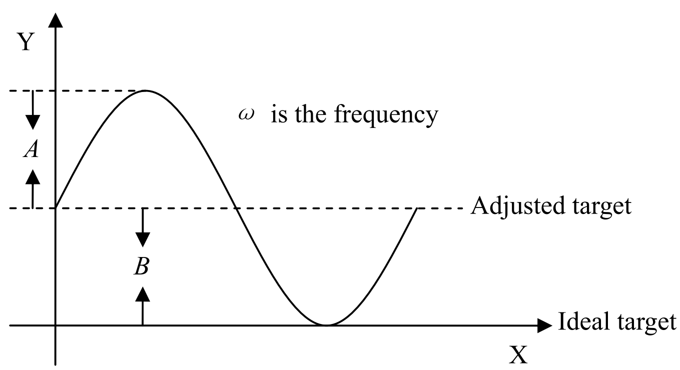

Figure 2. Sketch map of Eq. (2)

In the theory of WO, x-axis equals the ideal target of the system while the real equilibrium position is the adjusted target, A refers to the flexible range of the target, B indicates the buffer put into the system while ω accounts to the resilience of the system. Parameters A and B belong to the index system of tolerance, the greater is the value of A and B, the more space for uncertainties. While ω belongs to the index system of resilience, the greater is the value of ω, the faster bounce back to the schedule target from disrupted status. Our goal is to maximize the waviness of the system, i.e. the sum of A, B and ω, while minimize the operation cost. The objective function of the general model of WO tries to balance the trade-off between the operation cost and waviness benefit of the system, which can be expressed as below.

$$[\text{WO}] \quad \min Z = \mathrm{C}(X) - (A + B + \omega)\cdot M \quad (3)$$

$C(X)$ is the operation cost function, X is vector of decision variables; M is the waviness benefit coefficient. Here no longer mention the constraints of the general model. Moreover, it should be pointed out that the purpose of WO is to make the system possess the waviness (own the potential to perform as wave form) instead of keeping the wave pattern all the time. The general model of WO looks simple and tractable, but whether it is effective or not, we will apply it to the schedule design problem for liner shipping to verify, see the following sections.

3 Problem Description

When designing the vessel schedule for a liner ship route, the ports of call are predetermined and are visited in a fixed sequence. Define a set $I = \{1, \ldots, N\}$ to represent the total ports of call, and the ith leg is defined as the voyage from the ith port of call to the $(i+1)$th port of call, i=1,2, …, N-1, and the Nth leg is from the Nth port of call to the 1st port of call. We let t_i^{ber} (time unit: hour, the same below) be the estimated time of berthing of the vessel at the ith port of call (t_1^{ber}=0, as the time point 0), t_{N+1}^{ber} be the berthing time when the vessel returns to the 1st port of call. We assume a weekly service frequency and m ships are deployed on the route, so there's an equation relation as below shows:

$$t_{N+1}^{\text{ber}} - t_1^{\text{ber}} = 24 \times 7 \times m = 168m \qquad (4)$$

We use the estimated time of berthing other than the estimated time of arrival because shippers/consignees are more concerned about the actual start handling (discharging and loading of containers) time, it makes no difference for shippers/consignees whether a ship has arrived at a port but has to wait for berth (Wang and Meng, 2012b). Therefore, the pilot in time t_i^{in} and pilot out time t_i^{out} of the vessel at the ith port of call are also incorporated in the model.

A_i represents the flexible range of berthing time of the vessel at the ith port of call. We define t_i^{ber} as the published target point of berthing, while [t_i^{ber}, $t_i^{\text{ber}}+A_i$] as the published target window of berthing. If the vessel berths in the target window, it will be announced that the vessel is on schedule. B_i is the buffer time assigned to the ith leg. Let v_i be the sailing speed on the ith leg, subject to the range of $[V^{\min}, V^{\max}]$, and p_i be the productivity (quantity of containers handling per crane per hour) at the ith port of call, subject to the range of $[P_i^{\min}, P_i^{\max}]$. Then the resilience index ω_i including two parts in this paper can be expressed as following: (1) the room for improvement of productivity at the ith port of call (i.e. $P_i^{\max} - p_i$), and (2) the room for speeding up on the ith leg (i.e. $V^{\max} - v_i$). Assume Q_i is the predicted quantity of containers handling at the ith port of call, so the port time t_i^{port} can be formulated as below (assume usually two cranes serve one ship):

$$t_i^{\text{port}} = Q_i / (2 p_i) \quad \forall i \in I \qquad (5)$$

As mentioned earlier, the usage of target window of berthing bring flexible space for liner companies, but from the perspective of port, the vessel berths later than the target point will bring inconvenience since it may disrupt the operation schedule of container terminals. So we define an inconvenience penalty function $F_i(A_i)$ which is shown as below:

$$F_i(A_i)=\begin{cases}0, A_i \le Q_i/(2p_i)-Q_i/(2P_i^{\max}) \\ \varepsilon_i[A_i-(Q_i/(2p_i)-Q_i/(2P_i^{\max}))], A_i > Q_i/(2p_i)-Q_i/(2P_i^{\max})\end{cases} \forall i\in I \quad (6)$$

Eq. (6) indicates that if the time period of A_i can be recovered by improving the productivity p_i to the maximum, no penalty would occur. Otherwise, there's a linear function of penalty. We further define vector:

$$\lambda = (m, t_i^{\text{ber}}, t_i^{\text{port}}, v_i, p_i, A_i, B_i)_{i\in I} \quad (7)$$

The schedule design problem based on WO aims to determine the vector λ to balance the trade-off between ship operating cost, bunker cost, inconvenience penalty and waviness benefit.

4 Mathematical Model

Let t_i^{dep} be the departure time of the vessel at the ith port of call, L_i (n mile) be the length of the ith leg, C^{ship} (USD/week) represent the fixed operating cost of a ship deployed on the ship route, α (USD/ton) be the bunker price, and $g_i(v_i)$ be the bunker consumption rate (ton/n mile) at the speed v_i on the ith leg. As the daily fuel consumption of ships increases approximately proportional to the sailing speed cubed (Ronen, 2011), we can write $g_i(v_i)=\mu(v_i)^2$ since $g_i(v_i)$ is expressed in terms of tons per nautical mile (Wang and Meng, 2012b).

The schedule design problem based on WO can be formulated as a mixed-integer nonlinear programming (MINLP) model:

$$\min Z = C^{\text{ship}}m + \alpha\sum_{i\in I} L_i g_i(v_i) + \sum_{i\in I} F_i(A_i) - \sum_{i\in I}(A_i + B_i + \omega_i)\cdot M \quad (8)$$

Subject to:

$$t_1^{\text{ber}} = 0 \quad (9)$$

$$t_i^{\text{ber}} = t_{i-1}^{\text{dep}} + t_{i-1}^{\text{out}} + L_{i-1}/v_{i-1} + B_{i-1} + t_i^{in},\ i = 2,\ldots,N \quad (10)$$

$$t_{N+1}^{\text{ber}} = t_N^{\text{dep}} + t_N^{\text{out}} + L_N/v_N + B_N + t_1^{in} \quad (11)$$

$$t_{N+1}^{\text{ber}} - t_1^{\text{ber}} = 168m \tag{12}$$

$$t_i^{\text{dep}} = t_i^{\text{ber}} + t_i^{\text{port}}, \forall i \in I \tag{13}$$

$$t_i^{\text{port}} = Q_i / (2p_i), \forall i \in I \tag{14}$$

$$V^{\min} \le v_i \le V^{\max}, \forall i \in I \tag{15}$$

$$P_i^{\min} \le p_i \le P_i^{\max}, \forall i \in I \tag{16}$$

$$A_i \le 24, \ \forall i \in I \tag{17}$$

$$\omega_i = (P_i^{\max} - p_i) + (V^{\max} - v_i), \forall i \in I \tag{18}$$

$$m, A_i, t_i^{\text{ber}}, t_i^{\text{port}} \text{ nonnegative integers}, \ \forall i \in I \tag{19}$$

The first term in the objective function (8) is the ship operating costs, the second term is the bunker costs, the third term is the inconvenience penalty costs and the fourth term is the waviness benefits. Eqs. (9) – (11) answer the berthing time of the vessel at each port of call. Eq. (12) imposes the weekly service frequency constraint. Eqs. (13) – (14) define the departure time and port time of the vessel at each port of call, respectively. Eqs. (15) – (16) limit the varying ranges of sailing speed at each leg and productivity at each port of call, respectively. Eq. (17) enforce that A_i has to be less than or equal to 24 hours. Eq. (18) gives the expression of ω_i. Eq. (19) is for non-negative integer variables.

5 A Real-life Case Study

We carry out a real-life case study to validate the effectiveness of WO and the model we proposed. The MINLP model is solved by LINGO 11.0 running on a 3.2 GHz Dual Core PC with 2GB of RAM.

The case is based on the AWE2 ship route from a global liner company. The sequence of ports of call and the length of each voyage leg are as follows: Qingdao (1: 400) – Shanghai (2: 130) – Ningbo (3: 1100) – Yokohama (4:7800) – Panama (5: 1975) – New York (6: 380) – Boston (7: 559) – Norfolk (8: 1785) – Panama (9: 8800) – Qingdao (1). Other related data are: 4500TEU ships with speed range [10, 24.5] knots are deployed on the ship route; C^{ship} =450000, μ =0.0004, α =560, $\varepsilon_i = 20000, \forall i \in I$, M=2000; pilot in time at the ports of call respectively are {2, 1, 3, 2, 1, 3, 2, 3, 1}, and pilot out time are {2, 1, 3, 2, 0.5, 3, 2, 3, 1}, respectively; productivity range of each port of call all is [30, 60]; the predicted container handling quantity at the ports of call are {1600, 1500, 1000, 500, 1100, 1800, 1400, 900, 1100}, respectively, where the data of the port Panama is virtual since Panama is a canal, no container handling there.

The global optimal solution can be found within 12 minutes when the strategies of *Quadratic Recognition* and *SLP Direction* in "Options" settings are chosen. Since the schedule design problem is a tactical planning problem, the solving time is highly efficient. The computational result of the case is as follows: m=9; the berthing time t_1^{ber} to t_9^{ber} are {0, 55, 95, 181, 625, 759, 819, 882, 1004}, respectively, and t_{9+1}^{ber} is 1512; the port time t_1^{port} to t_9^{port} are {26, 25, 16, 8, 18, 30, 23, 15, 18}, respectively; the sailing speed v_1 to v_9 are {15.38, 11.82, 16.92, 18.01, 17.56, 15.20, 15.97, 17.33, 18.03}, respectively; the productivity p_1 to p_9 are {30.77, 30, 31.25, 31.25, 30.56, 30, 30.43, 30, 30.56}, respectively; A_1 to A_9 are {12, 12, 7, 3, 8, 15, 11, 7, 8}, respectively; B_1 to B_9 are {0, 0, 0, 0, 0, 0, 0, 0, 0}, respectively.

As can be seen, all the values of B are zero, but when we limit the speed at high level and in a tight range, e.g. [22, 24], positive values of B would be generated. This provides inspiring managerial insights that there's no need to assign buffer time to sailing legs in liner shipping since the speed varying range is wide and we can lower the speed to increase resilience while saving the fuel cost. However, in the realized schedule designed by the company, there's buffer time assigned to some legs and therefore ten ships have to be deployed on the ship route which would increase huge ship operating cost. Apparently, the optimized schedule is more reasonable and more cost-efficient than the realized schedule.

6 Conclusions and Future Work

This paper focuses on the schedule design problem for liner shipping to hedge against uncertainties. First, we propose a new optimization method – Wave Optimization (WO), which is flexible and more suitable for the socioeconomic system compared to Robust Optimization. Second, a MINLP model based on WO is presented to solve the problem. At last, the novel method and the mathematical model are verified through a real-life case study, and the global optimal solution can be found within promising time using the business software LINGO 11.0. Useful managerial insights are acquired from the computational result.

The future work may extend to the following directions: (1) further improve the WO theory, and (2) apply the method of WO to other industries, e.g. airline, railway, logistics and supply chain.

References

Alharbi, A., Wang, S., Davy P. (2014) "Schedule design for sustainable container supply chain networks with port time windows." *Adv. Eng. Informat.*, http://dx.doi.org/10.1016/j.aei.2014.12.001.

Brouer, B. D., Dirksen, J., Pisinger, D., Plum, C. E. M., Vaaben, B., (2013) "The vessel schedule recovery problem (VSRP) — A MIP model for handling disruptions in liner shipping." *Eur. J. Oper. Res.*, 224 (2), 362–374.

Gabrel, V., Murat, C., Thiele, A. (2014) "Recent advances in robust optimization: An overview." *Eur. J. Oper. Res.*, 235, 471-483.

Karlaftis, M. G., Kepaptsoglou, K., Sambracos, E. (2009) "Containership routing with time deadlines and simultaneous deliveries and pick-ups." *Transport. Res. Part E*, 45 (1), 210-221.

Mourão, M. C., Pato, M. V., Paixão, A. C. (2001) "Ship assignment with hub and spoke constraints." *Maritime Policy & Management*, 29 (2), 135–150.

Norstad, I., Fagerholt, K., Laporte, G. (2011) "Tramp ship routing and scheduling with speed optimization." *Transport. Res. Part C*, 19 (5), 853-865.

Notteboom, T. E. (2006) "The time factor in liner shipping services." *Maritime Econ. Logist.*, 8 (1), 19–39.

Øvstebø, B. O., Hvattum, L. M., Fagerholt, K. (2011) "Routing and scheduling of RoRo ships with stowage constraints." *Transport. Res. Part C*, 19 (6), 1225–1242.

Qi, X., and Song, D. P. (2012) "Minimizing fuel emissions by optimizing vessel schedules in liner shipping with uncertain port times." *Transport. Res. Part E*, 48 (4), 863–880.

Rakke, J. G., Stålhane, M., Moe, C. R., Christiansen, M., Andersson, H., Fagerholt, K., Norstad, I. (2011) "A rolling horizon heuristic for creating a liquefied natural gas annual delivery program." *Transport. Res. Part C*, 19 (5), 896–911.

Ronen, D. (2011) "The effect of oil price on containership speed and fleet size." *J. Oper. Res. Soc.*, 62 (1), 211–216.

Ting, S. C., and Tzeng, G. H. (2003) "Ship scheduling and cost analysis for route planning in liner shipping." *Maritime Econom. Logist.*, 5 (4), 378–392.

Vernimmen, B., Dullaert, W., Engelen, S. (2007) "Schedule unreliability in liner shipping: Origins and consequences for the hinterland supply chain." *Maritime Econom. Logist*., 9 (3), 193–213.

Wang, S., Alharbi, A., Davy, P. (2014) "Liner ship route schedule design with port time windows." *Transport. Res. Part C*, 41, 1-17.

Wang, S., and Meng, Q. (2011) "Schedule design and container routing in liner shipping. Transport." *Res. Record*, 2222, 25–33.

Wang, S., and Meng, Q. (2012a) "Liner ship route schedule design with sea contingency time and port time uncertainty." *Transport. Res. Part B*, 46 (5), 615–633.

Wang, S., and Meng, Q. (2012b) "Robust schedule design for liner shipping services." *Transport. Res. Part E*, 48 (6), 1093–1106.

Passenger Flow Organization of Large Passenger Stations during the Period of Spring Festival Transport

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Abstract: With the continuous development of railway passenger transportation enterprise, passenger traffic of railway station is rising, so the difficulty of passenger flow organization is increased. In order to organize the passengers transport during the Spring Festival accurately and efficiently, it is necessary to study passenger flow organization in the peak, to adapt the characteristics of single direction of passenger flow during peak passenger flow and complex passenger flow component , then realize passenger transport safety and orderly. This article firstly introduces the characteristics of passenger flow and its organization during the Spring Festival in China; then introduces the process of passenger in and out of the large railway station in the Spring Festival and according it to analyze the way of passenger flow organization , summarize the existing problems and put forward the suggestions to solve them; followed by Nanchang railway station for example, analyze the cause of passenger transport in the Spring Festival, for the status quo of passenger flow organization in the Spring Festival, analyze the existing problems of the Nanchang Railway Station about passenger flow organization in the Spring Festival and put forward the suggestions to solve them, finally predict the Nanchang railway station travel traffic in 2015.
Keywords: Large passenger station; Passenger flow organization; The Spring Festival transport.

The Spring Festival transport refers to the freight and passenger transport during the Spring Festival. It is specific phenomenon in our social and economic life and a product of the combination of customs and habits inherited from thousands of year in China and the planned economic. Analysis and research of passenger flow of the Spring Festival transport is the objective requirement of the socialist market and has an important reference value for passenger flow planning recent and network construction, arrangement of transportation, transport policy in the future.

Many domestic and foreign scholars have deeply researched on passenger station layout, passenger organization method, streamline design etc. Passenger flows of the Spring Festival transport in large passenger station are the main factors that seriously affect the capacity of the hub and this paper studies on how to or organize them.

1 The characteristics of passenger flow during the Spring Festival transport in China

To study the passenger flows organization method, first of all we must know affecting factors and characteristics of passenger flows of the Spring Festival transport, then analyze passenger transport organization combined with characteristics.

1.1 Causes and composition for passenger flow

Passenger flow of the Spring Festival transport belongs to the peak passenger flow which exhibit that far beyond the daily passenger flow in quantity. It has the general characteristics of passenger flow, the great quantity and the particularity of its period. The forming reason mainly has the following several points:

From economy: after the reform and opening up, with economic development, per capita travel times increased. From traditional culture: China is a country with an ancient civilization. Values, religious beliefs and customs largely contributed to the formation of large passenger flow. From national policy: passenger flow fluctuation and change of policy are almost synchronous. In addition, the disequilibrium of regional economic development causes the frequent labor force flow.

The passenger flow include student passenger flow, tourist flow, visiting flow, migrant workers flow.

1.2 Characteristics of passenger flow

After years of statistical analysis, the passenger flow of the Spring Festival transport has the following characteristics:

1) The passenger flow structure's unbalance: through passenger flow growth larger than the tube. 2)Imbalance of area distribution and flow : preganglionic passenger flow distribution in the economically developed southeast coastal area, the flow is mainly from the southeast coastal areas to the central and western underdeveloped area, postganglionic conversely. 3)The passenger flow's unbalance in time : passenger flow focus on when students leave school and back to and migrant workers go home and back to work. 4)The passenger flow composition's unbalance: from the travel purpose, visiting and tourist flow is the main part of the peak passenger flow, but from identity occupation, office workers, migrant workers and students constitute the main passenger. In addition, each of the above characteristics mutual influence.

2 Passenger flow organization analysis of large passenger station

2.1 Procedures of passenger flow into and out of the station in large passenger station

Large passenger station is the main place of railway passenger transportation, the passenger organization level depends on the passenger station space and streamline layout, the facilities' layout and utilization, the procedures and working methods of the passenger flow organization.

The procedures: for in of station, they are the ticket、pull in station、security-check、go to the corresponding waiting room、ticket check、through the tunnel or bridge into the platform and get on the train; for out of station, they are get off the train、through the tunnel or bridge and ticket check.

2.2 Organization analysis of passenger flow during the Spring Festival transport

2.2.1 Analysis of Facility capability

1) Analysis of waiting equipment ability: the waiting room should have comfortable waiting environment and convenient link with the main entrance and wicket and be near the station. The layout of waiting room has two forms:①

Centralized waiting mode, this arrangement have advantages of flexible use, high utilization, but waiting passengers difficult to maintain order;②Scattered waiting mode: The layout features are opposite with the centralized waiting's.

2) Analysis of inlet and exit capacity of the passengers: single inlet and exit ticket check capacity is an important factor affecting the passenger capacity and limited. So it's the key to set sufficient number of wicket ticket.

3) Booking capability analysis: ticket sale capability relates with ticket types, methods, speed of booking and per capita purchasing of passengers.

2.2.2 Streamline analysis

(1) The classification of passenger station streamline

Generally, from the direction of flow: Streamline can be divided in and out of the station. From the properties of flow: divided into passenger, luggage and vehicles streamline. When the passenger flow peak, streamline analysis should start from station square, meanwhile, streamline can be divided into passenger and vehicle streamline.

(2) Streamline of the peak analysis

1) Passenger Streamline: to convenient for station management and passenger travel, passenger streamline usually are divided into the following types:

①Into the station streamline: it includes ordinary passenger streamline which is the main streamline, has the largest number of passengers and need wait longer time; Transit passenger streamline which the passengers can directly transfer the corresponding when time isn't enough; Suburban passenger streamline which can immediately check ticket and get on the when arrive the station; VIP streamline which apart from others' streamline and has a few passengers; Groups of passenger and special passenger streamline which includes passengers of travel group, maternal and child, the weak or etc. and apart from other's streamline.②Out of the station streamline：its' passengers have the characteristics of concentration and short residence time. This streamline should be smooth and passengers should be evacuated as soon as possible to not affect the efficiency of passenger transport organization.③Tickets streamline: nowadays, although most passengers choose to buy tickets through internet in advance, some passengers still buy tickets in the station because of the contradiction between supply and demand and others' factors. We can see that tickets streamline is quite large.

2) Vehicle streamline: it includes streamlines of bus, postal vehicle, parcel special vehicle, taxis and other social vehicle. Planning various vehicles' stop in the station square well and reasonable organization of various vehicles' routes are very important.

3 Organization analysis of passenger flow of Nanchang Railway Station.

3.1 Overview of Nanchang Railway Station

Nanchang Railway Station is located in Nanchang City, capital of Jiangxi Province. It is the only provincial station in the Beijing Kowloon line. It focus on long-term development, forge ahead and now has developed into a modern railway station with traffic command, ticketing, baggage and parcel transportation, passenger service and commercial, catering, accommodation, entertainment function, etc.

3.2 The causes of large passenger flow during the Spring Festival transport in Nanchang

(1) From regional perspective: Nanchang, the capital city of Jiangxi province and the historical and cultural city, has a vast territory, abundant resources and natural landscape and important geographical position. It not only gave birth to the big local population, but also attracted many domestic and foreign tourists and workers etc. This is the basic cause.

(2) From culture and custom perspective: The Spring Festival is the most important festival for Chinese and also the concentrated period for visiting relatives and friends. People's travel frequency increases greatly during the period.

(3) From social economic development perspective: The development of social economy and transportation industry complement each other. Since Nanchang implemented the policy of economic reform and opening up, the city's GDP increase by 11.75% per year. Nanchang's Economic development will inevitably bring the rapid increase of demand for railway transport.

3.3 Passenger flow organization of Nanchang Railway Station

3.3.1 The present situation of passenger flow organization

The situation of passenger flow organization are as follows: 1) The grid type: EMU train, direct express train, express train, inter Bureau express train, HKMA express train and temporary passenger train.2) Security check: security work will be more strict during the Spring Festival.3) Tickets on sale: provide many methods for passengers to ticket, such as the telephone and internet booking, and ticketing through window, ticket vending machines and temporary ticket car.4) Waiting: Nanchang Railway Station set waiting shed in station square besides waiting room indoor.5) Ticket check: At present, the station check ticket by artificial way.6) Out of the station and transfer: passengers get out station and transfer according to the instructions.7)

Instruction and identification: Provide passenger information of tickets on sale, station layout and other' supplementary information.

3.3.2 The problems of passenger transport organization

The problems as follows: 1) Large passenger flow; lack of security check points; too much time for security check.2) Ticket booth deficiency; passengers get on the train without tickets; some people sell fake tickets to passengers.3) When passengers line in S shape in station square, the queuing disorder and exist security risks; low efficiency of ticket check by artificial; ticket checking tedious.4) The exit disorder; little of traffic for passengers to transfer; long distance after getting off train to transfer; instructions for getting out the station and transfer in the station aren't obvious.

3.3.3 Suggestions for solving the problems

The suggestions as follows: 1) Increase security inspection equipment and patrols; improve the efficiency of security.2) Increase ticket booth and ticket vending machines and arrange staffs to instruct passengers to ticket.3) Strengthen the management of the order in station square; adopt automatic checking method; simplify ticket check procedures.4) Arrange supervision personnel in the exit; clear the indicators.

4 Passenger flow prediction of Nanchang Railway Station during the Spring Festival transport

4.1 The concept of prediction

Prediction is that estimating trend of things possible evolvement in advance by scientific judgment method and econometric analysis. In recent years, the number of passengers of the Spring Festival transport increases dramatically, which brings great pressure to passenger station. If relatively accurate prediction can be made, passenger station will arrange work in advance. At present, about 15~20 prediction methods are really used in practice widely, such as the method of regression analysis, trend extrapolation, MarKoV, Deiphi.

4.2 Variation rule of passengers to send of Nanchang Railway Station

The Spring Festival transport time is generally 40 days, including 15 days before the holiday and festival 25 days. Before the Spring Festival, migrant workers return home concentrated in December 18~22 in lunar calendar, while visiting and travelling in December 26~New Year's eve. If the school holiday early, the peak can be alleviated relatively. After the Spring Festival, two peak flows appear in January 5~11 and 16~21 in lunar calendar.

Through the above analysis, we can conclude that the peak of passenger flow almost appear in the same time, passenger flow have roughly the same changing direction and amplitude every year and the time takes periodic fluctuation. The characteristics conforms to the required conditions by seasonal variation prediction method.

4.3 Prediction of number of passenger flow of Nanchang Railway Station

Nanchang Railway Station is a distribution station of large numbers of passenger and under great pressure of passenger organization of the Spring Festival transport. We can establish model to predict number of passenger flow for dealing with the problem in advance. The number of passengers to send during the Spring Festival belongs to the time series of the seasonal changes and the irregular changes which is suitable for seasonal level model.

Through characteristics of the passenger flow, we can establish seasonal level model, which as follows: $Y_t = Y * f_t$; f_t =the average of passengers the same day/general average of passengers in some year; Y is the daily average the year before predicted year; f_t is the seasonal index or coefficient.

According to the data, 2011～2014 passengers of the Spring Festival transport of Nanchang Railway Station is shown in table 1 as follows:

Table 1 2011～2014 passengers of Nanchang Railway Station during the Spring Festival

year	2011	2012	2013	2014
Passengers （10 thousand person）	294	282.8	283	325

2010～2013 annual average daily passengers of Nanchang Railway Station:

Table 2 2010～2013 annual average daily passengers of Nanchang Railway Station

year	2010	2011	2012	2013
Annual average daily passengers (person)	50986	48328	54187	53916

Using model: $Y = (50986 + 48328 + 54187 + 53916) \div 4 = 51854.25$ *(person)*

$f_{t_1} = 294/50986$; $f_{t_2} = 282.8/48328$; $f_{t_3} = 283/54187$; $f_{t_4} = 325/53916$;

$f_t = (f_{t_1} + f_{t_2} + f_{t_3} + f_{t_4})/4 \approx 0.0057$

The predicted passengers of Nanchang Railway Station during the Spring Festival in 2015 are $Y_t = Y * f_t = 51854.25 \times 0.0057 \approx 295.57$ *(10 thousand person)*

5 Conclusions

Passenger organization is a very complex system engineering especially in the Spring Festival. This paper summarize the existing problems and provide direction for optimization of passenger organization and suggestions on organization work through the analysis of the passenger flow organization of large passenger station during the Spring Festival. In addition, it builds model to predict the passengers of Nanchang Railway Station during the Spring Festival so that can take response measures early.

Reference:

Cui Huawei, Jia Junfang. (2007) Research on integrated transport hub streamline characteristic and organization of railway passenger transport. *Railway Transportation and Economy*, 29 (5):26-29.

Hu Mingwei, Xie Xiaodong. (2009) Evaluation of railway passenger station passenger streamline's design based on microscopic simulation. *Railway Transportation and Economy*, 3:33-37.

Yang Hao. (2010) Railway transport organization. Beijing: China Railway Publishing House.

Zhu Hongyu, Zhang Li. (2010) Research on Method for shortening the time of passenger into the station. Chinese Market, 2:128-129.

Zha Weixiong, Liu Huilin, Li Jian, Zhao Wangzi. (2008) Railway passenger flow, traffic flow theory and empirical analysis. Chengdu: Southwest Jiao Tong University Press.

Zhu Xiaojuan (2008) Research on passenger streamline layout of large railway passenger station. Chengdu, Southwest Jiao Tong University,

Security Analysis about a Train Control Center Based on a Bayesian Network

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Abstract: In this paper, by the study of the train control center, we will build a Bayesian networks model on the train control center in GeNIe, then we can use Bayesian networks structure learning algorithm combined with the corresponding original network optimization[1]; at the same time based on multiple fuzzy expert root node evaluation prior probability of Bayesian networks analysis algorithms we can get the root of its initial probability distribution, and through parameter learning of the Bayesian networks we can do quantitative safety analysis on the train control center. By the safety analysis model of the train control center based on Bayesian networks we can not only appropriate security risk quantification calculations train control center, but so analysis and diagnose the main factors which lead to different consequences and posterior probabilities.
Keywords: The train control center; Bayesian networks; Safety analysis.

1 Introduction

Train Control Center as a core part of the ground train control system directly affect the safety and reliability of high-speed train safety, therefore it is necessary to do further signaling system safety analysis, risk management and control of train control center in-depth study of great significance. Conduct research and analysis of security theory train control centers, research hazard identification technology train control center, train control center risk management and control technology research, to guide China's railway signaling system safety assessment is important.

2 Bayesian network's infrastructure

Bayesian network is a probabilistic network, which is based on probabilistic inference of graphical network, and Bayesian formula is the basis of the probability of the network. Bayesian network is a mathematical model based on probabilistic reasoning, it is to address the uncertainty and incompleteness issues raised, it has a great advantage on causes uncertainty and relevance to solving complex equipment the fault, is widely used in many fields.

BN is represented as a directed acyclic graph G = (V, E,θ), where a set of nodes $V = \{x_1, x_2, \cdots, x_n\}$ represent variables, there are set to edge E represents a direct dependency between variables, model parameter θ represents the conditional probability of each state of nodes, that each node $x_i \in X$ has a conditional distribution $(x_i|Pa(x_i))$, $Pa(x_i)$ represents the set of variables x_i in the parent node, thus, the joint probability distribution can be expressed as

$$P(x_1, x_2, ..., x_n) = \prod_{i=1}^{n} P(x_i \mid Pa(x_i)) \quad (1)$$

3 Analysis and modeling of train control center

Train control center is a huge and complex security systems engineering, therefore it is important to clarify the relationship between the central train control systems division level. This chapter describes overall the train control system from the system components, different angles functional level, the implementation process and the status of the transfer. This article focuses on the detailed modeling and analysis from a functional point of Train Control Center.

3.1 Train Control Center Architecture Reference Model

According to the technical specifications train control center and the interface diagram of the train control center combined with other devices, we can describe the static composition intuitive control center column system and its boundaries. The figure below shows the structure of the reference model train control center, as shown in Figure 1

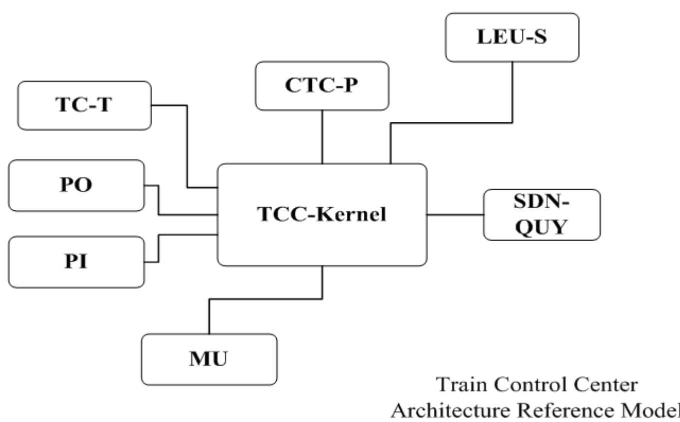


Figure 1.Train Control Center Architecture Reference Model

3.2 Train Control Center features layered model

According to the thoughts of constructing a hierarchical model, and referring to "train control center technical specifications", We can build a hierarchical model of functional architecture reference model train control center of each component unit, and have a detailed description of the function of each unit. Table 1 shows part of the train control center features a layered model

Table 1.Control center TCC-Kernel subsystem features layered model

Code	Functions	Sub-code	Sub-functions
TCCK-4	Track circuits coding	TCCK-4-1	Station track circuit coding
		TCCK-4-2	Interval track circuit coding
		TCCK-4-3	No wiring station track circuits coding
TCCK-5	Track circuit transmit code direction control	TCCK-5-1	Station track circuit transmit code direction control
		TCCK-5-2	Interval track circuit transmit code direction control

3.3 State transition model of train control center

According to Train Control Center Architecture Reference Model, and referring to "train control center technical specifications" of the state of the train control center for analysis and sorting, we can define system shutdown, offline, start the self-test, the communication is established, communication failures, initialization, initialization exception handling, running, trouble-free operation status transfer between processes and conditions

3.4 Sequence diagram model of train control center

Binding function hierarchical model we can conduct a detailed analysis and study of the implementation process state transition model for each state function. Figure 2 shows the station track circuit coding sequence diagram model.

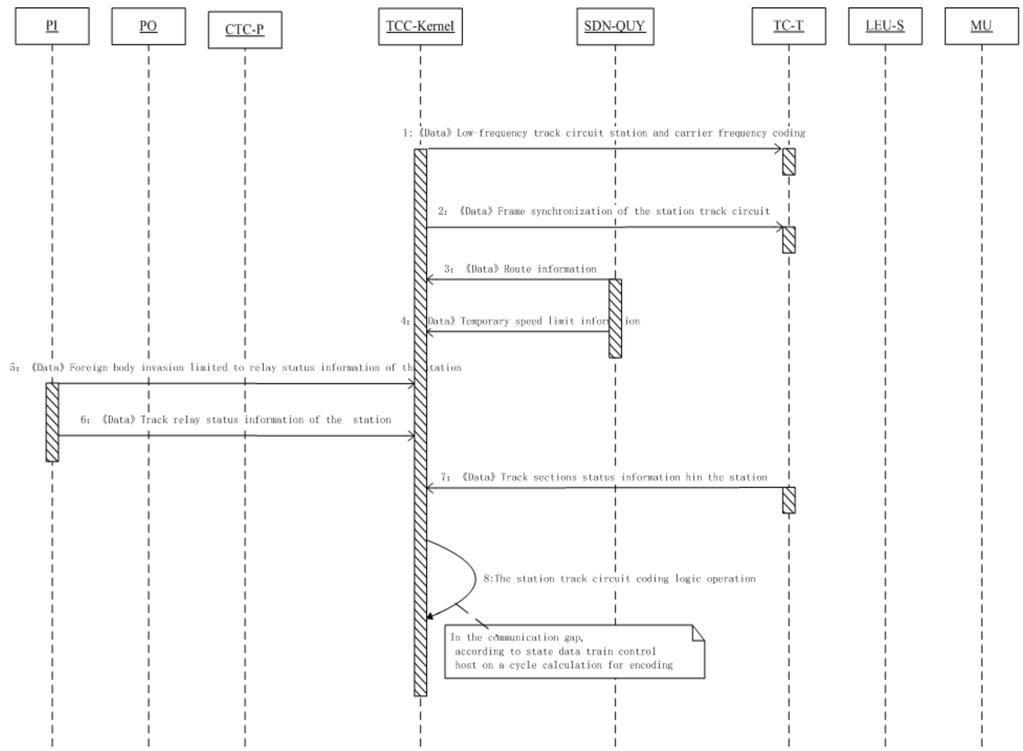


Figure 2. the station track circuit coding sequence diagram model

4 Bayesian network construction and analysis

4.1 Bayesian network building

In fully Bayesian network learning and research, combined with the above for the train control center analysis and modeling, we can build a Bayesian network model about the train control center on the track circuit coding function, and it can be detailed safety analysis. Bayesian network structure is shown in Figure 3.

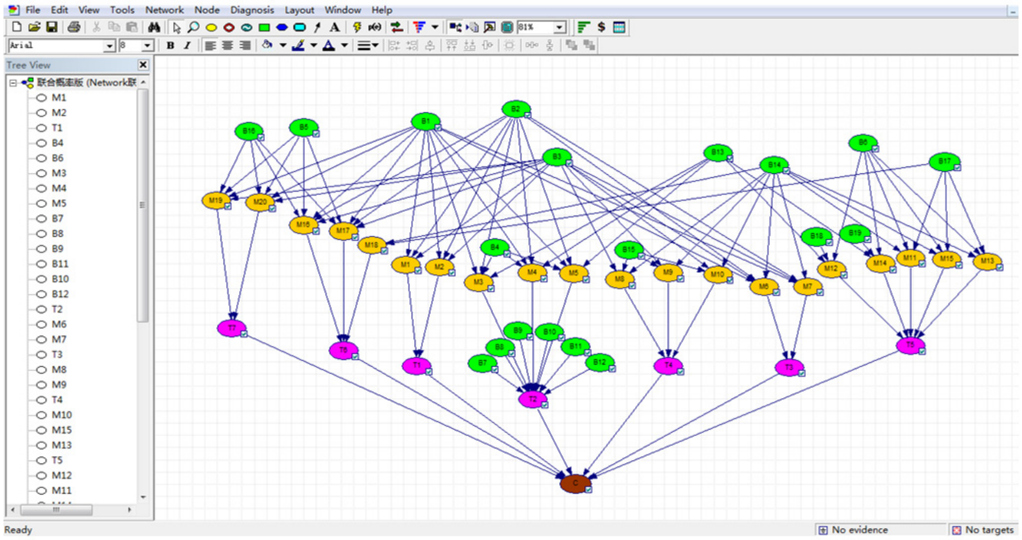


Figure 3.track circuit coding function model based on Bayesian network model

The determining of the Bayesian network model parameters

(1) Non-root conditional probability

Combined with expert opinion, we can determine the conditional probability distribution of nodes based on the logical relationship of each node in the model. For example, the node T6's conditional probability table:

Table 2. the node T6's conditional probability

M16	NORMAL	NORMAL	NORMAL	NORMAL	FOULT	FOULT	FOULT	FOULT
M17	NORMAL	NORMAL	NORMAL	NORMAL	FOULT	FOULT	FOULT	FOULT
M18	NORMAL	NORMAL	NORMAL	NORMAL	FOULT	FOULT	FOULT	FOULT
T6	NORMAL	FOULT	FOULT	FOULT	FOULT	FOULT	FOULT	FOULT

(2) Priori probability of the root node

Because of the high-speed railway development time is short, the statistical data related to the train control system is less and difficult to obtain, we can't be directly determined a priori probability of the root node. In terms of the prior probability of the root, it will be built on the experience and judgment of experts to determine.

We defined incident frequency of 10 levels, and give its value and description .Due to the level of language to describe fuzzy uncertainty, we according to the definition of fuzzy sets and fuzzy Numbers, define its corresponding failure probability and fuzzy number, based on the frequency distribution. Experts judge the frequency of the root node and give its language value, then according to the definition of fuzzy numbers it is translated into the corresponding fuzzy numbers and determined the λ- cut set. The results in the following table .

Table 3. Root node B1 expert judgment data

expert	Frequency of judgment	Failure probability of fuzzy numbers	λ- cut set
1	Seldom	$(6.27\times10^{-8}, 6.27\times10^{-7}, 6.27\times10^{-6})$	$[5.643\times10^{-7}\lambda+6.27\times10^{-8}, 6.27\times10^{-6}-5.643\times10^{-6}\lambda]$
2	Minimum	$(6.27\times10^{-9}, 6.27\times10^{-8}, 6.27\times10^{-7})$	$[5.643\times10^{-8}\lambda+6.27\times10^{-9}, 6.27\times10^{-7}-5.643\times10^{-7}\lambda]$
3	Seldom	$(6.27\times10^{-8}, 6.27\times10^{-7}, 6.27\times10^{-6})$	$[5.643\times10^{-7}\lambda+6.27\times10^{-8}, 6.27\times10^{-6}-5.643\times10^{-6}\lambda]$
4	Rare	$(6.27\times10^{-10}, 6.27\times10^{-9}, 6.27\times10^{-8})$	$[5.643\times10^{-9}\lambda+6.27\times10^{-10}, 6.27\times10^{-8}-5.643\times10^{-8}\lambda]$
5	Minimum	$(6.27\times10^{-9}, 6.27\times10^{-8}, 6.27\times10^{-7})$	$[5.643\times10^{-8}\lambda+6.27\times10^{-9}, 6.27\times10^{-7}-5.643\times10^{-7}\lambda]$

Then use the following formula to collect the expert evaluation data.

$$(\tilde{f}_j)_\lambda = \frac{1}{n}\sum_{i=1,2\cdots,n}(\tilde{f}_{ij})_\lambda \quad (2)$$

According to the following formula

$$I(\tilde{f}_j) = (1-\varepsilon)I_R(\tilde{f}_j) + \varepsilon I_L(\tilde{f}_j) \quad (3)$$

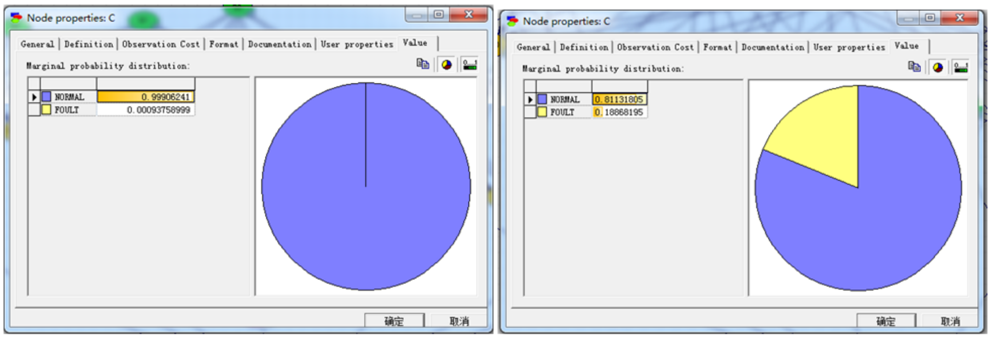
$$I_R(\tilde{f}_j) = |\frac{1}{2}\sum_{\lambda=0.1}^{1}(\tilde{f}_j)_\lambda^R \Delta\lambda + \sum_{\lambda=0}^{0.91}(\tilde{f}_j)_\lambda^R \Delta\lambda| \quad (4)$$

$$I_L(\tilde{f}_j) = |\frac{1}{2}\sum_{\lambda=0.1}^{1}(\tilde{f}_j)_\lambda^L \Delta\lambda + \sum_{\lambda=0}^{0.91}(\tilde{f}_j)_\lambda^L \Delta\lambda| \quad (5)$$

Using the integral method to blur, it is concluded that the root node of the prior probability. Finally the prior probability of B1 is 8.723×10^{-5}, when $\varepsilon = 0.5$.

4.2 Bayesian networks inference

Bayesian networks have two-way reasoning ability. Forecast analysis is as known reason push conclusion reasoning, is a kind of reasoning from the top down. When making causal inference, we can calculate the probability of any node occurs through between the conditional probability distribution of each node. We can use the GeNIe software based on the clustering algorithm in top-down causal analysis. Get track circuit functions of normal and fault probability under the given conditions. The figure below shows the results of Figure node C and non-root node in the probability conditional probability given root node.



In the case of B nodes normal, the probability of node C

In the case of B3 node failure, the probability of node C

Figure 4. Forecast analysis results in Fig.

Diagnostic analysis, also known as the diagnostic reasoning, is known to seek the reasons for the conclusions of reasoning, is a bottom-up reasoning. When making diagnosis reasoning when making diagnosis reasoning, Given the corresponding node observations (evidence of a node), We can learn that the probability of the cause of the result and reason.

The table is about the possibility of sorting class B and class T node failure, when C is under fault conditions

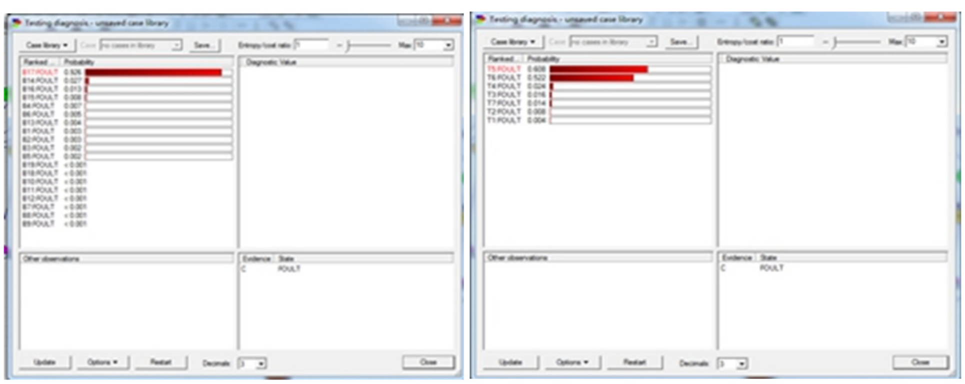


Figure 5. Diagnostic analysis results

When analyzing the chart we can conclude each intermediate node and the root of the failure probability while C fails. According that we can find and analyze the cause of the fault, and provide support for accurately and rapidly determine the cause of the accident!

5 Conclusions

High speed railway in our country this year has been rapid development, which put forward higher request to us. In this paper, on the basis of to learn the train control center, we can do hierarchical analysis model of the train control center, then use Bayesian network technology to build models in view of the train control center of a function, make full use of Bayesian network's uncertainty knowledge expression and the uncertainty reasoning ability, to deal with complex huge logical relationship and carry on the reasonable forecast and diagnostic analysis system.

References

Bjrn Axel Gran (2009). Assessment of programmable systems using Bayesian belief nets. Safety Science. 797-812.

Helge Langseth, Luigi Portinale (2007). Bayesian networks in reliability. Reliability Engineering and System Safety, 92:92-108.

JH Sigurdsson, LA Walls, JL Quigley (2001). Bayesian Belief Nets for Managing Expert Judgement and Modelling Reliability. Quality and Reliability Engineering International, 181-190.

P. Webern, G. Medina-Oliva, C. Simon, B. lung (2005). Overview on Bayesian networks applications for dependability, risk analysis and maintenance areas. Engineering Applications of Artificial Intelligence. 16(5):18-22.

Y W. Yin, W.X. Qian, and L.Y. Xie (2008), "A method for system reliabiltiy assessment based on Bayesian networks," Acta Aeronautica et Astronautica Sinica, vol. 29, no. 6, pp. 1482-89.

Zhang Yadong. (2013). Study on the safety tisk identification and analysis of train control syston of high-speed railway. Southwest Jiaotong University.

Train Timetable Buffer Time Setting Strategy and Affection

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Abstract: robustness is one of the key requests for train timetable. Generally, the train is determined to operate according to the given time on timetable, but in practical cases, however, the ideal timetable calls for a robust time that capable of absorbing, as much as possible, delays or disturbances on daily operation. Which reflected on train timetable formation is add extra time beyond the given section running time and station stop time. Spontaneously, there are two main sections for each train path to add this extra robust time: operating period between station and station stay period. This paper mainly studied the two different strategies` characteristics, and researched the effect of train timetable structure under same extra time add which the extra time is added on section and stop period, and pointed train timetable extra time limitation factors under different strategies, discussed the two strategies advantages and disadvantages.
Keywords: Train time table; Time table robustness; Extra time; Timetable structure.

1 Introduction

Train diagram is the core file for railway transport organization, it determines each train`s arrive and departure time of the track sector. However, train operation is open to the environment and could be affected by numerous of influences. Usually those influences will force the train to delay or early compared with the supposed time determined by train diagram, thus the train diagram should has the ability to absorb those influences in order to make the train operation safety and punctually. Salido (2008) presented the robustness problem from the point of view of railway operators an. D`Ariano (2007) adopted a detailed alternative graph model for the train dispatching problem, and solve the conflicts between different trains. Zwaneveld (1996) considered the problem of routing trains through railway stations and built a bi-level model to solve the problem then evaluated it. Vansteenwegen (2006) calculated the ideal buffer time according to the arriving train late and different kinds of passengers` time consummation, then designed a linear programing to improve the service level of the railway net. Those researches focus on the railway operation mentioned that the buffer time is very importation for train punctuality and the stableness of train diagram. However, many researches put the buffer time in the track sector and use the settled buffer time to absorb the disturbances the train received. These propose is practicable when the disturbance is little and the number of train operated in the track sector is not very much. While the train stop time could be used as buffer time as well, but few researched on the buffer time set during train stop time. This paper analyzed the buffer time set strategy and compared the buffer time influence on train diagram. The construction of this paper is as follows: in sector 2, the principle of ideal running time and buffer time is given. In sector 3, the buffer time set in track sector is analyzed. In sector 4, the buffer time set in station is analyzed. In sector 5, the two buffer time set strategy is compared and in sector 6, a conclusion is given.

2 Train Ideal Running Time and Buffer Time

Train`s operating speed is limited by the track speed limited, locomotive speed limited and vehicle speed limited. The ideal running time is the time that a train will take according to the distance of the track sector and the train operating speed. It is the smallest possible running time for the arriving train, from its previous station to the connection station. However, the train operating circumstances varies a lot and it is almost impossible for the train to operating at the top speed limit all along. So a buffer time is determined in order to assure the train will arrive on time influenced by all kinds of disturbances. The buffer time setting is shown in Fig.1

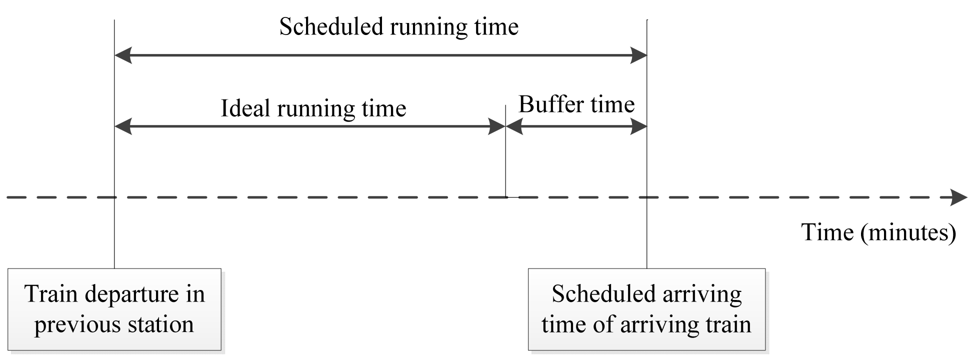

Fig.1 Buffer time setting

The buffer time is very important for train operating, since the trains` operating in the rail could be affected by many uncontrollable influences, it is impossible for the train driver and dispatcher to organize the train according to the set time strictly. The buffer time could allow the train operating deviate from the schedule in tolerance interval.

A train line will pass many track sectors and stations. Accordingly, the buffer time could be set on track sector or on station stop time. The different buffer time set strategy could have different features and affect the train diagram construction differently.

3 Buffer Time Set in Track Sector

If we set the buffer time on tract sector, the scheduled running time during the track sector is added by the buffer time, this make the schedule running time longer than the ideal running time and will cause the sector capacity waste. The buffer time set on track sector is shown in Fig.2.

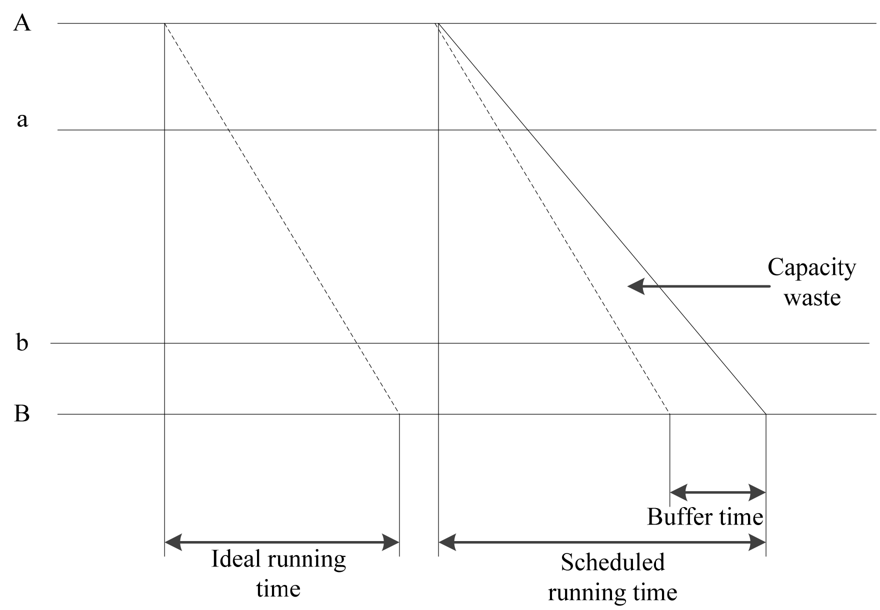

Fig.2 Buffer time set in track sector

From Fig.2 we can see, because of the buffer time set in track sector, the train scheduled running time was prolonged. This prolonged time could be used to absorb the disturbances the train suffered during operating. But however, this extra time period also occupied some track operating time available for the trains. This will cause the capacity waste, especially if the buffer time was set too much for each train in a density track sector, the capacity waste will be remarkable.

4 Buffer Time Set in Station

If we set the buffer time in station, the stop time in station will be prolonged and provide the buffer time to make sure the train will departure on time, this will make the train stop time longer than schedule and might cause the arrive late of the train. The buffer time set in station sector is shown in Fig.3.

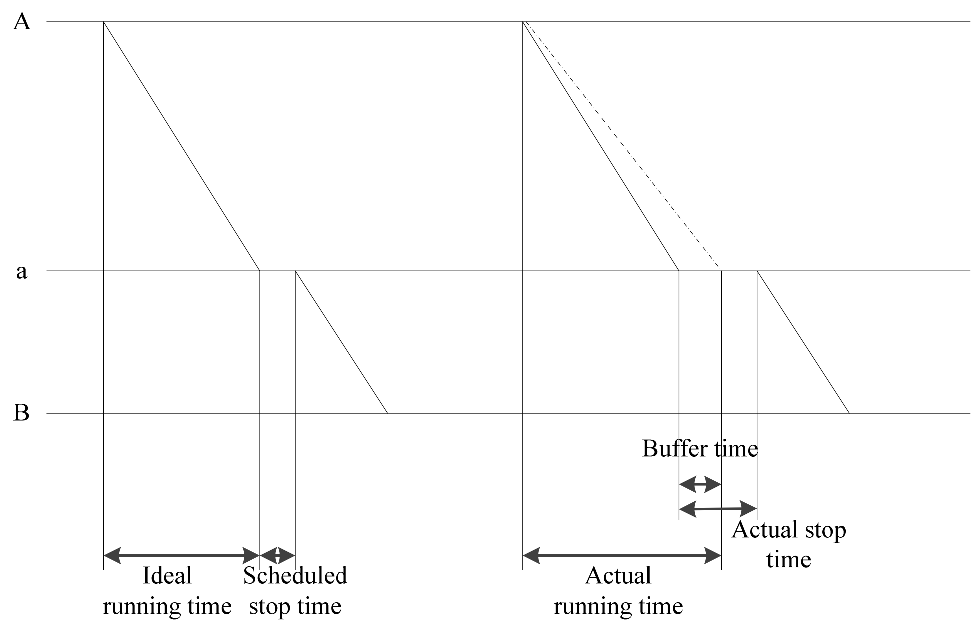

Fig.3 Buffer Time Set in Station

From Fig.3 we can see, because the train running time between the stations is set as the ideal running time, once the train operating is disturbed, the train will arrive at station later than the scheduled time. As the buffer time set in station, the disturbances will be absorbed during the train stop time in station and make sure the train will departure on time. In this situation, the buffer time could cause arrive late of the train or extra stop time for the train.

5 Strategy Compare of Buffer Time Set

According to the analyze in sector 3 and sector 4, we can find that the two buffer time set strategies has different influences on train diagram and both has advantages and disadvantages.

The buffer time set in track sector makes the train path more independent from each other, which means once the one train`s operating schedule is disturbed, the following train path will not be affected, especially for the train diagram density is high. This could make sure the train diagram has a strong robustness and make sure the train could arrive on time during certain disturbances. But the buffer time set in track sector will take some operating time available in the sector, this may cause the track capacity lost.

The buffer time set in station allows the track capacity to be fully utilized by drawing more train paths. And as the stop time is prolonged, the train may benefit it by a high possibility to departure on time, especially for some extreme busy sector where not allow too many buffer time set in track sector. But in this strategy, the train`s arrive punctuality might be effected as the buffer time set during train stop.

There are also other differences for the two strategies on train operating complexity. If we set the buffer time in track sector, the operating speed of each train is differ from each other, this requires a higher driving skill and dispatching management for the train operation; while if we set the buffer time in station, it is possibly each train could operating with the same speed, and the dispatching work force will decrease, this may benefit for the auto-control of train.

The compare of different aspects for the two strategies is shown in table.1.

Table 1. Compare of the two strategies

Buffer time set location	Track sector	station
Restrict feature	Sector capacity	Station line capacity
Drive complexity	high	low
Dispatch complexity	high	low
Range if a train delayed	narrow	wide

From the compare we can see:

1. The track sector buffer time set strategy has a better punctual affection than station set strategy. Precisely, if the track sector capacity is highly utilized, once train delayed, the track sector buffer time set has a narrow affect range; this makes the train diagram more robust.

2. The station buffer time set strategy has a lower complexity on driving and dispatch work. This makes it easier for the application of auto-drive and automatic train operation. However, this strategy may cause wildly arrive late once the train operation is disturbed, also, if the train density is high, the influences between train might cause large effect range once one train is delayed.

Thus, the buffer time set should consider the train density, track sector capacity, station line capacity and drivers` and dispatchers` work skill, set the appropriate buffer time both in track sector and station. The ratio of the buffer time set will be studied in the future work.

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References:

D`Ariano. A, Pranzo M, Hansen. I. A. (2007). "Conflict Resolution and Train Speed Coordination for Solving Real-Time Timetable Perturbations." *IEEE Transactions on Intelligent Transportation Systems*, 8(2), 208-222.

Salido M.A, Barber. F., Ingolotti L. (2008). "Robustness in Railway Transportation Scheduling." Proceedings of the 7th World Congress on Intelligent Control and Automation, China, 2880-2885.

Vansteenwegen P, Van Oudheusden. D. (2006). "Developing railway timetables which guarantee a better service." *European Journal of Operation Research*, 173(1), 337-350.

Zwaneveld P.J, Kroon. L. G, Romeijn. H. E, Salomon. M., Dauzère-Pérès S, Van Hoesel. S.P.M, Ambergen. H. W. (1996). "Routing Trains Through Railway Stations: Model Formulation and Algorithms." *Transportation Science*, 30(3), 181-194.

Optimization for a Direct Freight Train Plan in Loading Place Based on Logistics Cost

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Abstract: Recent years, in order to improve the quality of freight transportation, railway transport enterprise has done a lot of research on optimization of freight train working plan on thought of customer first. And it makes a great effect on improving the competitiveness of freight transportation. At first, this paper analyzes the current situation of direct freight train plan. Then, it points out some current drawbacks of direct freight train working plan and emphasizes the importance of logistics costs in freight marketing. At last, it discusses the optimization of direct freight train working plan in loading place on logistics cost and builds the structure of costs in the system.
Keywords: Direct freight train; Logistics cost; Restrictive relationships; Car flow organization.

1 The Current Situation of Freight Train Plan

Strong social demand, stable and concentrated flow of goods and maturing freight network provide support and ensurement for the direct transport of coal, even the whole bulk cargo. Simultaneously, heavy tasks have put forward higher requirements upon rail transport organization. In order to alleviate contradictions between growing demand and capacity tense of freight transport, with expansion of railway station at the same time, the effective approach is to improve the technical equipment and the existing transport organization further and organize direct transport in loading space rationally so that car flow can pass these tight-capacity marshallings without adaptation. And it is an important way of railway transportation of bulk cargo in our country at the present stage.

2 Drawbacks of Freight Train Plan

Reform on freight transport shows the change from commitment of single railway transportation to the entire process of logistics services. Transportation is an important part of logistics and total logistics is now the freight transport social market needs. Nowadays, on one hand, various transport modes are all actively adapt to the demand of social development, on the other hand, development of freight business processes in this area is relatively inadequate.

2.1 Complicated acceptance business

Time and expense customers consume on several formalities in the handling department of freight and yards can be calculated based on traditional freight handling process. Therefore, optimization and new service system should be pulled in so as to improve the quality and efficiency of accepting service.

2.2 Long residence time in the station

According to statistics, freight train spend 70 percentage of travel time on staying in station. On the way, there is no fixed time point and a great complexity in production process. And this leads to time wasting and low efficiency.

2.3 Complexity of delivery procedures

From the freight delivery business processes you can see that process of goods delivery contacts a number of departments, so transfer of information and data needs different people from different departments. Due to the time of arrival can't be confirmed, consignees are not allowed to receive the goods until get notification from station. However, there are a great number of delivery procedures before receiving the goods in many departments.

3 Logistics of Rail Freight Transport Organization

As rail transport market is deepening with each passing day, direct transportation organization service should be enhanced in continued competitive environment. On the other hand, the rapid development of information technology make information resources have greater openness and create a new railway transport organizational environment. Original boundaries between related enterprises have been broken and enterprises have built a win-win partnership instead of working alone. So, considering interests of shipper, consignee and transportation enterprise, rail transit organization plan must proceed from market multi-demand. Only in this way, transportation cost will reduce, customer satisfaction will improve and comprehensive optimization will be done.

3.1 Thought of the logistics system

As a form of system, logistics system has all the features of the system. It is the environment flow of goods and transport organization rely and dominant factor of transportation organization optimization. The system is consisted of interconnected and interacting organism with the overall function. So, logistics system is also consisted of interest groups and they are organically combined rather than accumulated simply. Additionally, there may be mutual restraint or other kinds of relationships between stakeholders. However, all these stakeholders are in same system. Each of them will obey the whole and pursue the overall goal instead of seeking the best interest of one stakeholder

3.2 Internal relationship of logistics system

Logistics system consists of a variety of stakeholders and there are restrictive relationships among different stakeholder. It means there is a contradiction between win and loss of active interest entities logistics system. That is to say optimization of one stakeholder may lead to a loss of interest of another one. And it is the relationship of shifting that exists commonly among stakeholders in logistics system.

① Restrictive relationships between level of service and logistics costs

Improvement of service-level always accompanies increase of logistics costs, and this phenomenon may cause game of stakeholder interest. For example, in order to reduce inventory and use freight system of small quantities, delivery times and transportation costs will increase greatly.

② Restrictive relationships among sectors of logistics

Goods will go through many sectors which are connected closely in moving process. The entire system will not work normally unless there is not a problem on each sector.

③ Restrictive relationships among different functional subsystems of service capabilities

If capacity of each subsystem does not match with each other, overall capacity of the logistics system will be affected. For example, strong handling capacity with low transportation force will bring waste of equipment and manpower.

④ Restrictive relationships among different functional subsystems of logistics costs

For example, to reduce the cost of inventory, small orders will be taken, but it increases transportation times, even costs of transport subsystem.

3.3 Connection with railway system and logistics system

According to restrictive relationships in logistics system, any unilateral approach would undermine the other parts of system more and is not conducive to achieving overall system goal. This theory can apply on transportation problem as well.

Market competition bring more opportunities and challenges to transport companies. In the competition, owners are looking for a more convenient, cost-effective mode of transport to reduce cost. This means that transportation companies should reallocate supply. On one hand, transport companies which are able to provide higher level service will get more supply, on the other hand, transport companies which are not able to meet the requirements will result in loss of supply. Transport companies and shippers must be closely linked together to achieve mutual benefit in this environment.

With reform of the railway transport system, transport organization research considering multi-stakeholder from perspective of logistics system have emerged. Rail transport systems belong to the logistics system as well. As possessing the characteristics of the logistics system, car flow organization can not get rid of the interests of stakeholders and exist in isolation. Therefore, it is necessary and feasible to optimize direct train organization in loading space by thought of connection with railway system and logistics system.

4 Optimization for Freight Train Plan on Logistics Cost

As important part of direct rail transport organization, direct freight train organization in the loading place show its inherent advantages gradually with increase of market demand and rapid improvement of hardware and software technology in rail transport systems. Direct freight train organization in the loading place is no longer unilateral thing for transport enterprises but related to interests of shippers and receivers. At Present, there are potential defects in optimization problems from only considering the interests of the railway transport enterprises. Such as it can not adapt to the market's high demand for transport or does not do good to improve competitiveness of rail transport. Thus, based on the entire logistics system, organizational problems should be optimized by considering various interests and targeting the total cost of the system.

4.1 Division of interests entities in car flow organization

In the logistics system, from loading space to unloading space, goods will undergo three sectors in direct transport mode, shipping sector, accepting sector and receiving sector. Each sector will involve its interests of stakeholders. In addition, as deepening and competition of the market economy, interest conditionality among three sectors has become closer. So, we divide interest entities associated with direct train organizational problems into three parts according to circulation of goods in logistics system and restrictive relationships in railway transport market, and they are shippers, transport companies and consignees respectively. Circulation of freight and division of interests entities are shown in Figure 1.

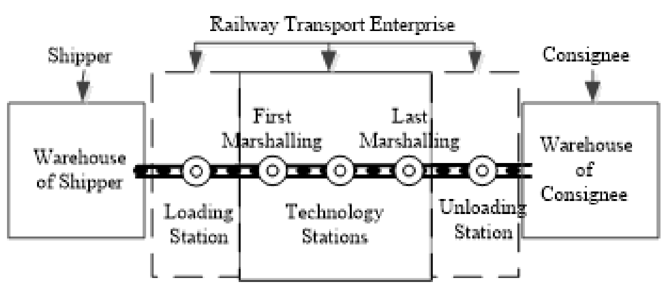

Figure 1. Related parts in the transportation process in logistics system

Based on Figure 1, we can make structure of optimization goal clear under logistics system. It consists of sub-goal of shipper, sub-goal of railway transport enterprise and sub-goal of consignee. Each sub-goal has its own typical interest elements. Restrictive relationships exist among various sub-goals and are shown as conflicts and discords among representing interest elements.

4.2 Mutual restrictive relationships among entities of different interests

Mutual relationships among costs of different interest entities are concrete embodiment of mutual relationships among interests of different entities. No matter inventory cost of shipper and consignee or organizational cost of transport railway transport enterprises is function of single transport order. However, single transport order is determined by organization of car flow. So, mutual interacting restrictive relationships exist in different interest entities because of influence of traffic organization. Inventory cost will increase with increasing single transport order. On the contrary, cost of transport organization have rendered opposite trend with increasing single transport order. With changes in quantity of transportation, trend curves of inventory cost, transportation cost and sum of them are shown in Figure 2.

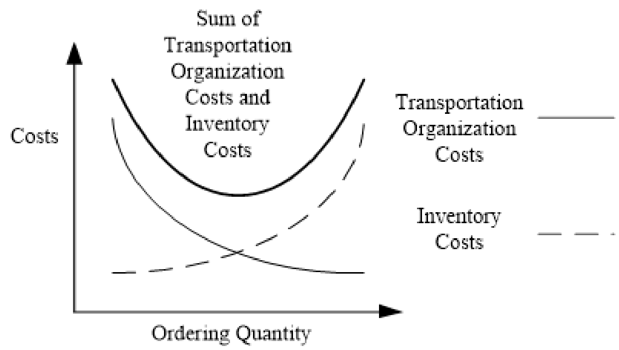

Figure 2.Changing trend of inventory and transport cost with ordering quantity

Minimum total cost point of system is neither on point of minimum transportation cost nor point of minimum inventory cost. There is an important phenomenon of "Interest Swap" in transportation and inventory. Reducing cost of any part unilaterally will pay the price of increasing cost of another. In a word, seeking optimization of integrated interest between transportation cost and inventory cost is optimization objective of car flow organization issue in loading space under logistics system.

4.3 Constitution of logistics costs for direct freight train in loading place

When it comes to optimization of car flow organization in loading space under logistics system, decision makers of transportation organization should break through the narrow thought of seeking interests only for its own but establish an idea for interest of the whole system. So that, it can optimize transportation organization of direct train in loading space and realize our dream of making cost of the whole system the lowest. Summarizing contents of each part above, structure of costs in the system is established as follow in Figure 3.

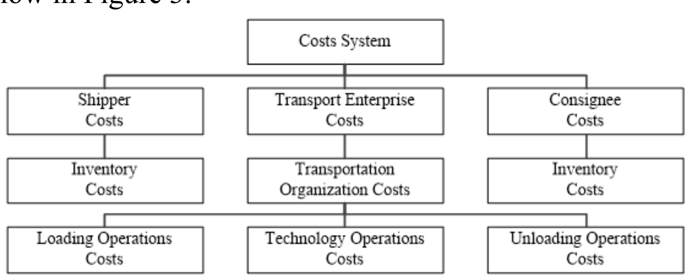

Figure 3. Structure of costs in the system

The figure of structure shows factors which constitute the cost of transportation organization. It is the transition of analysis from qualitative to quantitative, also, the basis of establishing cost function model. Based on the figure, considering all factors such as costs of transportation organization and inventory costs, cost function targeting the lowest cost of system can be set up. We can acquire optimization of freight train plan by analyzing and solving this cost function model.

5 Conclusion

Modern logistics break through the concept that transport capacity is the most important, and put the idea of customer first forward. Considering interests of customers, it seeks optimization of the production and organization under the whole system instead of railway system only. Furthermore, it makes costs of transportation service associated with other costs organically come true. According to this theory, in order to lay the foundation of transition from qualitative analysis to quantitative analysis, this paper focuses on restrictive relationships among different factors and establishing the structure of costs in whole system.

Acknowledgement

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References

Bao Xinzhong (2006). Logistics Cost Management and Control. Beijing: Publishing House of Electronics Industry, 27-44.

Cao Xueming, Lin Boliang, Yan Hexiang (2006). Optimization of Direct Freight Train Service in the Loading Place. *Journal of the China Railway Society*, (04).

Jiang Changbing (2007). Logistics System and Engineering. Beijing: China Fortune Press, 3-21.

Lin Boliang, Zhu Songnian, Shi Deyao, He Shiwei (1995). The Optimal Model of the Direct Train Formation Plan for Loading Area, 16(2),108-114.

Liu Hanle (2012). Study On the Function Expansion from Railway Cargo Transportation to Modern Logistics. Chengdu: Southwest Jiaotong University.

Analysis of the Demand and Supply of Regular Buses

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Abstract: Basing on the mechanism of supply and demand in bus-market and starting from its actual situation, we make an analysis according to survey data of 211. The analysis mainly includes two parts. Firstly, by analyzing index such as section volume, characteristics of passenger traffic on different times, traffic distribution of kernel density estimation, we know the demand situation. Secondly, on supply side, we dissect the index of capacity, traffic volume and departure interval. At the end, considering profit between bus-company and passengers, a departure interval optimization model can be established. Through this model, rationality and innovative of data analysis be verified and some suggestions can be put forward, thus achieve the purpose of equilibrium.

Keywords: Bus market; Demand; Supply; Departure interval.

1 Introduction

Regular-bus is one of main mode transportation in city public transports. It is the most used public transit for people and responsible for most travel demand. Imbalance contradiction between supply and demand is becoming prominently under high speed process of urbanization and motorization, causing quality of bus service and passenger satisfaction are low. Researches about balance mechanism of supply and demand is important for development of public traffic and residents travel (Wang, 2014).There are a lot of research about supply and demand in transportation, focusing on relationship of supply and demand and equilibrium problems in transport system network (Li,2010; Li, 2007), lacking case study and deep research in single bus line. In this paper, we will analyze survey data of Nanchang 211 bus referred to 211 bus as following and study its demand and supply situation.

2 Bus supply and demand mechanism

2.1 Research of bus supply mechanism

Transport supply is the number of variety transportation products that producers willing and able to provide at a time and in a variety of possible price levels (Wei, 2010). In bus supply analysis, we use "S" to represent supply level:

$$S=J(A_0,Q) \tag{1}$$

Where S is level of bus supply, J is supply function and A_0 is specific social environment.

Studies show departure frequency is an important indicator in bus supply. The smaller grid, the less waiting time, lower congestion and higher passenger comfort.

2.2 Research of bus demand mechanism

Transportation demand is a need for the ability to pay about displacement of people and goods in space (Feng, 2010). When influencing factors such as economic development and traffic environment are given, demand is mainly decided by service level (maximum waiting time of passengers, ride comfort, etc.). The shorter waiting time and higher comfort required, the higher supply level required, or, lower. So in certain cases, bus demand can be showed: We use trips "Q" to represent bus demand:

$$Q = D(A_0, T, R) \tag{2}$$

Where D is demand function, T is maximum waiting time of passengers, A_0 is specific social environment of bus and R is ride comfort (Yang, 2002).

3 Analysis about the demand and supply of 211 bus in Nachang

3.1 Demand analysis

Only adapting demand characteristics, can bus companies improve their interests and serve better. So demand analysis is an important aspect to study balance.

3.1.1 Section volume

Section volume is an important indicator representing passenger demand. It is the number of passengers cross a section in a certain time and single direction, including up section volume and down section volume. By analyzing the existing data we can get passenger distribution of 211bus in Figure 1. Figure 1 shows, Passenger demand in whole line are large, maximum on up and down reach 9000, 7500 (per) respectively.

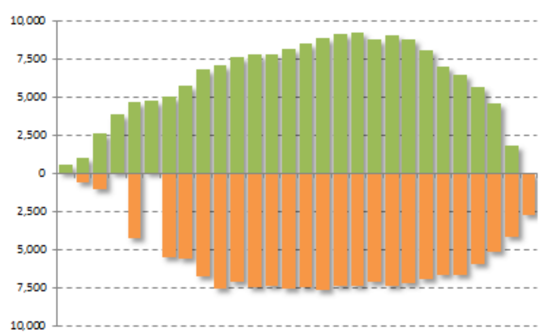

Figure1. Section volume on up and down of 211 bus

3.1.2 Traffic characteristic in different periods

To analyze differences of passenger demand, we divide 211-day times into three sessions: morning peak (7: 00-10: 00), flat peak (10: 00-15: 00) and night peak (15: 00-19: 00). In this paper, we use numbers of boarding index in unit time (1 hour) to analysis passenger traffic. Draw figure 2 of 211 bus boarding amount in unit time of each period by analyzing surveyed data.

Figure 2 shows, average boarding number is volatile, morning peak has the biggest number. Boundary of flat and night peak is obvious. Prior to Nantianyangguang boarding number in flat peak is more than night peak, after it night peak is higher. Charting trend is consistent with actual situation. 211 bus belongs to suburban lines, in morning peak residents go into urban working and learning. In night peak, residents have different needs and the flow shows one-way.

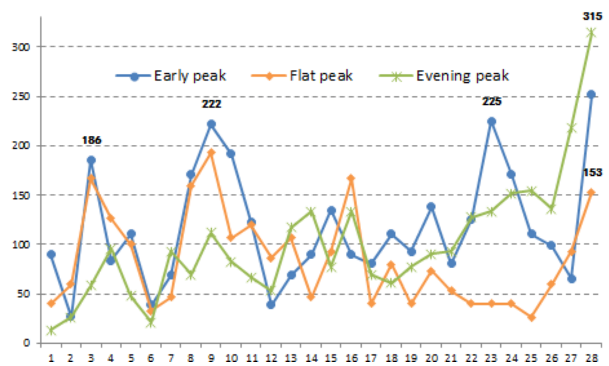

Figure2. Each section of passenger volume on per time of 211(p/hour)

3.1.3 Traffic characteristic in different periods

Kernel density estimation is a non-parametric method, which can use raw data to infer distribution curve, know value of probability density of each frequency in each site (Yang and Meng 2014). In this paper, we take passenger volume of each frequency in each site for a sample, chose Epanechnikov kernel function, use Eviews to estimate density curve of 211 bus.

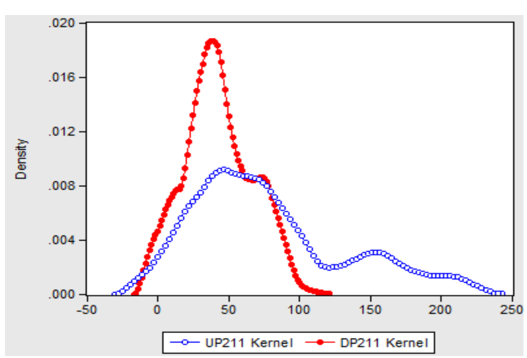

Figure3. Density curve of passenger volume on up and down about 211

Figure 3 shows density curve of up is right skewed and peaks at 50 people. It shows passengers number of a frequency at each site are mostly 50 people. Besides, the up ranges span, showing passenger demand in different frequency and site is unstable. Curve of down shows a narrow peak distribution, peaking at 25 people. It has smaller range span. Passengers demand of up is greater than down, value of probability density are all less than 0.1, showing large changes of passenger demand.

3.2 Supply analysis

3.2.1 Transport capacity analysis

Transport capacity is supply capacity of bus. In this paper, we represent it as product of rated capacity (76 passengers) multiply by actual departure times in all day. Based on surveyed data, we calculate 211 bus transport capacity and show in Table 1.

Table1. Transport capacity of 211 (persons)

Lines	Full day	Morning peak	Flat peak	Night peak
211	20267	5472	7600	7296

3.2.2 Other operating metrics of bus line

Other metrics include grid spacing, volume, non-equilibrium factor of section. By consulting bus companies, we know the departure frequency. Traffic volume is a sum of boarding numbers all day. Non-equilibrium factor of section is result of maximum section traffic divide average cross-section (one-way), which is suitable around 1.2.

Table2. Operation indicators of 211

operating metrics	Full day	Morning peak	Flat peak	Night peak
Grid spacing(min)	5.4	5	6	5
Traffic volume(person)	33168	9873	11967	11328
non-equilibrium factor of section	1.46	1.72	2.44	2.21

Table 2 shows: 211 bus has little change in grid spacing. Traffic volume is greater than transport capacity (33168>20267), indicating transport capacity is insufficient. Non-equilibrium factor of section of full-day is 1.46>1.2, which is appropriate. But flat and night peak are 2.44 and 2.21, indicating the two periods are overcrowding.

3.3 Comparative analysis of supply and demand

3.3.1 Cross-section saturation

Cross-section saturation is a ratio of actual flow to traffic capacity. That is the ratio of demand to supply. If this value is low, capacity is insufficient and supply is greater than necessary. Documentations show the ratio is suitable in scope of 0.5-0.7, by now the bus company can meet needs of residents and would not result in a waste.

Analyzing surveyed data, we can draw a graph of cross-section section saturation at all sites. Figure 4 shows saturation of 211 bus in all sites are high, part of have reached more than 0.75. It states this line is very crowded. In this case the comfortable and satisfaction of passenger is influenced badly.

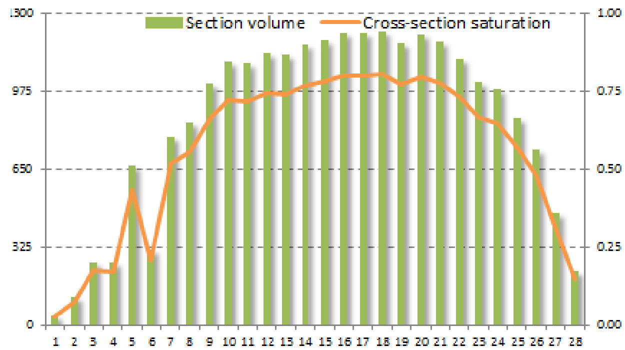

Figure4. The cross-section saturation of 211

3.3.2 Optimization model of departure interval

211 bus has the following characteristics: big passenger flows, high cross-section saturation, less supply, overcrowding and bad service. In order to achieve a balance and meet both passengers and bus companies, we must adjust supply amount. Multi-objective optimization mode can optimize grid spacing, draw a plan appropriate of departure, balance the interests of passengers and bus companies (Chen, 2014).

(1) Model assumptions

[1]Passenger traffic situation and section volume of up and down are known.

[2]Buses are the same, arrive and leave on time (Yu and Zhou 2004).

[3]Grid spacing are the same in one period.

[4]Unified fare in line.

(2) Variable definitions

l is amount of hours the line divided. $T_j(\min)$ is time span of j time bucket. n_j is departure times of j time bucket. $t_j(\min)$ is departure interval of j time bucket. m is number of sites in one-way across line. p_{kj} is passenger capacity throughput in k section of j time bucket. pu_{ij} is boarding number unit time in i site of j times bucket. pp is total traffic in all day. np is rated capacity of each vehicle. lr is minimum load factor. hr is maximum load factor. tr is load factor limitation accepted by passengers. mp_j is the maximum section volume of j time bucket. mt_j is the maximum grid spacing of j time bucket. ht_j is upper limit of waiting time accepted by passengers. c_1(yuan) is buses traveling expenses in one-way. c_2(yuan) is ticket price. bp is number of passengers complaining waiting, $bp=\sum_j\sum_i pu_{ij}$ if $t_j > ht_j$ bl is length of crowded road complained by passengers, $bl=\sum_k\sum_j p_{kj}$, if $p_{kj} > n_j * np * tr$. Among them i is the site, i=1,2⋯m. j is the time bucket of j, j=1,2⋯l.

(3) Model building

This paper selects three 3 goals: benefit cost ratio of enterprises, percentage of waiting complaint, percentage of crowded mileage. The model of optimization to grid frequency is as followed:

$$\min W=\min[-\lambda_1 *(c_2 * pp - c_1 * \sum_j n_j)/(c_1 * \sum_j n_j) * 100\% + \lambda_2 * bp / pp * 100\% + \lambda_3 * bl(\sum_k \sum_j p_{kj} * ml_k) * 100\%] \quad (3)$$

In order to ensure feasibility of the equation, we establish the following constraints:

① Average load factor is greater than minimum load factor: $\sum_{k-1}^{m-1} p_{kj} / n_j * np \ge lr$ (4)

② Passenger waiting time at the site does not exceed a certain time: $t_j \le mt_j$ (5)

③ There is no passengers stranded: $n_j * hr * np \le mp_j$ (6)

(4) Model solution

Calculation process focus on four major stations: Shuanggangdonglukou, East China Jiaotong University Institute of Technology, construction northbound and Changleng. The model simplify a scheduling problem of four sites, m=4. Full-day traffic volume in model use boarding passenger data in all day instead of four sites and the rest do not need to adjust (Yao and lv 2009). All parameter values are as follows: $T_j=[180\ 300\ 240]$, $np=76$, $lr=0.5$, $hr=1.2$, $tr=0.9$, $m_j=[5;\ 10;\ 6]$, $ht_j=[4;\ 8;\ 6]$, $c_1=120$, $c_2=1$, $\lambda_1=0.1$, $\lambda_1=0.5$, $\lambda_3=0.4$. Results shows in Table3.

Table3. Results of scheduling optimization

Line name	time bucket	Uplink		Downlink	
		Departure times	Grid spacing	Departure times	Grid spacing
211 bus	7:00-10:00	61(36)	2.9min(5.0)	47(36)	3.8min(5.0)
	10:00-15:00	55(50)	5.5min(6.0)	51(50)	5.9min(6.0)
	15:00-19:00	48(48)	5.0min(5.0)	56(48)	4.3min(5.0)

Remarks: Data in parentheses represent the actual departure times or grid spacing.

Model result agree with the previous conclusion. That is for different period we should implement different schedule to meet different passenger demand at each periods. So demand in different times has different size, we should implement unequal interval schedule in all day.

4 Conclusions

Based on demand and supply mechanism of bus market, this paper analysis the survey date of 211 bus, then make an analysis about the balance situation of this line. By analyzing, we know passenger demand are different at different times or different directions. On the supply side if you do not consider the difference in demand, it may lead to an imbalance between supply and demand. In order to achieve a balance, bus companies should be combined supply with demand, allocating resources rationally. Then meet the travel needs of residents.

References

Chen, Q., and Niu X. (2004). “Bus service frequency optimal model.” *Journal of highway and transportation research and development*, 21(2):102-105.

Feng, X. (2010). “Study on the development scale of taxi under the balance of supply and demand.” *Southwest Jiaotong Unlversity*, 12-17.

Yang Hai, Wong S C, and Wong K I. (2002). “Demand and supply equilibrium of taxi services in a network under competition and regulation”. Transportation Research: Part B, 36(9):799-819.

Li, H., and Chen, H. X. (2010). “Based on traffic demand and supply in the dynamic relationship between supply and demand of urban traffic.” *Logistics engineering and management*, 32(6):121-123.

Li, Q. R., Ma, S., and F, C. L. (2007). “Genetic algorithm approach to dynamic mixed behavior traffic network equilibrium problem.” *Journal of Chang,an University(Natural Science Edition)*, 27(6):87-90.

Wei, J., and Li, L. (2010). “Model of dynamic relationship between traffic supply and demand.” *Journal of Chang,an University*. 30(6):86-89.

Wang, Z. H., and Wang, X. S. (2014). “Research on public transportation priority solving the city traffic congestion.” *Shanxi Architecture*, 40(2):1-2.

Yao, J., and Lv, Z. L, and Ye, Y. (2009). “Model for Bus Dispatching Based on Satisfaction.” *Transport Information and Safety*, 29(4):67-69.

Yang, X. D., and Meng, X. H. (2014). “Comprehensive evaluation method of regular transit system in small and medium-sized cities.” *Transport Information and Safety*, 32(3):36-41.

Yu, B., and Zhou, W. Q. (2009). “Modeling and solutions for optimizing bus frequencies.” *Journal of harbin institute of technology*, 41(4):250-252.

Method of Making Trains Diagram with Computers

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Abstract: With the development of economy and culture, Chinese railway met with great market shock. The train diagram plays a basic role in the preparation for the train working. For a long term, the train diagram in china was prepared manually, and it need many human and material resources. Fortunately, in recent years, the experts and the professionals in traffic and transportation area had taken the work for preparing the train diagram with computer, and the achievement is salient, for an example, the passenger train diagram of all the road net is in practice. The train diagram is introduced firstly in this paper. Then some theories about train diagram, including the base element, the types and the evaluating indexes, are analyzed in details. And on the basis of them, three methods for making train diagram are shown: The first is called time-and-space rolling method. It's a mature method, and it has been implemented; the second one is called generic algorithm. The implementation of coding, permutation and aberrance in train diagram algorithm is the emphasis; The third method makes use of Common KADS Methodology, mainly its planning module and schedule module for the original train diagram and its adjustment. At last, through the research on the method of making train diagram with computer, I will take some suggestions for the development strategy of making train diagram with computer.
Keywords: Train diagram; Optimization algorithm; Common KADS; Development strategy.

1 Introduction

In the production process of organizing the passenger and freight transport, train running is a very complex part, it is to use a variety of railway technology and equipment, and requiring coordination and cooperation among all departments, all types of work and the various jobs to ensure traffic safety and improve transport efficiency. Railway departments complete the process of complex operation and management mainly through train diagram of the preparation and execution to achieve. However, the preparation of train diagram is an extremely arduous, complex and painstaking work, totally dependent on artificial Train Graph. With the rapid development of computer technology, many experts and scholars have been actively exploring the use of computer Train Diagram methods and techniques.

The Train Diagram with computer generally began in the late fifties at abroad. The US GRS in 1958 has been prepared in a simulation program trains and the single track sections of 160 kilometers were tested. Britain in 1965 in not too long a single line automatic block sections by computer simulation test train. Japan in 1960 began to study the use of computer preparation train schedules, and in 1964 worked out practical value can train schedule. In addition, Germany, Belgium, Czechoslovakia, Romania and other countries also have conducted a study of Computerized Train Graph, to varying degrees, with some success and experience.

In China, in 1962, Academy of Railway Sciences and Institute of Transport and Economy began to study the use of non-parallel computer shop drawing a single line diagram, in 1980, the Harbin Railway Bureau used the method of mathematical models, and made the computer a trial cargo train diagram by a two-lane section. In 1991, the Department of Transportation of the Southwest Jiaotong University and the Jinan Railway Transportation developed a two-train diagram preparation computer system in co-operation. After entering the new century, the Transportation of Southwest Jiaotong University has developed the whole railway passenger train operations preparation system by its own research, and used in the fifth railway speed transfer map work, and basically reached a practical level, this is an event of China railway operation in the history.

2 The definition and characteristics of train diagram

2.1 Definitions

Train diagram is the train technical documents that is used to indicate that the train moving time in the section and the arrival or through time in the station, which sets out the program of various train occupied sections, the arrival and departure (or through) time of the train arrived station, the train in the interval running time, the time of the train stops at the station and locomotive routing, etc. Therefore, it is the basis for the organization of railway traffic .

Train diagram provides a coordinated use of railway lines, stations, locomotives, vehicles and other equipment, the production process of railway transportation will strictly enforce the provisions of the program diagram (required by the road map), therefore, the train diagram is a comprehensive plan of production process of the railway transportation, it has a very important significance to ensure the safety of the railway, improve transport efficiency and improve the use of technical equipment and speed railway rolling stock turnover. In addition, the train diagram is an effective form that rail transport companies provide transportation capacity to the community. In this sense, the railway passenger train timetables for social and "Five fix" freight trains running program is the catalog of rail transport services in fact. Therefore, train diagram is a comprehensive plan of railway transportation production and product supply, and it is the link between production and rail transport links production factories and social life.

2.2 features

According to the definition of train diagram, the characteristics as following:

1) Train diagram is a graphical representation use the principle of the coordinates to the relationships of train running time and spatial, therefore, it is actually operation to the process of space-time. On the train diagram, the process of train operation diagram temporal can have two different forms. One is in the horizontal axis represents time and the vertical axis represents the distance, then the train diagram horizontal line indicates the centerline of the station, the spacing between the horizontal line represents the distance between the station, the vertical line indicates the time, which is currently used by China Railway representation. The other is the distance in the abscissa, the ordinate represents time. At this time, the horizontal line on the train represents time, the vertical line represents the centerline distance between stations, and the distance between the vertical lines represents the distance between stations.

2) Although the train diagram has a different kind of representation, they contain the following basic elements in common, namely: The train moving time in the railway section; The pausing time of trains at stages; The pausing time standard of the train in basic section and return section; The work procedure and work time standard of the train in the tech-station, the passenger transport station and the freight station; The interval time in station; The interval time of tracing train. Intermediate computing division distance in train stations in Figure 2-1.

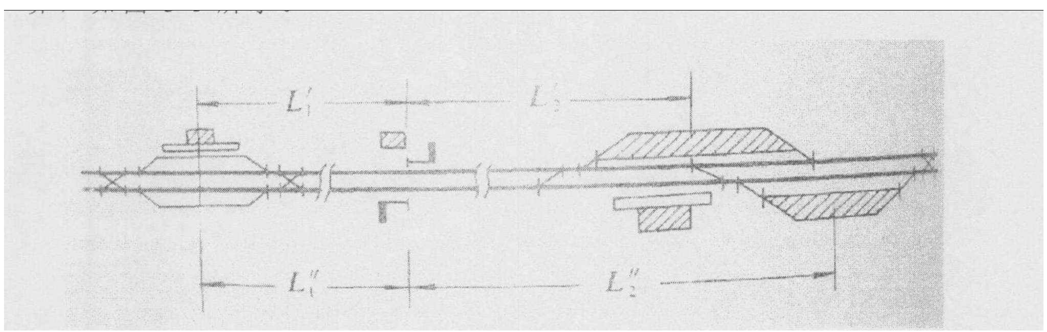

Figure 2-1 calculate the distance between the train station maps

3) Measure technical indicators of train diagram have two parts: the number indicators and quality indicators. For our train diagram, the main consideration is the following indicators: average technical speed of passenger train or freight trains, passenger trains average straight speed, average travel speed of freight trains, freight trains speed factor. These indicators are put into practice before running the figure given by direct plans to run the calculation. We can say that they are static analysis of the train diagram. Objectively speaking, this condition in the actual map compilation work is basically non-existent. Measure the quality of train diagram produced only by rail and concrete practice test to be concluded.

4) evaluate the quality of the preparation of a train running chart indicators in

addition to the merits of those involved in the previous section, another very important indicator is the balance of the overnight train line distribution, especially the balance of the train in the technology station, it will directly affect the through ability and work process of train, the impact of travel speed and the use of equipment and the use of the train station in the section of the locomotive and other quality indicators.

In addition, in order to meet the station's operation process, coordinating the work of vehicles, machines, labor, electricity, vehicles and other departments, railway department for train operation diagram prepared to run the line can achieve a balanced distribution. Because the ability of station is limited, if there is a large number of trains running figure dense arrive or depart in a period of time, it will give the station pressure, and even unable to cope, the result is a serious impact to the train locomotive traveling speed and quality indicators used in the sector or direction. Therefore, the evaluation of train operation diagram, in addition to these indicators, we must also analyze their balance and flexibility.

In summary, according to the definition and characteristics of train diagram, researching and developing a series of practical and feasible computer diagram system, the key is the accuracy of the algorithm used in map compilation and mathematical models.

3 The method of Computerized Train Diagram

3.1 The compilation of methods of computerized train diagram

Looking at the research of domestic and international for history of computerized train diagram, methods used are the following:

1) Simulation method

Simulation run into analog trains and modeling methods such as artificial shop painting. These methods are mainly based on the principles of artificial map compilation and experience to develop and generate computer criterion map compilation and execution of the program in order to achieve the whole process of manually compiled diagram

2) Move the train departure point

The method is generally used in the preparation of two-lane section of train diagram. At the first of all, figure given by a certain time interval train departure point, achieve recursive shop painting headway examination and a running line of treatment, and then check the spacing midnight between trains.

3) Recurrence interval by painting shop

This method is mainly used for single-line section of train operation diagram shop painting. Starts from one end of the section, in accordance with the order of the range appears to be checked and drawn.

4) Mathematical model approach

Use logic algebra, linear programming, graph theory and dynamic programming methods to achieve solving by computer programming. Looking at the results from the present study, due to train diagram involving a wide range of factors affecting complex, difficult to describe with a specific model, some of these factors is difficult to express with mathematical formulas, even among some of the factors in itself is contradictory and mutually conditioned.

5) Artificial intelligence expert systems approach

This is a use of intelligent programming language, the physical condition of the train diagram preparation and knowledge of the rules of artificial experience as fitness expert system to generate the map compilation, and in accordance with the order Traveling trains were running the experiment combinations. This article will introduce Common KADS application methods described in the preparation of the train running figure that belong to this class.

6) Range bound search tree method

The approach is to train diagram as a combination of the regional train order, and to bring the running time instead of running the shop painting line, which runs the establishment figure as a search problem to solve

As can be seen from the above analysis, the use of computerized Train diagram is a requirement for a combination of theory and practice, the technical difficulty of the work is very large, domestic and foreign scholars have done a lot of research work, tried many solutions, but they at the same time made some achievements, but there are all kinds of problems, but the root cause of these problems lies in the way they are used in the preparation of the issue of train operation diagram as a structured decision-making to deal with the problem all by computer. In fact, as discussed above, as the process of the preparation of train diagram is in limited rail transportation equipment and labor conditions, the trains run programs developed by the strategic plan into concrete layer train operation plan to implement the process. In this process, both structured decision-making problems, but also unstructured decision problem cannot be generalized processing. To this end, combined with China's actual situation, proposed the use of man-machine dialogue passenger train diagram preparation methods.

3.2 Several algorithm run establishment figure

The last section of the preparation method has been carried out train diagram representation. Here are some typical algorithms can be used to train diagram preparation.

1) Time-and-space rolling method

Time-and-space rolling method is calculated from Peng Qiyuan teacher of the Southwest Jiaotong University proposed a series graph algorithms. It is built on a 0-1 integer programming model will train diagram in time and space division, reduce the number of calculations to the extent you can use the computer operation.

2) Generic algorithm

This method is a mathematical model. Genetic algorithm is a probabilistic search algorithm, a method based on the theory of evolution and genetics. Because of the genetic algorithm to explore the space without limiting constraint is not necessary to solve the space has continuity, conductivity and its inherent parallelism and other properties. At present, although the algorithm has not been fully proven mathematically .

In summary, the first method is one of the methods currently used, while the second method is still not mature, but with the development of computer hardware and software technology, this approach will also be prepared to run the computer efficiently map one of the ways. The following section describes the simulation of artificial expert system used in the system.

3.3 The application of Common KADS Method in the preparation of the diagram

3.3.1 Introduction of Common KADS

Common KADS is a series of crystallization of international research and knowledge engineering projects, these studies can be traced back to 1983. After so many years, according to the results of the staff and scientists feedback, this method continue to be expanded. Common KADS indicate actual use, many systems project failed because of a technology-driven method is called cause. Only a clear system of color and its potential impact on the organization, and before the system development and system development during the two reached a high degree of consistency, an organization in order to successfully apply information and knowledge technologies. The purpose of the organization is to establish the analysis of an application-driven approach. This approach to users, clients and project stakeholders to ensure that the new system is able to solve practical problems or take advantage of real opportunities within the organization. Other useful features of this approach include the ability to solve complex modeling human-computer interaction, problem solving introducing new specification techniques to solve the problem definition of flexibility and can be configured to define risk-driven life cycle management approach, which replaces the waterfall model for information system projects.

3.3.2 Discussion Common KADS used in the preparation of the system diagram

Common KADS have developed own language, in the design and implementation of the system, we use the common run graph algorithms, using Visual C ten achieve. Through Common KADS system development process can be divided into three, namely: building a knowledge model, establish communication model and build design models. Methods listed below four main steps:

1) Operationalize requirements (operationalize (requirements-> hard-requirements + soft requirements)): This process analysis requirements, and can be converted into the desired representation. This process usually generates two kinds of requirements (constraints), i.e. hard and soft request requirements.

2) Generating a possible architecture system architecture (generate

(requirements-> possible-system-structure)): In this step, to generate all possible system architecture, which is the system has a static knowledge of potential system configuration.

3) Selecting the correct architecture of system configuration (select-subset (possible-system-structure+ hard-requirement-> valid-system-structures): In this step, the hardware requirements and constraints may be applied to a system configuration to filter out the correct system configuration. These constraints are usually designed based on experience or knowledge of the laws of physics, such as the station to the hair line constraints will drive the interval time.

4) In order of preference for the system to sort (sort (valid-system-structure + soft-requirements -> system-structure-list): Under normal circumstances, efficient design space is still very large. Therefore, the standard should be applied to reduce the set preference. In general, we use two preference level to be assessed.

As can be seen, the algorithm thought we described in the previous sections in common KADS method templates are reflected more or less, particularly in the inference of knowledge and knowledge of the task, they use methods of thinking with some of our algorithm ideas is consistent.

4 Development Strategy of computerized train diagram

For a long time, train diagram preparation has been the traditional way backward to complete the job by hand. Due to the preparation process of the diagram to solve complex problems, each whole road map compilation work often requires the completion of hundreds of people together to participate. Map compilation personnel at different skill levels, map compilation heavy workload but must split the case in hand, out of the running figure compiled by the quality varies greatly. Edited on computer research and development strategy map, the study said:

1) The current research should focus on further optimization of solving tensions single, double compilation graph algorithms;

2) promote the use of a computer programmed map depends largely on the quality level of computer software, map compilation, therefore, to do good success in translational research and development work to improve the commercialization of the standard map compilation software system;

3) above inter-bureau bus 2min unified grid map prepared by the Railway Company; tube passenger train diagram prepared by the railway branch, priority is to develop a more complete map compilation passenger train the whole way software systems and railways Bureau train diagram compiled based mapping software system.

5 Conclusions

Development of train operation diagram system is a huge project. At present, some foreign management information systems of diagram, such as Germany and

Japan, have been more mature. This is partly due to the development of advanced technologies, on the other hand due to road network conditions in different foreign and Chinese railway, which is China's railway system cannot directly reference this reason.

Although the peak of world railway construction has been going, but China's railway construction boom was still in full swing. Especially with the railway started to constantly reinvent the old line, the new production line construction and future passenger rail line construction, and an ever-changing and complex interwoven railway network, and it will presented greater challenges for train diagram. Making train diagram with computer is not just a technology, but a project. From the point of view that we need to look at engineering and systems and deal with such issues.

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References

Guns Schreiber. Knowledge Engineering and Management. Machinery Industry Press

Hu Jisi. Railway traffic organization .Beijing: China Railway Press

Lu Kaicheng (1983).Combination of mathematical algorithms and analysis .Beijing: Tsinghua University Press

Liu Jin. Figure compiled through passenger trains running computer optimization. Railway technology institute report

Peng Qiyuan. Theory and Methods of Computerized Train Graph. Southwest Jiaotong University Press

Qian Songdi(1990). Operations Research. Beijing: Tsinghua University Press

Sun Yan, Li Zhizhong (1993). Train diagram balanced standard. Changsha Railway University

Sun Yan, Li Zhizhong (1991). An optimization method of freight trains running singlet sector graph. Railway Society

Zhou Min(2001). Several improvements and application of genetic algorithms. Master's thesis of Chinese Academy

Calculation Method of the Carrying Capacity of High-Speed Railways Considering the Characteristics of Time Using

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Abstract: There are mainly two computing methods of the capacity of high-speed railway, named "Deduction coefficient method" and "tracking interval method". The two methods usually treat the time period which the train could use as an integral whole, and calculate a whole capacity of high-speed railway. Without considering the time period's characteristics, these methods have some disadvantages. For example, the preferences for choosing the time period of passengers will lead to creating some peak hours, in which there are some shortages of the capacity and some off-peak hours, in which there are some overage of the capacity. Based on the disadvantages, this paper considers subdividing the whole capacity hours into lots of time buckets and finds out a new calculation of the capacity of high-speed railway, according to the travel characteristics of passengers and the locations of the high-speed train sections.

Keywords: Characteristics of time using; High-speed railway; Capacity.

1 Preface

After the operation of high-speed railway in our country, comparing with the existing line, it has the advantages of high speed, large capacity, high punctuality rate and other characteristics. Thus, they two have a lot of differences on the transport organization. However, for dispatching, especially in the capacity calculating, high-speed rail still uses the traditional calculation method of the existing line. Thus, there is a problem that it's difficult to deal with the drawing of train path in the actual process of drawing train path when the practical calculated value can be satisfied it.

The reason why it happens is that in capacity of the high-speed rail calculation process, we consider all the time integration of a cycle（usually 24 h, besides the skylight time）but ignoring the time characteristics of available capacity. For example, the preferences of passengers for choosing the travel time will create some unoccupied hours. Passengers prefer choosing the same periods to take the trains, which would lead to the capacity loss in the free hours. Secondly, there also exists unoccupied hours between two multiple unit train depots, because of three elements: the set of maintennance-skylight, the locations of multiple unit train depots and the regulation periods of passenger trains (departing at 6:00 to 24 o'clock, and arriving at

7:00 to 23:00). So, it will cause a difference between the calculation results and the practical values.

2 Analysis of the characteristics of passengers' travel time

The characteristics of railway passengers are one of the foundations of high-speed railway carrying capacity calculation. Based on the analysis of the behavioral characteristics of passengers and the demands of passenger flows, we could find out the practical willing of them and start the research about the distribution characteristics of passenger flows with time and space(Xu Pan, 2012). Then we could also calculate out the carrying capacity of high-speed railway which is based on the passenger characteristics.

The time distribution of high-speed railway passenger flow is also known as the distribution in each time period of passenger flow volume in a day. The characteristics of passenger flows changes with the different spans of time periods. According to the length of cycle, the time distribution could be divided into three parts: day- distribution, week- distribution (namely the weekdays and weekends distribution) and holiday-distribution. This paper just discusses the general calculation of carrying capacity, thus it only takes the day-distribution (also called cycle-distribution) of passenger flows into consideration.

The distributions of passenger flow in a day means the value of passenger flow in every hour. Current studies typically divided the distributions into four types: single-peak type, double-peak type, full-peak type and spurt-peak type.

Meanwhile, according to the current studies, the passengers' travel time of high-speed railway is also related to the operation time of high-speed railway (Chen Xichun, 2013). Due to the initial operational stage of the high-speed railway in country, the skylight repair time is generally arranged in 0: 00-6: 00. Thus, the high-speed railway trains do not operate at that time period. General operating hours are 6: 00 to 24: 00 (Now, there are some trains operate overnight. This paper does not take them into consideration).

The changing regulations are usually influenced by trip purposes, layout of lines, structure of railway network and other elements. Mainly it has the following characteristics: preferring to take a trip on the morning (about 7:00 to 12:00); having relatively fixed high-peak of travel periods; having spare travel time periods.

3 The unoccupied time of high-speed railway train diagram caused by the set of multiple unit train depots and points

Unoccupied time is a parameter that could reflect the unavailable degrees of some equipment or some programs during the operation of railway. We all know that, the arriving and departing of a train have to be on the location of multiple unit train depots and points. Due to this limitation and the fixed skylight repair time, it would produce an unoccupied time period between two depots (Li Jun, 2013).

Schematic is shown by Figure 1 (Wuhan to Changsha section of Beijing-Guangzhou High-speed Railway). In order to ensure the normal operation between the two depots, a train could not depart for Changsha during the **time 1** of this diagram. Similarly, trains would not arrive at Changsha during **time 2** of this diagram. However, Changsha station could send out trains during **time 2**. Thus, the unoccupied time would be offset.

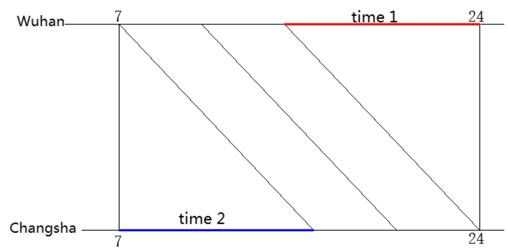

Figure 1. Schematic of travel lines between Wuhan-Changsha section

In summary, the set of depots and points would produce a period of unoccupied time at the last of the time cycle (usually before 24 o'clock). What's more, the length of unoccupied time is influenced by the operating speed of high speed trains, the stops and stop time of trains between the two depots and points and the distance between two depots and points.

There are three factors should be considered if we want to research on the values of unoccupied time: (1) the operating speeds of high speed trains; (2) the stops and stop time between the origins and destinations; (3) the distance between two depots and points. But the current calculations do not consider the lose time caused by the set of multiple unit train depots which causes that the calculated values are oversize than the practical values.

Assuming the unoccupied time which caused by the set of depots and points is T_l, the calculation formula is

$$T_l = \frac{L}{v_t}$$

L——the distance between two depots and points

v_t——the travel speed between two depots and points

According to the analysis of the practical data of the Beijing-Guangzhou, Beijing-Shanghai, Zhengzhou-Xi'an and Ha'erbin-Dalian high-speed railway, we figure out the unoccupied time which caused by the set of main depots and points and they are showed in Table 1.

Table 1. The unoccupied time caused by the set of multiple unit train depots and points

section	distance（km）	Time（min）
Beijing-Shijiazhuang	278	77
Shijiazhuang-Zhengzhou	414	112
Zhengzhou-Wuhan	539	120
Wuhan-Changsha	362	81
Changsha-Guangzhou	707	162
Taiyuan-Shijiazhuang	224	78
Xi'an -Zhengzhou	512	139
Beijing-Jinan	409	111
Jinan-Xuzhou	286	81
Xuzhou-Nanjing	332	90
Nanjing-Shanghai	298	90
Dalian-Shenyang	389	111
Shenyang-Changchun	305	87
Changchun-Harbin	240	66

3 The train diagram unoccupied caused by travel time characteristics of high-speed railway passengers

The carrying capacity of existing lines can be fully used. Because in a period of time, even if the passenger flows are less, which means the passenger trains are less too, the rest of the carrying capacity can be filled by freight trains. But for the high-speed railway, the calculation has to take the preferences of passengers for choosing the travel time into consideration. If the Railway operates trains at a no or low passenger flow, it would get a result of low attendance, wasting of capacity and increasing operation cost.

Therefore for the high-speed railway, we have to take the unoccupied coefficients caused by passenger flows into consideration when we calculate the carrying capacity with the minimum tracking interval method. This paper counts up the practical train plans of every high-speed line (regarded Wuhan-Guangzhou Railway as Beijing-Guangzhou high-speed Railway before 2012) and calculates the unoccupied coefficients of each time periods (divided by 1 hour). Because trains operate in pairs, the data just includes the down-line direction. Due to the large amount of data, this paper just lists Wuhan-Changsha section of Beijing-Guangzhou high-speed line as Example and shows in Table 2.

Table 2.The unoccupied coefficients caused by passengers' travel time between Wuhan and Changsha

section	Time period	2011	2012	2013	2014
Wuhan-Changsha	6-7	1.0000	1.0000	1.0000	0.9167
	7-8	0.6667	0.6667	0.6667	0.5833
	8-9	0.7500	0.7500	0.8333	0.8333
	9-10	0.6667	0.5833	0.5833	0.6667
	10-11	0.6667	0.7500	0.6667	0.6667
	11-12	0.5833	0.8333	0.6667	0.7500
	12-13	0.6667	0.7500	0.5000	0.5833
	13-14	0.6667	0.7500	0.5000	0.3333
	14-15	0.6667	0.6667	0.6667	0.5000
	15-16	0.5833	0.5833	0.5833	0.5000
	16-17	0.7500	0.6667	0.5833	0.5000
	17-18	0.5833	0.7500	0.5000	0.5000
	18-19	0.8333	0.8333	0.6667	0.5833
	19-20	0.8333	0.7500	0.8333	0.8333
	20-21	0.9167	1.0000	0.8333	0.8333
	21-22	1.0000	1.0000	1.0000	1.0000
	22-23	1.0000	1.0000	1.0000	1.0000
	23-24	1.0000	1.0000	1.0000	1.0000

Analyzing large amounts of statistical data and considering the regulation of the preferences of passengers for choosing the travel time, this paper draws a conclusion of the theoretical values of the every depots and sets the Beijing-Guangzhou high-speed railway as example. According to the unoccupied coefficients in 2014, every section could be divided into several time periods shown in the following table. In each time period, we choose the average value when the unoccupied coefficients are relatively similar in each unit hour. The results are shown in table 3.

Table 3.Average unoccupied coefficients between every depots of Beijing-Guangzhou high-speed railway in 2014

<table>
<tr><th>Time period</th><th>Beijing - Shijiazhuang</th><th>Shijiazhuang -Zhengzhou</th><th>Zhengzhou -Wuhan</th><th>Wuhan -Changsha</th><th>Changsha -Guangzhou</th></tr>
<tr><td>6-7</td><td>1.0000</td><td rowspan="2">1.0000</td><td rowspan="4">0.9167</td><td>0.9167</td><td>1.0000</td></tr>
<tr><td>7-8</td><td rowspan="4">0.4792</td><td rowspan="5">0.7000</td><td rowspan="6">0.5938</td></tr>
<tr><td>8-9</td><td rowspan="4">0.6667</td></tr>
<tr><td>9-10</td></tr>
<tr><td>10-11</td><td rowspan="3">0.6389</td></tr>
<tr><td>11-12</td><td rowspan="2">0.6667</td></tr>
<tr><td>12-13</td><td>0.7500</td><td>0.5000</td></tr>
</table>

13-14					
14-15	0.4792				
15-16					0.3500
16-17		0.6042	0.7708		
17-18					
18-19	0.6944				
19-20				0.8333	
20-21		0.9375	0.9583		0.7917
21-22	0.9444			1.0000	
22-23					1.0000
23-24					

According to the table above, we could see that the value of average unoccupied coefficients between every depots have transmissibility, which means the high-peak hour of a section front would have a delay and be showed on the next section. The value of the delay is related to the mileage of this section. This characteristic is consistent with the theory research.

4 Calculation methods for high speed railway available carrying capacity, considering the characteristics of time using period

The thoughts about the calculation method are as follows: Based on the minimum tracking interval method and considering the characteristics of time using period which is caused by the preferences of passengers for choosing the travel time, we put the carrying capacity utilization (1- unoccupied coefficients) of each time period which is based on the passenger flows into the calculation formula. Secondly, we make the result take away the unoccupied coefficients which caused by the setting of multiple unit train depot.

The improved section calculation formula is as follows:

$$\mathrm{N} = \left\{\sum_{i=6}^{23}\left[\frac{60}{I}\cdot(1-\Delta\gamma_i)\right]\right\} - \frac{T_l}{I}\cdot\Delta\gamma_l$$

In the formula, N——the carrying capacity of high speed railway section

i——the operation time of high speed trains, taking 6 -24

I——the minimum dispatch tracking interval on a high speed railway station

$\Delta\gamma_i$——the unoccupied coefficients of section carrying capacity based on the characteristics of passengers' travel time, taking high-peak value, flat-peak value and low-peak value aiming at different sections as Table 3 above

T_l——the unoccupied time caused by the setting of depot and point, values shown in Table 1

$\Delta\gamma_l$——the carrying capacity unoccupied coefficients of the time period of T_l. Because of the sharp cutoff of passenger flows after 21 o'clock, the unoccupied coefficients of T_l would acquire a large value. Thus we take 0.2(reserve capacity) for this coefficient.

5 Conclusions

This paper considers dividing a whole available operation cycle of high-speed railway trains into tiny time periods, based on the preferences of passengers for choosing the travel time, the locations of multiple unit train depot and other elements. On the basis of the minimum tracking interval method, this paper puts forward a new calculation method and calculation formula of carrying capacity utilization which considering the characteristics of time using period. However, with the development of high-speed railway network in our country, the counter change and connection of different lines would make up the unoccupied carrying capacity. Thus the calculation method in this paper is more available for single railways but insufficient for whole network.

References

Chen Xichun, Zhang Haowei (2013). "Time Value of Railway Passengers Based on Travel Purpose". *Computer Simulation,* 30(12): 149-153.

Li Jun, Yu Tao (2013). "Research on Train Diagram Evaluation Index System of high-speed railway". *Railway Computer Application,* 22(10):5-8.

Xu Pan (2012). "Research on Passenger Travel Demand and Temporal & Spatial Distribution of Passenger Dedicated Line". *Beijing Jiaotong University*.

Collaborative Optimization between a Passenger Train Operation Scheme and a Comprehensive Maintenance Gap in the Net of a Passenger-Dedicated Line

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Abstract: To solve the contradictions of operation and maintenance in the net of passenger dedicated line, the problem of optimizing passenger train operation scheme and comprehensive maintenance gap was addressed by taking into account the reasonable operation time of passenger train and the importance degree of key train. Aiming at minimize the importance degree of total passenger line influencing by maintenance gap , a collaborative optimization model was proposed, and a corresponding algorithm was designed. Computational results show that the best maintenance gap period is received, which is the train reasonable operation time with least importance degree of the key train. And with the increase of maintenance gap, the number of key train and importance degree has a tendency to increase.
Keywords: Net of passenger dedicated line; Operation scheme; Comprehensive maintenance gap; Collaborative optimization.

As a large-scale infrastructure project, the railway project mainly composes roadbeds, rails, bridges, stations, power supply units, communication signals, etc. In order to keep all equipment in good condition and to ensure the safety, smoothness and comfort of railway transport, daily routine maintenance and overhaul are essential for public works, power supply, electrical services and other equipment. During this period, no train, or some reduced trains are drawn in operation diagram. The time slot reserved for construction and maintenance is called maintenance gap. Comprehensive maintenance gap for passenger dedicated line principally refers to routine repair and maintenance for tracks, power supply, communication signals and other equipment in the network of passenger dedicated line. Since the completion of passenger dedicated railway network, trains are density in a high-level capacity. Not only the original-destination trains, but also a great number of cross-line trains run between large stations in the network. Day or night, there are operation requirements. It makes the passenger dedicated network relatively complex and leads to the serious contradictions of passenger train operation scheme and comprehensive maintenance gap. Therefore, setting comprehensive maintenance gap for passenger dedicated network must consider the traffic demands and operation characteristics, as well as maintenance. Hence, collaborative optimization is required.

(LUO,2007) Proposed that the main content of collaborative optimization is to optimize the time relationship between comprehensive maintenance gap and passenger trains. A probabilistic relational model of maintenance gap and operation schema is built to search for theoretical best gap time, during which period trains with lowest probability frequency are operated appropriately. (YUE,2007)Built a mathematical model to study the relationship between gap setting and train operation and to find optimal combination schema. (MIN,2008)Discussed gap setting method in Beijing-Shanghai high-speed railway from aspects of different methods and time for gap maintenance and the impact of transport organization and device configuration. (HAN,2009)Analyzed the characteristics of various form of maintenance gap, and hence studied appropriate forms of comprehensive maintenance gap for high-speed passenger dedicated line, the intercity rail and the fast track for mainly passenger and also cargo. (ZHAO,2002)Studied how to determine the method of comprehensive maintenance gap setting in Beijing-Shanghai high-speed railway, in order to ensure the organic coordination between comprehensive maintenance planning and organization of train operation. (XU,2010)Researched on rectangular gap and segmented rectangular gap's adaptability and capacity for evening-morning trains. From the point of operation characteristics and considering the maintenance gap setting in foreign countries, (ZHANG,2006)proposed maintenance gap setting schema for passenger dedicated line in regard with gag features of existing line, the characteristics of technic equipment and traffic demands. Given the operation schema of cross-line trains in Beijing-Shanghai high-speed railway, (HU,2011)applied analytic calculation method and graphic method to analyze and calculate the reasonable time period of evening-morning trains. It studied the collaborative relation between gap duration and trains, and ultimately determined the operation schema in different conditions of gap duration.

The collaborative optimization between passenger train operation scheme and comprehensive maintenance gap in the net of passenger dedicated line is an issue requiring further study. As a part of railway network, passenger dedicated network connects with existing lines. Passenger dedicated network runs not only trains between passenger dedicated lines, but also trains between passengers dedicated lines and existing lines, which makes it more complicate. Therefore, merely studying the quantity and ignoring the importance of different trains will lead to a result with limitation or to a possibility of several optimal solution, even to a large deviation between optimal solution and actual situation. Considering operation schemas for various types of passenger trains, this paper studies the collaborative optimization between passenger train operation scheme and comprehensive maintenance gap in the net of passenger dedicated line, according to the different importance degree of each type of trains.

1 Appropriate departure time domain for passenger train operation schema in the network of passenger dedicated line

Considering the convenience for passengers as a principle and the combination of various urban transportation vehicles, trains in passenger dedicated line are usually not earlier than 7h nor not later than 24h. Trains arrive at stations from 7h to 24h. With regard to this rule, assuming t the total travel time, D the one-way running days,

$D = \left\lfloor \frac{t}{24} \right\rfloor$. Therefore, the appropriate departure time domain for passenger trains is calculated as follows:

$$X = \begin{cases} [7, 23 - t + 24D], & 24D \le t < 7 + 24D \\ [7, 23 - t + 24D] \cup [31 - t + 24D, 24], & 7 + 24D \le t \le 16 + 24D \\ [31 - t + 24D, 24], & 16 + 24D < t \le 24 + 24D \end{cases} \quad (1)$$

2 Importance degree of passenger trains in the network of passenger dedicated line

The importance degree quantitatively embodies the importance of each unit in the system. The calculation of importance degree is, in certain physical sense, to order each unit of the system according to their importance.

Divided into proper-line trains and cross-line trains, the large number of passenger trains runs at speed of 200-300 km/h and 300km/h or above. They are distinguished from normal trains by initial letters. G means high-speed trains, D means multiple unit train, K means fast trains. For trains belong to the same type, for example trains initialed by G, the importance degrees are set into different value according to the political and economic influence of the cities they pass by. As for departure time, it is more attractive for business persons to travel in morning peak hour than at noon. These trains in peak hour have higher importance degrees. For trains with different OD in segments, the number of trains effects on their importance degrees. If only one train runs in certain segment, it has a higher importance degree than that a number of trains run in the segment.

The determination for classifying trains in passenger dedicated line by importance degrees is a kind of comprehensive evaluation. Since analytic hierarchy process (AHP) is currently a simple, flexible and practical comprehensive evaluation for qualitative problem, this paper use AHP to determine the importance degree of trains in passenger dedicated line, and to provide basis for the collaborative optimization between passenger train operation scheme and comprehensive maintenance gap in the net of passenger dedicated line.

Firstly classify the trains in passenger dedicated line by different level of running speed, next apply the AHP and Delphi method to compare the importance of pairwise trains, then build the judgment matrix $R = [r_{ij}]$ where $r_{ij} > 0$, $r_{ij} = \frac{1}{r_{ji}}$, $r_{ii} = 1$, r_{ij} is the scale value of relative importance of various types of trains. The judge scales are 1-9 as it is often applied in AHP.

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1j} \\ r_{21} & r_{22} & \cdots & r_{2j} \\ \vdots & \vdots & & \vdots \\ r_{i1} & r_{i2} & \cdots & r_{ij} \end{bmatrix} \quad (2)$$

Calculate the maximum characteristic root $\lambda_{\max}$ in judgment matrix and its proper vector W .Take consistency check for judgment matrix. Normalize each column of the judgment matrix, as follows:

$$\overline{r_{ij}} = \frac{r_{ij}}{\sum_{i=1}^{n} r_{ij}} \qquad i, j = 1, 2, \cdots n \quad (3)$$

Here n is the total number of types of passenger trains in the network of passenger dedicated line.

Calculated the following equation after the normalization of judgment matrix:

$$\begin{cases} \overline{w_i} = \sum_{j=1}^{n} \overline{r_{ij}}, & i, j = 1, 2, \cdots n \\ w_i = \frac{\overline{w_i}}{\sum_{i=1}^{n} \overline{w_i}}, & i, j = 1, 2, \cdots n \end{cases} \quad (4)$$

Get W_i as the weight of importance degree. Finally calculate the maximum characteristic root of judgment matrix, as follows:

$$\lambda_{\max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(BW)_i}{W_i} \quad (5)$$

Check the consistency of the matrix, calculate the deviation consistency index of judgment matrix $C.I.$. $C.I. = \frac{\lambda_{\max} - 1}{n - 1}$, find the consistency index in the average random consistency table, and then calculate the random consistency rate $C.R.$. $C.R. = \frac{C.I.}{R.I.}$, compare the random consistency rate $C.R.$ with 0.1 to determine whether the model is consistent and robust.

3 Problem description and formulation

Operation and maintenance are two determined problems concerning the passenger dedicated line. In order to meet the passengers' departure and arrival demand, the maintenance gap are set generally from 0:00 a.m. to 6:00 a.m. The paper explores the relation between the train operation and the maintenance without the constraint of fixed maintenance gap.

3.1 Assumption

The train operation and adjustment interfere with each other. Within the maintenance, the number of operational train shouldn't surpass the section capacity. The maintenance has little effect on sunset-departure and sunrise-arrival trains. In order to simplify the problem and make the model more realistic, the model established in the paper ignores the interference between trains, and concentrate the relationship between maintenance gap and train operation. Namely, the train within the network are independent. They aren't affected by the changes of the other trains.
Within the maintenance gap, the railway capacity is the constraint for the number of operational trains. Adjustment of the departure time for all trains are the key of the model, and it also satisfies the assumption.

3.2 Model description

The trains of different speed run on the passenger dedicated railway network. These trains are of different importance, and they have different operation planning. Due to the connection between the operation plan and the maintenance, a cooperative model is needed. Firstly, the appropriate departure time scale needs to be set, namely to calculate the impact on all trains from the maintenance $\sum_{i=1}^{n} W_i$, based on the maintenance gap $[m,n]$.The minimize value of $\sum_{i=1}^{n} W_i$ is the optimal maintenance gap scale and operation planning. The other trains aren't affected by the maintenance gap, or they can be adopted to avoid the impact.

3.3 Model formulation

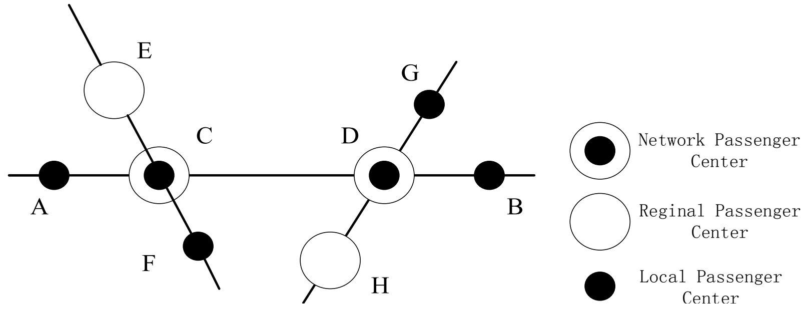

Figure 1. Network Simulation

As shown in the Figure 1, in the passenger dedicated railway network, Line AB is a busy main railway line, and section CD is the section of this main line. The passenger dedicated railway line is of two directions, in our paper, only one direction is calculated, and the other direction can be done in the same way.

The arrival time for all trains on the section CD are calculated based on appropriate passenger departure time scale. As shown in Figure 1, the departure station for i^{th} train is station E, and the arrival station is station H. The appropriate departure time scale at station E is $[c,d]$. The arrival time is y_i, and the arrival time scale is $[c+y_i, d+y_i]$, namely $[c_i, d_i]$.The maintenance gap is set as $[m,n]$. Generally, the relationship between maintenance and arrival time of passenger are listed in figure 2.

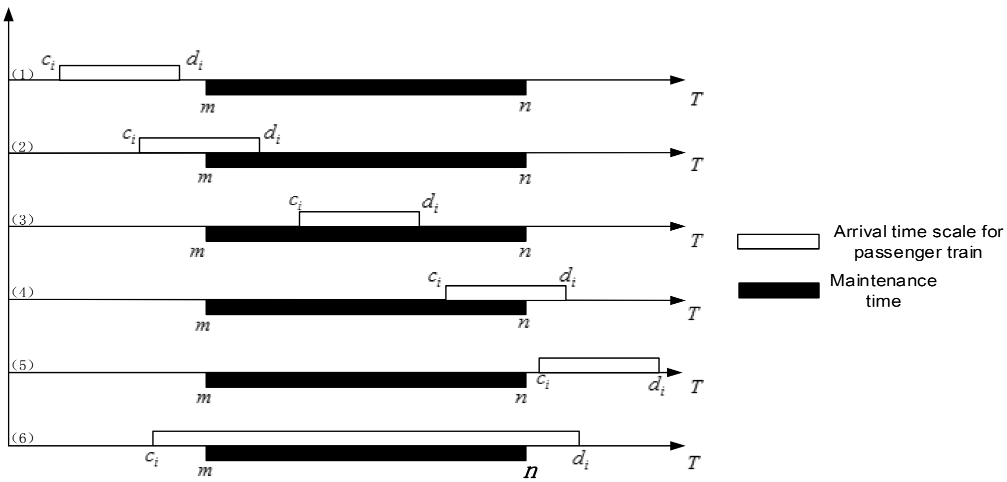

Figure 2. Relationship between maintenance gap and train arrival time

Then another parameter, the pass-through time is needed to determine whether the first and the second type train can pass through the section before the maintenance gap, namely whether the train is affected by the maintenance; the arrival time for the third type of train falls in the maintenance gap, and it's certainly affected by the maintenance; the arrival time of the fourth and sixth train overlapped the maintenance gap. It indicates that the conflicts exits, while the conflicts can be avoided by adjusting the operation planning; the arrival time of the fifth train doesn't overlap the maintenance, and it indicates the departure time aren't affected by the maintenance.

Now we'll discuss the first 3 cases concerning $[c_i, d_i]$ and $[m,n]$:

The first and second type train under the maintenance influence must satisfy the following condition:

$$\begin{cases} m \le c_i + t \\ n \ge d_i \end{cases} \tag{6}$$

The third type train must satisfy the following condition:

$$\begin{cases} m \le c_i \\ n \ge d_i \end{cases} \tag{7}$$

If the pass-through time for train on section CD is t, the train arrival scale is p, then $d_i = c_i + p$, the maintenance gap is q, then $n = m + q$. By (6) and (7), we obtain:

$$\begin{cases} m \le c_i + t \\ m + q \ge c_i + p \end{cases} \tag{8}$$

From the equation above, we can see for the train affected by the maintenance, the minus between maintenance starting time and departure and arrival time of passenger train is inferior the pass-through time. And this minus is superior the minus between train running time and maintenance gap. The train that meet the above condition can't be adjusted.

Under the influence of period of 24 hours, the equation (8) can be rewritten as bellow:

$$\begin{cases} m - t \ge 0 \\ m \le c_i + t \\ m + q \ge c_i + p \end{cases} \cup \begin{cases} m - t < 0 \\ m + 24 \le c_i + t \\ m + q \ge c_i + p - 24 \end{cases} \cup \begin{cases} m - t < 0 \\ \\ m + q \ge c_i + p \end{cases} \tag{9}$$

And m , t , $c_i \in [0, 24)$.

As a result, for every train of the section, if it meets the equation mentioned above, it's affected by the maintenance, and its influence is noted as W_i.For given pass-through time t, train departure time and maintenance gap, $\sum_{i=1}^{n} W_i$ can be calculated. We can obtain the value scale of m with the minimum $\sum_{i=1}^{n} W_i$. This is therefore the optimal starting time for maintenance. Therefore, the operation planning can be adjusted.

3.4 Calculation designing

STEP 0：Calculate the appropriate train arrival time on section CD, $[c_i, d_i]$ and make the order from the smallest to the largest. The total number of trains is set as N. And the rearranged train arrival time scale is set as $[c_n, d_n]$.

STEP 1：Set p_n as the arrival time scale for the k^{th} train, namely $d_n = c_n + p_n$, and calculate the p_n for all trains;

STEP 2：Set t_n as the running time for k^{th} train on section CD, Q as the number of affected trains, W as the importance and its initial value is 0. For a given q, calculate the value scale for c_n, t_n, p_n *and* m. If the passenger train satisfy the equation 6-9, then $Q = Q + 1, W = W + w_i$;

STEP 3：Calculate the minimum value for Q and W when $m \in [0, 24)$. When W reaches the minimum value, we obtain the optimal maintenance plan. When all trains are of the same importance, then the plan with the minimum Q is the most optimal plan;

STEP 4: Find out all the key trains based on the value scale of *m*. We can adjust the operation and maintenance gap based on *m*.

We should note that for trains with several departure scale, we have to calculate the departure time separately. If the train within several solution is always affected by maintenance plan, then this train is the key train. If not, the train can be adjusted to avoid the maintenance influence or it's not affected at all.

4 Experimental Study

According to the information found in literature, the basic information of Beijing-Shanghai high-speed railway is as follows:

(1) Setting mode of the comprehensive maintenance maintenance gap of Beijing-Shanghai high-speed railway is segmented vertical rectangular maintenance gap.

(2) Setting time of the comprehensive maintenance maintenance gap of Beijing-shanghai high-speed railway is 0:00 to 06:00.

(3) The evening-morning train running on the Beijing-shanghai high-speed railway departs generally between 18:00 and 23:00 in the evening, and arrives between 6:00 to 9:00 in the morning. The whole running time is between 7 to 15 hours.

According to case 3, a rational departure and arrival time range of evening-morning train running on the Beijing-shanghai high-speed railway can be calculated. Setting aside for a period of time between 0:00 and 06:00 as maintenance gap is necessary according to case 2. Since the running train of Beijing-Shanghai high-speed railway runs during the day and has no night driving demand. Thus, only the cross-line train can be influenced by the maintenance gap time. According to passenger flow OD, passenger flow density, layout of maintenance facilities, maintenance area and cross-line point's setting, dividing Beijing-shanghai high-speed railway into six running section (Referred to as section): Beijing-Tianjin, Beijing-Tianjin, Tianjin-Dezhou, Dezhou-Jinan, Jinan-Xuzhou, Xuzhou-Nanjing and Nanjing–Shanghai. According to the running section structure table of the cross-line train operation plan of Beijing-shanghai high-speed railway in 2015, which include 169 pairs of high-speed cross-line trains with a planning operation speed of 300km/h and above, 62 pairs of high-speed cross-line trains with a planning operation speed of 200km/h and above.

This paper selects Xuzhou-Nanjing section of Beijing-Shanghai high-speed railway as an example to verify the validity of the method. First, for the high-speed trains with a speed of 300km/h and above, and of 200-300km/h, respectively conduct importance assignment order (G>D>T>Normal) according to the initial letter of train. Based on the method for determining the importance degree of train grades in the text, obtained the importance degree of High-speed cross-line train with a speed of 300km/h and above is 0.75, the train with a speed of 200km/h and above is 0.25. The passenger train operation plan of Beijing-Shanghai high-speed railway in the above document 2015, the reasonable time period of its passenger train arriving at each section were calculated in accordance with the formula (1), according to the requirements of open time of different maintenance gap, depending on the maintenance gap, taking respectively 2.5 hours, 3 hours and 4 hours for example, using a computer program to calculate the sum of importance degree of the key train at different time range of maintenance gaps, as shown below.

After calculation, between 0:00 to 06:00, the reasonable arrival time range of evening-morning train with different weights to the section of Xuzhou-Nanjing section of Beijing-Shanghai high-speed railway is shown in Figure 3, where the high-speed cross-line trains with a speed of 300km/h and above is represented by red lines, speed of 200km/h and above is represented by the blue line.

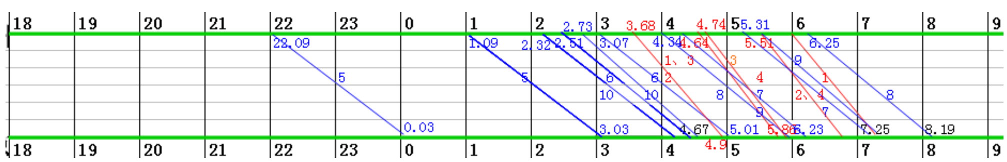

Figure 3. Reasonable arrival time range of evening-morning train to the section of Xuzhou-Nanjing section of Beijing-Shanghai high-speed railway

1. When maintenance gap time q=2.5h

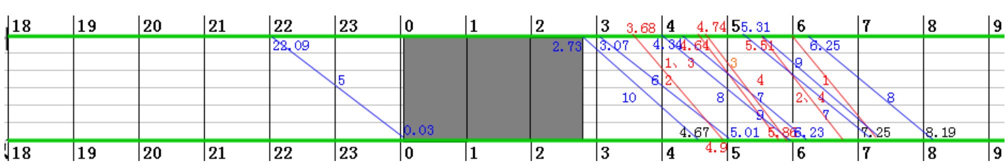

Figure 4. Case q=2.5h

The above figure shows that train No.5, No.6 and No.10 may be influenced by the maintenance gap when q=2.5h. After adjusting for the above three kinds of trains within the scope of $[c_i, d_i]$, they can completely avoid the influence of the maintenance gap set, namely, when q=2.5h, no train will be affected by the maintenance gap set. Thus, when q=2.5h, Q=0, W=0, we can obtain m=0.03, n=3.07, the open time range of maintenance gap is [0.03,0.07].

2. When maintenance gap time q=3h

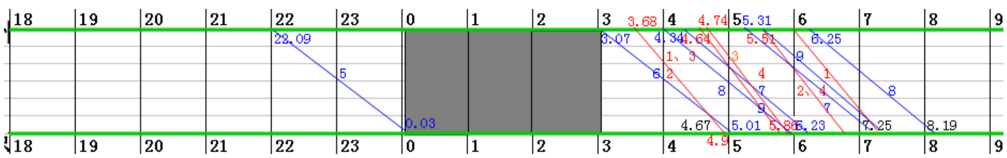

Figure 5. Case q=3h

The above figure shows that train No.5 and No.6 may be influenced by the maintenance gap when q=3h. After adjusting for the above two kinds of trains within the scope of $[c_i, d_i]$, No.5 and No.6 can completely avoid the influence of the maintenance gap set, but the arrival time range of No.10 fall entirely in the time set of maintenance gap, within the range of rational departure time, No.10 can not avoid the influence of maintenance gap set. Thus, when q=3h, Q=1, W=0.25, we can obtain m=0.03, n=3.07, the open time range of maintenance gap is [0.03,3.07].

3. When maintenance gap time q=4h

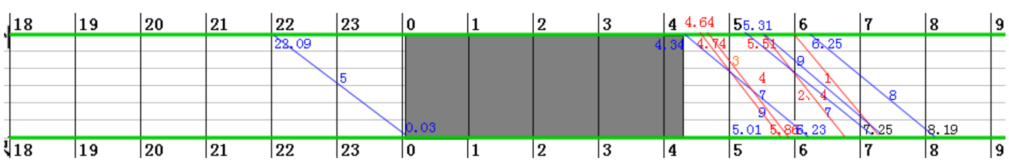

Figure 6. Case q=4h

The above figure shows that train No.1, No.2, No.3, No.5 and No.8 may be influenced by the maintenance gap when q=4h. After adjusting for the above two kinds of trains within the scope of $[c_i, d_i]$, No.5 can completely avoid the influence of the maintenance gap set, but the arrival time range of No.6 and No.10 fall entirely in the time set of maintenance gap, within the range of rational departure time, they can not avoid the influence of maintenance gap set. Thus, when q=4h, Q=2, W=0.5, we can obtain m=0.03, n=4.34, the open time range of maintenance gap is [0.03,4.34].

The main conclusions is as follows through the above analysis:

(1) The existing research results, in which the number of key trains are determined by optimal time set of comprehensive maintenance maintenance gap set,

but this paper uses the sum of importance degree of key trains to find the optimal time of comprehensive maintenance maintenance gap set, to reach collaborative optimization of train operation plan and the comprehensive maintenance maintenance gap, when the key train has the same degree of importance, the model is changed to take the minimum number of key train as the goal, which consistent with the conclusions of existing research results. Therefore, compared with the existing research results, this paper is possible to obtain an opposite conclusion with the previous results.

(2) Through research analysis, with the increase of maintenance gap time q, the key train number and the important degree also have a tendency to increase, as shown in figure 7.

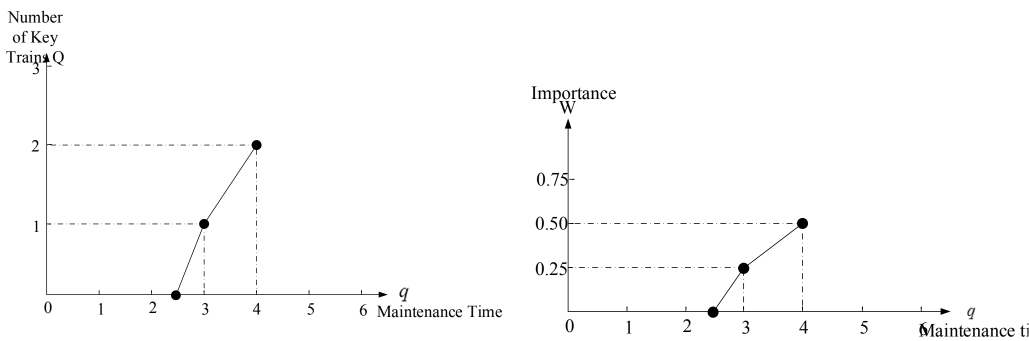

Figure 7. The Change trend chart of sum of number and importance of key train

5 Conclusion

For the problem of collaborative optimization of passenger train operation plan and comprehensive maintenance maintenance gap, this paper put forward the concept of the importance degree of passenger train and key train, and on this basis, established optimization adjustment model for passenger train operation plan of passenger dedicated line network based on comprehensive maintenance maintenance gap optimization settings, conduct algorithm design for the solving of model, and finally demonstrated the effectiveness of the method with numerical examples. This paper only considers the mutual influence between the passenger train operation plan and the comprehensive maintenance of maintenance gap, the next step is to research collaborative optimization model for passenger train operation plan of passenger dedicated line and the comprehensive maintenance maintenance gap under the condition that mutual influence of trains and time-phased reflect the importance of differences.

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Reference

China Academy of Railway Sciences. The Research on complex maintenance scheme of Beijing-Shanghai high-speed railway. Beijing: China Academy of Railway Sciences, 2009.

China Academy of Railway Sciences. The Operation of Sunset-departure and Sunrise-Arrival Trains influence maintenance gap. Beijing: China Academy of Railway Sciences, 2007

HAN Boling, TIAN Changhai, WANG Yubin. Comparative Study on the Forms of Comprehensive Maintenance "Window" for Passenger Dedicated Lines. China Railway Science.2009(05):95-99.

HU Xiuting. Arrangement on the Comprehensive Maintenance Window of Beijing-Shanghai High-speed Railway. Journal of Transportation Engineering and Information. 2011(3):103-110

LUO Jian, PENG Qi-yuan. Study on Collaboratively Optimizing the Coordination Between Train Running Schedule and the Comprehensive Maintenance Gap. Railway Transport and Economy. 2007，29(8)：65-67.

MIN Guoshui; HUANG Yongliu.Study on Scheme for Passenger Dedicated Line Between Beijing and Shanghai,Journal of Beijing Jiaotong University. 2008(03):16-20.

PENG Qiyuan. Transportation Organization of Passenger Dedicated Line. Beijing: Science press,2007.

The Third Railway Survey and Design Institute Group Corporation. New-built high-speed railway from Beijing to Shanghai preliminary design general specification. Tianjin: The Third Railway Survey and Design Institute Group Corporation, 2007.

XU Xiaoyong. Coordination between Maintenance gap Setting and Evening-Morning Train on Passenger Dedicated Lines. Urban Mass Transit.2010(10):77-79

XU Xingfang, XU Ruihua. Research on Passenger Train Operation Organization and Its Correlative Problems on Special High Speed Railway Lines. Journal of Tongji University. 2003(05):532-536.

YUE Wen; YUAN Chuan-bin. The optimum study on the running scheme of passenger train and maintenance gap on the speed-up busy Line. Technology & Economy in Areas of Communications. 2007(02):86-87.

ZHANG Jiyi. Research on the Setting Plan of “Window” for PDL. Chinese Railways.2006(10):24-27.

ZHAO Li zhen, ZHAO Ying lian, YANG Yue qin, FENG Chun lin. Ways of Opening Comprehensive Maintenance “Window” and Its Coordination with Traffic Organization for High-speed Railway. China Railway Science. 2002(02):127-131.

Port Rating Scale and the Structural Optimization of the Middle Reaches of the Yangtze River

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Abstract: In order to better describe the level of the middle reaches of the Yangtze River port of scale and promote the future development of the middle reaches of the Yangtze River port. The thesis analyses the Scale Structure of six major ports on the Yangtze River via port of first degree, rank - size rule and fractal theory method, while we calculate the rating scale of peacekeeping through the data of the middle Yangtze port from 2004 to 2011. The results show that: the middle reaches of the Yangtze River port size distribution has obvious fractal characteristics, using fractal theory is suitable for analysis of Scale Structure of ports in the region, the first role of the high times port is weak, ports tend to be independent, grade scale spatial layout is more balanced.
Keywords: The middle reaches of the Yangtze River port; Grading scale; Rank - size rule; Fractal theory; Structural optimization.

1 Introduction

The more common use of rank - size rule and fractal theory is in the study of urban rating scale, such as Chentao, Liujisheng. (1994) briefly describes the basic fractal theory, focusing on the fractal characteristics of urban systems, and discusses the urban system spatial distribution of the random diffusion and regularity size distribution. J. Friedmann (1986) studied the level of network system of the city, pointing out that the city hierarchy system will become multinational division reflecting the longitudinal production area. The innovation of this paper is to be applied to the rating scale analysis of the port, and finally verifying the rank - size rule and fractal theory to port rating scale analysis is reasonable through the results. Therefore, we can use the rank - size rule and fractal theory to study the characteristics of the scale structure of the port, to develop a reasonable development strategy of the port, thus contributing to regional economic development. By using this model to calculate, you can get the specific characteristics of the Yangtze River port rating scale, compared with other models, this model has a high practical significance.

2 The Theory Selected

2.1 rank - size rule

Gaochao. (2011) describes that Hausdauf fractal dimension is the fractal dimension of the most commonly used method estimates. Assuming the relationship between total n ports within a certain region, the size of the ports in descending order, If given a throughput metric scale r, the relationship between the port throughput that is greater than r which is N(r) and scale r to meet:

$$N(r) \propto r^{-D} \tag{1}$$

Where D is the Hausdauf dimension.

Taking the logarithm on both sides, we can get

$$\ln N(r) = A - D \ln r \tag{2}$$

Where A is a constant.

In general, the size of the port city obedience rank - size distribution pattern, the most common urban rank - size distribution model is G.K Zipf formula:

$$\ln \mathrm{P}_r = \ln P_1 - q \ln_r \tag{3}$$

Where r is port rank,P_r is r-bit port throughput,P_1 is theoretical maximum throughput of the port,q is a constant. What D means is as follows:

Table 1. What D means

The range of D	Port rating scale morphology
$D = 1$	Port rating scale to achieve the ideal state, port development in good condition, constrained rank - size distribution
$D < 1$	Port rating scale distribution of scattered, port development is not mature enough, the first port is a strong monopoly
$D > 1$	Port grade size distribution is more concentrated and more mature
$D \to 0$	The only port in the region
$D \to \infty$	Port rating scale is indifference

Each port of the middle reaches of the Yangtze River fell by rank and scale to the double logarithmic graph, we can make an objective division to rating scale of ports by a scatter plot. Then subjected to $y = bx + a$ form of regression analysis, according to one of the parameters on the rank port to judge the size of the type.

2.2 The fractal theory

Xujianhua. (2002) describes that fractal theory is a new theory of natural science, social science and scientific thinking across the mid-1970s. Allen P M.(1997) describes that fractal theory is that those very irregular and fragmented external geometry (or phenomena) has its own inherent regularity and self-similarity. The concept of fractal is an American mathematician Mandelbrot (B. B. Mandelbort) first proposed. In 1967 he published in the American Journal of authority of the "science" entitled "How long is the coastline of Britain?" We can not distinguish from the shape and structure of this part of the coast and that part of the coast of what is essentially different, and this is almost the same degree of irregularity and complexity instructions the morphology of the coastline is self-similar. That is the local morphology and the overall shape is similar. In 1975, Mandelbrot founded the fractal geometry. On this basis, the formation of the fractal nature of scientific research and its application, called fractal theory.

3 The Middle Reaches of the Yangtze River Port Rating Scale and Fractal

3.1 The middle reaches of the Yangtze River port rating scale studies

There are a large number of ports on the middle reaches of the Yangtze River, the paper we focus on selected six representative ports to be studied. According to 2012 "Yearbook of Chinese ports," we got the tables which include port cargo throughput and container throughput, specific data is shown in Table 2.

Table 2. 2011 middle reaches of the Yangtze River port throughput

port	cargo (10^3t)	Container (10^3TEU)
Wuhan port	7602	71
Yueyang port	9036	15.5
Yichang port	4635.87	6.11
Jiujiagn port	3907	14.22
Jingzhou port	2147.88	6.4
Huangshi port	1780.54	2.1

Source: 2012 "Yearbook of Chinese ports."

In order to weight the two indicators of this paper selected, we must first eliminate the influence of dimensionless, so we can use number two index values in the column divide the maximum dimensionless get two columns of data x_1 and x_2 through expert counseling and AHP to determine the weight of the two above-mentioned index weight, the result is:

$$W=(0.75, 0.25)$$

And the overall size of the final port is:

$$x = 0.75x_1 + 0.25x_2$$

Table 3. Comprehensive scale of 2011 middle reaches of the Yangtze River port

port	x_1	x_2	x
Wuhan port	0.84	1	0.88
Yueyang port	1	0.22	0.80
Yichang port	0.51	0.09	0.41
Jiujiagn port	0.43	0.20	0.37
Jingzhou port	0.24	0.09	0.20
Huangshi port	0.20	0.03	0.16

According to Mark • Jefferson's City first degree theory, we will apply it to the level of scale division ports, the ports can be drawn first index, the index is generally considered the first port should include two port index, 4 port and 11 port index index.

$$S_2 = P_1 / P_2$$
$$S_4 = P_1 / \left(P_2 + P_3 + P_4\right) \quad (4)$$

Formula: S_2 - represents 2 port index .

S_4 - represents 4 port index .

P_x - represented ranked No. x overall size of the port by port rating scale. x=1,2,3,4

According to city rank - size rule, 2 port index is 2,4 port index is 1 is the ideal state for a port structure. However, the analysis shows that the index was less than the standard, and from the point of S_2, the first port of monopoly is not strong, and has weak impact on the whole Yangtze River region rating scale; from the point of S_4, the middle rank of the harbor is relatively developed, and evenly distributed, no significant differences in the size of the structure, the values are shown in Table 4.

Table 4. The middle reaches of the Yangtze River port 2011 rating scale index

first degree	2011
2 port index	1.095
4 port index	0.556

To illustrate the role of the middle reaches of the Yangtze River port of first degree whether the strong better, we are out of the list of ports 2004-2010 first-degree value, National Bureau of Statistics. (2013) provides the data wo need, as is shown in Table 5.

Table 5. Middle reaches of the Yangtze River port of 2004-2010 first-degree

years	first degree
2004	2.187
2005	2.021
2006	2.533
2007	1.631
2008	1.161
2009	1.397
2010	1.572

Through the data were analyzed on the table, from 2004 to 2006, the first of the role of the port of Wuhan port is strong, among the years later, the first degree of effect is obviously insufficient, therefore, as a hub port on the middle reaches of the Yangtze River, Wuhan port should strengthen its own port construction and play a good role in its promoting.

3.2 The middle reaches of the Yangtze River port fractal characteristics

Here, we chose port's cargo throughput to represent the rating scale, according to the city rank - size rule, we obtained rank - size regression equation of 2011 the middle reaches of the Yangtze River port and calculate the fractal dimension.

Several groups of coordinates will be needed when painting graphics:

(0,-0.13),(0.7,-0.22),(1.1,-0.89),(1.4,-0.99),(1.6,-1.61),(1.8,-1.83)

Paint simulation using MATLAB, we can get the regression equation:

$$y = -0.9782x + 0.1310$$

The image shown the regression in Figure 1:

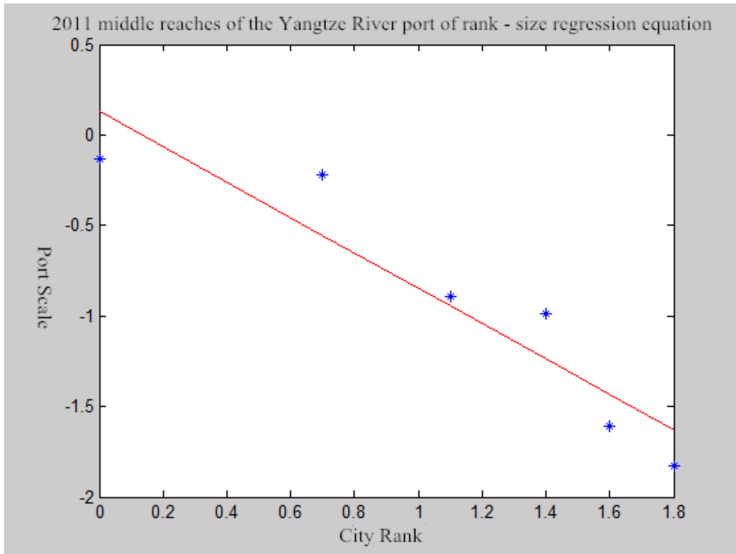

Figure 1. 2011 middle reaches of the Yangtze River port of rank - size regression

From the results obtained in the above MATLAB run can know, the absolute value of the slope of the regression line is 0.9782, the value of D is 1.022, more than 1, indicating the middle reaches of the Yangtze River port size distribution is a relatively balanced distribution type, the size of the high secondary port is not very prominent, close to the port distribution rank - size rule. After obtaining the regression equation, we can calculate the deviation between the theoretical value and the actual value, as shown in Table 6.

Table 6. The deviation of port scale between the theoretical and the actual value

port	deviation
Wuhan port	0.001
Yueyang port	-0.334
Yichang port	-0.055
Jiujiang port	-0.248
Jingzhou port	0.176
Huangshi port	0.200

From the above table, we can know that the actual size of Wuhan port, Jingzhou port and Huangshi port is smaller than their theory scale. Judging from the background of the port area, they have considerable development prospects. The actual size of Yueyang port, Yichang port and Jiujiang port is bigger than their theory scale which indicates port has a high development speed.

Using the same method, we can calculate the Yangtze River port 2004-2011 rating scale fractal dimension, the calculation results are summarized in Table 7.

Table 7. Yangtze River ports rating scale fractal dimension Results（2004-2011）

year	Formula	D	R^2
2004	$y = -1.2918x + 0.0977$	0.7741	0.9801
2005	$y = -0.9127x + 0.0323$	1.0957	0.9592
2006	$y = -0.8718x - 0.1243$	1.1471	0.9800
2007	$y = -0.9673x + 0.0607$	1.0338	0.9903
2008	$y = -0.9636x + 0.1083$	1.0378	0.9594
2009	$y = -1.1382x + 0.1820$	0.8786	0.9710
2010	$y = -1.1818x + 0.1433$	0.8462	0.9732
2011	$y = -0.9782x + 0.1310$	1.0223	0.9326

4 Conclusions

Data can be obtained in the above table, the correlation coefficients were greater than 0.93, indicating good correlation, indicating that the size distribution of the middle reaches of the Yangtze River port has obvious fractal characteristics, using fractal theory for analysis and research in the area Scale Structure of the port, which has a positive significance . Based on this, we should enhance the influence and the economic effect of the first ports to promote the development of all ports on the middle reaches of the Yangtze River, to create a thriving situation of the middle reaches of the Yangtze River ports. Specifically, we should focus on our attention to improve the economic effect of the port of Wuhan port and Yueyang port, make efforts to improve the first degree level of the two ports, make use of their advantages to promote the development of other ports in the middle reaches of the Yangtze River, to achieve a comprehensive and balanced development of the middle reaches of the Yangtze River port.

References

Allen P M.(1997). Cities and regions as self-organizing systems: models of complexity[. *Amsterdam: Gordon and Breach Sciences Pub*.

Chentao，Liujishegn. (1994).A preliminary study of fractal characteristics of urban system. *Geography* , 25—30.

Gaochao. (2011). Research on scale structure of the Bohai port city system. *Tangshan Teachers College （Natural Science）*, 116-119.

National Bureau of Statistics. (2013). China Port Yearbook（2005-2012). *Beijing: China Statistics Press*.

Xujianhua. (2002). Mathematical Methods in Modern Geography. *Beijing: Higher Education Press*, 392-401.

Frideman J R (1986). The world city hypothesis: development and change. Urban Studies, 23(2): 59-137.

An Optimization Model for Designing a Pedestrian-Oriented Signage System in a Large Passenger Hub

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Abstract: Large passenger transfer hub tends to have complex architectural spaces, wayfinding system plays a positive role in improving the service level of transfer and encouraging travelers to choose public transport. Based on the complexity of building space features and requirements of hub management function, the design of pedestrian-oriented signage system essentially can be summarized as complex decision problems. However, there are few researches on the determination of the locations and the content in order to make an acceptable wayfinding to all participants, especially considering the public transport priority and the sustainable finance. Aiming at this problem, the technique of multi-objective optimization is used as the core tool. The method converted this complex system decision problem into mathematical models based on three objectives (maximizing the level of space-guided, minimizing the financial investment, and minimizing the guidance distance).

Keywords: Design of pedestrian-oriented signage system; Transfer hub; Public transport priority; Sustainable finance.

1 INTRODUCTION

Contacting inside and outside, large passenger transfer hub is an integral part of a modern city. Transfer is the core function of a hub, which tends to have complex architectural spaces and uncertain visual conditions. The complex transfer conditions make travelers more easily confused. S. C. Wirasinghe (W.H.K. Lam, 2003) mentioned that most of travelers rely on pedestrian-oriented signage system except to ask people in wayfinding process. Signage system can ensure travelers have a clear guided in space and orientation in hub.

Design, content and location are key factors influencing whether people can effectively use pedestrian-oriented signage system (Arthur P, 1992). Existing theory has maturely study typesetting, fronts, and colors. As an important part, they have played an active role. But the wayfinding process has its logic including decision-making, implementation and final confirmation to reach the target point.

The process is completed collaboratively by many signage, which emplaced in different locations in transfer hub. The contents of each signage are also largely determined by their position.

As urban traffic congestion problem in China is getting worse, experts and government officials generally considered that a priority development of public transport is an effective way to solve traffic problems (Yanjie Ji, 2004; Xiaoyan Yan, 2007). Public transport in the city as a lever to reduce the amount of traffic demand can achieve the balance between transport infrastructure development and the growth of traffic demand. How to make the strategy of public transport priority to the level of signage system designing is lack of effective quantitative methods.

Both the strategy of public transport priority and sustainable finance to take into account to the design of signage system is a complex joint decision-making problem. From the point of existing research abroad, only little research has addressed the holistic research of oriented signage system, especially in the aspect of using mathematical methods to solve the determination of location and content. Subjective experience of designers, conceptual framework, and specific strategies are marked as a basic to design, which lack of quantitative analysis. Aiming at this problem, this paper develops a mathematical model to research the design of signage system in large passenger transfer hub from the overall perspective. The two core elements involving contents and location are optimized. The paper is organized as follows. Section 2 gives a literature review on holistic study in past and recent years. A multi-objective optimization model of the system design is presented in Section 3. The conclusions and suggestions for future research are given in Section 4.

2 RELATED LITERATURES

The research of signage system focuses on three aspects in the followings: design of signage, relationship between signage and wayfinding process, and assessment of oriented system. The design of signage includes their own attributes and the use of holistic design. The research in this paper belongs to the later, which considers public transport priority and sustainable finance.

Over the years, there is an in-depth research in the standardization of signage itself properties (Manual on Uniform Traffic Control Devices, 2009; BS 8502-2003, 2003), and China also developed the industry standard according to its own national conditions (GB/T 20501-2006, 2006). Wang (Zhe Wang, 2011) proposed that the ideal typesetting of information on the sign is not more than 3-4 lines, and the similar information should be summarized to a group.

But the more important is location and content when we study the use of holistic design. On the view of Arthur and Passini (Kevin Lynch, 1960; Passini R., 1996), wayfinding is the behavior to reach the destination in the space. The behavior can be used to determine location, content, and other design elements. Due to the different structure of the building, the flat is divided into different functional areas. Literatures

(J.R. Carpman, 1991; Xu H. & Kazuhiko N, 2002; Alice Beneicke, 2003; Caves, R.E., 2001; Seunghae Lee, 2014) conducted a detail study of the pedestrian-oriented signage system in libraries, museums, hospitals, terminal and other pedestrian distribution spaces. Series theory of the oriented signage system design based on wayfinding behavior and path selection was developed, and there were detailed design plans and steps according to needs of different places. Obviously, the wayfinding behavior provides an experimental method in the design of oriented signage system.

Meanwhile, scholars focused on the point of optimal decision to determine the layout of signage. Tam (Mei Ling Tam, 2011) attempt to tackle the problem of determining the appropriate locations for placing directional signs in airport terminals or other enclosed environments, with an objective of maximizing the visibility index (VI). Professor Zhang (Dongqing Han, 2008; Yanxin Han, 2010) carried out the initial pedestrian-oriented signage system design and optimization studies in Beijing South Railway Station. The model took the maximum of guidance levels as the objective, then used intelligent algorithms, which include genetic algorithms and simulated annealing algorithm to optimize the location choice in internal space. The model has a good exploration to solve the location problem in the design of oriented signage system. But in fact, the optimization of location faces different objectives, and the model using single target may get poor results in the other standards. People are more willing to accept the program that takes all aspects into account rather than pursuit the strictly optimal solution in only one objective. On these basis, Ling (Yu Ling, 2013) develops the optimization model which contains two optimization objectives, i.e., maximizing the level of space-guided and minimizing the guidance distance, and design an Infeasibility Degree Selection Operation which is inducted into Non-dominated Sorting Genetic Algorithm Ⅱ. However, the above models did not take both the strategy of public transport priority and sustainable finance into account. Still, these researches provide impressive suggestions to the design of pedestrian-oriented signage system, which inspired the model to be established below.

3 METHODOLOGIES

3.1 Description of the Problem

There are series alternative locations and several destinations in a large passenger transfer hub (**FIGURE 1**). The setting principles of alternative locations as follows: a. nodes in the conversion, b. based on the requirements of the continuity of guidance and psychological effects on the pedestrians, an alternative location set every i meters in a continuous sidewalk. Generally i values 30. An alternative location refers to positions in the space that may be set signage. Destinations refers to positions in the space that pedestrian may go to, such as the metro entrance, bus terminals, coach station entrances. All alternative locations compose the initial position set.

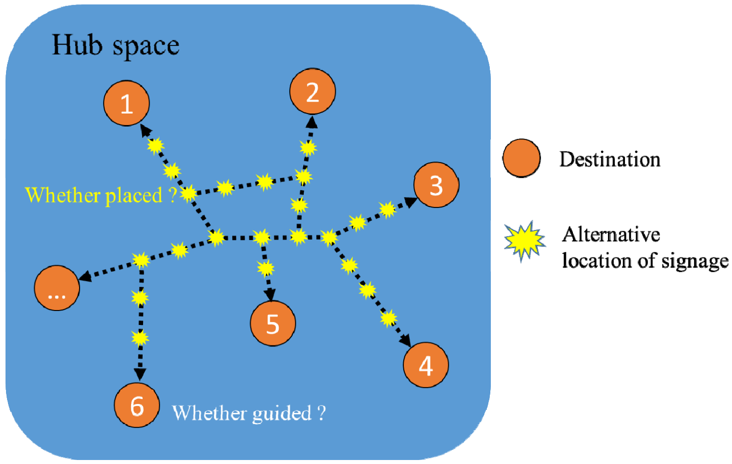

Figure 1. The conceptual model of pedestrian oriented signage system in hub

We can use two variables in Table 0-1 to express decision-making, which contains the location and the content.

$$X_a = \begin{cases} 1, & \text{set signage at the a alternative location} \\ 0, & \text{do not set signage at the a alternative location} \end{cases} \quad (1)$$

$$Y_{ab} = \begin{cases} 1, & \text{imformation in signage} \\ & \text{at the a alternative location contains the destination point b} \\ 0, & \text{imformation in signage at the a} \\ & \text{alternative location does not contain the destination point b} \end{cases} \quad (2)$$

Where a represents the alternative location, $a = 1,2,3,\cdots,m$. b represents the destination of travelers in the large passenger transfer hub, $b = 1,2,3,\cdots,n$, the hub here refers to building functional areas with a certain boundary which has a significance to set signage system.

In the actual the project, there will be a variety of signage with different functions such as comprehensive signage, grade one signage, grade two signage. Each signage can contain a different number of destinations. In order to count funding investment, the model does not consider the hierarchical functional differences among signage. This principle of simplification of signage in every alternative location as follows: a. for each alternative location, the number of signage do not exceed j, generally j values 4, b. for each signage, the number of destination that can accommodate up to k. The number of signage at each alternative location can be expressed by the formula below.

$$Z_a = \left\lceil \sum_{b=1}^{b=n} Y_{ab} \Big/ k \right\rceil \quad (3)$$

The optimization of pedestrian-oriented signage system can be described: according to the optimization objectives, select set A from the alternative locations, which the total number is m. While for each $a_0 \in A$, select set B_{a0} from the destinations which the total number is n.

3.2 Mathematical Model

(1) Multi-objective function

There are several management agencies and departments affecting the decision-making in the design of pedestrian-oriented signage system. The precondition of the overall objective is congruence, but various departments and agencies have their own separate or conflicting objectives. There are three departments affecting optimal decision in Shanghai South Railway Station Program: Shanghai South Railway Station Management Committee (management department), Construction and Transportation Committee of the Shanghai Xuhui District (investment department), travelers (pedestrian).

Management Department What the management department concerned is the efficiency of passenger transfer hub and the reflection of public transport priority. Due to limitations of ability for pedestrian to capture oriented information at an alternate location (too much setting of signage can cause pedestrian to stop to search for information, resulting in obstruction and congestion), the level of guidance cannot be improved by increasing the amount of information density and enlarging the distribution density. So the level of guidance is the average value of each location that is determined to emplace. The essential function of signage system is also here. We can use the function expressed as:

$$maxS_1 = \sum_{a=1}^{a=m} \sum_{b=1}^{b=n} (X_a * Y_{ab}) \Big/ \sum_{a=1}^{a=m} X_a \tag{4}$$

Meanwhile, another important goal for management department is to encouraging more travelers to choose public transport, i.e. the level of public transport priority. That is different destinations in the same space achieve different social value, and the importance for meeting the social needs of public transport to each destination is different. To each destination, we can use a coefficient to represent the degree of importance for implementation of public transport priority. Here we called it public transport priority factor T_b. The first objective function is to give:

$$\max S_2 = \sum_{a=1}^{a=m} \sum_{b=1}^{b=n} (X_a * Y_{ab} * T_b) \Big/ \sum_{a=1}^{a=m} X_a \tag{5}$$

Where T_b is the public transport priority factor, the principle of its value is as follow.

$$T_b = \begin{cases} 1, & \text{the destination } b \text{ is not public transport} \\ 1.5, & \text{the destination } b \text{ is public transport} \end{cases} \tag{6}$$

Investment Department Investment departments hope to achieve a minimum total construction costs, i.e. the number of signage in the entire hub is minimum. The objective function is:

$$\min S_3 = \sum_{a=1}^{a=m} \left\lceil \sum_{b=1}^{b=n} Y_{ab} \Big/ k \right\rceil * h \tag{7}$$

Where h as the price of each signage.

Travelers For travelers, the goal of oriented signage system is to guide the minimum distance. An alternate location do itself best to contain its nearest destination-oriented information. Without considering the importance of the destination, the nearer one needs to be firstly included in the content for an alternate location. This is because when people see pedestrian-oriented information, the destination guided is psychologically regarded as close to themselves that has been widely recognized in the actual emplace of oriented signage. A maximize functions can be used to represent as follows:

$$\max S_4 = \sum_{a=1}^{a=m} \sum_{b=1}^{b=n} (X_a * Y_{ab} * 500) \Big/ L_{ab} \tag{8}$$

Where $L_{ab}(a = 1，2，\cdots，m；b = 1，2，\cdots，n)$ is represents the distance between an alternative location *a* and the destination point *b*. Because there is a gross floor area of destination, it can be seen as the shortest linear distance between the alternative location and the boundary of destination. Large transfer hub often have vertical transfer bottleneck. When calculating L_{ab}, the research uses the model of pedestrian traffic flow - analysis of per capita space according to the literature (Highway Capacity Manual, 2000). The stairs facilities and escalators facilities can be converted to distance calculated by walking according to the design capacity.

(2) Constraint conditions

1) Each destination must appear at least once.

$$\sum_{a=1}^{a=m} \sum_{b=1}^{b=n} (X_a * Y_{ab}) > 0 \tag{9}$$

Formula (9) constrained the worst scenario that pedestrian find a destination. For each destination, it must be appears at least once in all of the signage. Otherwise, pedestrians will not be able to find the destination through the oriented signage.

2) Inherent relationship Constraints are:

$$\sum_{b=1}^{b=n} Y_{ab} = 0\,, \qquad X_a = 0 \tag{10}$$

$$\sum_{b=1}^{b=n} Y_{ab} > 0\,, \qquad X_a = 1 \tag{11}$$

$$\left\lceil \sum_{b=1}^{b=n} Y_{ab} \Big/ k \right\rceil < j \tag{12}$$

Formula (10), (11) constraints natural properties among the location, the content and the quantity. When an alternative location is not to be selected as an emplaced location, it cannot include the information of any destination. When an alternative location is to be selected as an emplaced location, it contains at least one destination. Formula (12) constraints the number of signage at each alternative location which described in the foregoing.

4 CONCLUSIONS AND FUTURE RESEARCH

This study provides a scientific method on how to emplace the location and the content of pedestrian-oriented signage system in large passenger transfer hub. The method converted this complex system decision problem into mathematical models based on three objectives (maximizing the level of space-guided, minimizing the financial investment, and minimizing the guidance distance).

However, the model ignoring the different function of signage is a weakness of this study. In addition, signage setting and the guiding route are closely related. Determining an optimal line in multiple routes to reach the destination in the hub must consider the pedestrian traffic flow and channel capacity. And another is to find an efficient algorithm for the optimization model to verify their logical in the design. These factors should be taken into account in future studies.

References

Alice Beneicke, Jack Biesek, and Kelley Brandon. (2003). *Wayfinding and Signage in Library Design*, the Libris Design Project.

Arthur P and Passini R. (1992). *Wayfinding: People, sign and architecture*. McGraw Hill Inc., New York.

BS 8502-2003. (2003). *Graphical symbols and signs—Creation and design of public information symbols-requirements*. British Standards Institution.

Caves, R.E., Pickard, C.D. (2001). *The satisfaction of human needs in airport passenger terminals*. Proceedings of the Institution of Civil Engineers-Transport 147, pp. 9-15.

Dongqing Han. (2008). *Research of Sign-oriented Set Project and Evaluation of Passenger in Large-scale Integrated Transport Station*. Beijing: Beijing Jiaotong University.

GB/T 20501-2006. (2006). *Guidance system for public information--Design principles and requirements of guidance elements,* the national standard of the people's Republic of China.

J.R. Carpman. (1991). *Creating hospitals where people can find their way (plant technology and Safety management Series, No. l)*. Oakbrook Terrace, IL: Joint Commission on Accreditation of Health Organization.

Kevin Lynch. (1960). *The Image of the City*. Mit Press, Cambridge.

Manual on Uniform Traffic Control Devices. (2009). U.S. Department of Transportation Federal Highway Administration.

Mei Ling Tam. (2011). An optimization model for wayfinding problems in terminal building. *Journal of Air Transport Management*, vol.17, pp. 74-79.

Parsopoulos K E, Vrahatis M N. (2002). *Particle swarm optimization method in multi-objective problems.* Proceedings of the 2002 ACM Symposium on Applied Computing, ACM Press, Madrid.

Passini R. (1996). Wayfinding design: logic, application and some thoughts on university. *Design Studies*, vol.17, pp. 319-331.

Seunghae Lee, Sibel Seda Dazkir, Hae Sun Paik, Aykut Coskun. (2014). Comprehensibility of universal healthcare symbols for wayfinding in healthcare facilities. *Applied Ergonomics*, vol.45, pp. 878-885.

Transportation Research Board. *Highway Capacity Manual*. (2000). TRB, National Research Council, Washington DC.

W.H.K. Lam, Mei-ling Tam, S.C. Wong, S.C. Wirasinghe. (2003). Wayfinding in the passenger terminal of Hong Kong International Airport. *Journal of Air Transport Management*, vol. 9, pp. 73-81.

Xiaoyan Yan. (2007). Bus priority: the only way to solve the problem of urban traffic—the Interview of Professor Qixin Shi in Transportation Research Institute of Tsinghua University. *Comprehensive Transportation*, vol.10, pp. 56-59.

Xu H. & Kazuhiko N. (2002). *Types of path choice in exhibition space in a museum-study on pedestrian path choice and spatial cognition in exhibition space in a museum.* In Culture, Space and Quality of Life in Urban Environment-Proceedings of the 5th International Symposium for Environment-behavior Studies, Huaxia Cultural Publishing Limited, Hong Kang.

Yanjie Ji, Wei Deng. (2004). A Review of the Development and Current Situation on Bus Priority at Intersections. *Journal of Transportation Systems Engineering and Information Technology*, vol.4, pp. 30-34.

Yanxin Han. (2010). *Optimization Method Research of Sign-oriented Identification System in Large Passenger Station*. Beijing: Beijing Jiaotong University.

Yu Ling, Li Kang. (2013). Multi-objective modeling and optimization for layout of pedestrian-guidance signs with IFD-NSGA-Ⅱ algorithm. *Journal of System & management*, vol.4, pp. 553-558.

Zhe Wang, Zaisheng Hong. (2011). Urban Design oriented identification System Design. *Journal of Harbin Institute of Technology (Social Sciences Edition)*, vol.13, pp. 89-93.

Critical Gap of a Roundabout Based on a Logit Model

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Abstract: Based on the analysis of drivers' gap acceptance process of roundabout, the video was used to record drivers' choice behavior when the vehicle entered roundabouts. Through the statistics and analysis of survey data, the results indicated that the gap acceptance behavior can be described by binary choice model—model. The calculation method of critical time headway was given which related with space headway and speed of the rear vehicle on major road. A conclusion was derived that the critical space headway would increase when the vehicles' speed on the major road increased from the calculation results by use of SPSS software.

Keywords: Roundabouts; Critical gap; Binary Logit model; Time headway; Space headway.

1 Introduction

The minimum time headway on the major road is critical gap when a vehicle on minor road enters the priority-controlled intersection. Critical gap is an important parameter which affects the capacity and delay. For roundabouts, it is the minimum value which entry vehicle can enter the circular lane using circular vehicles' time headway. The entry is minor road and the circle lane is major road on roundabouts.

A lot of research about critical gap has been introduced. Plus thought that critical gap decreased when drivers' waiting time increased and their relation curve looked like S shape. The experimental model of critical gap was built. Hammed et al. found the distribution type of time headways on major road vehicles was related to waiting time, drivers' social and economic circumstance, following-up headway, travel objective and so on. The average critical gap is related to conflict flow rate, lane amount of entry, the proportion of turn-left and the velocity of major road vehicles. They built the multiple regression model of critical gap. Based on the hypothesis of negative exponential distribution of time headway on major road and normal distribution of critical gap and accepted gap, Ashworth's method analyzed the distribution character of accepted gap, the average critical gap and variance. Miller derived calculation equation of critical gap based on Ashworth's method when critical gap followed γ distribution. Raff regarded the point of intersection between accumulative accepted gap curve and accumulative rejected gap curve. Raff's method was used in many countries. Brilon et al. pointed the siegloch's method could be only used in saturated flow condition.

Most of the methods were suitable of unsaturated condition. Lag method can be only the theoretical reference value. Logit process method used the similar process to the logit method of traffic planning. Probit method is partial when only considering normal distribution of critical gap because there is remarkable error for normal distribution of critical gap. Hewitt method is the further method of Probit process which calculation software is GAPTIM and PROBIT. The maximum likelihood method has a symphysis that all of accepted gap, maximum rejected gap and critical gap follow normal distribution, and estimate the average value and variance by use of the maximum likelihood method of probability theory.

2 Gap acceptance model of roundabouts

Every vehicle on the minor road needs to choose whether entering the intersection or not. So the gap acceptance operation can be described by Logit model.

$$\begin{cases} P_a = \dfrac{1}{1 + exp - (b_0 + \sum_{i=1}^{k} b_i x_i)} \\ P_r = 1 - P_a \end{cases} \tag{1}$$

Where P_a is accepted probability, P_r is rejected probability, x_i is influencing factor.

Factors which influence gap acceptance operation include space headway, time headway and velocity of rear vehicle on major road of roundabouts.

3 Evaluation of model parameters

The survey result only included rejection or acceptation of vehicles on minor road.

$$\begin{cases} y_i = 1 & \text{the vehicle rejected to enter the roundabout } i \text{ th time} \\ y_i = 0 & \text{the vehicle entered the roundabout } i \text{ th time} \end{cases}$$

For the ith gap acceptance operation, space headway, time headway and velocity of rear vehicle should be recorded.

The likelihood function can be derived by equation (1)

$$L^* = \prod_{i=1}^{N} P_a^{y_i} P_r^{1-y_i} \tag{2}$$

The equation (2) was taken the logarithm. It can be derived as follow

$$L = \mathrm{Ln}(L^*) = \sum_{i=1}^{N}[y_i \mathrm{Ln}(1 - P_a) + (1 - y_i)\,\mathrm{Ln}\,P_r] \qquad (3)$$

4 Application example

Fuming Square is a roundabout in Shahekou Distribution, Dalian and it was chosen as survey object. Vehicles flow were unsaturated flow for not rush-time, which can avoid disturbance to survey data. Survey data are is displayed as Tab.1.

Tab. 1 Survey data of Fuming Square (part)

time headway(s)	Space headway(m)	velocity of rear vehicle(m/s)	acceptance(1) /reject(0)
2	11	4.4	0
4.89	20	3.6	1
3.96	7	2.85	0
2.12	7	3.1	0
3.89	12	2.85	0
3	22	2.6	1
3.12	10	2.5	0
3.86	18	2.4	1
3.24	17	5	1
4.23	12	3.6	1

Tab. 2 Estimated values of parameters

parameter	Estimated value
β_0	-2.815
β_1	-0.382
β_2	1.188
β_3	0.111

The result can be found that drivers were inclined to accept larger space headway and enter the roundabout when the rear vehicle traveled slower. The follow model can be derived based on estimated values.

$$\begin{cases} P_a(s,v,t) = 1/\{1+\exp[2.815-1.188t+0.382v-0.111s]\} \\ \mathrm{P_r}(s,v,t) = 1-P_a(s,v,t) \end{cases} \quad (4)$$

Where, s is the space headway, v is the velocity of the rear vehicle on major road or roundabout, t is the time headway

The analysis result can be applied in the determination of the critical gap of roundabouts because the survey involved minor road drivers' choice whether to enter the roundabout.

For a fixed choosing probability ∂，$(0<\partial<1)$，the follow equation can be derived from equation (4)

$$P_a(s,v,t) = 1-\partial \quad (5)$$

The critical time headway is as follow when the velocity of the rear vehicle was determined.

$$t_a = \{\ln[(1-\partial)/\partial]+2.815+0.382v-0.111s\}/1.188 \quad (6)$$

When ∂=0.5,

$$t_a = (2.815+0.382v-0.111s)/1.188 \quad (7)$$

The results were as Tab. 3 for different velocities.

Tab. 3 Critical gap for different velocities

Velocity (km/h)	T1 (s)	T2 (s)	T3 (s)
22	3.83	3.36	2.89
24	4.05	3.58	3.12
26	4.22	3.75	3.29
28	4.40	3.93	3.46
30	4.58	4.11	3.64
32	4.76	4.29	3.82
34	4.93	4.47	4.00
36	5.11	4.65	4.18
38	5.29	4.82	4.36
40	5.47	5.00	4.54

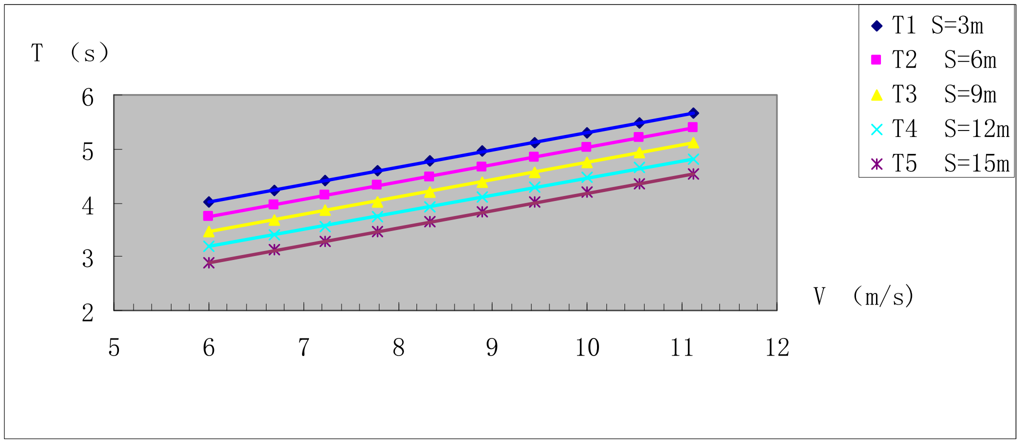

Figure 1. When the space headway is same, the critical gap for the different velocities

According to the Figure 1, when the space headway is same, the critical gap became lager with the increase of rear vehicle velocity. The increase of the critical gap shows that the branch entry the roundabouts become more difficult. In Figure 1 the five lines represent the critical time headway when the space headway is 3 m, 6 m, 9 m, 12 m, 15 m. It shows that in the same vehicle velocity, the critical gap will decrease with the increase of the space headway. What can be also interpreted that the increase of the space headway make the branch flow into roundabouts more easier, so the critical gap will be reduced.

The critical time headway is as follow when the space headway was determined. The results were as Tab. 4 for different space headway.

Tab. 4 Critical gap for different space headway

Space (m)	T1(s)	T2(s)	T3(s)	T4(s)	T5(s)
5	3.83	4.15	4.47	4.79	5.11
6	3.73	4.05	4.38	4.70	5.02
7	3.64	3.96	4.28	4.60	4.93
8	3.55	3.87	4.19	4.51	4.83
9	3.45	3.77	4.10	4.42	4.74
10	3.36	3.68	4.00	4.32	4.65
11	3.27	3.59	3.91	4.23	4.52
12	3.17	3.49	3.82	4.14	4.46
13	3.08	3.40	3.72	4.04	4.37
14	2.99	3.31	3.63	3.95	4.27

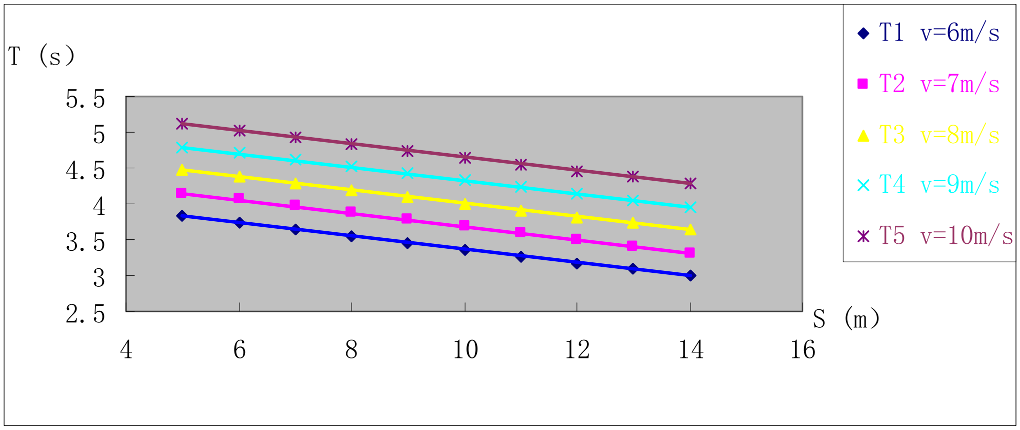

Figure 2. Under the condition of the same vehicle velocity space headway, the critical gap acceptance for the different space headway

Figure 2 is established on the rear vehicle velocity been given. Although, the graphical line in Figure 1 and Figure 2 are different, we can have the same conclusion. Drivers' operation of minor road was influenced by travel distance. The important parameter is critical gap. Regression analysis can be applied to obtain the gap acceptance model of roundabouts. Different parameters' influence to entering probability can be derived by numerical simulation. The critical gap became larger with the increase of rear vehicle velocity, which meant drivers on the minor road were inclined to reject the gap. In general the safety space headway for vehicle through the roundabout is 10 m. So the critical gap lied in the range of 3.36-4.65 s when the velocity is from 6 m/s to 10 m/s with the safety space headway.

5 Conclusions

Conclusions can be obtained that influence parameters to gap acceptance involve space headway and velocity of the rear vehicle on roundabouts. Drivers were inclined to enter roundabouts when space headway or time headway increased. The critical gap will increase when the velocity of major road increased. Drivers' estimations were different for different velocity because different drivers' operational characters.

References

Ashwoith R. (1970). *"The analysis and interpretation of gap acceptance data." Transportation Science,* 4: 270-280

Brilon W., Koenig R., Troutbeck R. J. (1999). "Useful estimation procedures for critical gaps." *Transportation Research Part A*. 33: 161-186

Guan Y., Zhang N. (2010). "Vehicle Merging Model for Acceleration Lane under

Condition of Changeable Critical Headway." *Journal of Highway and Transportation Research and Development*, 27(6): 117-120

Gao H. L., Wang W., Chang Y. L. et al. (2001). "A mathematical model for critical gap of unsignalized intersections." *China Journal of Highway and Transport*, 14(2): 78-80.

Guo R. J., Lin B. L. (2009). "Traffic Operation Performances at Roundabout Weaving Sections." *Journal of Transportation Systems Engineering and Information Technology,* 10(3): 29-34.

Hammed M. M., Easa S. M., Batayneh, R. (1997). "Disaggregate gap-acceptance model for unsignalized intersection." *Journal of Transportation Engineering*. 123(1): 36-42.

Hewitt R. H. (1983). "Measuring critical gap." *Transportation Science.* 17(1): 87-109

Miller A. J. (1974). "A Note on the Analysis of Gap—acceptance in Traffic." J*ournal of the Royal Statistical Society Series C (Applied Statistics)*, 23(1): 66-73

Polus A., Lazar S. S., Livneh M. (2003). "Critical Gap as a Function of Waiting Time in Determining Roundabout Capacity." *Journal of Transportation Engineering,* 129(5): 504-509

Raff M. S., Hart J. W. (1950). "A volume warrant for urban stop signs." *Eno foundation for highway traffic control: Saugatuck*, Connecticut

Shao C. Q., Rong J., Liu J., Liu S. J. (2007). "The Study of Drivers' Overtaking Behavior on the Two-Lane Highway." *Journal of Beijing University of Technology*. 33(3)

The Present Situation, Problems, and Prospects of the Nanchang Bus Special Service Corporation

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Abstract: With the development of transportation, the car has become an indispensable traffic tools in daily work and life. Bus special service problem is one of the hot issues of concern. Because of its fast speed and low cost, more and more large enterprises realized the importance that they can reduce production cost through the use of special service. With the tailored charter services for the enterprise, the bus special service corporation can provide the enterprise with low production cost and safe service. It is very conducive to achieve the development goals of the enterprise. In January 1, 2013, Nanchang Bus Special Service Corporation formally established that is the supplement and improvement of city public traffic. At the same time, it also marks the Nanchang bus special car will enter into standard unified management that was defected from the operating company of decentralized management. The author mainly analyzes the present situation, problems and Prospect of Nanchang bus special Service Corporation, through the use of comparative data on the detailed explanation to put forward some suggestions that can provide reference for the development of other city's Bus Special Service Corporation.

Keywords: Bus special service; Transportation way; Nanchang Bus Special Service Corporation; Prospect.

1 Introduction

With the diversification of transport vehicle and complicated transport network, there is a difficult problem how to transit special service to make their own innovation and characteristics. If the bus special service is a choice buy, it will directly affect the enterprise cost and enterprise benefit. Bus special service has become a trend and a basic way of existence that modern enterprise save the cost of production. More and more enterprises treat it as an approach and means to reduce the cost of production. Bus special service become a breakthrough in the bus company for marketing innovation, it is a tailored bus service to meet some special people's needs. On the other hand, the bus special service is changing the traditional way of travel. It can bring great convenience for the development of large enterprises and has become a new transportation way of general approval of enterprise. In order to conform to the trend of The Times, Nanchang Bus Special Service Corporation formally established that is the supplement and improvement of city public traffic in

January 1, 2013. At the same time, it also marks the Nanchang bus special car will enter into standard unified management that was defected from the operating company of decentralized management. The author mainly analyzes the present situation, problems and prospect of Nanchang Bus Special Service Corporation, through the use of comparative data on the detailed explanation to put forward some suggestions that can provide reference for the development of other city's Bus Special Service Corporation .

2 Current Status Analysis of Nanchang Bus Special Service Corporation

2.1 The current status of Nanchang Bus Special Service Corporation

With the development of the city public transportation, the special bus appears. It is in the charge of the operating company that is the subordinate company of the General Corporation of Public Transport. In recent years, there is an expansion trend of development in Nanchang city and has formed the suburbs, the industrial zones, campus etc. At the same time, it is hard for the coverage of city bus network. With the establishment of bus special service corporation, we will overcome some shortcomings including original process of special bus, bad service and so on. What's more, we can strengthen the management of the special bus and standardize the demand of the market in order to form the service of special bus.

In order to adapt to the changing of market situation and development needs, the company provides customers with all kinds of low and medium high-grade car and differentiated services to meet the social needs. Meanwhile, to meet the needs of different groups, the company makes a variety of business plans according to customers' requirements. There are nine special services in the Nanchang Bus Special Service Corporation, including services for large conferences and big activities designated by government departments; charter services for Large and medium-sized enterprises; charter services for All kinds of schools(spring and autumn activity, exams etc.) ; fixed bus services for large supermarkets; directional bus services for holiday celebration, conference and exhibition; services for cultural and sports activities; charter services for the public with a variety of cars; services for wedding. It is reported that the company provide special services for the Provincial Department of land resources, the city intermediate people's Court of Jiangxi Province, Xinhua printing factory, Transformer Co. Ltd.and so on. It is proved that the Nanchang Bus Special Service Corporation can provide high quality charter services for the society.

As we all know, special bus need a professional vehicle operation management team. To ensure the safety of operation, the corporation provide every car with GPS intelligent monitoring equipment in order to monitor the real-time speed, ensure the safe operation of the vehicle and avoid operating vehicle safety risk for the customer. At the same time, the special bus driver can receive professional training to get rich driving experience. In order to unify the construction of a specification of the special team, the company will always adhere to the "fine management, scientific development" business philosophy. Taking internal quality, outside image, scale operation, professional management, professional team, quality service and high-end technology resources advantage into consideration, we can create a new corporate image and make unremitting efforts for the overall development of Nanchang Bus Special Service Corporation.

2.2 The analysis of operating income of Nanchang Bus Special Service Corporation

Comparing with the cost of plan, the three kinds of consumption cost exceed frequently. According to the data, we find the main reason is that most of the bus before handover to the special company vehicle mechanical problems, even some vehicles have been unable to run normally, need to change battery, tires, but the company's operation kilometers cost plan has been to the operation of the company, so the company of the cost of maintenance repairs and tires than plan will increase.

According to the relevant statements of the company in 2014, there are four parts of operating costs. The first part includes the wages and bonuses of the drivers and management staff accounting for about 51%; the second part includes three big consumption(fuel, maintenance fee, tire) accounting for about 34% of operating costs; the third part includes the vehicle depreciation accounting for about 11% of operating costs; last part accounts for 4%. Comparing with the plan costs, the second part exceeded. The main reason is that many buses have mechanical problems, even some vehicles have been unable to run normally that need to change battery and tires before they were moved to the corporation. But the operating cost plan of the general corporation was put to the operating corporation. The cost of maintenance and tire will increase.

In addition, the annual plan income was 25 million yuan(including tax) issued by the general corporation in 2014. Until November in 2014, the actual income of Nanchang Bus Special Service Corporation was about 21 million yuan. Comparing with the annual plan, they completed the 95% plan. Comparing with the same period in 2013, the operating income increased 14 million yuan by 200%. Finally, the actual profit was the lost of 0.64 million yuan that reduced 1.23 million yuan with the adjusted plan.

2.3 The marketing of Nanchang Bus Special Service Corporation

There were 19 new special kinds of rental customers in the first half of 2014 units, which added 13 in the first quarter, second quarter increased by six, 41 new special cars. Nanchang Bus Special Service Company is actively negotiating with Nanchang Brewery, Taihao Anime, the people's bank of China and so on. The quantity of these institutions is relatively large and the average is about 5 or more.

Recently, the corporation aimed at Jiangling Group, Nanchang Jingsheng Cigarette Factories, Photo-voltaic, Aviation Group, RT-mart and other large transport unit, through various channels to be completed, but the effects were not significant. You can't image how complex the relation is!

In August 2014, expanding the scope of the"Huang Biao" limit line of Nanchang city, Nanchang Bus Special Service Corporation took this opportunity to seize the "yellow marked vehicle market". On September 1, 2014 in Jiangxi province, in order to strengthen the management of school bus safety, all middle school, primary school, nursery school shall use standard vehicles prescribed by the state. With the two points, there is new market opportunity for bus special service.

3. The Problems Existing in the Nanchang Bus Special Service Corporation

3.1 Shortage of drivers

As the city scale expands unceasingly, people travel demand for bus is becoming more and more big, but the bus driver is very scarce, even become the bottleneck of the public transport development. Those drivers work hard but they are not easy to get social recognition. On the other hand, it is very hard to get the driving license of A2. It resulted that there was in the shortage of special bus drivers.

Through the active efforts to develop the market, the volume increase gradually, but the driver's serious vacancies to keep pace with the development of the business. The Nanchang Bus Special Service Corporation is in a very passive situation.

3.2 The mobilization of drivers frequently

For safety operation and good services, the corporation made strict appraisal system that lead to some drivers who voluntarily apply for the redeployment of operating company. Because they thought that they got low wages but should obey strict rules. On the other hand, the operating corporation made promise to offer good wages and good promotions. A large number of drivers left that made serious influence to the operation of Nanchang Bus Special Service Corporation. To make matters worse, many drivers are not willing to renew contract.

3.3 Driver's self-management and self-discipline ability is poor

Because most drivers don't get higher education and ignore the importance of safety operation, they have some weakness including illegal behavior and violations. The driver's safety awareness has direct contact with safety of operation. The management of the corporation and all staff should pay much attention to it and take some actions to solve this problem.

4. Countermeasures of Nanchang Bus Special Service Corporation

4.1 Revision of relevant assessment system

Every driver is equipped with one car in the corporation. According to the rule of the General Corporation, if the driver has the red light violation behavior, he or she will be published that he or she must learn and stop driving for one month. In fact, there are not enough drivers for special bus service. Therefore the corporation revised the relevant management system, adjusted the assessment methods and made economic punishment according to the actual situation.

4.2 Strengthen the collection of funds

As we all know, it is very important work to collect funds for the corporation. Now, there are some people that are responsible for collection of special car business and scattered charter business. At the same time, the management of the corporation made the timetable of charter fund and the inspection regulations.

4.3 Adjustment of the salary rationally and stablement of driver team

According to different special line, the corporation made study on workload and the work difficulty. It took some drivers long time to go back to the corporation if they stop the bus in rental company. There are mangy plugging point for some special lines. How to solve these problems? In order to ensure the rationality of the salary structure, the Nanchang Bus Special Service Corporation try their best to collect the data to adjust the structure o the salary in order to stabilize the driver's team.

4.4 Strengthen the driver safety monitoring

According to the characteristics of operation of the wide regional special car line and he vehicle more scattered distribution, Nanchang Bus Special Service Corporation made many efforts to strengthen control of traffic situation. According to the non violation, illegal driving, mixed sections, they made such as early, lately inspection, and increased the strength of the inspection to the parking lot with cross examination and branch checks. Meanwhile, they made strict assessment of the vehicle and the driver for not complying with the provisions and the existing problem of the park.

4.5 Strengthen the driver safety training and education

Nanchang Bus special Service Corporation will continue to carry out "safety month" activities issued by the General corporation, to increase the "safety month" campaign, to analyze and explain the various types of accident case recently happened in the General corporation and the Nanchang Bus special Service Corporation.

5 Conclusions

The gold will shine. Nanchang Bus special Service Corporation will show the charm of its own in the city transportation. We need to explore its own path of development and to adopt a pragmatic, trial-and-error approach for its service program. We can learn from foreign bus company. On the other hand, we will try our best to provide different passengers with service diversification, private custom and so on. Finally, we will gain a foothold in the fierce competition in the city transportation market.

References

Beijing Industrial Research Institute. (2014). “Development situation of market and investment scale China city busindustry analysis report 2014-2019.” http://www.ynshangji.com/c3000000026443821/(July.18,2014).

China industry insight network. (2014). “China city bus industry market prospects and strategic planning and investment analysis report”, http://www.51report.com/research/3051372.html(Sept.24,2014).

Lu Yonghua. (2003) “improve the Intelligent Management of Transit Enterprises Shanhai Qiangsheng Bus Co., Ltd, *Urban Public Traffic*, 2003(4), 4-5.

Mei Ting. (2013). “Bus special service corporation, Bus special service order.” , http://www.ncgj.com.cn/mainpages/shuchu.aspx?NewsID=3182&NewsType=LE107(Feb.21, 2013).

Yang Zhaosheng and Hu Jianming.(2001).“Research on the Architecture and Implementary Scheme of Intelligent Public Transportation System in China”,*Journal of Transportation Systems Engineering and Information Technology*, 2003(4), 39-43.

Energy-Efficient Train Control: Analysis of Local and Global Optimization

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Abstract: In view of the hold phase in front of and behind the uphill or downhill of a track, the optimal switch point with Local optimal algorithm is not the one with the least cost. This paper finds its deficiencies, and presents an improved method to be applied in the global optimization to minimize the energy costs.
Keywords: Optimal train control; Energy efficient.

1 Introduction

Because of the rising energy prices and environmental concerns, the energy efficiency of transportation system becomes more and more important. Many people have taken part in the optimal train control to minimize the energy consumption (Howlett, 1995; Cheng, 1999; Khmelnitsky, 2000; Liu, 2003; etc).

The problem is to minimize the energy required to drive a train from one station to the next within a given time. The optimal strategy is essentially a *power-speed hold-coast-brake* strategy. The main energy cost is at *power* and *speed hold phase*. For long distance when *speed hold*, the control strategy will be interrupted by some uphill sections or downhill sections. Hence the optimal strategy becomes an optimal switching strategy. Considering the necessary conditions for optimal switching with Pontryagin analysis, Howlett et al. have shown that the switching points can be determined for each steep section by minimizing an associated local energy functional (Albrecht, 2011; Howlett, 2009; Zhou 2010).

They all deemed that for each feasible journey time, optimal strategy is unique, and using the local optimization to find switching points, the global optimal strategy could be obtained.

In view of the cost of hold phase, we find its deficiencies. The algorithm could not simply be applied in the local and global optimal strategy.

2 Model description and review

For a point mass train the equation of motion can be written as (Howlett, 1995):

$$vv' = \frac{p}{v} - q - r(v) + g(x) \quad (1)$$

where: x is the position of the train, $v=v(x)$ is the speed, $p=p(x)$ is the controlled power per unit mass, $q=q(x)$ is the controlled braking force per unit mass, $g(x)$

is the component of gravitational acceleration due to the track gradient at point x, $r(v)=a+bv+cv^2$ is the resistance force per unit mass. The total time taken is:

$$t(x)=\int_0^x \frac{1}{v}\,\mathrm{d}\,x \tag{2}$$

where: $v = v(x)$ is the solution of the equation of motion.

The cost is usually taken to be the total fuel consumed by the train. We assume that power per unit mass is directly proportion to the rate of fuel supply. The cost $J = J(x)$ is

$$J(x)=\int_0^x \frac{p}{v}\,\mathrm{d}\,x \tag{3}$$

The power per unit mass $p(x)$ is bounded with $0 \le p \le P_{max}$. The braking force per unit mass $q(x)$ is bounded with $0 \le q \le Q_{max}$. The cost of braking is generally ignored.

Write $\varphi(v) = v \cdot r(v)$, where $\varphi(v)$ is strictly convex with $v \ge 0$. Write $\psi(v) = v^2 \cdot r'(v)$, where $\psi(v)$ is strictly increasing with $v \ge 0$. Write $L_V = \varphi(V) + \varphi'(V)(v-V)$. V is the constant speed at hold phase.

3 Local optimal algorithm

The Hamiltonian is defined by

$$H=\frac{\beta-p}{v}+\frac{\alpha}{v^2}\cdot[p-qv-\varphi(v)+gv] \tag{4}$$

The adjoint variables $\alpha=\alpha(x)$, $\beta=\beta(x)$ are solutions to the differential equations:

$$\alpha'=\frac{\beta-p}{v^2}+\frac{\alpha}{v^3}\cdot[2p-qv-\varphi(v)+\varphi(v)+gv] \tag{5}$$

$$\beta'=0 \tag{6}$$

It is known that, on level track, the optimal strategy is *power-hold-coast-brake.* But, on steep track, the *hold phase* is interrupted by one or more *power phases* on the steep uphill section and one or more *coast phases* on the steep downhill section. Then, we expect that the optimal control should switch form *hold* to *power* at some point $x = a$ before the steep section and from *power* to *hold* at some $x = d$ beyond the steep section. It is shown in Figure 1. We define $\eta = \alpha/v-1$ and assume the optimal profile $v(x)$, then

$$\eta' - \frac{\psi(v)+p}{v^3}\cdot\eta=\frac{\psi(v)-\psi(V)}{v^3}$$

with $\eta(x) > 0$ for $a < x < d$, $\eta(a) = \eta(d) = 0$.The switch point is at a, $v(a) = v(d) = V$ and $\eta'(a) = \eta'(d) = 0$.

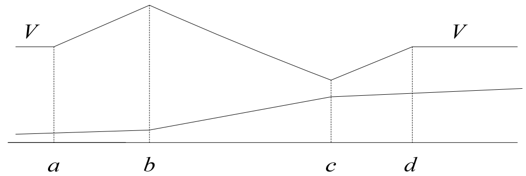

Figure 1. Optimal speed profile on steep uphill

Howlett (2009) and Zhou (2010) designed a function $J_e(v)$ to find the switch point. Consider a track with piecewise constant gradient with $x_0 < x_1 < x_2 <\ldots< x_{n+1}$ and $g(x) = g_j(x)$ for $x_j < x< x_{j+1}$, and where we suppose there is a steep uphill section (b,c), with $x_1<b<c<x_n$, and the switch points a, b, with $x_0 < a < x_1$, $x_n < d< x_{n+1}$.

$$J_e(v)=\int_V^{v(x_1)}\frac{[\varphi(v)-L_V(v)]v}{p-\varphi(v)+g_0 v}\,dv+\int_{v(x_n)}^{V}\frac{[\varphi(v)-L_V(v)]v}{p-\varphi(v)+g_n v}\,dv+\sum_{j=1}^{n-1}\int_{v(x_j)}^{v(x_{j+1})}\frac{[\varphi(v)-L_V(v)]v}{p-\varphi(v)+g_0 v}\,dv$$

$$x(v_{j+1})-x(v_j)=\int_{v(x_j)}^{v(x_{j+1})}\frac{v^2\,dv}{p-\varphi(v)+g_j v},\ j=1,2,\ldots n-1$$

We get the Lagrangian function:

$$F=J_e+\sum_{j=1}^{n-1}\lambda_j[(x_{j+1}-x_j)-\int_{v(x_j)}^{v(x_{j+1})}\frac{v^2\,dv}{p-\varphi(v)+g_0 v}]$$

$$=\int_V^{v(x_1)}\eta_0\cdot v\,dv+\sum_{j=1}^{n-1}\eta_j\cdot v\,dv+\int_{v(x_n)}^{V}\eta_n\cdot v\,dv+\sum_{j=1}^{n-1}\lambda_j[(x_{j+1}-x_j)$$

Where we set $\lambda_0 = \lambda_n = 0$, $\lambda_j \geq 0$, and define

$$\eta_j=\frac{\varphi(v)-L_V(v)-\lambda_j v}{p-\varphi(v)+g_j v}$$

To minimize J_e, we solve the equation $\frac{\partial F}{\partial v(x_j)}=0$.

The constrains are, for each j = 0, 1,2,…n:

$$\eta_{j-1}(v(x_j))=\eta_j(v(x_j))$$

$$\lambda_j=\lambda_{j-1}-(g_j-g_{j-1})\cdot\eta_j(v(x_j))$$

3 Simulation of the Local optimal algorithm

There is a track with steep uphill section from x = 5000 m to x = 6800 m. The train is passing with hold speed V= 20 ms^{-1}. Let x_1 = 5000 m, x_2 = 5600 m, x_3 = 6000 m, x_4 = 6500 m, x_5 = 6800 m with constant gradient accelerations by g_0= -0.075 ms^{-2} for $x < x_1$, g_1= -0.220 ms^{-2} for $x\in(x_1,x_2)$, g_2= -0.270 ms^{-2} for $x\in(x_2,x_3)$, g_3= -0.150

ms^{-2} for x∈(x_3,x_4), g_4= -0.200 ms^{-2} for x∈(x_4,x_5), g_5= -0.090 ms^{-2} for x > x_5. Here we have the power rating P = 3 m^2 s^{-3}, and a = 0.00675, b = 0, c = 0.00005 for $r(v)=a+bv+cv^2$.

We use an adaptive Runge-Kutta Scheme to solve the equations with matlab. Firstly, we set the *power phase* starting at (x,v) = (3399,20), then terminating at (x,v) = (8171,20), with η = 0. Secondly, we set (x,v) = (2500,20), then terminating at (x,v) = (8075,20), with $\eta > 0$. Thirdly, we set (x,v) = (4400,20), then terminating at (x,v) = (8293,20), with $\eta < 0$. The speed profiles are shown in Figure 2. The corresponding profiles for the adjoint variable η are shown in Figure 3.

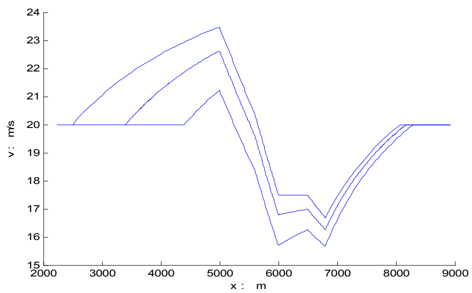

Figure 2. the speed profiles

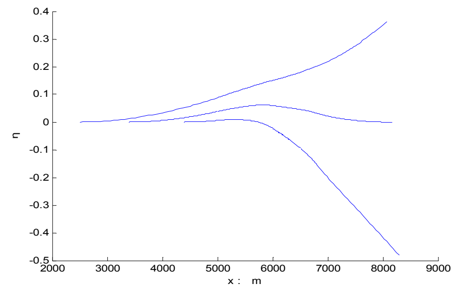

Figure 3. adjoint variable profiles

Now we can find the optimal profile with η (a) = η(d) = 0 and the switch point is at x = a = 3399 m where the optimal control should switch from *hold phase* to *power*.

4 Deficiencies of the Local optimal algorithm

While the point of train is at x < a or x > d, the train is at *hold phase*. From (1), we can obtain:

$$0=\frac{p}{v}-r(v)+g(x)$$

$$P_1 = v\,r(v) - vg(x) = 2.035 \text{ m}^2\text{ s}^{-3}, \quad \text{for} \quad x < a;$$

$$P_2 = v\,r(v) - vg(x) = 2.335 \text{ m}^2\text{ s}^{-3}, \quad \text{for} \quad x > d.$$

From the simulation, we compare the three occasions from 2500 m to 8293 m. The details are given in Table 1 and Figure 4.

Table 1: Compare of J_e, time and cost

occa-sion	η(d)	switch point	termi-nation	power time	J_e	hold phase	hold time	total time	total cost
1	= 0	3399	8171	196.6	3.2563	2500-3399 8171-8293	45.0 6.1	247.6	695.6
2	> 0	2500	8075	211.5	3.8278	8075-8293	10.9	222.4	660.0
3	< 0	4400	8293	172.2	4.2005	2500-4400	95.0	267.2	710.0

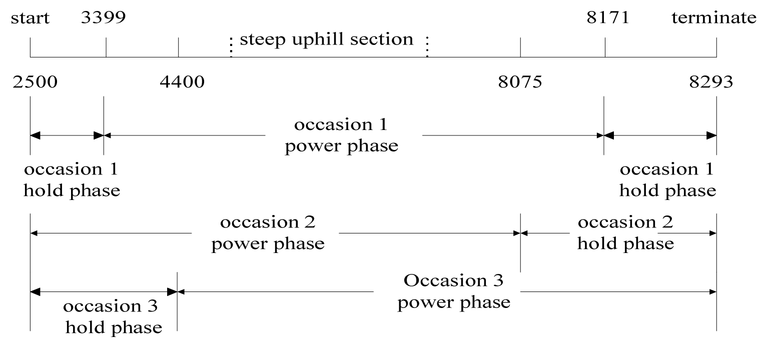

Figure 4. compare power phase with hold phase

Occasion1: a=3399 m, d=8171m, η(a) =η(d)=0, J_e=3.2563. From 2500 m to 3399 m and from 8171 m to 8293 m, the train is at hold phase.

Occasion2: a=2500 m, d=8075 m, η(a)=0, η(d)>0, J_e=3. 8278. From 8075 m to 8293 m, the train is at hold phase.

Occasion3: a=4400 m, d=8293 m, η(a) =0, η(d)<0, J_e = 3.2563. From 2500 m to 4400 m, the train is at hold phase.

The total time is power time plus hold time. The total cost is power cost plus hold cost.

From the Table 1 and the Figure 4, in occasion 1, η(a) =η(d)=0, it's J_e is the least of the three occasions, but in the global optimization from 2500 m to 8293 m, it's total cost is not the least again. Nevertheless, in occasion 2, η(a) =0, η(d)>0, it's J_e is not the least, but in the global optimization, it's total cost is the least yet.

On the analysis, we know that there are deficiencies with the Local optimal algorithm. It is not applied perfectly in the global optimization. However, the idea is valid. It could be improved and applied in some occasions well.

5 the improved Local optimal algorithm to global optimization

The simulation is as the same as the section 4, but the termination is at 8350 m.

The details are given in Table 2.

Table 2 Compare of J_e, time and cost with long distance

occa-sion	η(d)	switch point	termi-nation	power time	J_e	hold phase	hold time	total time	total cost
4	> 0	2800	8110	207.2	3.5198	2500-2800 8110-8350	15.0 12.0	234.2	680.1
5	> 0	3000	8130	203.9	3.3764	2500-3000 8130-8350	25.0 11.0	239.9	688.3
6	<0	4600	8320	165.9	4.6652	2500-4600 8320-8350	105 1.5	272.4	714.5
7	< 0	4800	8350	159.1	5.2472	2500-4800	115.0	274.1	711.2

Occasion4: a=2800 m, d=8110 m, η(a) =0, η(d)>0, J_e= 3.5198. From 2500 m to 2800 m and from 8110 m to 8350 m, the train is at hold phase.

Occasion5: a=3000 m, d= 8130 m, η(a)=0, η(d)>0, J_e= 3. 3764. From 2500 m to 3000 m and from 8130 m to 8350 m, the train is at hold phase.

Occasion6: a=4600 m, d=8320, η(a) =0,η(d)<0, J_e= 4.6652. From 2500 m to 4600 m and from 8320 m to 8350 m, the train is at hold phase.

Occasion7: a=4800 m, d=8350 m, η(a) =0,η(d)<0, J_e= 5.2472. From 2500 m to 4800 m, the train is at hold phase.

From Table 2, the least total coast is occasion 4, η(d) > 0, although J_e is not the least. Simultaneously, the total time is the least.

On the analysis, the switch point is more near to the train in the front, the total cost is less, and the total time is less. Moreover, in this example, the *hold phase* with constant gradient acceleration g_0= -0.075, P_1= 2.035 for x < x_1, and g_5= -0.090, P_2= 2.335 for x > x_5, $P_2 > P_1$. Of course, η(d) > 0.

So, we can get the improved optimal algorithm. The total cost and time are:

$$J = \min\left(\frac{x(a)-x_0}{V}\cdot p_1 + P_{\max}T_{power} + \frac{x_{n+1}-x(b)}{V}\cdot p_2\right)$$

$$T = \frac{x(a)-x_0}{V} + T_{power} + \frac{x_{n+1}-x(b)}{V}$$

The constrains are,

$p_1 = v\,r(v) - vg(x)$, $g(x) = g_0$, for hold phase;

$p_2 = v\,r(v) - vg(x)$, $g(x) = g_{n+1}$, for hold phase;

$vv' = \frac{p}{v} - q - r(v) + g(x)$, for power phase;

$T_{power} = \sum_{j=1}^{n-1}\int_{x_j}^{x_{j+1}} \frac{1}{v(x)}\,\mathrm{d}x$, x_1=a, x_n=b, for power phase.

The optimal control switch point should be searched according to the total energy cost, total time cost, the train, the line and other conditions.

6 Conclusions

The local optimal algorithm could be used to an independent tack with uphill section or downhill section. In view of the hold phase, and total cost, it does not work. Meanwhile, for global optimization, the improved optimal algorithm is valid.

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References

Albrecht, A. R., Howlett, P. G., Pudney, P. J., Vu, X. (2011). Optimal train control: analysis of a new local optimization principle, In Proceedings of the American Control Conference 2011 (pp. 1928–1933).

Cheng J., Davydova Y., Howlett P. G. and Pudney P. J. (1999), Optimal driving strategies for a train journey with non-zero track gradient and speed limits, IMA Journal of Mathematics Applied in Business and Industry, 10,89-115.

Eugene Khmelnitsky (2000), On an Optimal Control Problem of Train Operation, IEEE T Automat Contr, 45,7, 1257-1266.

Fangming Z. (2010), Research on Theoretical Model of Train Energy-efficient Movement and Method of Train Parameters Calibration. PhD thesis, Beijing Jiaotong University.

Howlett, P. G., & Pudney, P. J. (1995). Energy-efficient train control. In Advances in industrial control. London: Springer.

Howlett P. G, Peter Pudney and Xuan Vu (2009), Local energy minimization in optimal train control, Automatica, 45, (11), 2692-2698.

Liu, R. and Golovitcher, I. (2003), Energy-efficient operation of rail vehicles, Transport Res A-Pol 37, 917-932.

Reasonable Site Selection of Urban Rail Transit Park-and-Ride Facilities

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Abstract: Briefly introduced the concept and development status of P&R (Park-and-Ride). Analysis the importance and necessity about developing urban rail transit to the improvement of traffic congestion and realizing green traffic and low carbon travel. First, the problem research mainly discusses the permanent residents who live outside the urban central area with private cars and takes characteristics of the differences of service level of different travel modes as starting point. Then, establish logit travel mode choice model and figure out the utility of travelers from residence to urban central area by three travel modes such as urban rail transit for whole range, private cars for whole range and P&R. And determine the choice probability of travelers towards these travel modes according to this. At last, establish the site selection model of urban rail transit P&R based on choice behavior of residence. The goal of the model is to meet the demand of parking and riding of residence and reduce the number of private cars entering the urban central area and traffic corridor in the maximal degree. At the same time, it takes constraint conditions such as investment upper limit of facilities and the reasonable parking number of a single facility into consideration. This model provides a solution for site selection of urban rail transit P&R facilities.

Keywords: Urban rail transit; Park-and-ride; Mode Choice; Site selection model.

1 Introduction

P&R is a kind of management policy of traffic demand presented in the 1970s, which means providing a parking facility in order to realize a conversion of low carrying rates into the high carrying rates (Zhu Shunying, 2008). The conversion can be private cars, motorbikes and bikes to the ground public traffic, urban rail transit and so on. Internationally there are mainly two types of P&R at present. The one of them improves traveling efficiency and saves the cost of transit development and operating by using P&R. Because of the spread of the city in low density, the low density population and high operating cost of public transportation, which is typical in America and Canada. Another leads people from private cars to public transportation by using P&R because of the heavy load traffic results in high density development in downtown, hopping to reduce the number of motor vehicle, which is typical in Germany, Singapore and Korea. The research of P&R in these countries is comparatively earlier and mature.

With the acceleration of urbanization processes in China, the demand of vehicles keeps growing fast. We have 130 million vehicle population in China as of 2014, which further highlights the problem of environment and energy. What's more, the big city keeps expanding the surrounding though, there still are a number of citizen who live in the ambient area have to shuttle between their houses and city center because of the perfect facilities there. And the travelers driving their private vehicle among them increase the traffic load as a result. Considering the transport situations in our country, especially the development of urban rail transit, we try to attract the citizen who live in the ambient area and drive their private vehicle to the urban rail transit, which has a strong realistic significance in the improvement of traffic congestion and realizing green traffic and low carbon travel (XIE Xiaoqian,2012). This paper mainly discussed the model selection of urban rail transit P&R.

2 Analysis of the factors affecting the Site Selection

There are many factors which influence site selections of P&R facilities. To make research direction more concentrated and concise, this article mainly considers the following five factors which are more directly influential.

(1)Demand. The number of travelers who choose P&R directly influences the locations and the scale of facilities. Travelers can decide whether they choose the method of P&R according to the height of effectiveness in different travel modes. This article aims at travelers all with self-driving cars, so we can divide their travel modes in the round trip of central areas into three kinds (CHEN Rugang, 2012). The first one is all self-driving, the second one is walking to the stations of urban rail transit and choose it, the third one is driving to P&R Facilities of urban rail transit to park and choose urban rail transit.

(2)The Number of Berths. The number of berths is affected by both the demand and the construction conditions limit of berths (WANG Xianguang, 2013). The number of berths should satisfy the demand of travelers as much as possible. If the low demand leads to over decentralization of the berth number, we may not construct berths when being limited by the minimum berths to construct P&R Facilities. Conversely, we may just construct berths according to the upper limit of berth number if the demand is so large that even exceeds the upper limit of the berth number.

(3)Attracting Scope. P&R Facilities have some attracting scope and there is potential demand in the scope. In addition, attracting scope of different P&R Facilities should avoid reciprocal chiasmata so as not to cause competition and resource waste. Therefore, the study should focus on the special attracting scope of P&R Facilities, as well as ensure enough spatial distance among each other at the same time.

(4)Resource Constrained. The planning and site selections of P&R Facilities should be restrained by some resource constraint, as well as not exceed the investment upper limit.

(5)Benefit Goal. The goal which sites selection of P&R Facilities pursue is not only to satisfy and guide as many travelers as possible, but also guarantee travelers to complete P&R as soon as possible. It is the assurance of reducing vehicles entering city center and traffic jams of traffic corridors.

3 Establishment of the travel mode choice and site selection model

3.1 Model hypothesis

In order to simplify the calculation process, we make the following hypothesis:

(1)The selected P&R facility places are all in the urban rail transit stations.

(2)The potential P&R demand within the every P&R facility's attracting scope is known, namely the number of travelers who drive private vehicle and shuttle between their houses and city center is known.

(3)All of the P&R demand which was calculated from travel mode selection probability should be converted to actual P&R demand.

(4)Travelers are supposed to arrive the destination if they arrive the city center by vehicle or urban rail transit.

(5)We neglect the influence of traveler's characteristics when calculating the traveling utility because the targeted traveler's characteristics in this model are single.

3.2 Establishment of the travel mode choice model

We have mentioned in previous paper that there are three types that the potential P&R demand person can select to arrive at city center, namely driving in the whole range, riding the urban rail transit the whole range and P&R. According to the random utility theory of economics, travelers will pursue utility maximization. We can suppose that the travelers will select traveling modes according to the utility. The traveling mode selection model is shown in formula (1).

$$P_{ri}^{p\&r} = \frac{U_{ri}^{p\&r}}{U_{ri}^{p\&r} + U_{ri}^{metro} + U_{ri}^{car}} \quad (1)$$

Where $P_{ri}^{p\&r}$ is the probability that travelers select P&R at the i_{th} station of line No. r. U_{ri}^{car}, U_{ri}^{metro} and $U_{ri}^{p\&r}$ are the utility we can gain from the travelers driving the whole range, using urban rail transit the whole range or using P&R within the facility's attracting scope that is built at the i_{th} station of line No .r. The three utility functions can be described as formula (2)-(4).

$$U_{ri}^{car}=\alpha t^{car}(d'_{ri})+c^{car}(d'_{ri})+p^{car} \tag{2}$$

$$U_{ri}^{metro}=\alpha[(t^{walk}(d''_{ri})+t^{metro}(d_{ri})]+c^{metro}(d_{ri}) \tag{3}$$

$$U_{ri}^{p\&r}=\alpha[(t^{car}(d''_{ri})+t^{metro}(d_{ri})]+c^{car}(d''_{ri})+c^{metro}(d_{ri})+p_{ri}^{p\&r} \tag{4}$$

Where d_{ri} is the distance between city center and i_{th} station of line No. r. d'_{ri} is the average distance between city center and private cars within P&R facility's attracting scope at the i_{th} station of line No. r. d''_{ri} is the average distance between private cars and P&R facility within attracting scope of i_{th} station of line No. r. $t^{car}(x)$, $t^{walk}(x)$and $t^{metro}(x)$ are private cars, walking and metro time function taking distance as independent variable. $c^{car}(x)$ and $c^{metro}(x)$ are the fuel surcharge and the fare function of car and metro taking distance as independent variable. p^{car} is the parking fee in the city center. $p^{p\&r}$ is the parking fee in the i_{th} station of line No. r. α is the VOT coefficient which convert time to fees.

3.3 Establishment of the site selection model

Based on previous analysis and traveling mode selection model, we can establish a further site selection model, the objective function reflects the aim that meeting the demand of park and ride for more people and completing the park and ride in the downtown as soon as possible. The model is shown as formula (5)-(9).

$$\max Z=\sum_r\sum_i Q_{ri}^{p\&r}d_{ri}X_{ri} \tag{5}$$

$$s.t.\begin{cases}\sum_r\sum_i X_{ri}\le P \quad \forall r,i & (6)\\ X_{ri}=\begin{cases}0 & x_{ri}^b=0\\ 0\ or\ 1 & x_{ri}^b\ne 0\end{cases} & (7)\\ Q_{ri}^{p\&r}=Q_{ri}P_{ri}^{p\&r}=\dfrac{Q_{ri}U_{ri}^{p\&r}}{U_{ri}^{p\&r}+U_{ri}^{metro}+U_{ri}^{car}} \quad \forall r,i & (8)\\ \left|d_{ri}\text{-}d_{gj}\right|\ge 2D \quad \forall r,g\ \&\ i\ne j & (9)\end{cases}$$

Where $Q_{ri}^{p\&r}$ is the potential P&R demand at i_{th} station of line No. r. X_{ri}=0 means not to build any P&R facilities at i_{th} station of line No. r. X_{ri}=1 means build one. P is the upper limit of the amount of facilities. D is the radius of facility's attracting scope. x_{ri}^{b} is the amount of parking berth at i_{th} station of line No. r, which can be decided by Formula (10).

$$x_{ri}^{b}=\begin{cases}0 & Q_{ri}^{p\&r}<x_{\min}\\ Q_{ri}^{p\&r} & x_{\min}\le Q_{ri}^{p\&r}\le x_{\max}\\ x_{\max} & Q_{ri}^{p\&r}>x_{\max}\end{cases} \tag{10}$$

Where $x_{\min}$ is the minimum amount requirement of parking berth building a single P&R facility. $x_{\max}$ is the maximum parking berth amount building a single P&R facility. When the demand is not more than $x_{\min}$, we don't take building into consideration. When demand is more than $x_{\max}$, the amount will be $x_{\max}$. When demand is more than $x_{\min}$ and not more than $x_{\max}$, the amount will just be the demand.

As there are judging conditions in the site selection model constraint and it's a nonconvex programming problem which is relatively complex, we have to solve this kind of problem with a suitable algorithm. Such as Branch-and-Bound Method, Genetic Algorithm etc.

4 Conclusions

Among the factors that affect P&R site selection, there are some that are difficult to be quantified can also affect the results. Such as network configuration of the rail transit, Comprehensive traffic survey and urban development planning, etc. The influence remains to be further explored. What's more, we cannot realize the goal of improving traffic construction with P&R and realizing green traffic and low carbon travel simply considering site selection. The investment, construction mode and running mode of P&R all have an effect on its result. It's necessary to do an integration research in the further work.

References

Zhu Shunying. (2008). Planning and Management of Urban Rail Transit. Nanjing: Southeast University Press, 2008: 196-197.

XIE Xiaoqian. (2012). Model Study of Park-and-Ride Location. *Journal of Dalian Jiaotong University*, 2012, 33(1): 17.

CHEN Rugang. (2012). Study on Park-and-Ride Facility Location Model. Wuhan: Huazhong University of Science and Technology, 2012: 19-20.

WANG Xianguang. (2013). Study on Location Selection of Urban Rail Transit Park-and-Ride Facilities. *Modern Urban Transit*, 2013, (4): 73-74.

Incorporating Social Interaction Effects into a Travel Mode Choice Behavior Model

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Abstract: In central business district, the conditions caused by a lot of car travel have resulted in the severe negative effect upon passing on sidewalks, environment of the city, and traffic on roads. The local governments have implemented many related strategies in order to solve these problems. However, the car travel problem cannot be solved sufficiently. The reason is that many types of travel behavior including travel mode choice involve social interaction effect, leading society to deadlock in inferior equilibrium state (social dilemma). The previous travel behavior models, used to be bases for policy evaluation, assumed that individual behavior is independent of others and therefore it resulted in the constrained performances. In view of the above, this study designates the CBD of Dalian City as the study area where the data are collected to build the travel mode choice behavior model into which social interaction effect is incorporated.

Keywords: Travel mode choice behavior; Social interaction; Parking fee; Walking distance.

1 Introduction

In recent years, in large and medium cities, rush hour traffic jams have become a norm. Traffic congestion not only increases the travel time of all travelers, but also cause air pollution, resulting in the improvement of the external costs of people travel.

In the choice of travel modes, travelers are not just rational considerations of personal utility, where he will refer to other members' travel choice in the group, and this behavior is called social interaction. Due to the effect of social interaction, people often can observe the tendency of individuals to comply with the majority of action, which is likely to lead to a stalemate in the inferior social equilibrium, also known as "social dilemma" (Fukuda, 2007). Therefore, policy measures to solve traffic congestion, if only affect individuals and their statistical results for policy evaluation is not sufficient. The current mainstream of traffic behavior model tend to individual behavior independent of the behavior of others, this makes the effect of transport policy affected.

This article explores the city center area commuters travel choice behavior. If there is social interaction, set the transportation mode choice traveler behavior is not specific to the impact of most other travelers, and therefore belong to the whole domain of interaction. In the domain-wide interactive mode, we use the average behavior of the reference group as an alternative variables to describe the impact of interaction. In this paper, the average behavior of the reference group as explanatory variables of individual behavior, indicating that the formation mechanism of collective behavior characteristics.

In this paper, the interaction behavior of car commuters in the city center will be analysis based on the theory of social interaction proposed by Brock and Durlauf.

2 The Binary Choice Model Considering The Social Interaction

This study established a binary choice models based on expected utility theory. Individual decision-making process, in addition to considering individual utility, but also affected the population selection behavior of other members. As follows:

The choice behavior of individual i represented as binary variables w_i. If individual i choose plan A, w_i=1, if individual i choose plan B, w_i=-1. The utility of individual choice can be expressed as $V(w_i)$.

$$V(w_i)= u(w_i)+ S(w_i,\ \overline{m}_i^e)+\varepsilon(w_i) \quad (1)$$

$u(w_i)$:Observed individual utility

$S(w_i,\ \overline{m}_i^e)$:The social utility

$\varepsilon(w_i)$:Unobserved random utility

To reflect the multiplicative interaction between individual choice and group behaviors, The social utility can be expressed as follows:

$$S(w_i,\ \overline{m}_i^e)= Jw_i\overline{m}_i^e \quad (2)$$

$\overline{m}_i^e$: Individual's subjective expectations for the average collective choice, and its range is [-1,1], the formula can be expressed as:

$$\overline{m}_i^e = \frac{\sum_{j\neq i} m_{i,j}^e}{I-1} \quad (3)$$

I: the number of individuals in the group

$m_{i,j}^e$: the subjective expectations of individual i for individual j.

J is the numerical parameters measuring the extent of interdependence between individuals, it can be calculated as:

$$J = \frac{\partial^2 S(w_i, \overline{m}_i^e)}{\partial w_i \partial \overline{m}_i^e} \qquad (4)$$

We assumed that $U(w_i)=u(w_i)+S(w_i, \overline{m}_i^e)$, the probability of individual choice "plan A" can be expressed as:

$$\begin{aligned} Prob[V(1) \geq V(-1)] &= Prob[U(1)+\varepsilon(1) \geq U(-1)+\varepsilon(-1)] \\ &= Prob[\varepsilon(-1)-\varepsilon(1) \leq U(1)-U(-1)] \end{aligned} \qquad (5)$$

Assumed that unobserved random utility $\varepsilon(w_i)$ obey Gumbel distribution, the random utility of "plan B" and "plan A" is $\varepsilon(-1)$ and $\varepsilon(1)$ respectively, then $\varepsilon(-1)$-$\varepsilon(1)$ would be Logit distribution.

$$\begin{aligned} Prob[V(1) \geq V(-1)] &= \frac{1}{1+\exp(-\theta(U(1)-U(-1)))} \\ &= \frac{1}{1+\exp(-\theta(U(1))\times\exp(U(-1))} \\ &= \frac{\exp(\theta U(1))}{\exp(\theta U(1))+\exp(\theta U(-1))} \end{aligned} \qquad (6)$$

Equation (2) is substituted into equation (6) results in Equation (7). θ is the scale parameter of the random utility.

$$\Pr ob(w_i) = \frac{\exp[\theta(u(w_i)+Jw_i\overline{m}_i^e)]}{\sum_{v_i \in [1,-1]} \exp[\theta(u(v_i)+Jv_i\overline{m}_i^e)]} \qquad (7)$$

3 Variable Settings

In this paper, we used questionnaires to collect information needed for empirical analysis in downtown Dalian.

3.1 Options

The travel mode choice behavior was set to binary choice model, They are: commuting by public transport (bus or rail trips, is a cooperative behavior, $w_i = 1$), commuting by car (which is non-cooperative behavior $w_i = -1$).

3.2 The explanatory variables of individual utility

There are two part in the explanatory variables of individual utility, the individual specific variables(X) and the specific variable of reference groups(Y).

For the individual specific variables(X), because of commuter travel characteristics variables may affect the travel mode of choice, this article included the travel characteristics variables in the analysis model. For example, the travel distance, the work system, and the number of stops in commuting process.

Commuter travel decisions, not only affected by the individual's social-economic attributes and the travel characteristics, but also affected by travelers' mental states. Fujii proved that psychological factors plays a very important role in "cooperative behavior" in social dilemmas through a series of empirical studies. Therefore, this paper put "moral sense", "risk attitude" and "self-serving belief" and other psychological factors into the analysis model.

Specific variable of reference group is exogenous characteristics influence reference group choice behavior. This paper using parking fee and walking distance after stopping to assess the impact of policy variables

3.3 The explanatory variables of social utility

This paper set $\bar{m}^e$ as the individual's subjective expectation of reference groups choose public transport average level, referred to as select group average level. Since the model and questionnaire needs different types of data, the variables must be converted between the average level of choice ([-1,1]) and selection ratio ([0,1]). In other words, during the survey, in order to make it easy to imagine for a given situation, we used the proportion of group selection ($\bar{p}^e$) in data collection. When you import the model, you need to use ($\bar{m}^e = 2\bar{p}^e - 1$), the $\bar{p}^e$ is converted to average level of group selection.

Table 1 The explain variable's names and definitions

Variable name			Variable definitions
The individual specific variables (X_i)	Travel characteristic variable	Travel distance	$T_d \geq 10$km set as 1； $T_d \leq 10$km set as 0
		Number of stops	If parking in commuting set as 1， otherwise, 0
		Work system	Fixed working hours set as 1， otherwise, 0
	Psychological factors	moral sense	Factor analysis
		risk attitude	Factor analysis
		Self belief	Factor analysis
The specific variable of reference groups (Y)	Parking fee		10￥，20￥，40￥，60￥
	Walking distance		50m, 150m, 250m, 350m
The average level of collective choice（$\bar{m}^e$）			100%, 90%, 60%, 30%

4 Travel Mode Choice Model Considering Social Interaction

In this part, we used of a questionnaire survey to collect data, constructed the empirical model by introducing social interaction effect into travel mode choice behavior, and on this basis, to analyze the influencing variables of the travel mode choice behavior.

4.1 Model Estimation Results

The model is a binary choice model, we specify all the explanatory variables are the specific variables of "choice of public transport" to determine the impact of the program. In this case, the variable parameter is positive, indicating that the variables have positive impact on individual choice probabilities on public transport, on the contrary, have a negative sign indicates a negative impact. In addition, there were 192 effective respondents surveyed in this article. Because of each respondent need to answer four questions, there are 768 samples could be used to estimate the model.

This paper established four models, the estimated results were shown in Table 2. Model 1 did not consider personal property, Model 2 did not consider psychological factors, Model 3 considered all the factors, and Model 4 removed all insignificant variables.

Table 2. The travel mode choice model estimation results

				Model 1		Model 2		Model 3		Model 4	
The variable name			Parameter	Parameter value	t value	Parameter value	t value	parameter value	t value	parameter value	t value
Specific variables of individual (X_i)	Travel characteristic variables	Travel distance (x_{1i})	c'	——	——	-0.2050	-1.17	-0.2489	-1.4	——	——
		The number of stops (x_{2i})		——	——	-0.3296*	-1.90	-0.3133*	-1.77	-0.3416**	-1.98
		Working system (x_{3i})		——	——	0.5436***	1.96	0.4360*	1.91	0.4036*	1.84
	Psychological factor	MS (x_{4i})		——	——	——	——	0.3918*	1.79	0.3681**	2.36
		RA (x_{5i})		——	——	——	——	0.4270*	2.18	0.4563**	2.56
		SB (x_{6i})		——	——	——	——	-0.1224	-0.46	——	——
Specific variables of the reference group (Y)		Parking fee (y_1)	d'	0.0055***	6.83	0.0056***	6.88	0.0057***	6.94	0.0056***	6.99
		Walking distance (y_2)		0.0921***	7.37	0.0941***	7.43	0.0963***	7.48	0.0951***	7.55
$\overline{m}^e$			J	1.0824***	6.70	1.0983***	6.71	1.0552***	6.35	1.0510***	6.37
Constant			b	2.3834***	8.91	2.8478***	9.16	0.6001	0.75	——	——

Samples	768	768	768	768
$LL(0)$	-532.337	-532.337	-532.337	-532.337
$LL(\beta)$	-422.469	-413.994	-405.601	-406.783
ρ^2	0.206	0.222	0.238	0.236
$\bar{\rho}^2$	0.197	0.207	0.217	0.221

Note：*significant level at 0.1, **significant level at 0.05, ***significant level at 0.01.

Table 2 shows that the explanatory power of the model 1 is not good, $\bar{\rho}^2$（The adjusted likelihood ratio index）did not reach the model adaptation good standards (0.2). Compared with the model 1, the logarithm likelihood values (*LL* (*β*)) of model 2 produced a significant change (using the likelihood ratio test to determine: $16.9>\chi^2_{3,\ 0.05}=7.8$). The model 3 had a good explanation ability, but insignificant explanatory variables still exist in the model 3. After the analysis of the results, this paper took the model 4 as the analysis model.

4.2 Model Variables Impact Analysis

Specific variables of individual（x1i~x6i）shows the effect of various personal attributes. Among them, the "working system" of the parameter symbol shown that the fixed duty commuters will opt for "public transport". This may be due to the cumulative parking fee generated by repeatedly parked. Fixed duty of travelers are very understanding on public transport trips, routes and transfer information, so they are more inclined to choose public transport. The parameter symbol of "The number of stops" tells us that the more travelers' number of stops, the more inclined to commute by car. Probably because the car was very convenience, destination easy to adjust, thus, in this case people prefer to travel by car.

On the psychological factors, the parameter symbol displayed that travelers who have high moral consciousness inclined to choose public transportation, to avoid damage to the interests of others or the public interest. Compared with the risk-lovers, the risk-averts more inclined to public transport, in order to avoid the risk of driving such as traffic accidents, traffic violations and late for work.

Specific variable reference group shows: with the increase in walking distance and parking fee car travel, the tend of travel by car will decrease. Therefore, these variables can assess traffic policy, in other words, by improving parking fee and walking distance to increase the proportion of travelers commuting by public transport.

The average level of group selection has a significant positive effect on travel mode choice behavior. It is worth noting, the parameter J is used to measure the dependence degree of individual behavior, the value is greater than 1, description: strong social interaction (J>1) existing in the group, so the commuters exhibit a tendency to follow the behavior of others. The average level of the behavior choice (collective behavior) may exist multiple equilibria. These findings plays an important role for policy intervening travel mode choice behavior.

Finally, we discuss the deleted insignificant variables in model 3. Since the level of significant is not up to the standard, "travel distance", are not included in model 4. The parameters of model 2 and model 3 value symbol displayed if travel more than 10 km of distance, travelers more inclined to choose car travel. This may be when long-distance travel, people pay more attention to comfort and quickness. But other travelers thought that long-distance travel by car costs too high, preferred to take the low fares public transport. Self-serving belief facet mainly involves punctuality, economy and vanity factor. Bus travel has advantages in terms of economy, but travel by car has an advantage in terms of time savings, making it difficult to determine which option is more selfish.

5 Conclusions

In this article, we prove that psychological factors influence choice behavior to a certain extent, and it could enhance the explanatory power of the model. In addition, the model estimation results show that travelers have a tendency to follow other travelers' travel behaviors, and the strength of social interaction makes it possible that the collective behavior existing multiple equilibria. Therefore, in terms of policy intervention, it is necessary to analyze how to achieve a balanced transfer of collective behavior, in order to reduce social dilemma.

References

Ajzen, I. The theory of planned behavior. Organizational Behavior and Human Decision Processes, 1991, 50(2): 179–211.

Aronson, E., Wilson, T. D., Akert, R. M. Social Psychology. Upper Saddle River, NJ: Prentice Hall, 2010.

Blanck, P. D. Interpersonal expectations: theory, research, and applications. New York, NY: Cambridge University Press, 1993.

Dugundji, E. R., Páez, A., Arentze, T. A., Walker, J. L. Transportation and social interactions. Transportation Research Part A, 2011, 45(1): 239-247.

Fukuda, D., Morichi, S. Incorporating aggregate behavior in an individual's discrete choice: An application to analyzing illegal bicycle parking behavior. Transportation Research Part A, 2007, 41, 313-325.

Granovetter, M. Threshold models of collective behavior. American Journal of Sociology, 1978, 83(6): 1420-1443.

Hensher D A, Ton T T. A comparison of the predictive potential of artificial neural networks and nested logit models for commuter mode choice, Transportation Research Part E, 2000, 36(3): 155-172.

Hsieh, H. S., Hsia, H. C., Yeh, K. Y. Analysis of Policy Intervention to On-street Scooter and Bicycle Parking Considering the Social Interaction Effect. The 6th International Conference on Planning and Design, 2011, Taiwan.

Jakobsson, C., Fujii, S., Gärling, T. Determinants of private car users' acceptance of road pricing. Transport Policy, 2001, 7(1): 153-158.

Tim J. Ryley, Alberto M. Zanni. An examination of the relationship between social interactions and travel uncertainty. Journal of Transport Geography, 2013, 31(3): 249-257.

Electric Vehicle Charging Station Location Problem Research

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Abstract: Electric vehicle charging station is an important link of electric vehicle industry, and the construction mode of charging station is closely related to the development of electric vehicle. This paper put forward electric vehicle charging station's planning principle, ideas, process and established the charging station network layout planning method combining the centroid method and central place theory. Finally, carry on the instance analysis for the layout of electric vehicle charging station planning in Chengdu and verify the practicability of planning system.
Keywords: Electric vehicle; Charging station; Calculation mode.

1 Introduction

Due to the development of electric vehicle is at the primary stage, so the layout of electric vehicle charging station is still at the discussion stage. However, considering that electric vehicle charging station, gas station, LPG station are all vehicle refueling service facilities belonging to the city, and they have similar characteristics on refueling service function, so the electric vehicle charging station location problem can refer to the layout principle of gas station and LPG station.

Chiara Bersania established hydrogenated load forecasting model based on the historical oil demand data about gas station, optimized LPG station location from the perspective of cost-benefit analysis, put forward planning model suiting the LPG station; Martin Frick pointed out that in order to make the LPG become the large-scale market vehicle refuel, the common benefit analysis method must be used in LPG station layout to find the most optimal location of LPG station scheme; Michael put forward hydrogen station location optimization model based on vehicle maximum flow and made the preliminary hydrogenation infrastructure strategic planning with this model; Ren yulong established multi-objective optimization model by applying the idea of dynamic traffic network based on hard time window constraints. The model regarded the minimum charging cost of chargers and charging station investors as the optimization goal, put forward the two-phase heuristic algorithm to solve the model.

In this paper, we established the charging station network layout planning method combining the centroid method and central place theory for users' convenience and service level, and took Chengdu city as an example, providing reference for the urban planning of electric vehicle charging stations.

2 Standard Charging Station Planning

Determine the construction scale of standard charging station referring to the construction scale of gas station. Gas stations are divided into three types: the covering area is $2500m^2$, and the number of oil gun is 16; the covering area is $1500m^2$, and the number of oil gun is 12; the covering area is $1000m^2$, and the number of oil gun is 8. The construction principle of charging stations is "quick switching, and secondly quick charging", therefore the number of standard charging station's charging pile is 12 in total, including 2 quick charging piles and 10 fast switching piles.

Assuming that battery replacement time is 15 min and the charging station works for 24 h, so a quick service desk can serve 4 vehicles per hour at most. The largest service capacity of standard charging stations is calculated as follows:

$$C_{\text{standard}} = M_{\text{quick switching}} \times \mu_{\text{quick switching}} \times t \quad (1)$$

where, C_{standard}: the maximum service capacity of standard charging stations, vehicles/month;

$M_{\text{quick switching}}$: the number of quick switching pile, set for ten；

$\mu_{\text{quick switching}}$: the service rate of quick switching pile, set for 4 vehicles/h;

t: the service time of standard charging station, set for 24 h;

The maximum service capacity of standard charging station is 960 vehicles per day according to the formula (1). However, the charging station is not in the busy state at every time, and the service desk may appear empty demurrage. The empty demurrage includes the waiting time before customer's arrival and the invalid time. During 10 p.m. of yesterday to 8 a.m. of the next day, the empty demurrage is 8 h in total. Assuming that the invalid service time is 5 min per vehicle, so the design service capacity of charging station can be calculated as follows:

$$C_{\text{standard}} = M_{\text{quick switching}} \times \mu_{\text{quick switching}} \times t \times k \quad (2)$$

where, C_{standard}: the design service capacity of standard charging stations, vehicles/month;

$\mu_{\text{quick switching}}$: the service rate of quick switching pile, set for 3 vehicles/h;

k: the effective coefficient of charging station every day, usually ranging from 0.6-1.0.

The design service capacity of standard charging station is 480 vehicles per day according to formula (2). Details are shown in table 1.

Table1. Service Capacity of Standard Charging Station

Charging modes	Quick charging pile	Quick switching pile	Maximum service capacity (vehicles/day)	Design service capacity (vehicles/day)
Number of standard charging station	2	10	960	480

If the number and scale of charging station is too big, the resources may be in idle and wasted. If the number and scale is too small, the charging infrastructure can't meet users' demands, which leads to the long charging time of vehicle queue, affecting the normal travel of residents.

3 Location Theory Basis

3.1 Central Place Theory

Central place theory concretely discusses how to provide effective supply for urban production and service, how to configure different scale's cities, so as to form city system and market system with multiple levels. Electric vehicle charging station provides vehicle charging service for vehicle users and convenience for normal travel of residents. Due to the electric vehicle facility's location characteristics meet the requirements of central place theory, so this theory can provides a good method for the paper.

3.2 Centroid Method

Centroid method is usually used in the choice of single facility. The main factor of this method is to consider the distance between facilities and requirements of demands, so as to make the selected facility be close to the high demand's area as far as possible and acquire the center of the region's actual location. Based on this analysis, we can use this method to determine the charging station location optimization solution with the shortest mileage. However, this method doesn't consider economy, the possibility of site, and the actual optimal address is often difficult carry out, so we need to combine central place theory to determine the final solution.

4 Charging Station Location Choice Model

First, we use the network layout of central place theory to form service area, select location site within each service area using the centroid method. Second, due to the location site produced by centroid method may not achieve effect in reality, so choose *n* feasible coordinate solutions as alternative address, and determine the final address in the *n* feasible coordinate solutions by using location model.

4.1 Determine Service Scope in Central Place Theory

The essence of confirming service range is to obtain the maximum service radius of charging stations. The determination of service radius for electric vehicle charging station is based on the purpose of users' convenience. At the same time, we need to consider the profit situation of charging stations. At the primary stage, the number of pure electric vehicles is small. At this time, in order to promote using electric vehicles, the service scope of charging station can be slightly bigger. The electric vehicle charging station service radius will gradually be shorten with the rising number of electric vehicles, and the number of charging station will increase to meet users' demands. The upper limit of charging station service range is the longest charging service distance that consumers are willing to get to. Assuming that the maximum time which the driver spends on finding the charging station is 10 minutes, when the driver finds the insufficient battery, the driver will search the nearest charging station in 10 min to get the vehicle recharged

The construction of charging station should meet the customer's charging demands as far as possible, aiming at the customer's convenience. Therefore, we can determine the maximum service radius of charging station from the perspective of the biggest finding time that the customer can bear. Therefore, considering road condition near charging station, road traffic condition and the customer's biggest searching time, the service radius of charging station can be calculated as follows:

$$\mathrm{r} = \frac{V \times t}{\lambda} \tag{3}$$

where, V: vehicle driving speed, km/h;

t: the biggest searching time, min;

λ: road curvature coefficient, λ equals to the ratio between actual transport distance and the linear distance.

In generally, there are three types of road network forms: traditional checker-board type, freestyle type with limited connectivity and the combined type based on the first two. The connectivity of traditional check-board type is better, but the actual distance is 45% longer than the corresponding space distance.

Assuming that the average speed of urban road network traffic flow is 30 km/h and the vehicle can find the charging station within 10 min. On the basis of traditional check-board type network, set the road curvature coefficient 1.4, we can obtain that the maximum service radius of charging station is 5.5km according to formula (3) and the service area of charging station is 33.14km^2 according to the central place theory.

4.2 Primary Address of Centroid Method Model

Assuming that the charging demand distribution is known, the demand of one demand point is Q, its location coordinate is（x , y）, so the location coordinate of shortest charging station theoretically is:

$$\mathrm{X} = \frac{\sum_{i=1}^{m} Q_i \times x_i}{\sum_{i=1}^{m} Q_i} \quad \mathrm{Y} = \frac{\sum_{i=1}^{m} Q_i \times y_i}{\sum_{i=1}^{m} Q_i} \tag{4}$$

where, m: the number of charging station service demand point;

x_i, y_i: coordinates of demand point *i*;

4.3Determine the Final Solution

Location problem in each service community is a single facility location, aiming at making T_c from demand point *i* to facility point *j* be minimum value, the mathematical form of this model is as follows:

$$\min T_c = \sum_{i=1}^{m} E_{ij} d_{ij} \qquad (j=1,2\ldots.n) \tag{5}$$

where, *n*: number of alternative facility point;

m: number of demand point;

E_{ij}: demand intensity from demand point *i* to facility point *j*;

d_{ij}: distance from demand point *i* to facility point *j*.

5 Electric Vehicle Charging Facility Layout Planning in Chengdu City

Choose the per capita GDP、urban population、urban built area and virtual variable that stimulate to buy electric vehicles（1 for yes, 0 for no）as the independent variables, electric vehicle ownership in Chengdu as the dependent variable. Multiple linear regression model is set up as follows:

$$\mathrm{y} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \varepsilon \tag{6}$$

where, y: electric vehicle ownership in Chengdu;

x_1: per capita GDP in Chengdu;

x_2: urban population in Chengdu;

x_3: urban built area in Chengdu;
x_4: virtual variable that stimulate to buy electric vehicles;

Use SPSS and carry on heteroscedasticity testing, autocorrelation testing, find that the four independent variables have a significant impact on the dependent variable. The higher the per capita GDP is, the greater the electric vehicle ownership is. With the increasing of urban population, the electric vehicle ownership will also increase. The increasing of urban built area will promote the electric vehicle ownership. Do statistical analysis with data from 2000 to 2015 as samples, and forecast the electric vehicle markets and the number of charging infrastructure in Chengdu. The prediction result is as follows:

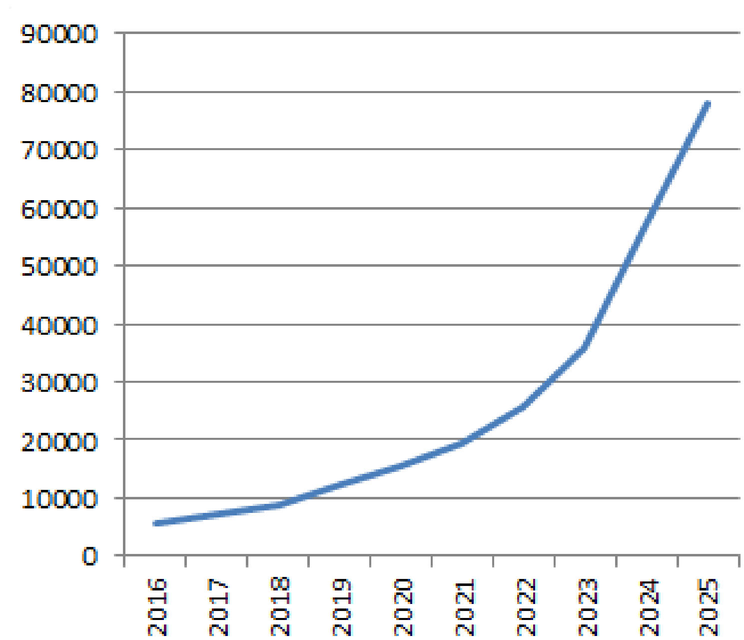

Figure1.Electric Vehicle Ownership in the Future Market

Under the action of market, the distribution of center area is based on the convenience for sales and service. With the development of electric vehicles, vehicle charging demand constantly increases. According to the distribution mode of central place theory, we can get the electric vehicles charging station planning chart combining service radius based on customer's convenience, as shown in figure 2.

Figure2. Electric Vehicles Charging Station Planning Chart in Chengdu

6 Conclusions

This paper studies the solution to the problem of electric vehicle charging station layout planning, uses centroid method and central place method to establish electric vehicle facility selecting model from the perspective of improving service level and users' convenience. Finally, carry on the instance analysis for the layout of electric vehicle charging infrastructure planning in Chengdu and verify the practicability of planning system.

References

DU Aihu, HU Zechun, SONG Yonghua, WU Junyang(2011), "Distribution Network Planning Considering Layout Optimization of Electric Vehicle Charging Stations." *Power System Technology*, 35(11), 35-42.

FAN Wenbo, MA Jian, JIANG Xinguo(2014). "Bilevel Programming Model for Locating Park-and Ride Facility." *J.URBAN PLAN D-ASCE*, 12(1), 1-9.

FAN Yonggeng, QIAN Weizhong(2010), "Discussion on the Planning and Construction of Charging Facility for Electric Vehicles." *East China Electric Power*, 38(11), 1671-1674.

Jaeyoung Jung, Joseph Y.J.Chow, R.Jayakrishnan, Ji Young Park(2014). "Stochastic Dynamic Itinerary Interception Refueling Location Problem With Queue Delay for Electric Taxi Charging Stations." *Transportation Research Part C*, 40(2014), 123-142.

LI Ling, LI Yanqing, YAO Yuhai, GE Man(2011), "Layout Planning of Electric Vehicle Charging Stations Based on Genetic Algorithm." *East China Electric*

Power, 39(6), 1004-1006.

TANG Xiangang, LIU Junyong, LIU Youbo, FENG Han, XIE Lianfang, MA Wei(2012), "Electric Vehicle Charging Station Planning Based on Computational Geometry Method." *Automation of Electric Power Systems*, 36(8), 24-30.

WANG Hengsong, HUANG Qi, ZHANG Changhua, XIA Aihua(2010). "A Novel Approach For The Layout Of Electric Vehicle Charging Station." *IEEE*, 4(5), 64-70.

WU Chunyang, LI Chanbing, DU Li, CAO Yijia(2010), "A Method for Electric Vehicle Charging Infrastructure Planning." *Automation of Electric Power Systems*, 34(24), 36-39.

XIONG Hu, XIANG Tieyuan, ZHU Yonggang, SONG Xudong, CHEN Hao, CHEN Hongkun(2012). "Electric Vehicle Public Charging Stations Location Optimal Planning." *Automation of Electric Power Systems*, 36(23), 65-70.

XU Fan, YU Guoqin, GU Linfeng, ZHANG Hua(2009), "Tentative Analysis of Layout of Electric Vehicle Charging Stations." *East China Electric Power*, 37(10), 1678-1682.

Prediction of a Reasonable Highway Network Scale in Wenzhou

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Abstract: The study of reasonable highway network scale is directly related to the network planning, construction and the achievement of social and economic benefits. Based on the analysis of influence factors, different types of highway development partition were proposed and the focus of highway development was discussed. After analyzing the shortcomings and characteristics of traditional methods such as territory coefficient method and connectivity method, the reasonable scale value was predicted by three appropriate methods and adjusted with the gini coefficient. Combining qualitative and quantitative analysis, a reasonable network scale of highway development and construction in Wenzhou was determined, which provides a theoretical basis for the highway network planning adjustment and gives a scientific guide to highway development.
Keywords: Highway; Highway network scale; Prediction method; Gini coefficient.

1 Introduction

This paper studies the reasonable highway network scale of Wenzhou, which reflects the difference and ensures the fairness in each region. First, influencing factors of the regional highway network scale are analyzed. Second, four different types of highway development subareas are proposed and the corresponding focus of development is discussed. Thirdly, after analyzing the applicability of traditional methods, the reasonable highway scale value of each region is predicted. Finally, the predicted value is checked with gini coefficient and adjusted with Lorenz curve, which reach the definitive conclusions.

2 Influencing Factors

The influencing factors of reasonable road network scale can be divided into three categories. The first category is demand factors such as population and its distribution, economic scale and industry layout, mainly reflects the road network supply capacity requirements for economic and social development. The next is the constraint factors, such as land resources, geographical characteristics, which reflects the restriction of resource endowment on road network development scale. The last category is the transportation development mode such as traffic composition and transportation development concepts, which reflects the road network functions to play and the demand to assume in transportation system, and the expected service status etc. The counties of Wenzhou are very different in topographic, geographic, social and economic aspects. So the influencing factors of counties are respectively analyzed in the following.

(1)Population and its distribution

Wenzhou downtown area (WDA), Ruian, Yueqing, Dongtou, Pingyang, Cangnan are mainly town concentrated area with a high population density over 800 persons per sq.km. Yongjia, Taishun, Wencheng of inland area are town dot-development area with a relatively low density between 200~400 persons/ sq. km, in which population and industry develop in places. According to the relevant planning, in 2020 Wenzhou city will have an urban population of 580~610 million, the urbanization level reaches 69~71%; the total population will increase in WDA, Ruian, Yueqing, Dongtou, remain in Yongjia, Pingyang and Cangnan, decrease in Wencheng, Taishun.

(2)Economy and industry

WDA, Dongtou, Pingyang, Cangnan, Ruian, Yueqing are national-level development area. Small commodity, electric, automobile and motorcycle industries locates in WDA, Ruian and Yueqing. It leads to the fact that he total value of GDP and per capita GDP of these counties are significantly higher than those counties. Dongtou, Yongjia, Pingyang, Cangnan belong to the medium level of development. Wencheng and Taishun are provincial-level ecological function areas, which need to limit economic development, so the economic indicators are the lowest.

(3)Geographical features

The overall terrain of Wenzhou is high in northeast and low in southwest, containing coastlines, hills, valleys, rivers, seas.Wencheng and Taishun locates in southwest and Yongjia in northwest ,where the mountain area accounts over 80% of the total area. WDA, Ruian, Yueqing, Pingyang, Cangnan are coastal areas, with hills, valleys, plains, river and other different physiognomy. Dongtou has island hilly terrain, no river, no typical river valley landform, many natural harbors and beaches, there are many navigable channels between each island.

(4) Traffic demand

The traffic demand is the direct factor influencing the regional highway network scale. Through the analysis of retaining volume of motor vehicles and statistical highway and waterway passenger traffic volume. The indicators are the highest level in WDA, while Dongtou, Wen Cheng, Taishun is much lower than the general level, the rest counties' statistical volumes differ in the medium level. Freight traffic volume is similar with passenger traffic volume, but the Dongtou because of its special nature as a harbor district, with the higher level of freight traffic than passenger traffic.

Four different types of highway development partition are proposed here based on the difference of the influencing factors. The first kind combines WDA, Yueqing, Ruian, Pingyang, Cangnan, where has a greater demand for highway development and suitable conditions for the highway development and construction. Secondly, Yongjia has contradiction of highway demand and supply because of its hilly topography. Wencheng and Taishun is the third type with a low highway demand and mountainous area as highway development constraints. Dongtou has a special demand of freight transport as the harbor function.

3 Highway network scale prediction

According to the difference of study ideas, the existing research methods can be divided into four categories: the first category (connectivity analysis): starting from the highway network layout, consider the degree of connectivity of nodes in road network, calculate the scale of road network based on minimum tree in graph theory, including connectivity method, efficiency curve method (Hu, 2012); The second category (time series) : analyze the trend of the development of highway network, including growth curve method (Pei, 1995; Zhou, 2003); the third category (factor analysis), after a comprehensive analysis of factors affecting road network scale of one or more, set up relevant influence factors and the related model to forecast the reasonable road network scale, including territory coefficient method, the production function method, highway volume analysis method, the economic index model method, elasticity coefficient method and multifactor regression analysis (Magnanti, 1984; Meyer, 2000; Gu, 2004, Wang, 2006; Yu, 2006); The fourth category (analogy), on the basis of factors analysis, select highway network in some areas similar with the target area in social and economic development, qualitatively analyze or establish a road network scale model with related influencing factors and the quantitative relationship to determine the regional highway scale, namely the analogy method.

Table 1 analyses the advantages and disadvantages of various methods. It's difficult to find out analogical objects familiar or same with Wenzhou because Wenzhou has a unique geographical conditions named ”seven mountain two water one field” and locates in the intersection of Yangtze river delta economic zone and channel west bank economic zone. From two aspects of the operability and accuracy, connectivity method, the coefficient method, the growth curve method are selected to calculate the regional reasonable road network scale in Wenzhou.

Table 1. Analysis of prediction methods

method	model	advantages	disadvantages	applicability
connectivity method	$L = C \cdot \varepsilon \cdot \sqrt{A \cdot N}$	can reflect the layout of highway network	nodes, connectivity, network deformation coefficient are not easy to determine in large or complex terrain	Small areas or areas without topographic change
efficiency curve method	$\sum Z = f(\sum L)$	Analyze the node importance based on connectivity method, more objective	data requirements are very high	the same as above
growth curve method	$L = K \cdot a^{b^t}$ or $L = \frac{1}{K + a \cdot b^t}$	consistent with the laws of development of things	Lack of consideration of other factors of population, economic development, also has high requirement to the data	Applicable to the prediction of highway network recently
territory coefficient method	$L = K_n\sqrt{P \cdot A}$	Consideration of land area, population, per capita GDP in most of these main factor	no consideration of other influencing factors, may reduce the accuracy of the prediction	applicable to most situations
elasticity coefficient method	$L_R = e \times E$	Built the relation model between highway construction growth rate and the economy growth rate	Hard to find out the relationship with the influence factors and determine the trend of development	More suitable for long term forecast of regional highway network
Highway volume analysis	$L = Q/(S \cdot C)$	directly establish the mathematical model between	Without considering the adaptation degree	Applicable to the prediction of

method		the traffic demand and supply	between the traffic supply and demand,	highway network recently
Analogy method	$L = f(I, P, A)$	The factors considered comprehensively, more close to the actual	analogical object and principle hard to grasp, weight variable factor of analogical various hard to determine	the results depends on the analogy process

4 Highway network scale correction

The gini coefficient were commonly used to evaluate regional unbalanced development in many aspects such as resources, income. It has been proved reliable to evaluate the highway infrastructure distribution in a specific area. The paper proposed that the highway network scale should be adjusted with gini coefficient in the reasonable range.

The reasonable value range of the highway network scale was got from the comprehensive analysis of the prediction results of the growth curve method, territory coefficient method and connectivity method (Table 2).The median value of the reasonable range is choose to be tested and amended as initial value with population gini coefficient, area gini coefficient and economy gini coefficient.(Wang,2006).

Table 2. Prediction of highway network scale

	growth curve method (km)	territory coefficient method (km)	connectivity method (km)	reasonable value range in 2020 (km)
WDA	1377	1371	1414	1371-1414
Ruian	2156	2142	2341	2142-2341
Yueqing	1360	1389	1550	1360-1550
Dongtou	220	196	135	135-220
Yongjia	2884	2869	2682	2682-2884
Pingyang	1875	1804	1960	1804-1960
Cangnan	1886	1679	1818	1679-1886
Wencheng	2011	1961	1802	1802-2011
Taishun	2286	2090	2041	2041-2286

Refer to the gini coefficient evaluation standard(Table 3), the network equilibrium is analyzed with the evaluation conclusion of the prediction value. When the conclusion indicates the highway resource allocation in equilibrium, the tested value can be accepted as a final reasonable result. Otherwise, the initial value adjusts modestly with Lorenz curve in the reasonable range to get the result accepted.

Table 3. gini coefficient evaluation standard

interval	0-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5-1.0
conclusion	absolute equilibrium	very balanced	relatively reasonable	unbalanced	Very unbalanced

Table 4 shows the final result corrected with gini coefficient. Table 5 shows that the prediction method concerns the difference in each counties so the gini coefficient in 2020 is bigger than the recent status. But the gini coefficients still keep close to the absolute equilibrium criterion.

Table 4. Correction of highway network scale

	reasonable value range in 2020(km)	Initial value (km)	Corrected value (km)
WDA	1371-1414	1393	1403
Ruian	2142-2341	2242	2188
Yueqing	1360-1550	1455	1421
Dongtou	135-220	178	200
Yongjia	2682-2884	2783	2682
Pingyang	1804-1960	1882	1845
Cangnan	1679-1886	1783	1717
Wencheng	1802-2011	1907	2007
Taishun	2041-2286	2164	2137

Table 5.evaluation of corrected highway network scale

	Population gini coefficient		Area gini coefficient		Economy gini coefficient	
	Data	Conclusion	Data	Conclusion	Data	Conclusion
Recent value	0.160	absolute equilibrium	0.064	absolute equilibrium	0.210	very balanced
Corrected value	0.178	absolute equilibrium	0.051	absolute equilibrium	0.218	very balanced

5 Conclusions

After the prediction and correction，it is the conclusion that the total reasonable highway scale of Wenzhou is 15600 km and the rational scale of each different counties is proposed in Table 4.The paper concerns the influencing factors of each counties which has a different level of highway development and predicts the reasonable highway scale. Using the gini coefficient, on the basis of the differentiation configuration it ensures the equilibrium configuration of highway infrastructure in Wenzhou, which helps the residents of different districts enjoy the fairness of the highway basic service and promotes the economic development of transport infrastructure lagging regions.

References

Gu,Zhenghua.,and Li,Xuhong.(2004). "Research on the reasonable scale of regional expressway network." *Journal of Highway and Transportation Research and Development*, 21(9): 78-81.

Hu,Qizhou.,Wu,Juan.,Yuan,Changwei.（2012） "Bi-level optimization model of highway network in economic circle based on diferential evolution algorithm."*China Journal of Highway and Transport*, 25(2):100-105.

Ji,Qiuzhi.,Zhang,Jia.,and Wang,Yuanqing.(2005). "Forecasting of highway construction scale for west region of China based on scene analysis method." *Highway*, (1):42-48.

Liu,Wengang.(2008). "Study on economic scale of urban road network."*Journal of Taiyuan University of Technology*, 39(2):137-139.

Magnanti, T.L. (1984). "Network design and trans- portation planning:models and algorithms." *Transportation Science*,18(2):1-56.

Meyer, M.D.(2000). "Transport planning for urban area:a retrospective look and future prospect." *Journal of Advanced Transportation*, 34(1):143-171.

Pei,Yulong.,and Zhang,Shusheng.(1995) "Research on the planning theory of highway network. "*Journal of Harbin University of Architecture and Enginering*, 28(2):106-14.

Tzeng,G.H.(1997). "Application of multiple criteria decision making for network improvement." *Journal of Advanced Transportation*, 31(1):49-74.

Wang,Jiangping.,Li,Jirui. (2006)"Analysis of Gini coeficient and highway development balance." *Transpoworld*, (11):66-69.

Wang,Xuancang.,Yu,Jiangxia.,Wang,Binggang.,et al.(2006)."Reasonable highway network scale prediction based on demand function."*Journal of Chang'an University:Natural Science Edition*, 26(3):59-62.

Yu,Jiangxia.,Yu,Jingqun.,Wang,Xuancang.(2006) "Highway network scale prediction based on BP neural network." *Journal of Chang'an University: Natural Science Edition*, 26(1):75-78.

Zhang,Changsheng.,Ma,Rongguo.(2010) "Equilibrium evaluation and development strategies for highway network in plateau mountain."*Journal of Highway and Transportation Research and Development*,27(8):114-119.

Zhou,Wei.,Xiang,Qianzhong. (2003)"Theory and method for post-evaluation of highway network planning." *China Journal of Highway and Transport*, 16(1):99-103.

Zhu,Hui.,Li,Peicai.,Chen,Shaoying.(2005)"Synthetic evaluation of highway network actuality."*Journal of Chan'an University:Natural Science Edition*,25(5):79-82.

Preliminary Exploration in Choice Behavior of a Parking Lot in a S/M City with a Logit Model

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Abstract: In recent years, along with the amount of our country's vehicle increasing year by year, the downtown areas or CBDs in many S/M Cities have appeared parking problems. To provide some effective decision-making reference for traffic management, this article tries to help S/M City find a method to solve its urban parking problem by studying persons' parking choice behavior. We have made the parking behavior surveys about 3 ground parking lots and 2 underground parking lots in Dazhou city, a S/M City in the east of Sicuan Province, and analyzed surveys data to regard the Saturation of Berth as a leading indicator, the distance to destination and the parking fee as two main factors that affect parking choice behavior. On basis of research we established the Binary Logit (BL) models to quantitatively depict the parking behavior. And according to the coefficients in model and the symbols of **t** value view, under the premise that the confidence level of **t** is 95%, the BL model owned a high precision. Finally, based on the qualitative analysis of parking fee, the article got a preliminary threshold of parking fee: the basic fee is 7 yuan/h, and when the parking fee exceeds the value, it has significant effect on adjusting the ground and underground parking lot choice behavior in Dazhou urban area.

Keywords: Choice behavior of parking lot; Logit model; S/M city; The threshold of parking fee.

1 Introduction

Currently, the analysis about the choice behavior of parking lot, as a research direction in the field of urban transportation planning, is playing a more important role increasingly. Yoram (1997) utilized parking behavior data to build a model to analyze people reflection. Rachel (2001) built 6 models that owned multiple different variables to identify significant behavior patterns of persons. Moshe (2004) has defined a mixed model after referring to the formers' achievement in research, and has realized it with MNL. However becautilize of cultural and economical difference, researches from abroad can't always work in our C/M City all time. So, this article tries to find a viable method to study parking choice behavior in our cities. The paper is engaged in parking choice behavior investigation in Dazhou City, and on the basis of analyzing data we utilize BL model and calibration model parameters. Finally we explore the threshold of parking fee which can affect the choice behavior of parking lot and provide a viable method for traffic management about parking problems in the city.

2 Survey overview

In order to grasp regular pattern about the choice behavior of parking lot in S/M City, this article finished 2 surveys on September 1st 2014 (Monday) and September 6th 2014 (Saturday), which tried to get information about the choice behavior of parking lots in Dazhou City, a S/M City in Sicuan Province.

The objects of the investigation are 3 ground parking lots and 2 underground parking lots in the main areas of Dazhou City. Considering that there are differences between persons' choice behavior of parking lot on weekday and weekend, the surveys were carried out on Monday and Saturday. We recovered 555 efficacious questionnaires and made the sampling rate of samples is 90%. The table is divided into 3 parts: instructions of table, information of respondents and survey content. The investigation objects are traveler in parking lot, and the investigation purpose is to obtain persons' reasons of parking choice behavior. Finally, the results are shown in Table 1 and Fig.1.

Table 1 the Overview of Parking Lot and the Saturation of Berth

Number	Name	Type	Fee	the Saturation of berth	
				Mon	Sat
1	Dongyu Parking lot	Ground	5 yuan/h	0.464	0.81
2	Moer Parking lot	Ground	6 yuan /h	0.601	0.827
3	Binjiang Parking lot	Ground	7 yuan /h	0.393	0.727
Average				0.486	0.788
4	Xinshang Parking lot	Underground	4 yuan /h	0.17	0.53
5	Shiji Parking lot	Underground	4 yuan /h	0.134	0.59
Average				0.152	0.56

(the Saturation of berth = the Average number of parking/the Total number of parking).

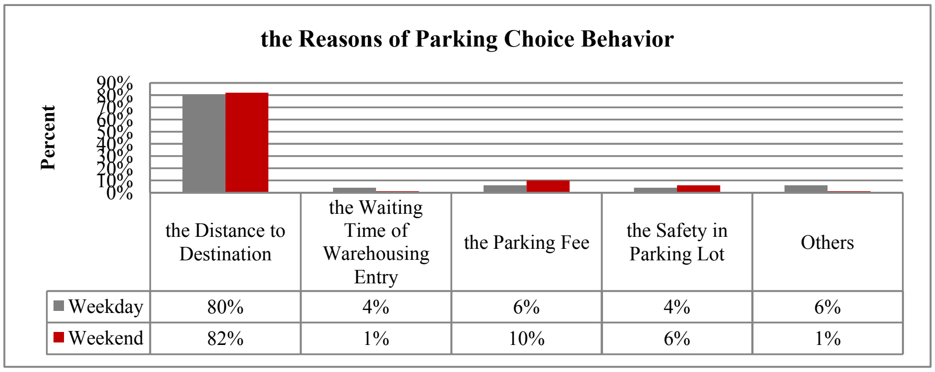

Fig.1 the Reasons of Parking Choice Behavior

3 Building logit models

In order to study on the affecting factors about persons' parking choice behavior, the paper utilize Binary Logit (BL) Model to analyze its problems.

3.1 Selecting model variables

According to Table 1, compared with the ground parking lots ,the Saturation of Berth in the underground parking lots is much lower not only on weekday but also on weekend, which makes their parking distribution unbalanced. So, the Saturation of Parking Berth should be a primary target for models and we should try our best to seek its maximum effectiveness.

On the other hand, according to Fig.1, among the factors with affecting parking choice behavior there are two factors, the Distance to Destination and the Parking Fee, which should become the most important ones(specifically the Distance to Destination, whose percent in Fig.1 is larger than 80%). Therefore, this paper utilizes the Distance to Destination and the Parking Fee as the arguments of BL model and regards whether chooses the ground parking lots or the underground parking lots as binary results (Guang Z.H,2000). The preliminary model structure is shown as following Table 2.

Table 2 the Model of the Parking Choice

Selecting results	Inherent dummy	the Distance to Destination	Parking Fee
Ground parking lot	1	X_{1n1}	X_{1n2}
Underground parking lot	0	X_{2n1}	X_{2n2}
Parameters	θ_1	θ_2	θ_3

3.2 Calibration model parameters

Selecting 500 samples from 555 questionnaires, we respectively build models on weekday and weekend. And the composition of samples is shown on Table 3. What's more, we utilize the Spss to calibration the model parameters with these samples. The results are shown on Table 4.

Table 3 the Composition of Samples

	Ground parking lot	Underground parking lot	Sum
Weekday	90	100	190
Weekend	166	144	310
Sum	255	245	500

Table 4 the Parking Choice Model 1 on Weekday and Weekend

Model 1	θ_1	t_1	θ_2	t_2	θ_3	t_3	H.R	ρ_2	$\overline{\rho^2}$
Weekday	-1.49	-3.77	-0.01	-7.41	0.11	0.22	0.34	0.36	0.35
Weekend	-0.36	-1.39	-0.01	-8.95	0.01	0.25	0.28	0.27	0.25

θ_i （$i = 1,2,3$）is the coefficient of the i^{th} variable, t_i （$i = 1,2,3$）is the t test value of the i^{th} variable, H.R is the Hit Ratio, ρ_2 and $\overline{\rho^2}$ are sensitivity coefficient and adjusted sensitivity coefficient.

From Table 4, it shows that the coefficient of factor parking fee is 0.11 on weekday or 0.01 on weekend, which is larger than zero (>0). This result reflects that when the parking fee is higher, the effectiveness of BL model is more notable, which is unreasonable and goes against the practical experience. And the H.Rs are also a little lower (<0.5).

However, if we abandon the parking fee from BL model, it can't reflect the impact of fee on persons' parking choice behavior. Therefore this article thinks that it is essential to calculate the threshold of parking fee which can make the fee do the deed.

4 Calculating the threshold

The threshold of parking fee is defined that when parking fee is larger than it, the parking fee will affect person's parking choice behavior observably.

According to Table 1, the fees of 5 parking lots all fall in the region [4, 7]. But now, the article will make the parking fee of underground parking lot constant, which is 4 yuan/h, and change the fee of ground parking lot from 0yuan/h to 10 yuan/h. And we utilize the ***Matlab*** to draw their effectiveness curves separately on weekday and weekend. The results of curves are shown in Fig.2.

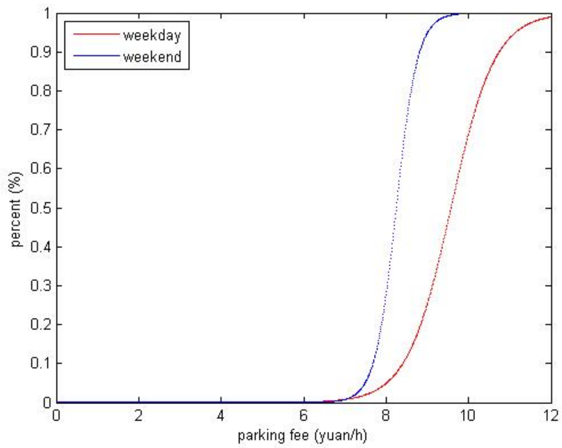

Fig. 2 the Effectiveness Curves of Parking Fee on Weekday and Weekend

According to the above figures., the threshold falls in the region [6,8], which is approximately 7yuan/h, which means that if we get a new parking fee of ground parking lot that is larger than 7yuan/h, the influence of parking fee on the person's parking choice behavior will be notable. So, let's make that the parking fee of ground parking lot is 8yuan/h and 10yuan/h separately (which are larger than 7), and utilize the Spss to calibration model parameters again. The results are shown in following Table 5.

Table 5 the Adjusted Parking Choice Model 2and Model 3 on Weekday and Weekend

Model 2	θ_1	t_1	θ_2	t_2	θ_3	t_3	H.R	ρ_2	$\overline{\rho^2}$
Weekday	-0.99	-3.19	-0.01	-6.12	-0.04	-1.83	0.56	0.31	0.30
Weekend	-0.60	-2.31	-0.01	-7.46	-0.05	-1.97	0.53	0.23	0.22
Model 3	θ_1	t_1	θ_2	t_2	θ_3	t_3	H.R	ρ_2	$\overline{\rho^2}$
Weekday	-1.03	-3.07	-0.01	-6.13	-0.03	-2.35	0.63	0.31	0.30
Weekend	-0.55	-2.10	-0.01	-7.49	-0.02	-2.41	0.58	0.23	0.22

Model 2 is a model whose parking fee of ground parking lot is 8yuan/h;

Model 3 is a model whose parking fee of ground parking lot is 10yuan/h.

5 Conclusions

From Table 5 the effectiveness of BL models will be notable if the parking fee exceeds 7yuan/h. All coefficients of the models are lower than zero (<0), which is coincided with reality. And studying from H.R, ρ_2 and $\overline{\rho^2}$, the accuracy of models is very high. So finally this article can make the conclusions that the threshold of parking fee in ground parking fee is approximately 7yuan/h and if the fee is larger than 7, it can help adjust the Saturation of Berth between the ground parking lots and the underground parking lots to a balanced level in Dazhou City.

Reference

Engels H. Numerical quadrature and cubature with SPSS. New York: Academic, 2008

Guang Z. H, Modeling the Response to Parking Policy, July 2000

Moshe .A Estimation of Switching Model from Revealed Preferences. Research, Vol.22, pp 102-107

Rachel. T. K, Applied Discrete-Choice Modelling, Haisted Press Book, 2001

Yoram. D. Structural Analysis of Discrete Data with Econometric Applications, MIT Press, 1997.

Rational Allocation of Passenger Transportation Structures in a Metropolitan Area

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Abstract: In light of the rapid development of urbanization, this essay mainly studies the new type of metropolitan area during city evolution and researches about the rational allocation of intercity passenger transportation in metropolitan areas. Based on analyzing the mode and the demand characteristics of the metropolitan transportation, in terms of both sides of transportation supply and demand, establishes the objective function, maximizing the passenger transport efficiency and minimizing residents' cost of travelling, and builds the Multi-objective programming model using restraining variables such as economy, environment, efficiency and service in the passenger transport system. To solve the question above, we apply genetic algorithm (GA) and get the most reasonable transportation structure in metropolitan in sustainable development. Given the same city transportation capacity, different travelling mode split can result in different utilization efficiency, with which we can assess the rationality of the transportation allocation. Finally, we take the Wuhan metropolitan as an example and use the model to allocate the rational transportation structure from Wuhan city to Xiaogan city.
Keywords: Metropolitan area; Transportation structure; Multi-objective programming; Genetic algorithm (GA).

1 Introduction

With the fast development of urbanization in China, it is inevitable for metropolitan to form and grow under the combined effect of aggregation and diffusion. With the same city transport capacity, different travelling mode results in different utilization efficiency. That is to say, a rational transportation structure not only brings the infrastructure to its fullest, but also has a great impact on the total transportation capacity. Also, how to construct a rational transportation structure in metropolitan area is a urgent subject nowadays because it is the key to solving many problems against city development, such as sustained population growth, increasing traffic demand, enormous increase of motor vehicles and insufficient road capacity.

2 Passenger Transportation Systems in Metropolitan Area

2.1 Way of thinking in the model and modeling assumptions

The passenger transportation system in the whole metropolitan area can be divided into two parts: one is the supply, the government enterprise is in charge of the funding and the running. Another is the demand, residents choose travel mode. In terms of the supply side, the main purpose of the government providing the public traffic facilities is pursuing the max social effect instead of an economic one, so the objective function is to achieve the maximum transportation efficiency. Meanwhile, in terms of the demand side, residents all wish to choose the best mode to travel. Generally, the best mode means costing the fewest amount of time and money, which we also use as the objective function to build a multi-objective programming model. And the restraining variables are economy, environment, efficiency and resources.

The modeling assumptions：

(1) The transport structure in this model means the reasonable combination of different transportation mode, excluding the route and network.

(2) Generally speaking, residents travelling cost in metropolitan area consists of the ticket price and extra service fee. Residents choose best mode on their own .

(3) The supply side allows all kinds of travelling vehicles meet traveler's needs at the highest frequency in terms of the transport condition and organization.

2.2 Notation Definitions

Table 1. Notation Definitions Schedule

Symbol	Definition
$_{ij}^{k}$	The volume of passenger flow from location i to location in transport mode
t_{ij}^{k}	The time cost from location i to location j in k transport mode
t_{ij}^{min}	The fewest amount of time from location i to location j
Q_{ij}	The traffic demand from location i to location j
pr_{ij}^{k}	The transport system pollutant discharge form location i to location j
E_{ij}	The biggest transport system pollutant discharge the environment can handle from location i to location j (according to the government standard statistic)
l_{ij}^{k}	The dynamic area from location i to location j the k transport method covers
L	The average road area per person from location i to location j
M	The congregation of all the transport mode
B	The amount of investment in transportation construction
minF^{k}	The fewest passenger capacity from location i to location j in the k transport mode
maxF^{k}	The largest passenger capacity from location i to location j in the k transport mode
C_{ij}^{k}	The residents travelling costs from location i to location j in the k transport mode

3 The Allocation Model Formulation of Passenger Transportation Structure

3.1The objective functions

Maximizing efficiency of the passenger transportation system, minimizing the residents travelling costs, also.

$$\max Z = \sum_i \sum_j \sum_k f_{ij}^k \cdot \frac{t_{ij}^{min} \sum_k f_{ij}^k}{\sum_k f_{ij}^k t_{ij}^k} \tag{3-1}$$

$$minZ' = \sum_i \sum_j \sum_k f_{ij}^k \cdot C_{ij}^k \tag{3-2}$$

3.2 The restraining variables

$$\sum_k f_{ij}^k = Q_{ij} \tag{3-3}$$

$$\sum_k f_{ij}^k \cdot pr_{ij}^k < E_{ij} \tag{3-4}$$

$$\frac{\sum_k f_{ij}^k l_{ij}^k}{\sum_k f_{ij}^k} \ll L \tag{3-5}$$

$$\mathrm{minF}^k \ll f_{ij}^k \leq \mathrm{maxF}^k \tag{3-6}$$

$$\sum_i \sum_j \sum_k X_{ij}^k Y \leq B \tag{3-7}$$

$$C_{ij}^k = \propto_1 \cdot p + \sum_\beta \alpha_\beta \cdot C(p, \beta) \tag{3-8}$$

$$\alpha_1 + \sum_\beta \alpha_\beta = 1 \tag{3-9}$$

$$\forall \mathrm{i} \in \mathrm{O}, \forall \mathrm{j} \in \mathrm{D}, \forall \mathrm{k} \in \mathrm{M}$$

Generally speaking, the cost equals the transportation freight rate and other extra expenses, including comfort level and timing values. α_1、 α_β are parameters; p is the average price from location i to location j; $C(p, \beta)$ are other expenses including comfort level and timing values.

3.3 Analyzing the restraining variables and statistic application

(1) Meeting the overall transport demand

Without a doubt, the purpose of the passenger transportation system in metropolitan area is to meet the residents' demand.

Formula (3-3)，which expresses that the sum of passenger in entire traffic mode must meet the demand of residents travel. Besides, the travel demand of planning year can be calculated by the theory of growth rate.

(2) The environment capacity

Nowadays many metropolises are advocating 'green transportation' and 'sustainable development transportation', because of the traffic pollution. Therefore as city planners, we should consider limiting pollutant discharge, mostly in air pollution and noise pollution. In this model, we only consider the air pollution, for which we choose CO_2、NO_X as restraining variables.

Formula(3-4), expressing that the sum of pollutant emissions in all traffic mode cannot exceed environmental restrictions.

(3) Land coverage restriction.

Land use pattern is very closely related to transportation. Once the land use pattern changed, the travel will also be changed.

$\frac{\sum_k f_{ij}^k l_{ij}^k}{\sum_k f_{ij}^k} \ll L$, which represents the dynamic relationship between road traffic capacity and passenger transportation structure in metropolitan, and l_{ij}^k can be caculated by:

$$l_{ij}^k = \mathrm{D}^k \times d^k / b \tag{3-10}$$

D^k : safe lateral clearance of safety driving of k traffic mode(m);

d^k: safe spachead way of k traffic mode(m); b: average passenger volume of each mode(people/car).

(4) Each mode has its own transit capacity

Under the condition of its transportation tools and infrastructure being determined, each traffic mode has its maximum capacity of saturated state.

Formula(3-6), expressing that each mode has its own capacity limit. Lower limit reflects the complementary of different traffic mode and social fair competitiveness. While，upper limit reflects restrictions of social resources, environment capacity and so on.

(5) Investment constraint

Infrastructure and transport tools of each travel mode needs to spend a lot of money, so we must measure each mode, and try to choose a project which could meet the total investment constraints and achieve the maximum efficiency of transportation.

Formula(3-7)，representing that the investment of various has a fixed limit.

4 Algorithms

The model intends to get the solution through genetic algorithm. The basic idea of this model is: To obtain a set of solutions by encoding which can generates an initial, random population of individuals for a fixed size, to evaluate their fitness, to exert selection, crossover or mutation and other genetic manipulations to achieve population search, and to make the population evolved to the stage which includes the approximate optimal solution.

Step1：The model obtains a set of solutions by encoding, which generates an initial population. In the model, the basic operating parameters of Genetic algorithm are set: Population size $size(U) = 100$, Iteration limit $N = 100$, Crossover and mutation probabilities are taken at 0.5 and 0.05; Randomly generate an initial population; Calculate value of the fitness function for each chromosome, determine the minimum function value and the corresponding chromosome at the temperature of t_1, and make the number of iteration as $k = 1$.

Step 2：According to the population "Fitness" to evaluate the current chromosome of the population. Evaluation criteria is the efficiency value of passenger transport system.(The objective function formula(3-1))

Step 3：Use the constraints to modify evaluating value, select the probability according to the proportion of evaluation value, then go on cross, mutation and other genetic operations for iterations to generate a new population $U^{(k+1)}$.

Step 4：Continue to evaluate the current population of chromosomes(as Step 2).

The process of algorithm as shown in Fig.1.

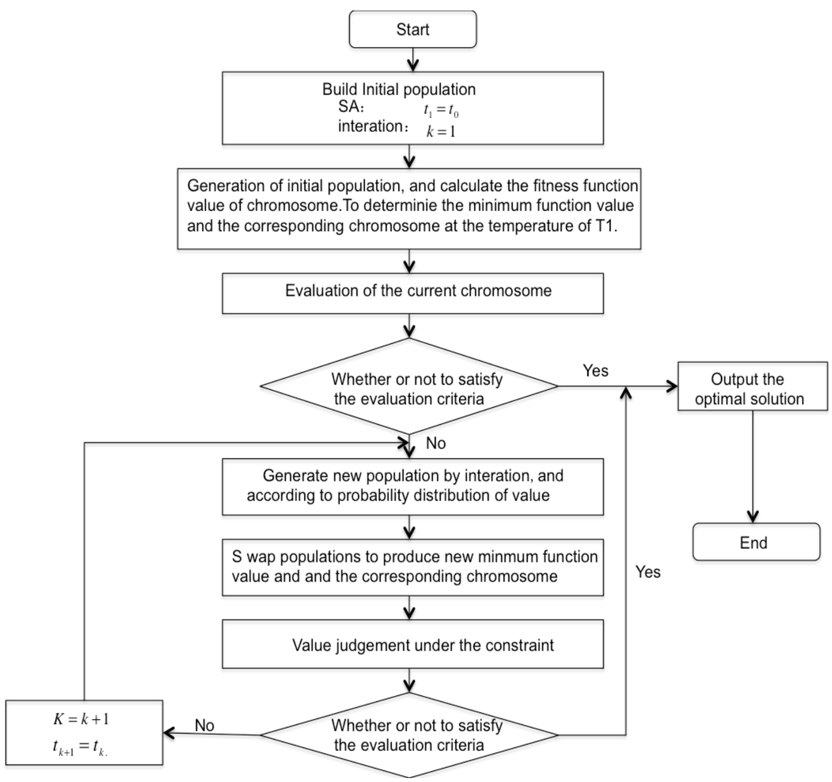

Fig. 1 Flow chart of genetic algorithm

5 The Rational Transportation Structure Allocation of Wuhan Metropolitan

5.1 The "Mode-Path" transportation characteristics from Wuhan to Xiaogan

Taking the central city and a peripheral city –"Wuhan to Xiaogan" in Wuhan metropolitan as an example, it can demonstrate how to allocate the reasonable transportation structure of metropolitan.

The “Mode-Path” in Wuhan-Xiaogan: car-road, car-highway, express, scheduled bus and the developing intercity railway(opened in 2016), as shown in Figure 2.

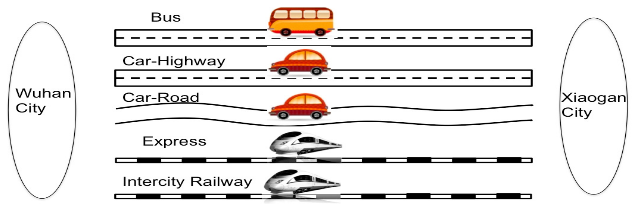

Fig 2. “Mode-Path” transportation from Wuhan to Xiaogan

1) Collecting and preparing data

According to the policy of Hubei Provincial Government, the almanac of Hubei Provincial Government, the planning of Wuhan metropolitan and expert opinions, it is capable of calculating the limit of environment capacity and pollution emission and per capita road area in Wuhan metropolitan. There are some transportation characteristics of 5 kinds of “Mode-Path” in Wuhan-Xiaogan, as shown in Table 2.

2) The total demand of passenger transport

According to the research in Wuhan metropolitan, it is known that the average daily passenger flow between Wuhan to Xiaogan is 3766 person trip(XU Wenxue,2007).We can predict that passenger flow would be 2.128m person trip in 2016, and the average daily demand is 5830 person trip，which is the total passenger travel demand between Wuhan and Xiaogan.

Tab2.Characteristics of intercity passenger transport “mode-path” in Wuhan-Xiaogan

Transportation Mode	Car-highway	Car - Road	Express	Bus	Intercity -Railway
Dynamic area(km^2/per)	50	2.5	0.5	5	0.5
Average price (yuan)	65	45	38.5	23	22
NO_X Emissions (g/ person·km)	6	7.5	0.18	1.5	0.18
CO_2 Emissions (g/ person·km)	1.2	1.4	0.04	0.15	0.04
Travel time(min)	40	55	30	65	30
Transportation capacity(person)	Min: 500 Max: 2915	Min: 500 Max: 2915	Min: 700 Max: 2500	Min: 1000 Max：2500	Min：1500 Max：3500

5.2 The results of the passenger transportation structure allocation model of Wuhan – Xiaogan

1) The results

Solving by the multi-objective programming model of metropolitan transportation structure allocation proposed in Section 3 and using the MATLAB software to run Genetic Algorithm, we can get the rational transportation passenger structure allocation between Wuhan and Xiaogan, as shown in Table 3.

Table 3．Rational passenger volume of transportation structure in Wuhan-Xiaogan

Mode-Path	Car-Highway	Car-Road	Express	Bus	Intercity -Railway
Daily passenger flow(person)	882	630	1275	1004	2089
Share	15%	11%	22%	17%	35%

5.3 The analysis of the solution

According to Tal.3, we know that car shares 26%, railway (express and intercity railway) shares 57% and passenger bus shares 17%.

The share of railway, bus and car travel separately are 12%, 12% and 46% in the passenger flow of Wuhan metropolitan in 2008(Institute of Comprehensive Transportation of National Development and Reform Commission, 2010), which is far more different from the transportation structure allocated by the model in this section.

According to the maximum efficiency of passenger transportation system in the objective function, the utilization of the Wuhan metropolitan's is 55.6% in 2008. However, the utilization is 74.1% after using allocation model in 2016.And there is 33.3% promoted of efficiency after being optimized by this model.

As shown in the Fig.3, from the point of car, the share should be decreased to 26% from 46%. The reduction of the private car's share is beneficial to the environment capacity and the road utilization; from the angle of rail transit, its share should be increased from 12% to 57%. It is chiefly because that the intercity railway from Wuhan to Xiaogan opened in 2016 will help achieve "Long-distance workers" and "Railway as public bus". Whether from the capacity, the frequency and the quality of service, the intercity railway is much better than the scheduled bus.

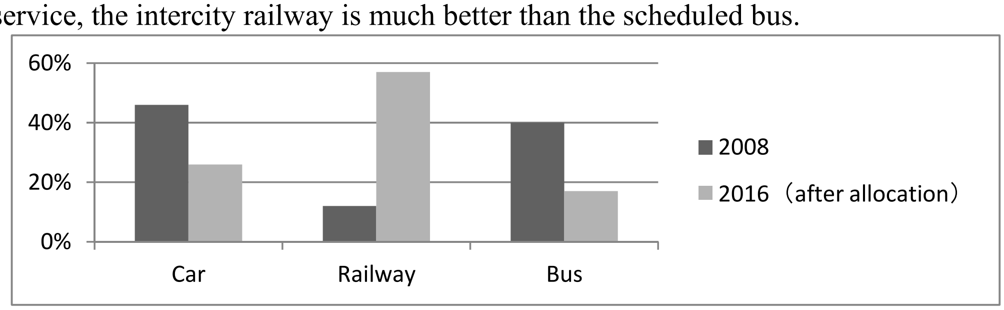

Fig.3 The changes between before and after allocation

6 The Development Suggestion of Transportation from Wuhan to Xiaogan

(1)The rapid development of railway is in line with the status quo of our country which has a high density of population and high aggregation of land. But the transfer between terminals of railway and urban areas also very important, otherwise the residents will reduce the probability of selecting railway.

(2)In order to reduce private transportation split rate, the government can enact the tail number limit and other policies to reduce the trip time of cars.

(3)The reasonable changes in passenger bus. Once operating in the intercity railway between Wuhan and Xiaogan in 2016, the split rate of bus will be transferred to the railways'. It's a challenge to change the operation of intercity bus.

References

Institute of Comprehensive Transportation of National Development and Reform Commission(2010). *Comprehensive transportation hub planning research report in Wuhan city*, Beijing

XU Wenxue and JIA Yuanhua(2007). *Transportation development strategy and countermeasures research on Wuhan metropolitan,* Beijing

Non-Motorized Vehicle Parking Demand at a Suburban Railway Station

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Abstract: A survey was made on non-motorized vehicle parking lot scale of line Tsukuba in Tokyo, the influence factors like station passenger flow, distance between station, land development around station, distance from city-center are analyzed, then fuzzy algorithm was built among the four influence factors and non-motorized vehicle parking lot scale. At last, non-motorized vehicle parking demand at suburban stations of metro line 7 was estimated as an example based on the fuzzy algorithm and the influence factors survey data.
Keywords: Suburban station of rail transit; Parking demand of non-motorized vehicle; Line Tsukuba in Tokyo; Fuzzy algorithm.

1 Introduction

Nowadays, with the irrational expansion of city and the problem it caused, great efforts were made to build sub-center or satellite city in China, thus suburban railway system is during rapid development for it is the traffic foundation for suburbs development and bear mass commuter trips. Since entry and exit are usually the weakest parts of thetransport chain, the access traffic system determines the service level and competitiveness of suburban railway to a degree.

For the high house price in city center and the traffic convenience of suburban railway, there are plentiful residential land around the suburban railway station in 3km, and for these residents, railway is usually chosen as a commuter tool. The commuter trip is regular and of high frequency, Non-motorized transportation, which is an important access mode within 3km, and characteristic of flexibility and mobility, has great advantages and potential to be the access mode of suburban railway. But currently, planning and design of non-motorized vehicle parking lot at suburban railway station are not given much consideration to, parking capacity is inadequate, management is poor and facility is simple, which result in share of non-motorized vehicle as access mode for rural railway transit is less than 10%, when in developed country, like Holland and Japan, the figure reached 30% or higher.

Currently, theory of non-motorized vehicle parking around suburban railway station, like parking demand predict, parking lot location, size and layout are lack of specificity and enforceability, The theories available are unable to effectively guide the actual design work, so this paper took Shanghai Railway Transit Line 7 as an example to predict non-motorized vehicle parking demand at suburban railway station.

2 Existing methods

In general, methods available only describe the calculation idea, lacking of a thorough calculation process, and parameters like share of non-motorized vehicle in access trips, transfer impedance can not be got properly for lacks behavior characteristics date. Thus methods available are lack of specificity and enforceability. There are mainly three method:

1) Model of attract rates

This model determines the parking lot scale by calculate the total parking demand in peak time, and this is relevant to land use and density around the station.

$$P_a = \sum_{i=1}^{q} b_i t_i \tag{1}$$

P_a— peak time parking demand（veh）;

t_i — land scale of various land type， km^2;

b_i— average vehicle attract for various land type per km^2。

The problem is that the model calculates parking demand for trip destination but not for transfer, while non-motorized vehicle parking at suburban railway station is usually for transfer to railway.

2) Estimate parking demand through make a survey on non-motorized vehicle share in transfer trip at an exit station

This method neglect problems exist in non-motorized vehicle parking, like inadequate capacity, not standardized management, poor safety guarantee, etc., resulting in the potential non-motorized vehicle transfer demand has been suppressed. It also neglects the difference between suburban and center city in non-motorized vehicle transfer and parking characteristic, trip of non-motorized vehicle to railway station is usually in larger number and of longer distance in suburban area, and parking time is also longer.

3) Logit model

This model need transfer impedance of non-motorized and its competitors to do modal split, but behavior characteristics data of residents around suburban railway station is unavailable and is difficult to get by a small survey. Besides, when using logit model, the assignment is based on the value of the resistance, for example, the impedance of the two lines are 5 and 10, respectively, or 95 and 100, respectively, the assign result is the same. But some factors of impedance can't be quantified like safety, convenience, etc., thus the impedance can't be obtained properly.

3 Comparative analysis

3.1 Parking problem of Shanghai metro line 7

Shanghai railway transit line 7 planned to originate at Baoshan district and destination at Pudong district, the north part of line 7 is a typical suburban railway ,connect a satellite town with center city, assume mass commuter and school trip. So B+R (Bike+ride) mode is suitable for the north part of line 7, especially for the suburban station, for that in suburban area passenger is less, so bus line is rare and the frequency is low, which means long walking distance or waiting time.

Through survey, we found that suburban station of line 7 is deficient in non-motorized vehicle parking facility, induce many illegal taxi and motorcycle. And it is difficult to give the accurate capacity of some exist non-motorized vehicle parking lot, for these parking lots are not experience careful planning and design, and the identification of parking scope is vague. From the quality point of view, non-motorized vehicle parking condition is poor, facility is simple, parking security can't be guarantee. Non-motorized vehicle parking is confusion and sometimes even affect the pedestrian traffic and vehicle traffic. The poor condition of non-motorized vehicle parking lot suppress the true parking demand.

3.2 Parking situation of Tokyo Line Tsukuba

The paper tried to calculate non-motorized vehicle parking demand at suburban railway by learning the advanced experience of foreign countries.

Tokyo and Shanghai are similar in urban characteristics, residents travel characteristics and railway transit scale in future. so the paper decide to make a comparative analysis between Tokyo transit and Shanghai transit.

Tokyo suburban rail transit line Tsukuba approved by Japanese government in non-motorized vehicle feeder organization, is similar with the north part of Shanghai rail transit line No. 7. It is opened in 2005, and the passenger flow is mature and stable now.

The two line are similar in line location, line function, they both connect the city center and the suburban area, and bear a lot of commuter trips.

In traffic theory parking demand is considered to relevant most to land use around, passenger flow, station distance from city center and average distance between stations. Table 1 shows the figures of the parameters of Tokyo Line Tsukuba. And fuzzy algorithm was used to build the relationship between non-motorized vehicleparking demand with the four factors mentioned above.

Figure 1. Location of Tokyo metro line Tsukuba

Figure 2. Location of Shanghai metro line 7

Table1. Non-motorized vehicle parking lot scale and situation of four influence factors of line Tsukuba

Station	average passenger flow (per day)	development level of land use	average distance between station (km)	Station distance from city center (km)	non-motorized vehicle parking capacity (veh)
Tsukuba	15,117	16	2.7	58.3	410
Kenkyū-gakuen	3,691	12	3	55.6	0
Bampaku-kinenkōen	1,684	12	3.25	51.8	300
Midorino	2,360	9	3.75	48.6	0
Miraidaira	2,800	16	5.45	44.3	100
Moriya	11.863	16	6.15	37.7	220
Kashiwa-Tanaka	2,640	1	3.85	32	80
Kashiwanoha-campus	11,010	16	2.75	30	1600
Nagareyama-ō takanomori	27,753	12	2.85	26.5	660
Nagareyama-centralpark	2,745	1	2.2	24.3	0
Minami-Nagareyama	26,165	9	2.5	22.1	270
Misato-chūō	7,368	12	3.25	19.3	1600
Yashio	13,424	9	3.65	15.6	50
Rokuchō	9,358	9	2.5	12	410
Aoi	5,625	12	2.25	10.6	500
Kita-Senju	193,976	25	2	7.5	300
Minami-Senju	14,597	6	2.2	5.6	230
Asakusa	8,111	12	2	3.1	80
Shin-Okachimachi	33,754	25	1.55	1.6	350
Akihabara	224,608	25	1.6	0	120

4 Fuzzy algorithm

Fuzzy algorithm is especially applicable to the subject investigated with fuzzy concept and fuzzy logic[8], based on that there is correlation between parking capacity and four factor but the relationship is not clear, fuzzy algorithm is used for design fuzzy inference method by information fusion of influence factors.

First, the issueshould be expressed by fuzzy mathematics model. In the fuzzy reasoning machine, surrounding land developed level M (i), site distance from city center D (j), average station distance S(k), passenger flow volume P (l) wasdefined as input, and non-motorized vehicle parking lot scale PK as output, the domain of each variable are: M(i)=[0,25];D(j)=[0.60];S(k)=[0,6.5];P(l)=[0.15000]

Each variable was divided into 5 grades from 1(low) to 5(high). Design fuzzy inference rules by factors, and designed membership function as shown in figure 3.

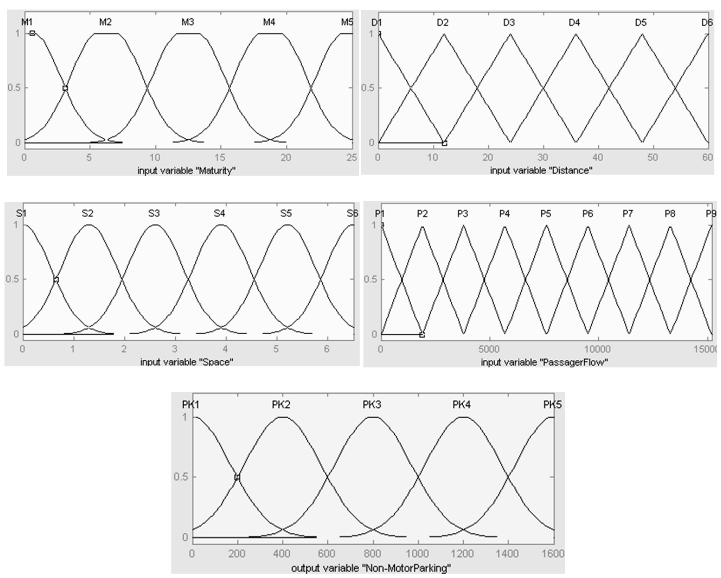

Figure 3. Membership function of each variables

By using the MATLAB fuzzy control toolbox for operation, select the Mamdani method for fuzzy reasoning, and gravity center method for defuzzification process, then we get the fuzzy control rules.

Finally，the model above was used as an example with the statistical station data{M (I), D (J), S (k), P (L)}of Shanghai metro line 7 as the input of fuzzy reasoning machine, to make the estimation of non-motorized vehicle parking capacity more accurate and reliable. The results can be seen in Table 2.

5 Conclusion

Non-motorized vehicle parking demand of south part station of Shanghai metro line 7 was obtained by comparative analysis between Shanghai metro line 7 and

Tokyo metro line TSUKUBA by fuzzy algorithm, but this is only applicable to this case, further study should focus on more general model. For it is difficult to get the predict passenger flow, data used in model is current flow, with the new line built and put into operation, the passenger flow will change , and so will the non-motorized vehicle parking capacity of the station.

Acknowledgements

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Table 2. Non-motorized vehicle parking demand of Shanghai metro line 7 station

station	development level of land use	Station distance from city center(m)	average distance between station(m)	average passenger flow(per day)	non-motorized vehicle parking demand
Meilan Lake	12	18,443	--	10,414	648
Luolan xin cun	4	17,096	1347	4,676	358
Panguang Road	4	14,266	2830	3,235	330
Liu xing	8	13,286	980	7,781	542
Gucun Park	12	11,586	1700	20,016	1086
Qihua Road	2	8,877	2709	1,948	810
Shanghai University	12	7,186	1691	14,598	708
Nanchen Road	6	6,249	937	5,435	416
Shangda Road	6	4,906	1343	6,707	397
Changzhong Road	12	3,560	1346	13,120	784
Dachang Town	6	2,328	1232	4,764	386
Xingzhi Road	18	1,291	1037	19,483	815
Dahua Three Road	20		1291	21,265	952

References

Anderson D H，Hall L O MR.(1999) FIS: Mamdani rule style fuzzy inference system// Systems, Man, and Cybernetics. Tokyo, JAPAN： IEEE International Conference,:238-243.

Cao Ping, Chen Jun.(2008)Bicycle-metro station locating and its demand predicting. Technology & Economic in Area of Communication,10(3):87-89.

Economic Information Department of CCPIT. (1998)Japanese Bike market Dialysis. China's Foreign Trade, (1):39-40.

Liu Shao-cai. (2010)Navigate to talk Japan bicycle. China Bicycle, (2):54-58.

Piet Rietveld.(2000) The accessibility of railway stations: the role of the bicycle in The Netherlands. Transportation Research:Part D, (5):71-75.

Yin Qiumin, Deng Wei.(2008)Planning and Management of the Transfer between Bicycle and Urban Mass Transit. Transportation Science & Technology, (2):92-94.

Comprehensive Development Scale of a High-Speed Railway Station Based on TOD

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Abstract: TOD refers to transit-oriented development. This paper analyses the development scale of foreign high-speed railway stations and the surrounding areas by referencing the successful experience of TOD mode in foreign cities and combining the related information of land development and city development. It comes out that the development scale is different from various kinds of high-speed railway stations and the surrounding areas, and summarizes the differences as well. In the meanwhile, this paper puts forward the calculation basis of the development scale of high-speed railway stations based on TOD mode through analysis, as well as the basic ideas and method of determining the upper and lower bounds.
Keywords: TOD; High-speed railway; Stations; Comprehensive development; Scale.

1. Introduction

TOD refers to transit-oriented development. The concept was first proposed by American architect and planner Peter Calthorpe in order to solve the unrestricted spreading problem of USA cities after World War II, and it takes the public transport as the center to build comprehensive development of urban pedestrian district. The public transportation is mainly included subway, light rail and bus lines, and it takes bus stations as the center, 400~800 m (5~10 minutes' walk) as the radius to establish the center square or city center. Its characteristics lie in that it sets work, business, culture, education, living as a whole to achieve the purpose of "mixed use".

The research on comprehensive development of traffic and land started early in foreign countries. In 1993, Peter Calthorpe put forward that the TOD mode could replace the unrestricted spread development mode in outskirts district in his book *The American Metropolis-Ecology，Community，and the American Dream*, and he worked out a set of detailed rules for the city land use based on TOD strategy. In 1997 Cervero and Kockelman brought forward the "3D" rule of TOD, which is "density", "diversity" and "design".

Li Yan established a combined model of dividing traffic mode and traffic distribution in *Research on Sustainable Development of City Rail Transit Based on TOD*, which was suitable for the characteristics of China's traffic and TOD community.

Zhao Jing discussed the special background and conditions of implementing TOD in *Research On the TOD Programming Method Suitable for Chinese Cities* , and put forward the definition of TOD mode suitable for Chinese city's characteristics by adopting the SWOT analysis method.

The TOD mode of comprehensive development of high-speed railway in our country is still in the exploratory stage, but the successful experience by utilizing TOD mode in foreign urban rail transit provides a reference mode for it. The comprehensive development scale of high-speed railway stations based on TOD mode varies from development patterns and spatial structure.

1.1 Industrial park pattern

Taken Taoyuan, Xinzhu, Tainan, Taichung, Chiayi station in Taiwan as example to analyze this pattern.

The development of high-speed railway station surrounding areas (high-speed railway special district, Fig. 1) in Taiwan is with particular emphasis on the development of the industry, giving full play to the multiplier effect of high-speed railway and the leading industry itself. It develops high-speed rail industrial parks in the high-speed railway station surrounding areas, and these specific areas are divided into station special district and special industrial zone and other contents. For example the special district of Xinzhu station takes the advantages of science and technology park in Xinzhu county to develop the biomedical science and technology; Taichung Station special district combines the advantages of traffic, the surrounding industrial infrastructure and human resources, to develop super scale commerce, entertainment and shopping facilities, administrative center and science and technology industrial park.

Fig.1 Planning map of Taoyuan, Xinzhu high-speed

On the whole, the scale of high-speed rail station surrounding areas in Taiwan are small, from 100 hectares to 400 hectares. The land scale of Taoyuan, Xinzhu, Taichung, Chiayi, Tainan and other sites around the stations are listed in table 1. The sites give full consideration to the needs of stations and industrial development when utilizing land.

Table 1. Area statistics of five station special district in Taiwan

Station	Special district area（hectares）	Function positioning
Taoyuan	490	International business city
Xinzhu	309.22	Biomedical science and technology city
Taichung	273.35	Entertainment and shopping city
Chiayi	135.24	Leisure and Recreation City
Tainan	299.72	study of Ecological City
Total	1507.53	

The spatial structure characteristic of high-speed railway station surrounding areas for industrial park comes that high-speed railway station (hub) +industrial park+ peripheral general city built-up area structure， and the land-use scale mainly depends on the basis of the original city industry and the land-use conditions of high-speed rail station surrounding areas . The better the foundation of the city Industry is, the larger comes the scale. In general the land scale of high-speed railway station surrounding areas for industrial park is relatively large, usually about 1~5 square kilometers.

1.2 City center pattern

Through the case analysis of high-speed railway station surrounding areas in Europe and Japan, it comes out that the high-speed railway station surrounding areas based on TOD has some differences in the scale due to the impact of urban development potential and other factors, ranging from 0.5~1.0. In general, the central area or deputy district scale formed from the high-speed railway station surrounding areas in small city is relatively smaller, around in 0.5~0.8 square kilometers, while the city in larger scale, the scale of its high-speed railway station surrounding areas of the city center or vice center size is relatively large, about in 0.8~1.0 square kilometers. There are also some exceptions that can reach 1.5 square kilometers (table 2).

Table 2. Foreign high-speed railway station surrounding areas

number	name	area（ha）
1	Tokyo station surrounding areas	126
2	Ikebukuro Station surrounding areas	85
3	Shinagawa Station surrounding areas	65
4	Shinjuku Station surrounding areas	114
5	Nagoya Station surrounding areas	50
6	New Osaka station surrounding areas	105
7	Brussels North Station surrounding areas	100

8	Kobe Sannomiya station surrounding areas	43
9	World Trade Center Amsterdam station surrounding areas	130
10	Fukuoka Hakata Station surrounding areas	101
11	Yokohama station surrounding areas	110
12	new Yokohama station surrounding areas	125
13	Kaihin-Makuhari station surrounding business areas	78
14	Kyoto Station surrounding areas	62
15	Frankfurt central station surrounding areas	138
16	Germany Stuttgart High-speed Rail station surrounding areas	109
17	Lille France surrounding areas	120
18	France Ladd Fong Slovakia District Station surrounding areas	160

2 Calculation of comprehensive development scale

2.1 calculation basis

Most high-speed railway cities delimit a large range of area for the development land use of high-speed railway station surrounding area. In the meanwhile, the scale of high-speed railway station surrounding area exists great differences and varies from 2~3 square kilometers to 30~40 square kilometers.

The scale, populations and economic development level of the cities can have direct impact on the passenger flow and traffic flow of high-speed railway stations. Generally speaking, the bigger the city scale is, the larger the passenger flow and traffic flow will be.

As the node of high-speed railway network, high-speed railway station surrounding area has a large volume of passenger flow getting in and out, and these flow needs to be distributed to the station surrounding area, as well as the periphery city space. In the meanwhile, the high-speed railway station and its surrounding area absorb passenger flow from the periphery city space, and deliver these flow to other nodes of high-speed railway station network. The number that needs to be absorbed and distributed requires passenger flow prediction to calculate the exact volume. After obtaining the passenger flow, the composition and proportion of all kinds of passenger flow need to be analyzed based on the survey data and experimental figures. In addition, the demand volume of the functional facility for the development project can be computed out according to the demand.

The above are the general calculation basis for the development scale of high-speed railway station surrounding area. In the specific project, the development scale and proportion should be flexibly adjusted according to the development positioning strategy made by development project of high-speed railway station surrounding area.

2.2 Methodology

Because the comprehensive development of high-speed railway station in the future will bring a large number of passenger flow, which would be superimposed with the existing passenger flow channel. Therefore, the superimposed passenger transport demand will exceed the station load-carrying capacity, or will result in land loss due to over exploitation. Thus the basic ideas and method to determine the upper and lower bounds of comprehensive development of high-speed railway station and its surrounding area based on TOD mode are put forward.

(1) Method to determine the upper bound

The passenger demand that produced by all kinds of land development type and scale cannot exceed the load-carrying capacity of the high-speed railway station. The basic model to determine the upper bound can be expressed as the following formula:

$$r_{sta} = \sum_{i=1}^{m} x_i y_i z_i \tag{1}$$

Where

r_{sta} is the passenger flow getting in and out of the high-speed railway station;

x_i is the *i* kind of land scale of high-speed railway station;

y_i is the *i* kind of land development intensity of high-speed railway station;

z_i is the passenger flow that produced by the *i* kind of unit land construction area of high-speed railway station.

The passenger flow distribution model can be established by taking advantage of the passenger flow getting in and out of the station, as well as its spatial distribution characteristics. The model is shown as (2).

$$D = f\left(r_{sta}\right) \tag{2}$$

Based on this, the one-way traffic volume (r_{seci} (*person time*) , *i=1, 2,…, n*) of each section in rush hour can be worked out.

Set the one-way traffic volume of maximum section in rush hour not exceeding the load-carrying capacity of station as the controlling condition, and determine the upper bound of development. The limit condition can be expressed as (3).

$$r_g = r_{seci}\left(max\right) \le r_{\sec}^{up} \tag{3}$$

Where

r_g is the one-way traffic volume of maximum section in rush hour;

$r_{\sec}^{up}$ is the load-carrying capacity of station.

(2) Method to determine the lower bound

High-speed railway passenger transport is one kind of transport mode with a large capacity, which is involved with huge amount of investment. Once the passenger flow of high-speed railway station is insufficient, great investment waste will be caused, which would make the operator side and investment side encounter with huge losses. Therefore, in order to avoid insufficient passenger flow and to guarantee the transport efficiency, the lower bound of the development scale needs to be controlled.

From the angle of investment and operating efficiency of high-speed railway stations, the passenger flow generated by various types of land development cannot be under the minimum traffic flow that makes assurance of high-speed railway station financial balance (at a given policy subsidy).

The basic model to determine the lower bound of development scale for high-speed railway station surrounding area is shown as (4).

$$f(r_r)+R_c(r_g)+R_s+R_t=f_\beta(r_r)+C_c(r_g)+C_{yy}(r_g)+C_j+C_s+C_{dx} \quad (4)$$

Where

$f(r_r)$ is the operating revenue function whose main calculation basis consists of daily passenger flow volume and other revenues such as advertisement, internal station commercial rent. These commercial revenues would be calculated pro ratio to simplify the model;

$R_c(r_g)$ is the residual value of cars and residual value function; R_s is the residual value of the equipment; R_t is the residual value of building project; $f_\beta(r_r)$ is the tax function; $C_c(r_g)$ is the car purchase fee function; $C_{yy}(r_g)$ is the operation fee function; C_j is construction cost, which mainly consists of building project construction cost, advance fee, reserve funds and other project cost. The construction period of all costs is four years, and the costs should be calculated 25% of every year; C_s is equipment cost which represents purchase equipment fees and equipment replacement cost;

C_{dx} is cost of overhaul.

The calculation method of each cost and profit is as follows:

$$f(r_r) = 365 r_r p_p (1+\alpha)\left(P/A_I, N\right) \tag{5}$$

$$R_c(r_g) = \frac{2r_g l}{DV} YFc_{dj}\left[\left(\beta_c + \beta_c^w\right)/(1+I)^N + \sum_{j=1}^{n_{gz}-1} \beta_c/(1+I)^{jL_c}\right] \tag{6}$$

$$R_s = c_s^d l\left[\left(\beta_S + \beta_S^w\right)/(1+I)^N + \sum_{j=1}^{n_{gz}^s-1} \beta_c/(1+I)^{jL_s}\right] \tag{7}$$

$$R_t = c_t^d l \beta_t/(1+I)^N \tag{8}$$

$$f_\beta(r_r) = 365 r_r p_p (1+\alpha)\beta\left(P/A_I, N\right) \tag{9}$$

$$C_c(r_g) = 0.0731Bc_{cgl}\left[\frac{r_g}{BD} Y\left(2+4h_{cg}+H_p\right)\right]\left(P/A_I, N\right)(1+I) \tag{10}$$

$$C_j = c_j^d l(1-\alpha_b) \tag{11}$$

$$C_s = c_s^d l\left[(1-\alpha_b) + \sum_{j=2}^{n_{gz}^s}\left(P/F_I, (j-1)L_s\right)\right] \tag{12}$$

Where

r_r is daily passenger flow of station, $r_r = \sum r_{sta}/2$; p_p is the ticket fee corresponding to average distance ; α is the proportion that other incomes account for total fees; $\left(P/A_I, N\right)$ is equal value pay series present value factor; I is the social discount rate; N is the cycle of high-speed railway station project; r_g is he one-way traffic volume of maximum section in rush hour; l is the length of track line; D is the specified number of train staff; V is the travelling speed of the train; Y is the capacity reserve coefficient; F is the maintenance and car reserve coefficient; c_{dj} is the unit price of cars; β_c is the car life salvage value rate; β_c^w is the residual value rate of unused cars at the end of project; n_{gz}^s is the purchase number of equipment during the lifetime of project; L_s is the lifetime of equipment; β_t is the residual value coefficient of building construction; β is the ratio of tax; α_b is the government subsidy coefficient; c_{cgl} is the unit price of operating fees; h_{cg} is the second coefficient in rush hour; H_p is the departure pair number in daily normal time.

3 Conclusions

Through the above analysis, the conclusion comes that the scale of high-speed railway station surrounding areas in foreign cities is basically the same. Generally speaking, the high-speed railway station surrounding area of small city is relatively small, while in large scale city it is larger. The scale of surrounding areas in different types of high-speed railway stations is basically various.

References

Calthorpe P. The next American metropolis: Ecology, community, and the American dream. *Princeton Architectural Press*, 1993.

Li Yan. Research on Sustainable Development of City Rail Transit Based on TOD. Harbin Institute of Technology, 2008.

Wang Zhi, Ye Xiafei, Ming Ruili. Research on the Reasonable Land Development Scale along City Rail Transit Lines. Journal of Tongji University: Nature Science Edition, 2011, 39(3): 376-380.

Zhao Jin. Research on the TOD Programming Method Suitable for Chinese Cities. Highway Engineering, 2009, 33(6): 64-68.

Ranking of Transit Network Optimization Schemes Based on Set Pair and Entropy Analysis

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Abstract: Due to many uncertainties involved in the transit network optimization evaluation process, many existing methods could not portray different types of uncertainty. So the evaluation results couldn't objectively reflect actual problem. Based on the research results of previous scholars, this paper proposed set pair and entropy analysis in the ranking of transit network optimization schemes and constructed decision-making models. The method was applied to an example. Results showed that the method could solve the problem of non-unity between several indexes and the uncertainty of subjective opinions could be reduced. The calculation process was simple and easy to use. The method provided new ideas for the analysis of uncertainties for the public traffic network optimization.
Keywords: Transit network; Ranking of optimization scheme; Set-pair; Entropy.

1 Introduction

Urban public transit is very important for passenger's travel. Optimal transit network can improve service level of public transit and bring convenience to people. It also can alleviate traffic tension and promote the healthy and sustainable development of public traffic. Hu Qizhou and Zhang Weihua presented the decision making model for the optimization of urban public transport network by using grey related degree (Hu Qizhou and Zhang Weihua, 2007).They also set up the decision making model by quantum analysis and cosine formula(Hu Qizhou and Zhang Weihua, 2008).NI Jie and LIU Zhiqiang analyzed the restraint condition of the public transport optimization and plan the public transport network by using Ant algorithm method (NI Jie and LIU Zhiqiang, 2007). Tang Kefu and Wu Dawei proposed a new optimization model and developed an adapted genetic algorithm to solve the model (Tang Kefu and Wu Dawei, 2004). However, many uncertainties will happen in the process of public transit network optimization evaluation. Some methods cannot characterize different types of uncertainty. So the actual problems maybe not be reflected. In this paper set-pair and entropy is used for the public transit network optimization. The model can analyze the internal connections of the systeminlocal and overall ways. It is easy to use and the process of calculation is simple.

2 Set Pair - Entropy Analysis Method

2.1 Set pair analysis

Set-pair analysis (SPA) is a new system theory which was put forward by Zhao Keqin (Zhao Keqin, 2000). His main point is that certainty and uncertainty can be regarded as one system. Set pair is consisted by two related sets. It can be separated by the relationship of the two set as "Same", "Different", and "Opposite". And the uncertainty caused by fuzziness, random and information shortage can be uniformly processed by SPA.

Under certain conditions, the connection degree can be defined as follows:

$$\mu = a + bi + cj \qquad (1)$$

μ is connection degree of the two sets. i is the difference degree mark. j is opposite degree mark. i and j are both regarded as coefficients, j=-1, $i \in [-1,1]$.

$$a + b + c = 1 \qquad (2)$$

Assuming that the comparison of public transit network optimization schemes does not consider the difference, the relation degree expression is used to highlight the same and opposite degree. The object to be evaluated and the ideal scheme form one set-pair for set-pair analysis.

$$a + b + c = 1, \quad b = 0, \quad c = 1 - a \qquad (3)$$

2.2 Entropy weight coefficient

In order to reduce the subjective factor in decision making, in this paper entropy weight of objective method is adopted to determine the weight vector of the index. The procedure is as follows:

The entropy of the j optimization objective is defined as follows.

$$H_j = -\frac{1}{\ln n}\sum_{i=1}^{n} f_{ij} \ln f_{ij}, j = 1,2,\ldots,m \qquad (4)$$

$$\text{Where, } f_{ij} = \frac{r_{ij}}{\sum_{i=1}^{n} r_{ij}}, i = 1,2,\cdots,n; \; j = 1,2,\cdots,m \qquad (5)$$

And if $r_{ij} = 0$, make $f_{ij} = 0$.

$$w_j = \frac{1 - H_j}{m - \sum_{j=1}^{m} H_{ij}}, j = 1,2,\cdots,m \qquad (6)$$

$$W = \{w_1, w_2, \cdots, w_j\}, j = 1,2,\cdots,m \qquad (7)$$

In multi-objective decision making, the scores of all the schemes by one measurement should be normalized before calculating entropy as the objective weight of this measurement.

2.3 Evaluation method of set pair and entropy

$M_1, M_2, \cdots, M_n$ are the objects to form the set to be evaluated. There are measurements $C_1, C_2, \cdots, C_m$ and every measurement has a measure score $f_{ij}(i=1,2,\cdots,n; j=1,2,\cdots,m)$ .Construct the multi-object evaluation matrix A as follows.

$$A = \begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1m} \\ f_{21} & f_{22} & \cdots & f_{2m} \\ & & \vdots & \\ f_{n1} & f_{n2} & \cdots & f_{nm} \end{bmatrix} \quad (8)$$

$$A_0 = \left(f_{01}, \quad f_{02}, \quad \cdots f_{0i} \cdots \quad f_{0m}\right) \quad (9)$$

Where f_{0i} is the ideal score of the i measurement for the ideal scheme.

Comparing all the scores of the evaluation matrix with the scores of the ideal scheme matrix will get the identical degree of d_{ij} ,If $f_{ij} \prec f_{0j}$ (benefit type) $d_{ij} = \frac{f_{ij}}{f_{0j}}$; If $f_{ij} \succ f_{0j}$ (cost type), $d_{ij} = \frac{f_{0j}}{f_{ij}}$

- **Model one**

The non-weighted connection degree matrix U between the to-be-evaluated object and the ideal scheme is constructed as follows.

$$U = \begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1m} \\ d_{21} & d_{22} & \cdots & d_{2m} \\ & & \vdots & \\ d_{n1} & d_{n2} & \cdots & d_{nm} \end{bmatrix} \quad (10)$$

We calculate the weights of all characteristics following the equation 4-7 to determine the weighted connection degree matrix R of A. The objects to be evaluated and the ideal scheme are defined as follows.

$$R = U \times W = \left(u_1, u_2, \cdots, u_n\right) \quad (11)$$

$$u_i = \sum_{j=1}^{m} w_j d_{ij} \ (i = 1,2,\cdots n, j = 1,2,\cdots m) \quad (12)$$

The ranking of the evaluated objects can be determined by the values of u_j. The bigger the value of u_j, the closer to the ideal scheme, and the better the evaluated object. The object with the biggest connection degree is the optimal line net optimization scheme.

- **Model two**

Firstly we normalize all attribute value of all evaluation index of each evaluation scheme. According to equation 10, we construct the similarity degree matrix for evaluation scheme and ideal scheme U_A and U_C.

$$U_A = \begin{bmatrix} d_{A11} & d_{A12} & \cdots & d_{A1m} \\ d_{A21} & d_{A22} & \cdots & d_{A2m} \\ & & \vdots & \\ d_{An1} & d_{An2} & \cdots & d_{Anm} \end{bmatrix} U_C = \begin{bmatrix} d_{C11} & d_{C12} & \cdots & d_{C1m,} \\ d_{C21} & d_{C22} & \cdots & d_{C2m} \\ & & \vdots & \\ d_{Cn1} & d_{Cn2} & \cdots & d_{Cnn} \end{bmatrix} \quad (13)$$

Where $d_{Aaj} + d_{Cij} = 1$. If d_{ij} is the identical degree, $d_{Aij} = d_{ij}$. If d_{ij} is the opposite degree, $d_{Cij} = d_{ij}$.

Based on the Entropy and Weight method, we calculate the weights of similarity degree matrix U_A and U_C.

$$W_A = \{w_{A1}, w_{A2}, \cdots, w_{Aj}\} W_C = \{w_{C1}, w_{C2}, \cdots, w_{Cj}\}, j = 1,2,\cdots,m \quad (14)$$

Then we will calculate the connection degree matrix of weights of the evaluated objects A and C and the ideal scheme.

$$R_A = U_A \times W_A = (u_{A1}, u_{A2}, \cdots, u_{Am}) \; R_C = U_C \times W_C = (u_{C1}, u_{C2}, \cdots, u_{Cm}) \quad (15)$$

The identical degree is a positive index and the bigger the better. The opposite degree is the negative index and the smaller the better. The ultimate ranking can be achieved by similarity degree and the similarity degree ranking method as follows.

$$R_i = \frac{R_A}{R_A + R_C}, i = 1,2,\cdots m \quad (16)$$

The bigger the value, the closer the scheme is to the ideal scheme. Therefore evaluation can be based on the value of similarity degree.

Model two divides equation (10) into two parts. The uncertainty can be evaluated from the relation between the part and the whole.

3 Example

The above method is applied to the case mentioned in the paper by HU Qizhou and ZHANG Weihua (HU Qizhou and ZHANG Weihua, 2008). The city government requires the transportation department to optimize the current public transit network in order to improve the utilize efficiency of current traffic resource and alleviate the conflict between demand and supply of traffic. Transportation planning and design institute put forward five schemes. The value of constraint is as follows.

Table 1. The value of constraint

Constraint	Scheme 1	Scheme 2	Scheme 3	Scheme 4	Scheme 5
non-linear rate/%	1.29	1.35	1.40	1.37	1.58
flow unevenness coefficient/%	1.32	1.43	1.47	1.48	1.36
average transfer times/ time	1.80	2.20	1.90	2.00	1.90
the efficiency of network load/%	0.73	0.79	0.68	0.72	0.78
line overlap factor /%	2.30	2.80	2.10	2.90	2.70
walking time /min	7.00	6.90	7.50	6.50	5.80
line length /km	12.20	11.90	10.20	11.30	13.60

The five schemes can meet the constraint condition of city public transit network optimization. We set six targets mentioned in Table 2.

Table 2. The objective function value of schemes

Scheme	Economic benefits of Public transportation enterprise / million	Line coverage rate /%	Direct ratio /%	Daily load factor of transit network /%	Passenger travel time /min	Efficiency of transit network /%
1	60.5	159.8	65.5	60.5	35.7	60.1
2	58.5	185.5	58.5	55.5	20.2	40.3
3	69.5	150.2	75.5	45.5	30.5	90.7
4	65.5	165.8	62.5	50.6	25.3	50.6
5	63.5	180.5	77.3	40.5	25.5	80.2

Note: Indexes are benefit type except the total travelling time of passengers is cost type.

The best scheme is required to be selected from the five schemes. So the decision-making matrix is defined as follows.

$$A = \begin{bmatrix} 60.5 & 159.5 & 65.5 & 60.5 & 35.7 & 60.1 \\ 58.5 & 175.5 & 58.5 & 55.5 & 20.2 & 40.3 \\ 69.5 & 150.2 & 75.5 & 45.5 & 30.5 & 90.7 \\ 65.5 & 165.8 & 62.5 & 50.6 & 25.3 & 50.6 \\ 63.5 & 180.5 & 77.5 & 40.5 & 25.5 & 80.2 \end{bmatrix}$$

Connection degree matrix calculated by model one as follows.

$$R = (0.798, 0.826, 0.865, 0.806, 0.866)$$

There is no difference among all the evaluation schemes. And the ranking result is 5, 3, 2, 4 and 1. The fifth one and the third one are so close to differentiate and this method is not precise.

By model two, the similarity degree matrix is calculated as follows.

$$R = (0.788, 0.696, 0.812, 0.734, 0.788)$$

The ranking result is 3, 5, 1, 4 and 2. The third one is the best one. The fifth one came close to the first one.

From the above process, it can be inferred that the optimal scheme is different by different models. We should use the right model according to the conditions. Then the scheme selected is the best one.

4 Conclusions

Based on the set pair and entropy weight theory we construct two decision-making models. The problem of non-standardized dimensions of all measurements has been solved. The subjective uncertainty has been reduced. We have achieved reasonable results. This method can provide new analysis method for public transit network optimization.

References

HU Qizhou and ZHANG Weihua(2007). "Grey related degree model for the optimization of urban public transport network". *Journal of Systems Engineering,* 22(6)

HU Qizhou and ZHANG Weihua(2008). "Cosine prioritizing method for the optimization scheme of public traffic network based on information entropy". *Systems Engineering-Theory & Practice,* 28(12)

Hu Qizhou and Zhang Weihua (2009). City public transportation system optimization model and evaluation method. Beijing: Science Press

NI Jie and LIU Zhiqiang(2007). Public Transport Network Optimization Method Based on Ant Algorithm. *Computer and Communications,* 25(1)

Tang Kefu and Wu Dawei(2004). "Study on the optimization methods of bus network based adapted genetic algorithm". *Journal of Chongqing Jiaotong University*

Zhao Keqin (2000). Set pair analysis and its preliminary application. Hangzhou: Zhejiang science and Technology Press

Construction Sequence of an Urban Rail Transit System Based on Multi-Objective Lattice Order Decision Making

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Abstract: To further explore the construction of urban rail transit network in the timing of each line, constructed the index system related factors and proposed a multi-objective decision algorithm based on lattice order. Firstly, by constructing a series of rail-building program more objective evaluation system lattice order decision, based on indicators of the type of indicators dimensionless processing, integrated power and data policymakers subjective right to compute the dispersion of objective evaluation of the relative weight of heavy and binding decision matrix, by calculating the difference between the value of comprehensive programs to achieve grid sequence of ordering options, the application of the decision-making method Chengdu alternative rail transit construction to evaluate the timing of the program. The results show that: the usage of multi-objective decision algorithm lattice order determined by the results and the actual timing of the construction is consistent, and the algorithm can effectively avoid over-dependence on the actual objective data and rational decision-makers of the limited nature of defects and other problems, indicating that the model to provide a method for the construction of urban rail transit timing.
Keywords: Urban rail transit; Construction schedule; Multi-objective lattice order decision making; Case verification.

1 Introduction

Relative usage of traffic demands and the limited road resources make urban rail transit development(Jinjian,2006), much attention has been paid to rail transportation network as a backbone of urban public transportation, for the travel characters of different passenger corridor and passenger transportation tasks at the same time also determines the level of a city public transport services. Determine the sequence of rail network construction quality will directly affect the future development trends and the economic benefit of city rail and even affect the expansion of urban spatial axis, so the rail transit network construction of time-series analysis has important affect.

At present, both at home and abroad has do some research for the city rail transit network construction and puts forward some principles of qualitative analysis or quantitative analysis of the algorithm, but too much subjective factors such as quantitative parameter selection weight is differ, too many constraints, lead the model's methods adaptability is not enough. Such as Huang Rui (Huangrui,2012) to the grade of rail transit network, set up based on node important degree - line importance of rail transit construction sequence model, through the construction of comprehensive importance size sequence. The algorithm of node selection is largely based on the overall urban planning, and the node important degree and the surrounding land, traffic also is closely linked, difficulty of quantitative research. Zhang Jiamin (Zhangjiamin,2013) by technical and economic characteristics of urban rail transit project, based on the Monte Carlo simulation to improve the level of analysis algorithm, according to the average accumulative grading evaluation to determine the sort of construction projects. This method is with interval number to represent the weight range, but if the hierarchical values more discrete, weaken the statistical average values represent the real project classification of reliability. To (Chenghua,2010) in qualitative analysis, such as the recent construction on the basis of the fixed number of year, the scale of the recent construction funds, puts forward recent line construction schedule based on cost - benefit optimization algorithms, due to the complex model, constraint condition is more, difficult to apply in the field of engineering.(Chen yuanduo,2010) combined with geographical factors such as Chen flower, traffic conditions, economic factors, such as screening of various track site node and important degree is calculated, and then in combination with geographical factors, determine the construction schedule plan. Node selection on the algorithm is still is too casual, lack of effective quantitative analysis of the shortcomings. GuoYanyong (GuoYanyong, 2013) analysis such as the six influence factors of urban rail transit construction, established the corresponding evaluation index system of timing and based on AHP and entropy weight - an ideal solution of the integrated model, by determining the line decision index and the negative ideal solution of Euclidean distance to determine the construction sequence. Although the algorithm able to objectively according to the statistical index, but it can't effectively avoid reverse problems arising from the algorithm and defect problems brought by the Euclidean distance itself. The above results to rail transit project construction schedule study provide a different way of thinking, but there are some defects with more or less.

In order to arrange the sequence of rail transit construction is more reasonable and efficient is proposed in this paper a kind of based on lattice order decision making is mainly used to solve the total order characterization for complex system of optimal scheduling problem, solutions for different decision preference elements constitute a lattice, lattice order than the total order more truly reflect the preference structure, thus for multi-objective alternative multielement complex system merit, lattice order decision making is total order decision-making more scientific and reasonable(GuoYanyong,2013).

2 The conception the Multi-objective Lattice Order Decision Making

With lattice order decision making method, first, to eliminate the unit of each evaluation index and the dimension of the non uniformity and not commensurability, need dimensionless processing of various index data, after the dimensionless data can be considered as policymakers on each index of different schemes of satisfaction. Decision makers should be taken into consideration when making index weight depicting index data of personal subjective preferences and objective discreteness. On the premise of the above information is complete, will be the effective decision information fusion, constructive solutions set decision matrix, on the basis of selecting the indexes of great sets and the minimal set of positive and negative ideal solution, and are seen as top and bottom element as two virtual solution (using the lattice theory to prove that the introduction of virtual scheme does not change the order relation of the original solution concentration between elements), and extending the decision scheme for the case .Finally, using the Euclidean distance to measure the decision scheme and top elements and bottom elements, the difference between decision principle for the solution and the distance of the top element as small as possible.

3 Rail transit construction sequence index system of influencing factors

As the urban rail transit construction project is a long-term and complex systems engineering, and affected by many factors determine the sequence of construction, the current engineering and academic circles have no a recognized evaluation index system. In view of the above characteristic, this paper finishing excavation with references [7] ~ [9] in the high frequency reference indexes, and indicators of teasing out Pearson correlation analysis, eliminate correlation of high index ($R^2 = 0.9$), the resulting index system as shown in Table 1.

Table1. Urban rail transit construction sequence evaluation index

The target	No.	index	methods	type
Temporal factors affecting rail transit construction	U_1	The length	The statistical	quantitative
	U_2	Line layout is important index	Experts assess	qualitative
	U_3	Passenger turnover	Traffic prediction	quantitative
	U_4	The intensity of load	Traffic prediction	quantitative
	U_5	Uneven coefficient of passenger flow sections	Traffic prediction	quantitative
	U_6	Track of bus passenger traffic	Traffic prediction	quantitative
	U_7	Coordinate with urban land use	Experts assess	qualitative
	U_8	Coordinate with urban traffic system	Experts assess	qualitative
	U_9	The difficulty of engineering	Experts assess	qualitative

4 The construction of the rail transit construction sequence selection index system

The construction of the rail transit construction sequence selection index system should be established based on wire mesh city characteristics, from the operating effect, network structure, social benefits and implementation of strategic development, construction, and urban development, environmental protection coordination of reasonable construction are chosen in the actual project indicators should be considered in three aspects: the evaluation index should be into system, fully reflect the characteristics of the urban rapid rail transit network as much as possible; Considering the index data availability and operability of the evaluation process; As far as possible to reduce the correlation between indicators, to ensure that the evaluation precision.

4. 1 Indicators of dimensionless processing

Due to the different indicators have different units, the lack of male sex, so to index evaluation data points forward, backward, moderate index and interval index dimensionless processing respectively, specific as follows(Ma Chaoqun,2007). Positive for type indicators

$$p'_{ij} = \begin{cases} 1 & p_{ij} > U_i \\ \dfrac{p_{ij}}{B_i} & 0 \le p_{ij} \le U_i \end{cases} \qquad (1)$$

Negative type indicators

$$p'_{ij} = \begin{cases} 1 & p_{ij} < L_i \\ \dfrac{U_i - p_{ij}}{U_i - L_i} & L_i \le p_{ij} \le U_i \\ 0 & p_{ij} > U_i \end{cases} \qquad (2)$$

Moderate type indicators

$$p'_{ij} = \begin{cases} \dfrac{p_{ij} - M_i}{U_i - M_i} & M_i \le p_{ij} < U_i \\ \dfrac{M_i - p_{ij}}{M_i - L_i} & L_i \le p_{ij} \le M_i \\ 0 & p_{ij} \le L_i \text{or} p_{ij} \ge U_\text{j} \end{cases} \qquad (3)$$

Interval type indicator

$$p'_{ij}=\begin{cases}1 & M_j^1 \le p_{ij} < M_j^2 \\ \dfrac{p_{ij}-L_j}{M_j^1-L_j} & L_j \le p_{ij} < M_j^1 \\ \dfrac{U_j-p_{ij}}{U_j-M_j^2} & M_j^2 \le p_{ij} \le U_j \\ 0 & p_{ij} \le L_j \text{or} p_{ij} \ge U_j\end{cases} \quad (4)$$

and: p'_{ij} For value (after dimensionless processing); L_j For the lower limit index; U_j For the lower limit index; B_i Parameters for evaluating indicators; M_j^1 、 M_j^2 、 M_j Intermediate values of indicators.

4. 2 The determination of the weights

Weighting calculation methods at home and abroad mainly include subjective judgment, such as: rail transit network plan is more than the selected target 77 objective analysis of two types of lattice order decision method, subjective judgment method of faults for relies too much on expert experience, and objective analysis, the defect to ignore the expert knowledge and experience, the calculation results and the actual deviation is bigger. In view of the above, this article will be effective the above two kinds of method is to use a set of legal union, is now on its process in detail.

4. 2. 1 Determine the objective of discrete degree of right

Set an objective evaluation indexes weight vector for discrete degrees

$W^*=(w_1^*,w_2^*,\cdots,w_1^*)$

$\sum_{j=1}^{n}(w_j^*)^2=1$

$\lambda_{ij}(w_j^*)$

According to the first item I the first j a evaluation index evaluation scheme With the index the sum of the deviation of the other schemes evaluation,

$$\lambda_{ij}(w_j^*)=\sum_{k=1}^{m} w_j^* \left|p_{ij}-p_{kj}\right| \quad (5)$$

Namely,

$\lambda_{ij}(w_j^*)$ Said in the first j a evaluation index, evaluation of all parties Case the total deviation,

$$\lambda_{ij}(w_j^*) = \sum_{i=1}^{m}\sum_{k=1}^{m} w_j^* \left| p_{ij} - p_{kj} \right| \qquad (6)$$

Namely,

According to the principle of determining the weight of maximizing deviations, the evaluation index weight should make all evaluation indexes of maximum total deviation, and made the $\sum_{j=1}^{n}\lambda_{ij}(w_j^*)$ biggest。Construction goal programming $F(w^*)$ as:

$$\begin{cases} F(w^*) = \sum_{j=1}^{n}\lambda_{ij}(w_j^*) = \sum_{j=1}^{n}\sum_{i=1}^{m}\sum_{k=1}^{m} w_j^* \left| p_{ij} - p_{kj} \right| \\ s.t. \quad \sum_{j=1}^{n}(w_j^*)^2 = 1 \qquad w_j^* \geq 0 \end{cases} \qquad (7)$$

And the normalized processing, objective weight vector for:

$$w^0 = (w_1^0, w_2^0, \cdots, w_n^0)$$

$$w'^0_j = \frac{w_j^*}{\sum_{j=1}^{n} w_j^*} \qquad (8)$$

4. 2. 2 The determination of important degree of subjective rights

Using the AHP analytic hierarchy process (AHP) to qualitative evaluation experts. Processing, the method of AHP hierarchy with reference to relevant processing method, subjective weight vector for after processing $w^s = (w_1^s, w_2^s, \cdots, w_n^s)$

4. 2. 3 The synthesis of total weight

An index of total weight should be related to the subjective weight and objective weight.For this consideration, define total weight vector

$$w = (w_1, w_2, \dots, w_n)$$

$$w_j = \frac{w_j^s w_j^0}{\sum_{j=1}^{n} w_j^s w_j^0} \qquad (9)$$

4. 3 The calculation of decision matrix

Define the operator $d_{ij} = w_j p_{ij}$, The decision matrix

$$D = \begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1n} \\ d_{21} & d_{22} & \cdots & d_{2n} \\ \vdots & & & \vdots \\ d_{m1} & d_{m2} & \cdots & d_{mn} \end{bmatrix} \qquad (10)$$

4. 4 Ranking

On the basis of lattice ordered related theory, positive and negative ideal solution, respectively.

$$\begin{cases} M^+ = \{\max(d_{i1}), \max(d_{i2}), \cdots, \max(d_{in})\} & (11) \\ M^- = \{\min(d_{i1}), \min(d_{i2}), \cdots, \min(d_{in})\} & (12) \end{cases}$$

The Euclidean distance between positive and negative ideal solution:

$$L = \sqrt{\sum_{j=1}^{n} [\max(d_{ij}) - \min(d_{ij})]^2} \qquad (13)$$

Plan I and Euclidean distance between positive and negative ideal solution, respectively.

$$L_i^+ = \sqrt{\sum_{j=1}^{n} [\max(d_{kj}) - d_{ij}]^2} \qquad (14)$$

$$L_i^- = \sqrt{\sum_{j=1}^{n} [d_{ij} - \min(d_{kj})]^2} \qquad (15)$$

Define comprehensive difference value of the I.

$$L_i = q\,\frac{L_i^-}{L} + (1-q)\,\frac{L_i^+}{L} \qquad (16)$$

Q is optimistic coefficient, $0 < q < 1$, can be given by the expert subjective.

5 The example analysis

Recommendation from the vision of the rail transit network of Chengdu (2005 edition) tech-oriented altogether is composed of 7 lines, 255 km line network scale, combining with expert evaluation to obtain the indicators of statistical prediction value, as shown in table 2.

Table 2. statistics of original index of line

Index	U_1	U_2	U_3	U_4	U_5	U_6	U_7	U_8	U_9
1#	30.0	9.8	800.30	4.42	4.85	0.104	9.1	8.9	7.5
2#	50.1	9.5	1175.59	3.16	4.25	0.118	9.5	8.6	8.1
3#	47.6	8.9	1057.60	2.36	3.87	0.088	8.8	8.1	8.8
4#	34.6	8.2	456.08	2.08	3.85	0.057	8.7	7.8	8.3
5#	20.9	7.8	282.03	2.51	2.86	0.041	8.0	7.2	8.0
6#	38.6	7.5	319.80	1.59	2.65	0.048	8.1	7.4	8.1
7#	33.6	8.7	374.90	2.16	3.11	0.057	8.5	8.4	8.5

Using formula (1), (2) of the basic data in table 2, standardizing, easy to know the cost index, the rest are efficiency index. The calculation results are shown in table 3.

Table 3. index standardization processing

index	U_1	U_2	U_3	U_4	U_5	U_6	U_7	U_8	U_9
1#	0.312	1.000	0.580	1.000	1.000	0.818	0.733	1.000	1.000
2#	1.000	0.870	1.000	0.555	0.727	1.000	1.000	0.824	0.538
3#	0.914	0.609	0.868	0.272	0.555	0.610	0.533	0.529	0.000
4#	0.469	0.304	0.195	0.173	0.545	0.208	0.467	0.353	0.385
5#	0.000	0.130	0.000	0.325	0.095	0.000	0.000	0.000	0.615
6#	0.606	0.000	0.042	0.000	0.000	0.091	0.067	0.118	0.538
7#	0.435	0.522	0.104	0.201	0.209	0.208	0.333	0.706	0.231

Formulas (8), (9) are used to get the optimal weight vector formula (10) are used to get the weighted after the standardization of the matrix Z, then using the formula (12) to carry on the coordinate transformation, the origin of coordinates translation to ideal solution, the calculation results such as table 4.

Table 4. the weighted matrix after translation

index	U_1	U_2	U_3	U_4	U_5	U_6	U_7	U_8	U_9
1#	-0.079	0.000	-0.042	0.000	0.000	-0.019	-0.030	0.000	0.000
2#	0.000	-0.014	0.000	-0.050	-0.030	0.000	0.000	-0.020	-0.056
3#	-0.010	-0.043	-0.013	-0.082	-0.050	-0.041	-0.053	-0.052	-0.121

4#	-0.061	-0.077	-0.080	-0.093	-0.051	-0.084	-0.060	-0.072	-0.075
5#	-0.115	-0.096	-0.100	-0.076	-0.101	-0.105	-0.113	-0.111	-0.047
6#	-0.045	-0.111	-0.096	-0.112	-0.111	-0.096	-0.105	-0.098	-0.056
7#	-0.065	-0.053	-0.089	-0.090	-0.088	-0.084	-0.075	-0.033	-0.093

According to the type (13), various solutions to the ideal solution are calculated separately, and the "vertical distance" is: $\mathrm{D}_i = (0.014, 0.010, 0.056, 0.061, 0.099, 0.093, 0.062)^T$ .To each scheme of the vertical distance from small to large in this arrangement, the optimal sorting B line construction can be got. $D_2 < D_1 < D_3 < D_4 < D_7 < D_6 < D_5$ .Through "vertical distance" size relations, each line sequence is: the construction of line 2 and line 1 and line 3 and line 4 to 7 lines, line 6 and line 5.Chengdu metro line 1, in fact, the first phase has been opened to traffic in 2010, south extension line # 1 at the end of 2014 opened; The first phase of line 2 has been open to traffic in 2012, opened in 2013, along the west east along the end of 2014;Metro line 3 and line 4 is opened in 2015, metro line 7 opened in 2016, is expected to line 5 and line 6 are currently conducting project feasibility study, has not yet started construction. As you can see model calculation results are consistent with the actual construction schedule of chengdu basic, from the side to verify the rationality and validity of the model.

6 Conclusion

(1) On the basis of previous literature on the sequence of rail transit construction, tease out a set of factors affecting construction schedule auditions index system, and to create the indexes of Pearson correlation analysis, eliminate the higher correlation index ($R^2 = 0.9$), effectively avoid the effect of the correlation between indicators.

(2) In view of the traditional TOPSIS model in the reverse order, the weight values of strong subjectivity and Euclidean distance their own defects, puts forward the improved algorithm, the algorithm by index transformation will absolutely ideal solution, and establish a decision-making plan to absolute ideal solution and negative ideal solution is absolutely a weighted distance optimization model, using the Lagrange multiplier method to solve the model to get the optimal weight vector, the introduction of "vertical distance" instead of the traditional "Euclidean distance", the methods by measuring vertical distance determines the optimal construction schedule plan.

(3) In this paper, the proposed algorithm was applied to chengdu city rail transit network construction sequence analysis.The results show that the model calculation results are consistent with the actual construction schedule of chengdu basic, from the side to verify the rationality and validity of the model.

(4) This modle is not considered for the construction of the existing line for new

line timing effect, this is the next step to be further discussed.

References

Cheng hua, He fanghui,Li junfang,(2006).Methodology for time scheduling of short-term urban rail transit construction.Urban Transport of China,2010,8 (3) :13-16.

Chen yuanduo,Xu jimin.(2006).Scheduling of urban rail traffic construction items based on"node importance andtraffic location".Transport Information and Safety,2010,28(3) : 60-62.

Chenxumei，Lifengjun．(2006).The studyonthe criterionsystem for comprehensive evaluation of the urban railnetwork. City Planning Review，2001 25(10) :61-64.

Guo Yanyong,Liu Pan,Wu Yao.(2006). Development of aMethod for the Construction Schedule of Urban railTransit Lines.Journal of Wuhan University Of Technology,2013(6):75 － 80.

Huangrui，Liangqinghuai．(2012). Based on the nodesimportant degree theory of rail transit construction"． Urban Rapid Rail Transit,25(3) : 21-24.

Jinjian,ZhangDianye,Guozhizheng.(2006). Demand.Mechanism Model Analysis of
Rational Scale of Urban Rail Transit Network.Journal of the China railway Society,2006, 28(5): 16-20.

Jijialun，Lifuzhi．(2006). A study on the synthetic evaluation index system of urban rail transit line network planning scheme .Systems Engineering theory ＆ Practice，2004(3) : 129-133.

Machaoqun,Wangyupin,Chenkuanmin.(2006).Comprehensive evaluation for urbanrail transit network based on grey weight relation.Journal of Chan'an University(Natural ScienceEdition) ,2007,42(3) : 38-39.

Zhangjiamin. (2006). Construction Sequence of Urban Rail Transit Project Base on Monte Carlo ＆ AHP Simulation,Urban Rapid Rail Transit 2013,15(12): 120-124.

Urban Traffic Corridor System Configuration Optimization Research under the Background of Low Carbon

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Abstract: Environmental conditions of urban traffic corridor was not only related to the comfortableness of the around residents living, but also related to problem of lessen fule-comsumption and gas-letout of urban traffic. So it became one of the urban traffic focus recently. This paper first researched attracting scope of urban traffic corridor. This part concluded the universal and accurate method of determining covering scope. Then, based on the relationship between different traffic modes and carbon emissions, a model which contains all traffic modes was established to calculate transport carbon emissions. After that, a bilevel programming model was established to optimize system configuration of traffic corridor, where the upper model minimizes the system carbon emission, while the lower model optimums for the users' trip. And based on Genetic Algorithm, we designed an arithmetic to resolve this bilevel programming model. Finally, this paper used Chengdu to Longquanyi district traffic corridor as an example. By the application of origin and destination data from the dwellers within the covered scope of traffic corridor, this paper completed corridor system optimization configuration, to prove the feasibility of the model in this paper.
Keywords: Attracting scope; Bilevel programming model; Carbon emission; Genetic algorithm.

1 Introduction

Urban transport corridor area undertook most traffic travel in the intensive land use area, where carbon emissions of traffic in this zone is very large. In the view of low-carbon, we should effectively plan urban transport subsystems of transportation corridor, which not only helps to reduce carbon emissions but also provide a more comfortable living environment for residents.

Priority corridor study is to determine the specific configuration coverage of corridor through researching attract features of internal transit corridor and the method to divide the scope of the corridor. Then, on the basis of the residents traffic characteristics in different areas and the relationship between traffic modes and emission, the paper establishs the emission model, including individuals and all modes. Finally, the paper establishes a bilevel programming model to optimize system configuration of traffic corridor, where the upper model minimizes the system carbon emission, while the lower model optimums for the users' trip, which can provide the optimal allocation program of corridor to reduce carbon emissions.

2 Corridor coverage and carbon emission model

2.1 Corridor coverage model

As urban corridors contain various modes of transportation, passed by various land use and contact with the surrounding regions of people flow, traffic, logistics, it is unreasonable to simply draw a rough range to determine the scope of the traffic corridor. Therefore, in consideration of the land use and transportation modes, the steps to determine corridor coverage as follows:

Step 1: Based on the present OD data of transport corridor, forecast the planning OD data and obtain the desired travel pathway map.

Step 2: According the desired travel pathway map, combined with the situation of road network, analysis traffic direction and the maximum section traffic of corridor, determine leading public transport mode.

Step 3: According the person flow direction, the capacity of each road, and the conditions of corridor, determine the corridor coverage.

2.2 Attractive bent law with effect field

As we all know, traffic lines have attracted characteristics, which is similar with that of gravity and effect field theory. While along the corridor area gathered high person flow with its powerful attraction to people and business, and form a cluster effect field.

Take the traffic lines as conductors and the study area as the space medium, then the traffic volum will be took as current. Thus, around the "traffic lines". will generate the magnetic field.

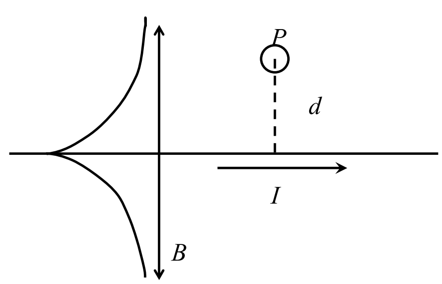


Figure 1. the effect field of current-carrying conductor in Electromagnetic Field

As the Figure. 1, Since the distance d between P point and conductor is much less than the length of the conductor, so we can think that the conductor is infinitely long. According to BisSisL law, the field strength of P point B is:

$$B=\frac{\mu I}{2\pi d} \quad (1)$$

Where, I is the current strength , here it means person flow on traffic lines; d is the distance d between P point and conductor, here it means the distance between passengers and traffic lines; μ is permeability of the point P, reflecting the sensitivity of the lines.

Because the corridor includes multiple lines and can't be ideal straight, add the distance correction factor k to modify the model. Therefore, assume the total number of lines is n and i represent any of lines, and the field strength is converted into corridor effect field. Finally, we can get the formula as follow:

$$E(d)=\int_0^d \frac{\mu I}{2\pi(kd)^a}\mathrm{d}(d)=\frac{\mu I}{2\pi k^a}\int_0^d d^{-a}\mathrm{d}(d)=\frac{\mu I}{2\pi k^a}\bullet\frac{d^{1-a}}{(1-a)} \quad (2)$$

2.3 carbon emission model

The traffic modes in urban corridors can be broadly divided into six kinds, respectively bus, railway, car, motorcycle, taxis, walking. According to the static by US Bureau of Transportation Statistics in 2009, the carbon emission factor (p_i) for different modes are shown as Table. 1. Moreover, through a lot of investigation and relevant data, the average passenger number of different modes as shown in Table. 2:

Table 1. different modes of transport of carbon emission factor (g/(personiskilometers))

Mode of transport	bus	Rail	Private car	Bicycle	taxi	walk
Carbon Emission Factor	30	8	120	0	150	0

Table 2. different modes of transportation average number of passengers (passengers)

Mode of transport	bus	Rail	Private car	motorcycle	taxi	walk
The average number of passengers	29	1368	1.60	1.06	2.31	1

Based on the above two tables, we can see the total carbon emissions of whole city transportation corridor system can be expressed as:

$$C_{total}=\sum_{i=1}^{6}C_i=\sum p_i\cdot x_{a,i}\cdot l_a \quad (i=1,2,...,6) \quad , \; s.t.\; x_{a,i}\le\beta_i\cdot\sigma \tag{3}$$

Where: C_{total} is the total carbon emissions of the urban transport system; C_i is carbon emissions of the i-th mode; p_i is the carbon emission factor of the i-th mode of transport; $x_{a,i}$ is the average passengers number of the i-th mode on the section “a”; β_i is the average passengers number of the i-th mode; l_a is The length of the section “a”.

3 Corridor System Configuration Optimization Model

This paper established system configuration optimization model mainly from system optimal and user optimal two aspects, at the same time, the two levels influenced each other.

3.1The upper model

The upper model involved the transportation corridor total carbon emissions minimum and maximum benefits of investment in infrastructure, etc. this paper defines a comprehensive benefit index, the index measures the total cost including investment and system total benefit. Getting comprehensive benefit goal as follows:

$$\min E=\phi_1 W_n+\phi_2[\sum_i\sum_a p_i x_{a,i} l_a-\sum_i\sum_a p_i x_{a,i}^0 l_a]M+\phi_3[x_a t_a(x_a)-x_a^0 t_a(x_a^0)]S \tag{4}$$

Where W_n is cost of n traffic management strategy(RMB), $n\ge 1$; S is per unit time output of the corresponding urban residents(yuan); $t_a(x_a^0)$ is impedance of road before strategy implementation, usually referred to the travel time.; M refers to the unit mass of carbon emissions on the international market price (RMB). Due to three parts of magnitude is not in the same field, this paper introduced three parameters ϕ_1、ϕ_2、ϕ_3, $\phi_1+\phi_2+\phi_3=1$ and $\forall\phi_i\in(0,1)$.

W_n is relevant with the size of traffic strategy: $W_n=\sum_i U_i\bullet e_i$ .Where, U_i is i.st strategy, e_i is i.st investment costs; $S=\frac{GDP_{ave}}{365*8}$, GDP_{ave} is per capita gross domestic product; $M=56RMB/\text{ton}$.

The upper model pursuits the minimum of traffic corridor carbon emissions and maximum benefits of investment in infrastructure, transportation demand management measures should be limit of government spending, namely: $W_n=\psi(y,q)\le W_{\max}$.

3.2 The lower model

In this paper, the lower model with user optimal angle analysis, considered the generalized cost, including passengers must pay for travel time delay and methods on the transportation cost, as follows:

$$c_p^{ij} = \sum_a st_a \delta_{a,p}^{ij} + w_p^{ij}, \forall i, j, a \tag{5}$$

Where, c_p^{ij} is the cost of travel for any OD points (i, j) to choose the path p ; w_p^{ij} is the cost of price for any OD points (i, j) to choose the path p ;

$$\delta_{a,p}^{ij} = \begin{cases} 1, & \text{if roads } a \text{ is on paths p between of } (i, j); \\ 0, & \text{others.} \end{cases}$$

A_c is the cost of driving: $A_c = l_c \bullet \lambda$ .where, l_c is the driving distance, $l_c = \sum_a \delta_{a,p}^{ij} \theta_{a,c} \varphi_{a,c} l_a$; λ is unit fuel costs of travel distance. A_b is the cost of bus, $A_b = 2$.

A_{r1} is subway fares; A_{r2} is light rail fares; A_r is rail transit fares: $A_r = \xi_{a,r1} \bullet A_{r1} + \xi_{a,r2} \bullet A_{r2}$.

t_a is the time spent on network of either roads a . $t_{间}$ is the public transport departure intervals(frequency). V_n represents the average speed of transportation n , X_a is motor vehicle traffic capacity (veh/ h), C_a is road capacity (veh/ h). According to the American federal highway BPR road resistance function model, analyzing the impedance of different modes of transport, we can get the results as follows: $\alpha = 0.15$, $\beta = 4$,

$$\text{t analysis.} \begin{cases} t_r = \frac{l_a}{V_r} + \frac{t_{间}}{2} \\ t_{brt} = \frac{l_a}{V_{brt}} + \frac{t_{间}}{2} \\ t_{bus} = \frac{l_a}{V_{bus}} \left[1 + \alpha \left(X_a / C_a \right)^{\beta} \right] + \frac{t_{间}}{2} \\ t_c = \frac{l_a}{V_c} \left[1 + \alpha \left(X_a / C_a \right)^{\beta} \right] \end{cases} \tag{6}$$

So we can get t_a : $t_a = \sum_{s=r, brt, bus, c} \theta_{a,s} \varphi_{a,s} t_s$ .Where:

$$X_a = \sum_{i,j} \sum_p f_p^{i,j} \bullet \delta_{a,p}^{i,j} , \quad \sum_p f_p^{i,j} = q_{i,j} , \quad \sum_j q_{i,j} = O_i , \quad \sum_i q_{i,j} = D_j .$$

Travel time affected by OD traffic volume, in turn, would affect the traffic capacity of network. Therefore, the traffic distribution—combination of traffic assignment model is established, to reflect the feedback:

$$\min Z = \sum_p \int_0^{X_a} c_p^{i,j} \, dx + \frac{1}{\gamma} \sum_{ij} q_{ij} (\ln q_{ij} - 1) \tag{7}$$

Due to the lower model involves the user's travel choice problem of the network, the network itself are the restricting conditions of the lower model. According to the urban public transport planning standards, we get bus system of traffic corridor as follows:

$$s.t\begin{cases} t_0 \le \min\left\{T_{\max}, \frac{l_{\max}}{v}\right\} \\ n_a = \left[\frac{x_a}{t_{\text{间}} m}\right], \forall a \\ p \le \sum_a n_a \\ 0 \le n_a \le 5, \forall a \\ 0 \le t_{\text{间}} \le t_{\text{间}\max}, \forall a \end{cases} \tag{8}$$

Where, N is the bus traffic planning route within the research scope; m is the public transport vehicle (column) capacity; $T_{\max}$ is the biggest travel time for different size of the city; $l_{\max}$ is the bus lines maximum length for different scale of the city;; v is the design speed of the urban corridor bus system; n_a is the public transportation line number on the road a; $t_{\text{间}\max}$ is the biggest bus service frequency within the research scope.

4 Example analysis

4.1 Example seletion

The paper selects a traffic corridor from Chengdu urban area to Longquanyi as example, including metro line line 2 east extension line, Yidu avenue, Chenglong avenue and some linking roads, as shown in Fig. 2. This corridor mainly influences the Tongan subdistrict, Damian subdistrict, Longquan subdistrict, Shanquan town, Chadian town and Baihe town, so the paper selects above subdistricts and towns as trip generation points derecting to Chegndu.

According to the corridor coverage model proposed in the 2nd section, considering the place of bus stops, the place of metro stations, travel distance and land use surrounding the corridor, the paper has determined the coverage area of corridor, shown in Fig. 3. Moreover, in the base of some projections, we obtained the OD data of trip generation points, as shown in Table. 3.

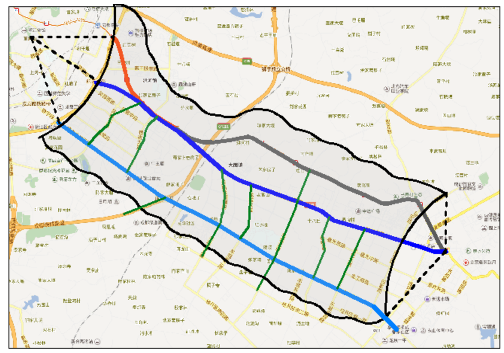


Figure 2. Study area of the traffic corridor Figure 3. The coverage area of corridor

Table 3. the OD data of trip generation points in 2014

towns (subdistricts)	metro	car	Public bus	sum
Tongan subdistrict	253	1133	852	2234
Damian subdistrict	342	1543	1160	3043
Longquan subdistrict	1119	5093	3829	10042
Shanquan town	2126	9675	7275	19078
Chadian town	693	3122	2347	6156
Baihe town	6432	29271	22009	57719

This example does not consider the external passenger traffic demand due to newly built traffic facilities and new strategies of TDM and TSM. The example only analysis the benefits of carbon emission in the base of original passenger traffic demand

4.2 Discussion of Results

Firstly, selec above datas as input of optimal allocation model proposed in chapter 3rd . Then, use the Genetic Algorithm to solve this model. Finally, through programing based on the MATLAB, we obtain the result of this optimal allocation model.

Through the statistical analysis of result, we can see that the number of newly built P&R parking lot berths is 563 and the total investment needs $ 67.5 million RMB. (The example does not consider the investment of builting the metro line line 2 east extension line, so the upper limit of the total investment is $ 67.5 million RMB, called W_{max} .) Furthermore, the changes of carbon emissions, passenger volume and traffic volume are obvious.

1. After the implementation of the program, the carbon emissions of cars and buses are significantly reduced, respectively, 7.327 t and 9.089 t. But, the emissions of metro increase by 3.002 t, as shown Table. 4. Finally, the carbon emissions of the traffic corridor decrease by 13.14%.

2. The passenger volume of metro increase significantly and is 27102 persontime, basically corresponds the actual passenger volume (about 20000

persontime), obtained from the metro department. Specific changes in passenger volume as shown in Table.5.

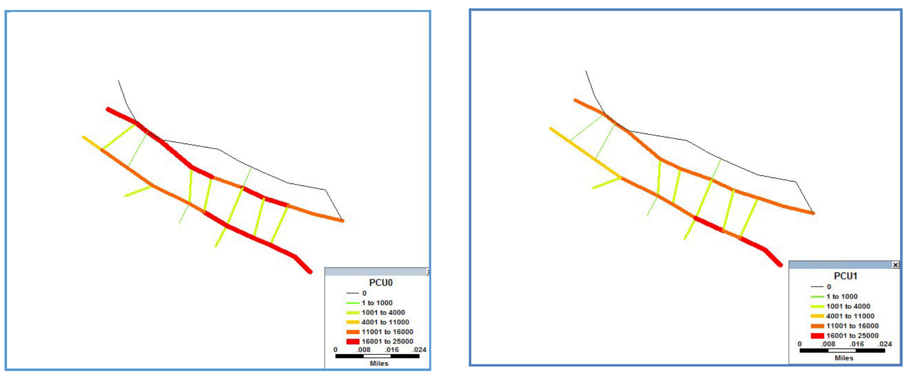
3. The traffic volumes of Yidu avenue and Chenglong avenue respectively decrease by 2000 pcu and 1000 pcu per day, which show that the effect of metro attract Yidu avenue is greater than that of metro attract Chenglong avenue. Specific changes in passenger volume as shown in Fig. 4.

Table 4. Specific changes in carbon emissions

traffic modes	Before the implementation of the program			After the implementation of the program		
	metro	car	Public bus	metro	car	Public bus
carbon emissions	0. 178	83. 551	18. 379	3. 180	76. 224	9. 271

Table 5. Specific changes in passenger volume

traffic modes	Before the implementation of the program			After the implementation of the program		
	metro	car	Public bus	metro	car	Public bus
passenger volume	5726	51293	43937	27102	48293	17313



Before the implementation of the program After the implementation of the program

Figure 4. Specific changes in passenger volume

5 Conclusions

The paper has established a bilevel programming model to optimize system configuration of traffic corridor, where the upper model minimizes the system carbon emission, while the lower model optimums for the users' trip. Through the model, we can see that optimal allocation model not only can effectively reduce carbon emissions, but also improve operational efficiency of corridor system. Finally, the paper use the example to verify this model, which show that the model proposed by this paper has accuracy and practicality with a certain.

References

Taylor G (1949). Urban Geographyisa study of site, evolution, pattern and classification in villages, towns and cities. London: Methuen & Co. Ltd. 278is300.

Whebell C F J. (1969) Corridors: A Theory of Urban Systems. Annals of the Association of American Geographers, 1(59): 1is26.

Rimmer P J C C.（1991）Transforming the Asiais Pacific's Strategic Arthitecture: Transport and Communications Platforms, Corridors and Organisations Asiais Pacific Security. Nexus. (ed.): Harris, S. & Mark, A.

David Chapman D P P I. (2003) Concepts and definitions of corridors sevidence from England Midlands. Journal of Transport Georaphy, 5(2): 179is191.

GAKENHEIMER, R. & MEYER, M. D, (1990). Urban Transport Corridor Planning.. In: Dimitrou, H. T. Routledge (ed.) Transport Planning for Third World Cities. 11 Hew Fetter Lane London. 319is347.

Gao Z Y, Song Y F. (2002) A reserve capacity model of optimal signal control with user is equilibrium route choice. Transportation Research is B, 36:313is323.

Freight Transportation Network Expansion Plan to Meet Urban Logistics

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Abstract: With the rapid development of urban modern logistics, traffic capacity of freight transport network cannot satisfy the requirement of cargo distribution and delivery. Therefore, it is very urgent to enlarge and optimize the freight transport network. In this thesis, based on the analysis of proposed transport network, the state of the increasing flow, and transport time, transport cost, road congestion and the cost of unit capacity, an optimization model is built to enlarge the capacity of the freight transport network, and then an algorithm is devised to solve it. Eventually, an example is used to verify the validity of the model and the algorithm. This thesis is likely to offer a theoretical method for making decision, optimizing and designing freight transport network.

Keywords: Freight transportation network; Optimization of network capacity; Maximal flow.

1 Introduction

With the rapid development of urban modern logistics, the demand for lane capacity of freight vehicles exceeds the existing capacity. However, traditional way to distribute goods on traffic network is within the scope of lane capacity. It limits the development of urban logistics industry greatly. Therefore, it is urgent to ease the conflicts on the existing roads system between the supply and demand.

At present, control on freight traffic implements include the following policies in most domestic and foreign cities: First, policy to prohibit and restrict management sessions, road or vehicle, such as London of England and Chengdu of China; Second, policy to limit the number of parking spaces to control the road traffic (Lu, 2004), which is mainly used in places near city's CBD; Third, policy to charge some congested roads to control traffic flow; Fourth, policy to use the indicative signs to guide the smooth flow of freight vehicles (Li, 2013); Fifth, policy to control the freight transport demanding, which is used in most cities of Japan. Although these policies ease some of the city's traffic congestion to a certain extent for a period of time, it has also brought a lot of inconvenience to the development of urban economy, especially the development of urban logistics industry. For example, on the one hand, it separates the integration of logistics system, increasing the cost of logistics services, extending time of goods distribution and reducing the overall quality of service of logistics system; On the other hand, it exacerbates the urban traffic congestion and causes other problems to a certain extent (Li, 2013).

Based on the existing control measures on urban transport and its adverse effects on logistics industry, and the existing researches mainly focused on solving urban passenger traffic network capacity optimization, which rarely considered transport time, transport costs and other factors, an optimization decision method will be designed to reduce traffic restrictions on urban logistics development through the expansion of existing transportation network construction to meet the development trend of urban logistics and put forward some ideas of expansion and optimization for freight transport network that cannot meet the requirements in this thesis.

2 Freight traffic volume survey method

Freight traffic volume means the number of traffic that pasted one point or one section on the road in the period time. The main purpose of surveying freight traffic volume is found the problems existing in the current region, provided the basis on the traffic management and planning, mastered various traffic phenomena in the study area, to provide data for predicting freight traffic volume.

At present, the survey methods have artificial counting method and mechanical counting method. Mechanical counter method has pressure tube type detector, the induction coil detector, ultrasonic detector; floating car view method and video observation method; according to the survey duration time divided into investigation of intermittent traffic volume and continuous traffic investigation (Li, 2004). When survey the freight traffic volume can be based on different conditions and requirements, to choose the means of investigation method.

3 Freight traffic volume prediction method

Freight traffic flow prediction means through investigating the status of freight traffic flow and analysis the data, use modern information technology and means to build all kinds of prediction model, the scientific prediction and analysis carried out for the implementation of freight transportation network planning management. Freight traffic flow prediction aims to ease the congestion on freight traffic network, balance the freight traffic distribution in space and time, and provide the basis on the urban transportation network of project management and renovation project. There are a lot of freight demand forecasting methods. The specific methods should be selected depending on the actual situation. The main methods are:

(1) Multiple regression prediction model.

Regression forecast method needs to find out the relationship that between the freight volume forecasting object (the dependent variable) and the effect of various factors of object prediction (independent variables), and establish the corresponding regression equations, then based on the value of independent variables, obtained the value of the dependent variable. Because the predicted freight volume is closely linked with social economy, we can select number n economic indicators as independent variables, study on the relationship between them and the freight volume, calculate the regression equation (He, 2004). In this way, we can predict the shipment volume.

(2) Time series forecasting model

Ahmed and Cook presented time series forecast model in traffic flow field as the first people. Box and Jenkins created ARIMA model that was used widely:

$\hat{x}t(l) = \sum_{j=1}^{\infty} G_{1+j} a_{t-j}$.Time series prediction of $\{x_t\}$ that, if XT is known, need to predict the number of $(t+1)$. This model is especially suitable for the freight traffic flow stability. If the flow condition changes greatly, the amount of computation will be very large, the model will expose serious deficiencies in prediction. In addition, this model does not consider the relationship between upstream and downstream sections of the flow.

(3) Prediction model of elastic coefficient method

Through the study on the transportation elasticity, grasp the development trend of transportation in general. Mathematical model of elastic coefficient method is: $y_t = y_t^1(1+i)^1, i = E(s)q = i^\wedge 1 \,/\, q^\wedge 1 \, * q$. Usually, the economic growth will promote the development of the transport industry, when the economy development is rapid, the transportation industry will become the factors that restrict the development of it. When we use the model, can obtain Freight rate of changing by multiplying the changeable rate of economic and freight volume elasticity, calculate the elasticity coefficient and relevant economic rate and calculate shipping volume (Ji, 2013).

(4) The exponential smoothing forecasting model

Forecasting strategy of exponential smoothing method is a historical observation extrapolated to the future, then according to the adaptive principle, revised the demand pattern that has changed. This method is often used in three kinds of trend changeable conditions that they are level, linear, and two curves.

(5) Model of grey system

Grey prediction method is based on the past and now known or uncertain information, and establishes GM model from the past to the future, in order to determine the system development tendency in the future, and provide a basis for planning and decision making. $GM(1,1)$ is $d_x/d_t + a_x = u$, due to the random quantity or noise are often mixed with original series, in the control system theory, often need to use filtering method to eliminate the noise, the way in the grey prediction of sequence is equivalent to the filtering processing method (Zhang, 2001).

(6) The historical average model

The historical average algorithm is simple because the parameter can use the least square method to estimate, which can solve the problem of traffic flow changes at different time and different period. But it cannot solve the prediction of static, because it can not reflect the basic uncertainty and nonlinear characteristics of dynamic traffic flow, especially cannot overcome the influence of random factors, no way to deal with traffic accidents and other emergencies in the system.

4 Freight transportation network expansion construction

Through the series of cargo survey and forecast, analyzed the demand of the freight traffic volume in a certain period of time. Now there are some researches which have expanded and improved the road network capacity of lowest unit cost (Zhang, 2010) or have taken into account two factors that the unit cost of road expansion and road congestion level to improve freight network to make establishments of the network capacity optimization objective function (Kou, 2012). This paper designs a multi-objective mathematical model below based on minimum transport costs, shortest transportation time, the lowest unit cost of road expansion, the highest level of road congestion.

$$\begin{cases} Min\ P = \sum p_{ij}\,\Delta c_{ij} & \text{(the unit transport cost)} \quad (1) \\ Max\ M = \sum o_{ij} & \text{(the congested road)} \quad (2) \\ Min\ M = \sum m_{ij} & \text{(the unit transport time)} \quad (3) \\ Min\ P = \sum q_{ij} & \text{(the unit transport cost)} \quad (4) \end{cases}$$

where: p_{ij} = the unit cost of expansion project of line (v_i, v_j) ;

Δc_{ij}= the addition of traffic network capacity of line(v_i, v_j);

o_{ij} = crowded conditions of line (v_i, v_j);

m_{ij} = freight vehicles travel time of line (v_i, v_j);

q_{ij}= transportation costs of line (v_i, v_j).

To optimize the network, as while it needs to be meet the following constraints:

1) Freight vehicle transporting time on the road transportation network is not higher than vehicle transporting time of the free traffic;
2) Traffic network expansion is limited to the conditions of road itself which cannot exceed the ceiling of the road capacity;
3) Each section of the actual traffic flow cannot exceed the maximum traffic capacity;
4) Optimization and expansion of freight transportation network is to meet the expected traffic flow.

$$\begin{cases} m_{ij} \le F \\ \Delta c_{ij} \le X \\ 0 \le f_{ij} \le c_{ij} \\ max\ v(f) = Q \end{cases}$$

where: $F =$ vehicle travel time that traffic flow is in the free flow state of line (v_i, v_j);

$X =$ the maximum acceptable expansion of line (v_i, v_j);

f_{ij} = traffic flow of line (v_i, v_j);

c_{ij} = maximum capacity of line (v_i, v_j);

$v(f)$ = maximum traffic network flow;

Q = expected network traffic flow.

This model is a multi-objective decision-making model, it is very difficult to solve directly. General ways to solve this kind of problem, there are two methods. The first one: according to the relevant requirements, decide the weight of each object and make different target weighted linear. The second, make some certain objectives transform into constraints, and make the original problem transform into a double objective decision or single objective decision (Wei, 2005). This paper considers the difficulty to take into account the weight of each target. so the paper chooses the second way to transforms the multi-objective model into a single objective model.

The new model:

The objective function:

$$Min\ P = \sum p_{ij}\ \Delta c_{ij}$$

Constraints:

$$\begin{cases} m_{ij} \geq m_{mn} & \text{(The unit transport time of the expansion road is not less than the other sections)} \\ q_{ij} \geq q_{mn} & \text{(The unit transportation cost of the road expansion is not less than other sections)} \\ o_{ij} \geq o_{mn} & \text{(The expansion road's congestion level is not less than the other sections)} \\ m_{ij} \leq F \\ \Delta c_{ij} \leq X \\ 0 \leq f_{ij} \leq c_{ij} \\ max\ v(f) = Q \end{cases}$$

A multi-objective decision-making model is transformed into a single-objective decision-making model. To find out the optimal solution, it needs an optimization algorithm, with this optimization algorithm to get the program that meets the expansion and optimization of the urban logistics freight transport network.

In this paper, the idea of model optimization algorithm is that using the shortest path algorithm to seek the most ideal expansion road, then gradually getting the quantity added to the expectation of volume. This model determines the expansion section that requires take into account the transport time, transport costs, road expansion unit cost and road congestion level. So this paper decides to use the multiplier of transit time, transportation costs, road expansion unit cost, and road congestion as a total factor.

As the following formula:

$$w_{ij} = q_{ij} \times m_{ij} \times o_{ij} \times \left(p_{ij} \times \Delta c_{ij}\right) \tag{5}$$

Where: w_{ij} = the total factor of line (v_i, v_j);

q_{ij} = unit transport cost of line (v_i, v_j);

m_{ij}= unit freight transport time of line (v_i, v_j);

o_{ij} = crowded conditions of line (v_i, v_j);

p_{ij} = unit expansion project cost of line (v_i, v_j);

Δc_{ij} = traffic quantity added of line (v_i, v_j).

And because unit transport time(m_{ij}) = road length(L_{ij}) / vehicle speed(V_{ij}), vehicle transport costs(q_{ij}) = unit transport cost(c_{ij}) × road length(L_{ij}), crowded conditions(o_{ij}) = traffic capacity(c_{ij}) / traffic flow(f_{ij}). Therefore, the formula (5) can be converted to the following：

$$w_{ij} = \left(C_{ij} \times c_{ij} \times {L_{ij}}^2 \times p_{ij} \times \Delta c_{ij}\right) / \left(V_{ij} \times f_{ij}\right) \quad (6)$$

The total factor w_{ij} of equation (6) is the weight of the shortest path algorithm, while seeking the best expansion sections of freight transport network with Dijkstra shortest path algorithm.

At present, this problem can be solved by precise algorithm and heuristic algorithm. The precise algorithm has branch and bound approach, dynamic programming approach, cutting planes approach, and network flow approach. The heuristic algorithm has constructive algorithm, two phase algorithm, and metaheuristics algorithm.

Based on the above analysis, the paper designs optimization expansion steps, as follows:

step 1: Based on the current traffic network $G = (v, e, c, f, P, O, M, Q)$, each road traffic flow does not change, current flow of the network as initial flow;

step2: In accordance with formula (6), calculate w_{ij} in each section, then mark w_{ij} to a new transport network $= (v, e, w)$;

step3: According to w_{ij}, use Dijkstra shortest path algorithm to find the shortest path from v_s to v_t ;

step4: In the shortest path from step3, the line $v_i v_j$ quantity added $c_{ij}^* = min(f_{ij})$. If $f_{ij} < c_{ij}$, $f_{ij} = c_{ij} - f_{ij}$;If $f_{ij} \geq c_{ij}$,$f_{ij} = c_{ij} + x_{ij} - f_{ij}$. Add the minimum quantity c_{ij}^* to each line in the shortest path of v_s to v_t;

step5: Calculate the maximum flow $\sum f_{sj}$ of the network. If $\sum f_{sj} = Q \leq c + X$,turn to step9. If $\sum f_{sj} < Q \leq c + X$, turn to step6;

step6: In the shortest path from step3, cycle the step4, until $\sum f_{sj} = Q \leq c + X$, turn to step9, or $\sum f_{sj} < Q \leq c + X$,and $c_{ij}^* = 0$ turn to step7.

step7: Calculate the shortest path again that this paths have not been expanded. Cycle the step4 to step5, If $\sum f_{sj} = Q \leq c + X$, turn to step9; If $\sum f_{sj} < Q \leq c + X$, turn to step8.

step8: Cycle step7, if it cannot meet $\sum f_{sj} = Q \leq c + X$, the original freight transport network has no optimal solution, end of the algorithm.

step9: Have found the optimal solution , the algorithm end.

In the above steps, c_{ij}^* represents the flow added of each time, f_{sj} represents the flow that connect v_s.

5 Numerical studies

There is a freight traffic network, the maximum flow of it can reach 15, it has reached 14, near saturation. After survey and prediction, the freight traffic flow will reach 18 in the coming period, so the freight transportation network needs to be expanded. The number on paths represents (c_{ij}, f_{ij}) as the figure1.

It is known the roads weights of freight transportation network, calculate the shortest path from v_s to v_t , obtained the expansion road, expand on it. ((X_{ij}, w_{ij}) represents the expansion restrictions and expansion of the total factors, as the figure 2. Using ideas of this article, Calculated expansion sections are $v_sv_3, v_2v_5, v_5v_t, v_6v_t$, expanding energy is 1,2,1,1 respectively, the total consideration of expansion is 20, shown in Figure 3.

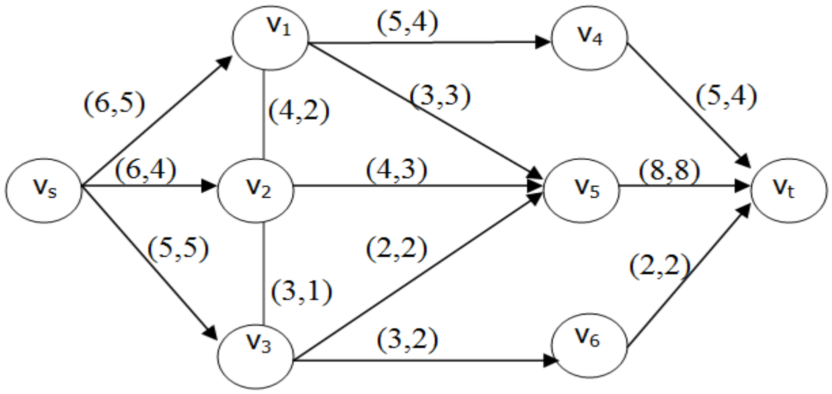

Figure 1. Capacity and flow of a transport network

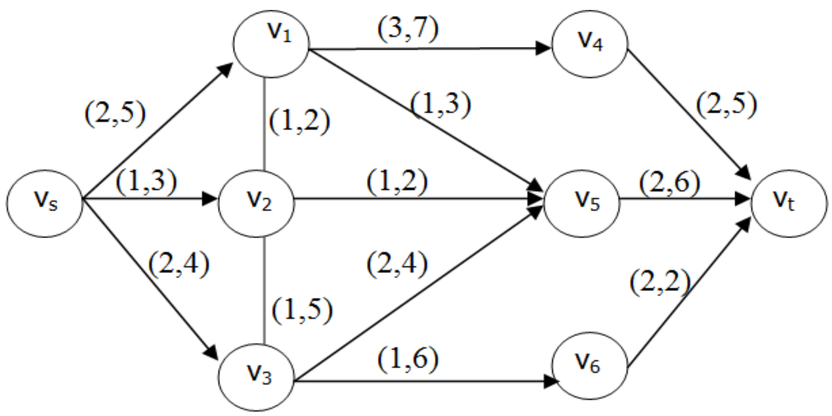

Figure 2. Capacity and flow of a transport network

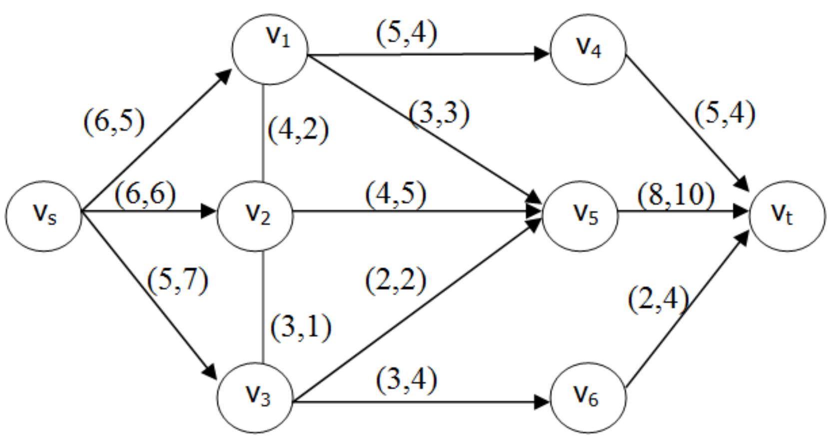

Figure 3. Adjusted transport flow

This is a simplified example of practical problems, mainly in order to illustrate the feasibility of the idea and the construction of freight transport network expansion planning. The actual complex problems can be calculated by MATLAB.

5 Conclusions

This paper studied the urban freight transport network and established an expansion optimization model about urban freight transport network with the shortest transportation time, the lowest transportation costs, the unit capacity cost minimum and the least road congestion status. At last a corresponding algorithm was designed in this thesis. This thesis focused on the urban freight transport network without considering the impact of traffic part of pedestrians and non-motorized vehicles for freight transport network. Therefore, the further study on considering various factors compulsively, and establishing a more rational optimization expansion model will be necessary.

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References

Lu Huapu (2004). Intelligent Transportation Systems. Beiing: Chinese Railway Publishing House.

Li Yanyan (2013). The Research on Urban Freight Traffic Organization Mode and Optimization. Chengdu. Southwest Jiao tong University.

Li Yanlin, Hua Guang, Sun Dongquan (2013). Analysis China's urban freight vehicle traffic management policy impact on logistics. *Transportation Construction & Management*, 11:74-77.

Li Baoling, Sun Shujuan (2004). Investigation on traffic volume. *Heilongjiang traffic science and technology*, 2.

He Ping. Mathematical statistics and multivariate statistics. Chengdu: Southwest Jiao Tong University press.

Yang Yunxia (2005). Time series forecasting model and its application. *Journal of Taiyuan Normal University*, (4).

Ji Kexiang (2013). Analysis of the applicability in the traffic prediction of elastic coefficient method. *The world of communications*, 5/6, 185-186.

Liu Tingxin, Li Zhenyu (2002). Application of exponential smoothing method in short-term prediction of traffic in the parameters. *Journal of Shandong Jiaotong University*, 3.

Zhang Xintian, Luo Xiaohui (2001). Application of grey system theory and model in traffic volume forecast. *Highway*, 8, 4-6.

Luo Xia, Liu Lan (2008). The traffic management and control. The people traffic press, Beijing.

Zhang Fan, Tian ZhiQiang, Song Qi (2010). Optimization Algorithm for Enlarging Capacity of Transportation Network. *Highway Transportation and Logistics*, 02/03, 36-39.

Kou Weihua, Cui Haoying (2012). Optimizing Study on Enlarging the Capacity of Traffic Network to Meet the Need of the Increscent Flow. *Journal of Transportation on Engineering and Information*, 12(4), 19-25.

Wei Hang, Pu Yun, Li Jun (2005). A shortest path algorithm with two goals. *Systems Engineering*, 7, 113-117

A Quantitative Method of Urban Road Hierarchy

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Abstract: Road classification and hierarchy are the fundamental of road network planning and road design, and a set of strict and quantitative hierarchy method can reduce or even eliminate the subjectivity and uncertainty in urban planning. Based on summarizing deficiencies in existing road classification method, this paper focus on the road structure importance in network with complex network analysis techniques, building an index to describe road comprehensive importance and quantified road hierarchy method. The index built here takes both of road structure characteristic and road width into account. Through the case study of Mianyang, we find that, to some extent, there is a good similarity between results of this new method and the traditional method. This new method could help planners classify and rank urban roads more accurately and faster.
Keywords: Urban road network; Road hierarchy; Complex network; Betweenness; Road width.

1 Introduction

Road hierarchy, a usual measure and form of classification of road in which each kind of roads has a ranking with respect to the whole set of kinds, is a vital part of the design of urban road network. The reason is that we can't ensure appropriate management, engineering standards and maintenance practices applied to a certain road until its hierarchy is determined.

The kind method in Highway Functional Classification: Concepts, Criteria, and Procedures (Federal Highway Administration, 2013) is typical of many kinds of road classification and hierarchy in use around the world. In this typical method, functional classification is used to categorize road with the two primary transportation functions of roadways, i.e. mobility and access, and some other factors helping determine the proper category. Roads providing a high level of mobility are called "Arterials", those providing high level of accessibility are called "Locals", and those providing a mix of both of them are called "Collectors".

In China, almost relative design specifications and criteria identify four hierarchy levels of urban road classification, with comprehensive consideration of status (or importance) of road in the urban road network, transportation function and service function to buildings along the road (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2012). However, no more description has been given about how to determine a road hierarchy in practical work. Existing conventional road classification and hierarchy methods are based on different functions and status of roads, while they are qualitative. As a consequence, planners and engineers probably determine a road hierarchy by their own experience, which is easily affected by subjective factors.

Therefore this paper introduced a quantitative method of urban road hierarchy with building an index used to describe comprehensive importance of urban roads.

The rest of this paper is structured as follows. Section 2 is literature review. In section 3, we mention the methodology used and show how the index is defined and calculated. Calculation hierarchy method introduced in this paper is particularly presented in section 4 with a real case study. Then the result is further analyzed in section 5. Finally section 6 concludes the paper.

2 Literature Review

Official hierarchies of urban networks almost are based on local or national design specifications and criteria, and may reflect features and relations of urban roads in some degree. Those hierarchy methods have been widely discussed (Eppell, McClurg, and Bunker, 2001; Marshall, 2004). Often those conventional and official hierarchy methods are vaguely stated, so planners and designers have to decide by subjective judgment.

Other than conventional hierarchy methods, there're many studies of road hierarchy from different directions. Stevens (Stevens and Coupe, 1978) proposed that people have hierarchy structures organized in their cognition to road networks of some cities, and gave direct evidence for hierarchical structure in cognitive maps. Hirtle (Hirtle and Jonides, 1985) extended Stevens's work to a natural environment that has no predetermined, well-defined hierarchical structure. And how the hierarchies of roads form and grow and are used in our perception and cognition was investigated by Tomko (Tomko, Winter, and Claramunt, 2008).

Many real networks in nature and society share two generic properties, i.e. scale-free and high degree of clustering, and it has been proved that these two features are the consequence of a hierarchical organization (Ravasz and Barabási, 2003). Jiang (2007) studied topological patterns of urban street networks of 40 U.S. cities and found that all the topologies of urban street networks demonstrate a small word structure and a scale-free property for both street length and connectivity degree. Salingaros (2005) and Jiang (2008a) articulated that urban street networks demonstrate an ordered hierarchical structure of connections at the different levels of scale, but they didn't quantify hierarchy levels and provided how to divide each road to a certain hierarchy level.

3 Methodology and Index Definition

3.1 Methodology

In this study, we first tried to define and build a quantitative index to describe the importance degree of road in network, with which all roads can be ranked in order. Then under the process of calculation hierarchy method (section 4) we would get a classification result where each road is divided to a hierarchy level. Finally we compared the result with real classification of city network to demonstrate the reliability of this method.

3.2 Topological structure characteristics and mobility

In urban road network, for one road, there is an inverse correlation between its mobility and accessibility. In general, an arterial road has a more high status and is more important than a collector or local road. So to some extent, mobility is positively related to importance of the road in network. Hence, we could use the structure importance of road to reflect mobility.

An important arterial road with high level of service will not connect many roads directly, while most traffic transfer between collectors or local roads must go through it. In other words, an arterial road plays a role like 'hub'. Betweenness, as a centrality measure of a vertex within a network (Freeman, 1977), could describe degree of the 'hub' effect of a vertex in network (Wasserman and Faust, 1994; Jiang, 2008a). Therefore this paper chose betweenness as an indicator to reflect structure importance of road. Betweenness of the vertex is defined as follows:

$$C_i^b = \sum_{\substack{j,k \\ j \neq k \\ j,k \neq i}} \frac{|\sigma_{jk,i}|}{|\sigma_{jk}|}, \text{ or normalized: } \overline{C}_i^b = \frac{C_i^b}{(|V|-1)(|V|-2)} \qquad (1)$$

We analyzed urban road network and got its topological representation on the basis of strokes (Thomson, 2003; Jiang and Liu, 2008b), which is a dual graph and where vertices represent strokes, then betweenness of each vertex can be calculated by Eq. 1.

3.3 Limit of road width

A stroke is naturally merged urban road segments with a good continuity of direction (Thomson, 2003; Jiang and Liu, 2008b) which is based on the Gestalt principle. Gestalt principles, or gestalt laws, are rules of the organization of perceptual scenes and aim to formulate the regularities according to which the perceptual input is organized into unitary forms (Todorovic, 2008). Because of the influence of urban land use planning, the width of boundary line of each road segment ranges. Some stroke which crosses through the whole city and can be as a traffic corridor has a high betweenness, but one road on this stroke may be narrow so that the hierarchy level of this road wouldn't be too high. In general, narrow road is with bad mobility but good accessibility whose importance is relatively low in real network.

Although other factors such as speed limit and volume can also influence determining road classification and hierarchy, in this paper, we just choose road width as another component of the index we build. The reason is that road width is a stable factor, which will not easily change in a long time, so that the effect of road width to hierarchy is reliable.

3.4 Index calculation

This paper took into account both structure importance and road width to build an index, called *CI* (comprehensive importance), which is used to describe the comprehensive importance of road in network. For the road r_i, betweenness of the stroke which it belongs to is C_i^b and width is w_i, then CI_i should have a relation with them like $CI_i = f(C_i^b, w_i)$. We could compare the comprehensive importance of different roads with the relative values of *CI*, so we just need to express the correlation correctly. We defined the CI as

$$CI_i = g(w_i) \cdot \exp(C_i^b) \qquad (2)$$

where $\exp(C_i^b)$ is to eliminate zero value effects of C_i^b, and $g(w_i)$ is standardization of w_i with $g(w_i) = w_i / \max(w_i)$.

4 Calculation Hierarchy Method

In this section, we chose road network of Mianyang city for our study and introduced how to rank roads and get hierarchy of them, which we called calculation hierarchy method. First we need a GIS file of Mianyang network shown as Figure 1, then process this file to get its topological representation with strokes and compute betweenness using UCINET 6. Betweenness of road equals to the stroke it belongs to, next, we can get CI of each road by Eq. 2. On account of difficulties of getting data about the width of the whole roads, we estimated the width according to the number of lanes.

Table 1. Attributes of partial roads of Mianyang network

LinkID	SID	Length (km)	g(w)	Betweenness	CI
1	1	0.207	0.69	0.032	0.7113
2	2	0.295	0.36	0.177	0.4244
3	3	0.054	0.20	0	0.2
4	4	0.085	0.36	0	0.3556
5	5	0.08	0.18	0.003	0.1783
6	5	0.038	0.36	0.003	0.3566
7	2	0.695	0.36	0.177	0.4244

Table 1 shows attributes of partial roads of Mianyang network, where LinkID is road number and SID is stroke number.

Figure 1. Urban road network map of Mianyang

We ranked all roads in descending order of *CI*, and the higher *CI* road had, the higher level hierarchy road was. *CI* is continuous but road hierarchy is discrete. Thus we must select appropriate threshold values of CI to divide the range of *CI* into three parts. Each hierarchy of roads has a sum of length and a proportion in the network in urban road planning, so we can divide *CI* according to the length and proportion of each hierarchy of road and confirm the thresholds. Table 2 shows length and proportion of each hierarchy of Mianyang network. Under the ranking condition, roads with top *CI* are arterials until the sum of road length is close to 75.8324km, and the lowest *CI* among them is the first threshold. It is notable that in all probability we can't exactly find a road segment in the method to make the total length of some hierarchy level equal to that length in real network. Analogous, we can get collectors and the second threshold, and the remaining road are local roads. The result is shown in Table 3. In this way all roads in network are classified. The structures of road hierarchy in both real network and result of calculation hierarchy method are shown in Figure 2 and Figure 3.

Table 2. Road hierarchy of real network

Hierarchy	Length(km)	Proportion
Arterial	75.8324	18.74%
Collector	138.01	34.11%
Local	190.808	47.15%
Total	404.6504	100%

Table 3. Road hierarchy of calculation hierarchy method

Hierarchy	Length(km)	Proportion
Arterial	75.8194	18.74%
Collector	138.023	34.11%
Local	190.808	47.15%
Total	404.6504	100%

(a) arterial subnet (b) collector subnet (c) local subnet

Figure 2. Subnet of each hierarchy level in real network

(a) arterial subnet (b) collector subnet (c) local subnet

Figure 3. Subnet of each hierarchy level in calculation hierarchy result

By comparison between Figure 2 and Figure 3, it seems that in both cases subnets of each hierarchy have similar structure. But arterial subnet of calculation hierarchy method (Figure 3a) looks more smooth and has fewer short branches than the real (Figure 2a).

5 Discussion of Results

It is hard to compare road hierarchy of both situations effectively just from graphs. In this section we analyzed and compared their similarities and differences from two aspects, sizes and compositions of the same hierarchy in both situations. Size ratio r_s is the ratio of total length of some hierarchy in calculation hierarchy result to the total length of the same hierarchy in real network. And composition ration r_c is the ratio of total length of those roads with same hierarchy in both situations to the total length of that hierarchy in calculation hierarchy result. When they're similar in size, the r_c can reflect the degree of conformity of the result of calculation hierarchy method with the real result.

Table 4. Compositions of each hierarchy level in both situations

Hierarchy	$L^{real}_{arterial}$ (km)	$L^{real}_{collector}$ (km)	L^{real}_{local} (km)	Total	r_c
$L^{calc}_{arterial}$ (km)	69.3474	6.472	0	75.8194	0.9146
$L^{calc}_{arterial}$ (km)	6.485	131.538	0	138.023	0.9530
$L^{calc}_{arterial}$ (km)	0	0	190.808	190.808	1.0000
Total	75.8324	138.01	190.808	404.6504	
r_s	0.9998	1.0000	1.0000		

We could conclude from Table 4 that this calculation hierarchy method is credible. Although affected by subjective factors due to the limits of conventional methods, our planners must design roads and determine road hierarchy correctly in general. In that way, the result of calculation hierarchy method are also credible largely because of high conformity.

6 Conclusions

This paper introduced a new index CI to describe the integral importance of roads in network and a new method to rank and classify road quantitatively. Special focus was on the definition of the index and how to use it classify roads. Through a case study of Mianyang road network, it is indicated that the index can work well and the new hierarchy method is reliable. Applying this index and method to practical work can simplify and accelerate the progress of road classification and hierarchy, meanwhile, can mitigate adverse effects of subjectivity.

7 Recommendations for Future Research

About the definition of the index, we can take other factors into account in addition to road width and study whether the effect of a multiple-factor index is better than the one-factor index. Besides, we will have more case studies of other cities road networks to prove that the index and method have a general applicability.

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References

Eppell, V., McClurg, B. A., and Bunker, J. M. (2001). “A four level road hierarchy for network planning and management.” In Jaeger, Vicki (Eds.), 20th ARRB conference, Melbourne, Australia.

Federal Highway Administration. (2013). “Highway Functional Classification: Concepts, Criteria, and Procedures 2013ed”, available at http://www.fhwa.dot.gov/planning/processes/statewide/related/highway_functional_classifications/fcauab.pdf

Freeman, L. (1977). “A set of measures of centrality based upon betweenness.” Sociometry 40: 35–41. doi:10.2307/3033543.

Hirtle, S. and Jonides, J. (1985). “Evidence of hierarchies in cognitive maps.” Memory and Cognition, 13, 208–217.

Jiang, B. (2007). “A Topological Pattern of Urban Street Networks: Universality and Peculiarity.” Physica A: Statistical Mechanics and its Applications, 2007, 384: 647 – 655.

Jiang, B. (2008). “Street Hierarchies: A Minority of Streets Account for a Majority of Traffic Flow.” arxiv.org/abs/0802.1284.

Jiang, B. and Liu C. (2008). “Street-based topological representations and analyses for predicting traffic flow in GIS.” International Journal of Geographic Information Science.

Marshall, S. (2004). “Streets and Patterns.” Spon Press, London and New York.

Ministry of Housing and Urban-Rural Development of the People’s Republic of China (2012). “Code for design of urban road engineering” Professional standard of the People’s Republic of China, China Architecture & Building Press, Beijing.

Ravasz, E. and Barabási, A. L. (2003). “Hierarchical organization in complex networks." Physical Review E, 67, 026112.

Salingaros, N. A. (2005). "Principles of Urban Structure." Techne: Delft.

Stevens, A. and Coupe, P. (1978). "Distortions in judged spatial relations." Cognitive Psychology.

Thomson, R. C. (2003). "Bending the axial line: smoothly continuous road centre-line segments as a basis for road network analysis." Proceedings of the Fourth Space Syntax International Symposium, University College London, London.

Todorovic D. (2008). "Gestalt principles." Scholarpedia, doi:10.4249/scholarpedia.5354

Tomko, M., Winter S. and Claramunt C. (2008). "Experiential hierarchies of streets." Computers, Environment and Urban Systems, 32.1, 41 – 52.

Wasserman, S. and Faust, K. (1994). "Social Network Analysis." Cambridge University Press, Cambridge, UK.

Study on Macro Regularity and Control Strategies of Road Traffic Accidents—Take Jiangxi Province as an Example

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Abstract: Road traffic safety is a complicated system engineering. This study makes a study on the macro regularity and control strategies of road traffic accidents systematically. Compared with other developed provinces, Jiangxi province lags much behind in road traffic safety construction. A large number of traffic accident data of Jiangxi province are collected and analyzed quantitatively using SPSS software. In this study, the macro regularity of road traffic accidents in Jiangxi province is found out and corresponding control strategies are put forward. As a result, goals of reducing traffic accidents and improving the road traffic safety level in Jiangxi province are reached. The research could meanwhile be of value to related research and formulate policy control of other cities.
Keywords: Road; Traffic accidents; Macro regularity; Control strategies; Safety.

1 Introduction

As the main artery of the national economy and bearing 87.3 percent and 76.3 percent of passenger and freight volumes, road transportation is the significant motivation and power for developing national economy and improving people's living standards. Statistics show that since 1899, over 30 million deaths have been caused by the car crash accidents worldwide. According to statistics data from Traffic Management Bureau, Ministry of Public Security , the number of accidents which caused casualties totals 210821 in 2011, killing 62387 people, which ranks first in the world six years in a row. Through the analysis of traffic accident data, the causes could be found and effective strategies of improving traffic safety could thus be sought out. Jiangxi province is representative in traffic safety problems due to its middle-level economic development and the increasing number of motor vehicles. This research makes a study on the macro regularity of road traffic accidents Jiangxi province systematically. According to the local investigation situation, corresponding control strategy is put forward then.

2 Data and Method

2.1 Data Resource

In this study, data on traffic safety accidents and related influencing factors, 2000-2013, in Jiangxi province are collected. These data come from Jiangxi Statistical Yearbook (2000-2014), Memorabilia: Jiangxi Public Security and Traffic Management, 1987-2007, Jiangxi Road Traffic Safety Accidents Report (2008 -2013). As is shown in table 1and Figure.1.

Table 1. Four indexes of road traffic accidents of Jiangxi province(2000-2013)

year	the number of accidents(accident)	the number of death(person)	the number of injuries(person)	direct property loss(ten thousands yuan)
2000	17591	3222	13988	7225
2001	17696	3355	14754	7150
2002	17772	3163	14669	7456
2003	13998	2818	11542	7783
2004	10531	2760	10004	6370
2005	8585	2428	8370	7698
2006	9449	2332	10759	6496
2007	8080	2060	9250	6261
2008	6350	1945	7370	6160
2009	5872	2161	7148	4564
2010	4126	1603	4938	4184
2011	3411	1733	4135	4857
2012	3145	1579	3479	4542
2013	2915	1492	2977	3738

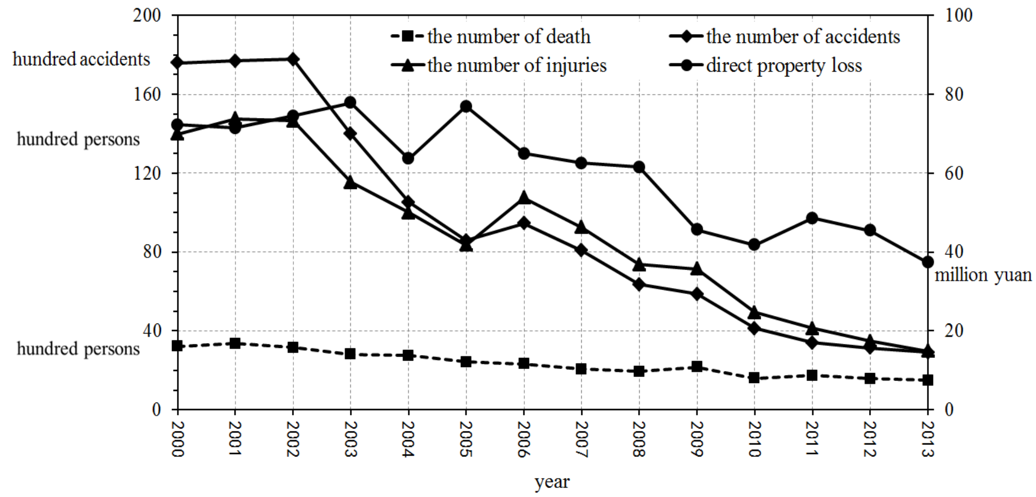

Figure 1. Four indexes of road traffic accidents of Jiangxi province(2000~2013)

Seen from the four indexes in recent years, the traffic safety situation in Jiangxi province is improving and the number of accidents is shrinking. However, severity of death, injury and property loss vary in traffic accidents. Therefore, it is difficult to compare the statistics of death, injury and property damage of different regions and in different years. In this study, the reference standard is that the death, injury and property damages are all converted to total loss of the traffic accidents.

According to the yearly regulations from 2000 to 2013 in Compensation Standards of Traffic Accidents and Personal Injuries in Jiangxi Province:

Death compensation = per capita income in the place where the appellate court is located×20years (1)

Disability compensation = per capita income in the place where the appellate court is located×disability coefficient×compensation period (2)

In the above formula, per capita income could be obtained by statistical yearbook, and disability coefficient and compensation period could be fixed hierarchically according to the accident investigation report from traffic administration departments. Afterwards, the number of deaths and injuries and direct property damages in road traffic accidents in Jiangxi province could be converted into the total loss of traffic accidents. The case of each year is shown in Figure.2.

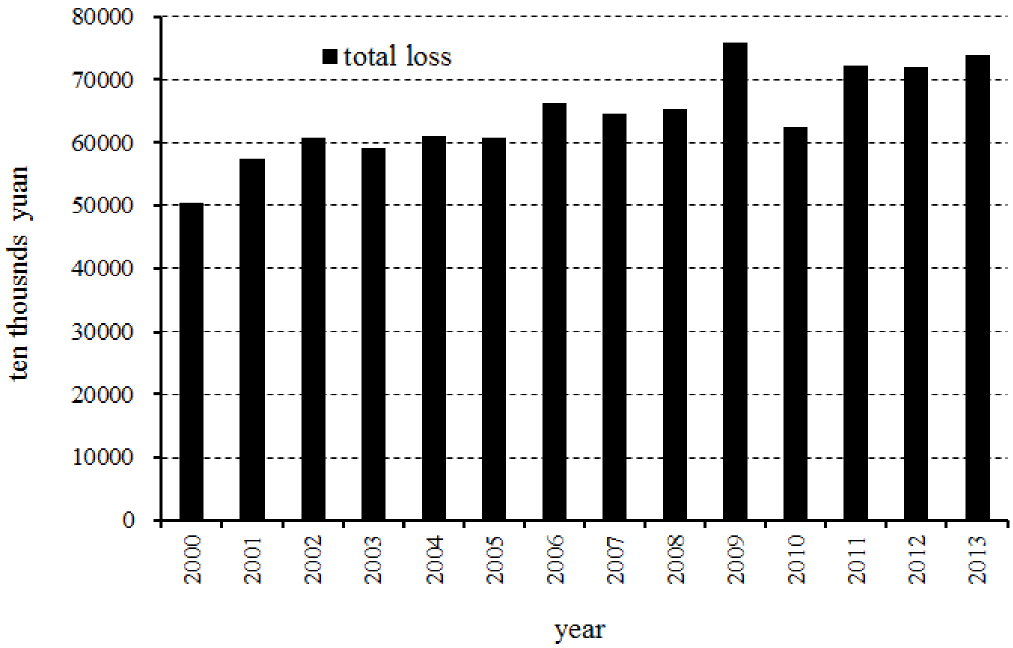

Figure 2. The total loss of road traffic accidents, 2000 to 2013, in Jiangxi province

It could be seen from figure 2 that the total loss of road traffic accidents in Jiangxi province is on the rise and that the traffic safety situation is very grim. Based on relevant theories and research literature of road traffic safety, this study chooses population, urbanization rate, highway mileage, the number of motor vehicles and drivers as influencing factors. The collected data are shown in Table 2.

Table 2. The influencing factors of traffic accidents , 2000 to 2013, in Jiangxi province

year	population （ten thousands persons ）	（%）	road length （hundred kilometre）	the number of vehicles （ten thousands vehicles）	the number of drivers （the thousands persons）
2000	4149	28	603	114	79
2001	4186	30	605	136	91
2002	4222	32	607	154	103
2003	4254	34	612	191	107
2004	4284	36	619	218	110
2005	4311	37	623	302	109

2006	4339	39	1282	352	109
2007	4368	40	1307	399	273
2008	4400	41	1338	446	313
2009	4432	43	1370	505	356
2010	1189	45	1406	569	391
2011	1210	46	1466	631	453
2012	1232	48	1506	684	875
2013	4522	49	1547	752	929

2.2 Method

Fig. 3 shows the model of traffic accidents generating rules analysis.

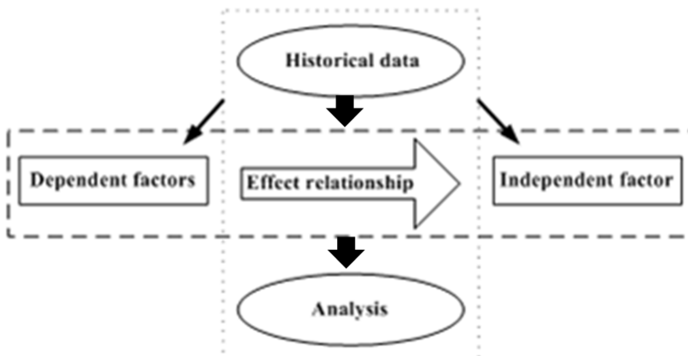

Figure 3. Conceptual model of traffic accidents analysis

The correlation coefficients $\mathbf{r_{lj}}$ are introduced to discuss the relation between road traffic safety accidents and influencing factors in Jiangxi province. Simple correlation coefficients between $\mathbf{y}$ and $\mathbf{x_{li}}$, and between $\mathbf{x_{li}}(\mathbf{l=1,2,\cdots,k})$ and $\mathbf{x_{ji}}(\mathbf{j=1,2,\cdots,k})$ could be calculated separately by the sample values $\mathbf{y_i},\mathbf{x_{1i}},\mathbf{x_{2i}},\cdots,\mathbf{x_{ki}}$, $\mathbf{i=1,2,\cdots,n}$. The formula can be written as follows:

$$r_{xy} = \frac{COV(x,y)}{\sigma_x \, \sigma_y} \tag{3}$$

Where, r_{xy} denotes correlation coefficients between x and y; $COV(x,y)$ denotes covariance between x and y; σ_x denotes standard deviation of x; σ_y denotes standard deviation of y.

Through the simple correlation coefficient of the sample, the size of the correlation coefficient of $\mathbf{y}$, namely dependent variable, and $\mathbf{x_j}$, namely independent variable, could be observed.

In the study, simple correlation coefficients are calculated with the aid of SPSS software. The result of output by SPSS is shown in table 3.

Table 3. Correlation

Correlation	Population	Urbanization rate	Length of highway	Vehicle possession	Number of drivers
Accident of total loss	-.275	.875	.824	.853	.738
Sig	.171	.000	.000	.000	.001

3 Results and Control Strategies

3.1 Results

The results show that strong correlation exists between the urbanization rate, length of highways, the number of motor vehicles and drivers and the total loss caused by traffic accidents. They not only verify the traditional traffic safety theory, but also further throw light on road traffic safety control strategies of Jiangxi province.

Based on the above research and taking into consideration other accident data and field investigations, it is found that the road traffic accidents in Jiangxi province have the following rules:

(1)High traffic accident fatality rate

Traffic accident fatality rate is the ratio of the total number of deaths and injuries in traffic accidents. The rate is about 14 percent to 20 percent in Jiangxi province, while remains between 1 percent and 4 percent in developed countries.

(2) Large proportion of vulnerable road users in accident victims

Vulnerable road users (mainly pedestrians, cyclists and two-wheeled vehicle users) account for more than 50 percent in terms of the number of deaths, injuries, accidents or other indexes of traffic accidents. Among these, the proportion of motorcyclists in the number of deaths and injuries is 23.58 percent and 28.52 percent respectively.

(3)Accident-prone segments

Dangerous and hazardous segments and accident black spots became the worst-hit areas of traffic accidents. For example, K194-K204 road of Daguang Expressway (from Ganzhou to Suichuan) accounts for 9.5 percent of the whole road mileage statistics, while the number of accidents and deaths has accounted for 31 percent and 71 percent.

(4)High proportion of traffic accidents on roads in mixed traffic status, without traffic control and with imperfect traffic facilities

Statistics show that traffic accidents occurring on roads without traffic control account for about 40 percent to 50 percent of those occurred throughout the year in Jiangxi province. The resulting death toll accounts for 55 percent to 65 percent of that in a whole year.

(5) Non-motor vehicle users and pedestrians violation being the main cause of urban road traffic accidents

Around a third of urban road traffic accidents in Jiangxi province are caused by violation of non-motor vehicles and pedestrians.

(6)Relatively high traffic accident rate of operating vehicles

Over the recent 10 years, the number of accidents, deaths and injuries related to operating vehicles accounts for 37.75 percent, 47.13 percent and 35.79 percent respectively of the corresponding index of the total number of traffic accidents.

3.2 Road Traffic Control Strategies

(1) The control of human unsafe factors

First of all, a strict and efficient driver training, appraisal, supervision and management mechanism should be established. Then, the regulation of key illegal behaviors must be strengthened, including both motor vehicle drivers and non-motor vehicles users and pedestrians. For different violations, different treatment schemes should be formulated. Finally, transport enterprises should strictly implement the responsibility system for production safety. What's more, transportation enterprises and the qualifications of drivers should be supervised for strict carry-out of the transport market access system.

(2) Improvement and enhancement of vehicle safety

Gradually increase the security of overall vehicle constitutes. Provincial Development and Reform Commission and Bureau of Quality Supervision should organize experts to participate in the analysis of road accidents. Under the guidance of the motor vehicle industry development policy, supervision of the auto companies should be strengthened from the source of the car manufacturers. At the same time, the motor vehicle inspection system should be strictly enforced and regulations on motor vehicle production, modification, maintenance, inspection and mandatory retirement should be strengthened as well.

(3) Improvement and enhancement of road system safety

Establish an effective of road traffic safety audit system. In addition, the provincial and local governments and transportation departments should effectively increase investment on, reasonably set up and improve the traffic safety facilities.

Comprehensive investigation and remediation should be made on road accident black spot and segments with security risks. Relevant departments should jointly formulate the investigation and remediation norms and standards of accident-prone segments, and identification, monitoring and evaluation system should be established, too. What's more, sound security risks investigation and remediation mechanism should also be formed.

(4) Improvement and enhancement of road traffic safety management

To begin with, set up road traffic safety committee in the charge of the government, leaders as main officials. The members consist of many traffic safety related departments. Make sure that all departments involved work collaboratively on it.

It is necessary to make a reasonable increase in the police force and an introduction of high-level professionals. On the other hand, the police force could be released by means of social forces. For example, part of the traffic safety management work can be carved out of the traffic control department. Funded by the Government, a tender is initiated and the task is then turned over to the successful bidder, a professional business or team.

(5) Enhancement of road traffic safety propaganda and education

Gradually improve the traffic safety propaganda system dominated by the government, in the charge of the road traffic safety committee and participated by other relevant departments. At the same time, establish long-term mechanism of traffic safety propaganda and undertake traffic safety propaganda activities regularly.

Education and traffic police departments could organize the writing of books and periodicals on traffic safety propaganda and education for children and adolescents of different ages. Make traffic safety education part of the legal education in schools at all levels.

(6) Establishment of sound traffic safety policies, laws and regulations

Accelerate the formulation of local regulations, governmental rules and regulations, and regulatory documents supporting the provincial traffic safety administration. Implement them reasonably. For instance, the formulation of Road Construction Designed to Implement Traffic Regulations, Guidance on Road Transport Facilities Installation, Motorcycle and Electric Car Regulations, School Traffic Safety Implementation Outline, The "Four Synchronous" Requireme*nt of Road Transport Facilities Construction* .

4 Conclusions

In the future, rapid development of motorization will be accompanied by increased traffic casualties. In this study, through statistical analysis of accident data, correlation is built between people, vehicles, roads, urbanization rate and traffic accidents. Together with other traffic accident data and research, the macro regularity of road traffic accidents in Jiangxi province is analyzed. Corresponding road traffic control strategy is then proposed, which is aimed at establishing a road traffic safety control system theory and technology system.

Acknowledgement:

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References

Gras M, Sullman M, Cunill M. Spanish drivers and their aberrant driving behaviors.Transportation Research Part F, 2006, 9(2): 129-137.

Haynes R, Lake I R, Kingham S, et al. The influence of road curvature on fatal crashes in New Zealand. Accident Analysis and Prevention, 2008, 40(3): 843-850.

Huang H, Abdel-Aty M, Darwiche A. County-level crash risk analysis in Florida: Bayesian spatial modeling//89th Transportation Research Board Annual Meeting CD-ROM.Transportation Research Board of the National Academies, Washington, D.C., 2010.

Lee C, Abdel-Aty M. Comprehensive analysis of vehicle-pedestrian crashes. Accident Analysis and Prevention, 2005, 37(4): 775-786.

Machin M A, Sankey K S. Relationships between young drivers' personality characteristics, risk perceptions, and driving behavior. Accident Analysis and Prevention, 2008, 40(2): 541-547.

Wong S C, Sze N N, Li Y C. Contributory factors to traffic crashes at signalized intersections in Hong Kong. Accident Analysis and Prevention, 2007, 39(6): 1107~1113.

World Health Organization. global status report on road safety: time for action. Genevese, Swiss: World Health Organization, 2009.

Wu Chaozhong, Lei Hu, Ma Ming, et al. Severity Analyses of Single-Vehicle Crashes Based on Rough Set Theory//Proceedings of 2009 International Conference on Computational Intelligence and Natural Computing. Wuhan, 2009: 324-327.

Reasonable Shoreline Length of a Fishing Port by Simulation Software Arena

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Abstract: Simulation software Arena is used to build fishing port system simulation model. According to the actual operation characteristics of the fishing port, the flexible berthing way is to assign a certain length of coastline in accordance with the length of the fishing boat, no fixed berths. Through many simulation experiments, reasonable length of coastline corresponding to different annual throughput is obtained. After analyzing the simulation results, I achieved the formula for calculating the corresponding reasonable length of shoreline, which can be used as a fishing port planning and design.
Keywords: Annual discharged volume for fishing port; Port; Reasonable length of coastline; Flexible berthing; Simulation.

1 Introduction

The fishing port production process can be seen as a service process for random arrived boats. Queuing theory is used to handle random service issues traditionally. Representatives ship needs to be selected. But types are complex, therefore, the use of queuing theory can't accurately describe the service process. With aid of computer, we uses simulation approach to deal with random service problems which has demonstrated good results. However, the preparation of a computer program is too complex to promote. The emergence of management system simulation software leads to the convenience to greatly improve the efficiency and increase the promotion of the use.

2 Analysis of reasonable length of fishing port shoreline by simulation software Arena

2.1 Model Introduction

Arena is a management system software that combines ease of use and flexibility of high-level language emulation emulator. The most basic modeling tools are the modules which connect together to build a variety of different simulation models (David Kelton, 2007). Model is divided into boat subsystems, waiting subsystems, berthing and unberthing subsystem.

Boat subsystem is to determine the arrival time interval of fishing boat, the proportion of ship carrying amount of fish. etc. Subsystem records boats' waiting time, the time for same type of ship is divided into the total waiting time and average waiting time for each boat. Moored subsystem is to record total work time and average working hours. The leave subsystem record the needed time of departures after the work is completed.

Model takes flexible berthing approach. Fixed Berthing approach will lead to some equipment idle in the port, negatively affect the overall operational efficiency, thereby causing unnecessary economic losses. So many fishing ports began to arrange a flexible berthing operating plan based on a certain length of fishing boat, assign shoreline length to substitute fixed number of berths. When fishing boat working, the specific shoreline and its front area stay as a whole, which has no clear distinction with previous design. Flexible berthing method enables the number of fixed berths to exceed original division ones, maximizing the use of quay length, thereby reducing the overall staying time in the port. Meanwhile, this way not only takes full advantage of shorelines, but also improve the unloading equipment utilization, shortening the waiting time in port.

2.2 Model data and results

Control variables in the model is average time interval, the proportion of boat types and shore length. Entity attributes include shoreline occupied by different boats and volume of fish per boat, also statistical data like when fishing boats in and out and working time in port.

This paper simulates the fishing port in the amount of discharge port from 10,000 to 20 0,000 tons, 20 kinds of unloading ports capacities. Different unloading port capacity corresponds to different time intervals, the proportion of boat types, contained volume. Obviously, with the increasing amount of fish volume: the arrival time interval will be shorter, large fishing vessels in the proportion will increase, small fishing vessels will be lower.

According to the queuing theory, when the number of fishing boat obey Poisson distribution (GUI Jinsong, 2000), arrival interval time obeys the negative exponential with the parameter same λ. The probability density for interval time as t is:

$$g(t) = \lambda \cdot e^{-\lambda t} \tag{1}$$

According to related data provided by Zhapo, Fujian Dongshan, Tongling, Dalian Xingshu ports, daily arrival boats are 25 to 69 , 40 to 55 for eighty thousand tons of yearly unloading volume port. Average arrival time can be calculated by the number of daily arrival fishing boats and its volume. Fishing ports in the model calculations presented in this paper and corresponding to the amount of the average time interval is in Table 1 below.

Table 1. Average arrival time interval of fishing boat (various annual throughput)

The quantity of annual fishing [Ten thousands/year]	1	2	3	4	5
The average interval time of fishing boat [h/ships]	4.07	2.04	1.4	1.01	0.82
The quantity of annual fishing [Ten thousands/year]	6	7	8	9	10
The average interval time of fishing boat [h/ships]	0.68	0.59	0.505	0.45	0.4
The quantity of annual fishing [Ten thousands/year]	11	12	13	14	15
The average interval time of fishing boat [h/ships]	0.37	0.34	0.31	0.29	0.27
The quantity of annual fishing [Ten thousands/year]	16	17	18	19	20
The average interval time of fishing boat [h/ships]	0.26	0.24	0.23	0.21	0.2

In view of 12,000 statistical random sampling groups, small-sized fishing boats 45%, medium 34%, and large 21%. Its improvement and uncertainty are taken into account. The proportion of various types of fishing boats are as follows:

Small fishing boats: Medium fishing boats: large fishing vessels=0.4:0.3:0.3;

Small fishing boats: Medium fishing boats: large fishing vessels=0.35:0.35:0.3;

Small fishing boats: Medium fishing boats: large fishing vessels=0.3:0.35:0.35;

Small fishing boats: Medium fishing boats: large fishing vessels=0.25:0.4:0.35.

Through statistical analysis of 12,000 sets of fishing boats, the length of 3 types of standards design are 14.2 m for small boats, 34.32 m for medium-size, 45 m for large. Based on documents (XIN Hongfu, 2000) fishing port berth length is calculated as follow.

$$L = L_b + 0.15L_b \tag{2}$$

with L_b: the length of design standards for fishing ship.

By analyzing *Xingshu fishing port throughput and ship unloading capacity statistics* (one year) and *Zhapo fish market statistic tables* (three years), the amount of fish cargo loading of each model fishing boats are shown in Table 2.

Table2. The amount of fish cargo loading of each model fishing boat

Small fishing boat		Medium-size fishing boat		Large fishing boat	
Deadweight [t/ship]	Membership	Deadweight [t/ship]	Membership	Deadweight [t/ship]	Membership
2	0.3	4.5	0.3	7.5	0.3
3	0.45	6	0.45	8.5	0.4
4.5	0.25	8	0.25	10	0.3
Weighted average [t/ship]	3.45	Weighted average [t/ship]	6.05	Weighted average [t/ship]	8.65

According to the literature (XIN Hongfu, 2000) we know that the efficiency of human-labor is 2~4 t/h, cranes unloading is 5~9t/h, mechanic is 10~15 t/h. Occupied shoreline is 17 m for small fishing boats, berth occupancy time is 1.5 h; medium-size 38 m, 2.8 h; large 52 m, 3.5 h. 365 days is regarded as an operation cycle, the fishing moratorium time is three months. So 275 working days a year and 24 working hours a day. Ensuring fishing port annual throughput unchanged, we change the length of shoreline, so that I can get the corresponding optimal quay length of throughput (Comprehensive minimum charges including the cost of idle boats and the waiting boats for berth). According to the literature (David Kelton, 2007), the ratio of small fishing boat is 2.3:1; the medium-size is 2.9:1; the large is 4.1:1. As follow table 3.

Table3. The simulation results

the annual throughput[ten thousand tons/year]	1	2	3	4	5	6	7	8	9	10
the length of quay [m]	225	300	380	500	550	600	650	700	750	800
the utilization	35	35	37	36	37	37	36	36	37	38

of quay [%]										
the cost of comprehensive[/t]	0.13	0.12	0.11	0.11	0.095	0.085	0.079	0.075	0.071	0.07
the annual throughput[ten thousand tons/year]	11	12	13	14	15	16	17	18	19	20
the length of quay [m]	810	820	830	835	840	840	845	845	850	850
the utilization of quay [%]	38	42	44	42	45	36	51	51	53	56
the cost of comprehensive[/t]	0.065	0.066	0.064	0.058	0.058	0.056	0.056	0.055	0.054	0.054

Table 3 shows that with the increase of fishing port annual throughput the length of quay will increase, the cost of comprehensive will gradually reduce; when the fishing port annual throughput reaches a certain amount the length of quay will increase gradually slow, the cost of comprehensive gradually decrease too; the fishing port annual throughput resches above 150000t, the length of quay will remain the same baisclly, the cost of comprehensive will be similar and remain unchanged basically.

Abtained:

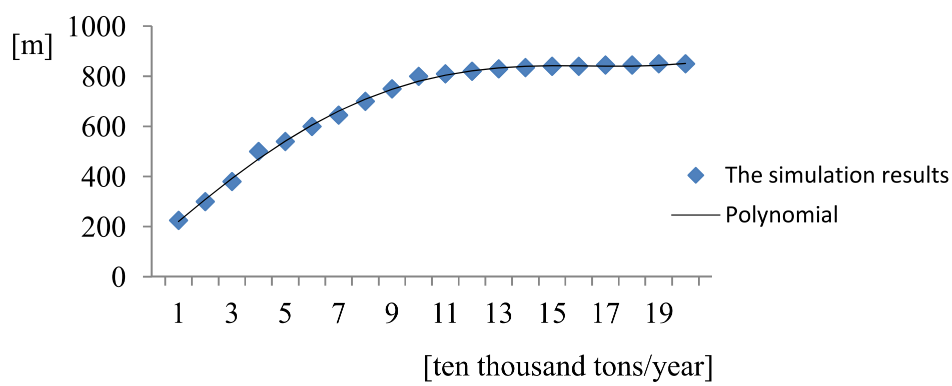

Figure 1. Analsis of simulation results

The picture 1 shows that the points represent the simulation calculation results, the curve represents the fitting result. By the above picture the information can be obtained is that the curve fitting correlation coefficient reached 0.9974, meets the requirement of the fitting.

The formula in the picture is：

$$y = 0.0086x^4 - 0.2635x^3 - 1.0156x^2 + 93.045x + 128.69 \qquad (3)$$

3 Conclusions

Here we may draw the following conclusions.

(1) According to the different requirements of fishing port annual throughput, average arrival interval time under various conditions of an annual throughput can be known;

(2) With the statistics of actual fishing port data, ratio of various fishing boat is obtained;

(3) Using simulation software Arena to simulate the working conditions of fishing port, the fishing port quay length corresponding to different fishing port under annual throughputs are acquired.

(4) The formula to calculate the relationship between the fishing port annual throughput and the length of quay is obtained.

References

Chinese Ministry of Agriculture Fisheries Bureau, The overall design specification of fishery, SC/T9010-2000.

Daganzo, C.F. (1989). The crane scheduling problem. *Transporation Research-B*, 23(3):159-175.

David Kelton, W., Randall P (2007). Sadowski, David T. Sturrock, Simulation: the ues of software Arena, *Machine Press*, Beijing, China.

GUI Jinsong, ZHOU Maoyuan (1999). Using Queuing Theroy to Calculate the Optimal Utility Factor of Fish Landing. *Journal of Dalian University*, (12): 49-52.

GUI Jinsong (1999). The research on the distribution regularity of fishing vessels arrived randomly in harbor. *Journal of Dalian Fishing University*, (9) 03-0067-04.

Merkuryev, Yuri, et al (2000). Arena-based simulation of logistics proceses at the Baltic Container Terminal. *Proceedings of the 2000 European Simulation Multiconference*. May 23-26, Ghent, Belgium, SCS, P.433-437.

Jinsong Gui, Shengde Li (2000). Research of reasonable berth occupancy for fish

unloading, *Ocean Engineering*, Dalian, China.
Reference to a book
Pidgeon E D (2008). Modeling the effects of a transportation security incident upon the marine transportation system. Monterey, California. Naval Postgraduate School.
W. David Kelton (1997). Simulation with Arena. *McGraw-Hill Higher Education*.

Traffic Safety Evaluation Based on the Inherent Safety Principle

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Abstract: Different from traditional safety studies which focus on the probability of accidents, inherent safety research takes one step further to judge the possibility of the inherent hazards. The method in the paper is necessary to analyze the risk of the urban road, especially it is necessary to avoid the traffic conflict or traffic accident's occurrence on the aspect of the source. This paper built an evaluation index based on the inherent safety principle. The evaluation index consists of inherent people safety, inherent automobile safety, inherent road safety and inherent environment safety, and each aspect contains sub-indexes. Finally, the paper will quantify evaluation index which influence the traffic safety by the extension evaluation model. Based on the evaluation results, it was found that the traffic safety evaluation based on inherent safety is more reasonable and valuable.
Keywords: Traffic safety; Inherent safety; Extension evaluation; AHP.

1 Introduction

Different from traditional safety studies which focus on the probability of accidents, the ultimate goal of inherent safety (IS) is "avoiding hazards rather than keeping them under control" (Kletz 1998). IS mainly applied to the construction of nuclear power plant, coal mining and other dangerous industries, and its purpose is to ban accident extremely. It has two meanings about the traffic safety: on the one side, it avoid the occurrence of traffic accidents, on the other side, it analyze safety evaluation indexes based on IS if there is a traffic accident. The paper analyze the essence of evaluation index about traffic safety from the first aspect to. Now typical evaluation index systems contain: Ed-wards and Lawrence proposed Prototype Index for Inherent Safety (PIIS) in 1993 (Edwards. DW 1993); Heikkila proposed Inherent Safety Index (ISI) in 1996 (Heikkilä A-M 1996); Palaniappan proposed i-Safe index in 2002 (Palaniappan C 2002); M. Gentile proposed evaluation method based on the fuzzy method in 2003 (M. Gentile 2003); Yuan Manrong proposed a intersection safety evaluation model based on extension principle in 2013 (Yuan manrong 2013) Research in this study from point view of the traffic system, the evaluation index which influence the traffic safety consist of the inherent people safety、inherent automobile safety、inherent road safety and inherent environment safety, and each evaluation index contain some second indexes.

2 Extension evaluation principle

2.1 Definition of Matter Element

The theory of the extension evaluation principle is extension set theory. Assuming $R = (\mathrm{N}, \mathrm{c}, \mathrm{v})$ is a multidimensional matter element, c_1、$c_2 ......c_n$ is a characteristic vector , and v_1、$v_2 ......v_n$ is a value vector of c_1、$c_2 ......c_n$, then a multidimensional matter element is using the following formula:

$$R = \begin{pmatrix} N & c_1 & v_1 \\ & c_2 & v_2 \\ & \cdots & \cdots \\ & c_n & v_n \end{pmatrix} = (\mathrm{N}, \mathrm{c}, \mathrm{v}) \qquad (1)$$

2.2 Matter Element Model

Matter element model is a practical method which applied on the evaluation issue. Assuming a comprehensive evaluation issue named N and has a number of impact factors, the matter element model is as following formula. (Yuan manrong 2013)

$$R = (\mathrm{N}, \mathrm{c}_j, \mathrm{v}_j) = \begin{pmatrix} N & c_1 & v_1 \\ & c_2 & v_2 \\ & \cdots & \cdots \\ & c_n & v_n \end{pmatrix} = \begin{pmatrix} N & c_1 & < a_1, b_1 > \\ & c_2 & < a_2, b_2 > \\ & \cdots & .... \\ & c_n & < a_n, b_n > \end{pmatrix} \quad (j = 1, 2....n) \qquad (2)$$

$< a_i, b_i >$ is classical field, in the practical study, a_i is the average index value of evaluation index, and b_i is the design value of evaluation index.

2.2.1 Matter element calibration

Evaluating matter element calibration is an important step. The safety grades, indexes and measure value used in the model, the formula is as follows:

$$R_i = (\mathrm{N}_i, \mathrm{C}, \mathrm{X}) = \begin{pmatrix} N_i & C_1 & x_1 \\ & C_2 & x_2 \\ & \cdots & \cdots \\ & C_n & x_n \end{pmatrix} \quad (3)$$

Where N_i is traffic safety level, which can divide into 5 grades as shown in table1(Yuan li 2010).

Table 1. intersection safety level

Safety degree	very safe	safer	less safer	little safe	dangerous
d	$0 \le d < 0.5$	$0.5 \le d < 0.8$	$0.8 \le d < 1$	$1 \le d < 1.2$	$1.2 \le d$
Safety grades	A	B	C	D	E

$C_i(\mathrm{i}=1,2,\ldots\mathrm{n})$ is the evaluation index, $C_{ij}(\mathrm{i}=1,2,\ldots\mathrm{n};\mathrm{j}=1,2\ldots\mathrm{m})$ is the evaluation sub-index. $x_i(\mathrm{i}=1,2,\ldots\mathrm{n})$ is the actual measured value about C_{ij}.

2.2.2 The weight ratio

General weight ratio can take AHP method to solve, can also take the weighted average method, this paper mainly adopts the latter.

2.2.3 The correlation function

Correlation function usually has many methods to determine, such as bigger and more optimal or smaller and more optimal. For some problems which have more stronger fuzzy, it can also use the method of fuzzy mathematics. This paper apply the smaller and more optimal algorithm because of the selected factors are some unfavorable factors .

$$k(\mathrm{x}_i) = \begin{cases} \dfrac{x_i - a_i}{b_i - a_i}, x_i \text{ are advantage factors} \\ \dfrac{a_i - x_i}{a_i - b_i}, x_i \text{ are disadvantage factors} \end{cases}$$

The explanation of a_i, b_i, x_i is the same as the above.

2.2.4 The degree of safety

d is a comprehensive related final degree, is also safety grade which mentioned in the paper. The concrete is calculated as follows:

$$d = \sum_{i=1}^{n} w_{c_i} \max(\mathrm{w}_i \cdot (\mathrm{k}_i)) \qquad (4)$$

Where d is safety degree, w_{c_i} is evaluation index, not evaluation sub-index, k_i is correlation function of evaluation sub-index.

3 Building traffic safety evaluation system based on inherent safety principle

Traffic system is a complex system consists of people, automobile, road and environment. Each factor of the system has a significant function for the traffic system safety and influence each other. The traffic safety system based on inherent safety is as shown in figure 1.

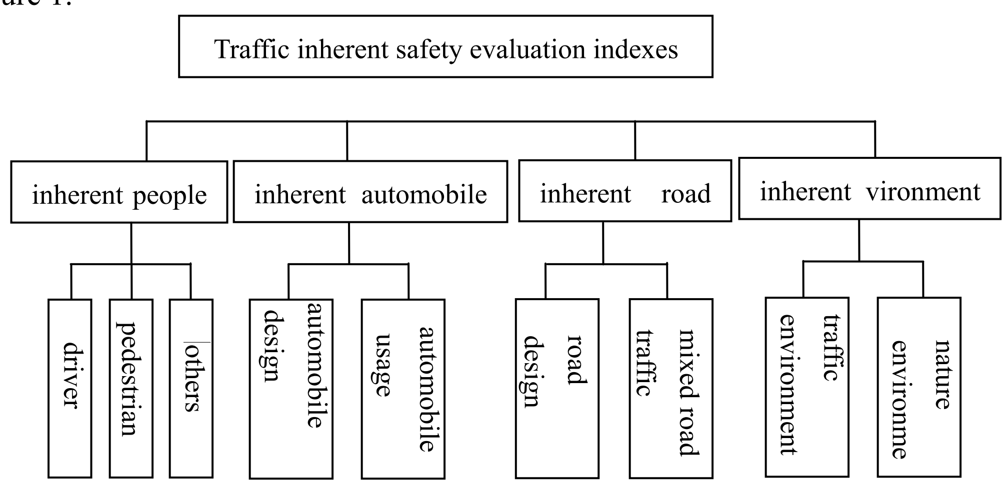

Figure1. traffic safety system based on inherent safety

(1) Inherent people

Inherent people is the main factor which influence the traffic safety, especially the driver's improper behavior, bad mental state and other factors. Moreover, the pedestrian and the people of bicycle is secondary factors which influence the traffic safety of the inherent people. due to lack of the Consciousness.

(2) Inherent automobile

Inherent automobile is key factor which influence the traffic safety, which consist of the automobile design and automobile usage. Active and passive safety devices of the automobile is more and more prevalent. On the other hand, good drive habit of the automobile is equally important.

（3）Inherent road

The people and the automobile act on the road. Physical condition of the road design and mixed traffic condition is belong to inherent road.

（4）Inherent environment

Inherent environment is consist of the traffic environment nature environment. Traffic signal, traffic marking and traffic timing of the traffic environment influence the traffic safety directly. Meanwhile, abnormal weather is equally important.

3. Case study

The case study take Tianjin road traffic safety level as an example, the paper determine the weight ratio by Delphi method and the weighted average method, to determine the correlation ratio by using the minimum optimal principle, so using the above formula can be obtained corresponding data such as shown in table 2.

Table 2. the traffic safety degree based on extension evaluation

		a_i	b_i	x_i	w_{c_i}	w_i	k_i	d_i
inherent people	driver	90	85	80	0.8	0.2125	0.5	0.1063
	pedestrian	25	20	10	0.8	0.025	0.3333	0.0083
	others	25	20	10	0.8	0.0125	0.3333	0.0042
inherent automobile	automobile design	0.05	0.02	0.01	0.02	0.2	0.75	0.15
	automobile usage	0.8	0.4	0.1	0.02	0.05	0.5174	0.0286
inherent road	road design	0.05	0.02	0.01	0.1	0.2	0.75	0.15
	mixed road traffic	85	80	70	0.1	0.05	0.3333	0.0167
inherent environment	traffic environment	70	65	60	0.08	0.05	0.5	0.025
	nature environment	25	20	10	0.08	0.2	0.3333	0.0667

$$d = \sum_{i=1}^{n} w_{c_i} \max(\mathrm{w}_i \cdot (\mathrm{k}_i))$$

$$=0.8\times 0.1063+0.02\times 0.15+0.1\times 0.15+0.08\times 0.0667=0.1084$$

The correlation function of each evaluation index, can be obtained by calculating the influence factors of road traffic safety, it can conclude that human driver is the main influencing reason of the inherent people, car design is the main influencing reason of the inherent automobile, road design is the main influencing reason of the inherent road, natural environment is the main influencing reason of the inherent environment.

This is consistent with the actual road safety evaluation. Finally, ten times magnification of 0.1084, it calculated by the evaluation of traffic safety in the case of road is the D level, and unsafe state.

4 Conclusion and Future Research

The evaluation of the traffic safety which use of extension theory for traffic safety, selection of evaluation factor is based on the inherent safety, the selected method in traffic safety has not been applied, so the strong innovation. The paper also has some deficiencies, especially the evaluation factor values determined subjectivity, how to use fuzzy mathematics association.

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Reference

Alessandro Tugnoli, Gabriele Landucci (2009). “Quantitative Inherent Safety Assessment by Key Performance Indicators (KPIs).” 9th International Conference on Chemical and Process Engineering17:457-462

Edwards DW, Lawrence D (1993). “Assessing the inherent safety of chemical process routes: is there a relation between plant costs and inherent safety.” Process Saf Environ Prot 71: 252–258

Heikkilä A-M, Hurme M, Järvela ïnen M (1996). “Safety considerations in process synthesis.” Comput Chem Eng 20:115–120

Palaniappan C, Srinivasan R, Tan R (2002). “Expert system for the design of inherently safer processes.” Route selection stage. Ind Eng Chem Res 41:6698–6710

M. Gentile, W.J. Rogers, M.S. Mannan (2003). “Development of a Fuzzy Logic-Based Inherent Safety Index.”

Yuan manrong, Cheng wei (2013). “Safety evaluation of the urban road intersections based on extenics.” Practice and cognition of Mathematics 43:26-32

Yuan li, Yuan hewei (2010). “Safety evaluation of signalized intersections using traffic conflict technique.” Traffic information and safety 28:117-120

Combined Effects of Road Pricing and Rail Transit on Land Use, Transportation Systems, and Vehicle Emissions

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Abstract: Recognizing the role of public transit in support of road pricing and vehicle emissions reduction, this paper studies the combined effects of road pricing and rail transit on land use, transportation system, and vehicle emissions under different development scenarios. A comprehensive analysis of the impacts using a quantitative method, which combines the integrated land use and transport interaction model (TRANUS model), the scenario-planning techniques, and the emission factor model-MOBILE 6, has identified a number of important results. First, joint implementation of road pricing and transit-oriented development (TOD) strategy has better effects on land use, transportation system, and vehicle emissions. Specifically, combined implementation of these two strategies can not only alleviate the negative impact of road pricing on population and commercial, but also improve the operating conditions of the entire road network. More importantly, road pricing and TOD strategy can play mutually reinforcing roles in reducing the vehicle emissions of the entire region.
Keywords: Road pricing; Rail transit; Land use; Transportation system; Vehicle emission.

1 Introduction

The implementation of road pricing policy is bound to have a wide range of effects on both land use and transportation system (Zhong et al., 2013, 2015a, 2015b). In particular, the environmental impact of road pricing is an urgent question that needs to be answered. Previous studies on environmental effects of road pricing usually use the method that combines the traffic demand model and the vehicle emissions model. In fact, road pricing could not only stimulate a variety of changes in people' short-term travel behavior, such as route choice, time of travel, travel mode choice, trip frequency. Moreover, in the long-term, road pricing may also affect (re)location decisions of households or firms, such as residential or work locations (Banister, 2002). More importantly, such long-term (re)location decisions have again implications on the short-term travel behavior decisions, in the sense that relocations will influence travel patterns, mode choices, traffic densities, and level of service (LOS) of the transportation network (Tillema et al., 2010), ultimately affecting vehicle emissions and air quality. Therefore, the goal of sustainable development of the city can only be achieved by considering land use, transport, and environmental protection together (Bandeira et al., 2011). Furthermore, public transit, especially large-scale rail transit system, is often recognized as an effective tool to reduce vehicle emissions. However, existing studies have not investigated the joint quantitative impacts of road pricing and rail transit on vehicle emissions. Therefore, the main purpose of this paper is to evaluate the combined impacts of road pricing and rail transit on land use, transportation system, and vehicle emissions, from the land use and transportation integration perspective. What separates this from most previous studies is that it combines the integrated land use and transport model, the scenario-planning techniques, and the emission model to assess the joint effects of road pricing and rail transit.

2 Methodology

Firstly, the integrated land use and transport model (TRANUS) and the scenario-planning techniques are applied to simulate the changes of land use and transportation system under different regional development scenarios and road pricing schemes. Then the traffic flow parameters obtained from TRANUS are inputed into the vehicle emission model (MOBILE 6). Finally, we can estimate the urban traffic related atmospheric pollutant emissions, namely, CO, NOx, TOG under different development scenarios and pricing schemes.

2.1 Study Scenarios and Road Pricing Schemes

Jiangyin is a city in China's Jiangsu province on the Yangtze River. Jiangyin is selected as the study area for this research for several reasons, including available high-quality data on parcels, the land market and the transportation network; a recently completed (2011) comprehensive plan is available. More importantly, as a rapidly developing city, Jiangyin is facing a serious traffic congestion and air pollution problems in the central urban area.

There are several kinds of road pricing applied worldwide. In order to narrow the topic, we mainly investigate cordon pricing, which involves charging a fee to enter or drive within a congested area, usually a city center. In order to test the impacts of toll rates on vehicle emissions, we consider two levels of toll rates. Vehicles entering the downtown between morning and evening peak hours are subject to the payment of a charge of 10 Chinese Yuan (CNY) or 20 CNY.

The future regional development scenarios are subdivided into four categories:

- Scenario A: Business as usual (BAU) scenario, which aims to characterize the future regional development on the assumption that no new land use or transportation policies will be adopted.

- Scenario C: Scenario A plus road pricing.
- Scenario T: Scenario A plus rail transit system. We call this scenario the TOD scenario in which a regional rail transit system is introduced.
- Scenario D: Scenario T plus road pricing.

2.2 Land Use and Transport Modeling

The TRANUS software is adopted as the research platform in the paper. TRANUS is an integrated land use and transport analysis software based on decision theory and input-output analysis. It combines land attributes (location of population, economic activity, land consumption) and transportation model (trip generation, trip distribution, mode split, and trip assignment) (De La Barra et al., 1984). As an integrated land use and transport software, TRANUS is more conducive to the interactions between land use analysis and travel behavior.

In order to establish of Jiangyin integrated model, we need first to select the components of the land use and transport system. The land use system elements in this paper considering fourteen sectors, including industrial employment, retail employment, government employment, entertainment employment, health employment, education employment, population, industrial land, retail land, residential land, office land, health land, education land, and entertainment land. For the establishment of the transport system, we consider five categories of passenger transport modal, including rail transit, bus, car, walk, bike. The transportation network is composed of road network, bus network, and rail transit network.

For the calibration of the Jiangyin integrated model, a piecewise estimation approach is adopted. In a piecewise estimation approach, land use model and transport model are first calibrated individually before the parameters that define the interaction between both models are set (Abraham and Hunt, 2000). Specifically, the Jiangyin application is calibrated using the following three stages: First, calibration of the land use model as a stand-alone application; Second, using the result obtained by the land use model to calibrate the transport model as a stand-alone application; Finally, calibration of the interaction parameters between both models using the complete integrated land use and transport model. Overall, we have calibrated the land use and transportation outputs of TRANUS with observed values for 2010 (for more details, please see Zhong et al., 2015). Comparisons between TRANUS modeled and observed values reveal that the observed and modeled values are close enough to allow the use of TRANUS for forecasting into the future.

2.3 Vehicle Emission Modeling

Using the calibrated Jiangyin integrated model, we can simulate the influences of different regional development scenarios and road pricing schemes on land use and transportation system of the region. In the next step, we further apply the U.S. Environmental Protection Agency's (EPA) emission factor model-MOBILE 6 to estimate vehicle exhaust emissions. Link-based tailpipe emission factors are estimated from basic emission rates (BERs) obtained using the MOBILE6 model, and correction factors. Thus,

$$EF_{Y,f,V} = BER_{Y,f,v} \cdot TECF \cdot HCF \cdot PCF \cdot CCF \cdot SCF_{f,V} \quad (1)$$

where $EF_{Y,f,V}$ is the real-world link-based emission factor (mg/sec) for calendar year Y, facility type f, and link-based average speed V; $BER_{Y,f,v}$ is the basic emission rate (mg/sec) for calendar year Y, facility type f, and average cycle speed v under standard temperature, pressure and humidity; $TECF$ is the temperature correction factor (dimensionless); HCF is the local relative humidity correction factor (dimensionless); PCF is the local pressure correction factor (dimensionless); CCF is the cycle correction factor to convert BER at Federal Test Procedure (FTP) cycle speed to real world link-based emissions at the same average cycle speed; $SCF_{f,V}$ is the speed- and facility-specific correction factor (dimensionless); f is the facility type; v is the standard driving cycle speed (km/h); V is the average speed on roadway link (km/h); Y is the calendar year.

Link-based emissions models are coupled with link-level activity data (obtained using the TRANUS model) to estimate emission inventories. Total emissions for a single link for a given facility type are estimated from Equations 2 and 3 below:

$$t_i = 3600 \cdot L_i / V_i \quad (2)$$

$$TE_{i,f} = EF_{Y,f,V_i} \cdot t_i \cdot vol_i \quad (3)$$

where i mean the link ID; V_i mean speed of vehicles traveling on link i (km/h); L_i is the length of link i (km); t_i mean average travel time on link i (sec); vol_i is the vehicle volume on link i (veh/hr); $TE_{i,f}$ mean total emissions on link i for facility class f (mg/hr).

Summing TE across all links on a network produces an emission inventory estimate. Emission factors are coupled with outputs from the TRANUS to estimate an emission inventory. Finally, the impacts of different regional development scenarios and road pricing schemes on regional vehicle emissions are quantified.

3 Results and discussion

3.1 Land Use Impact Analysis

The key results of the land use impacts of different scenarios and toll rate are provided in Figure 1. We can see that road pricing has a negative (decentralizing) effect on both retail employment and residential density within the pricing cordon area under the BAU scenario. Different from the BAU scenario, the retail employments and population under the TOD scenario increased slightly when the congestion toll is 10 CNY. This indicates that the joint implementation of both road pricing and rail transit can inhibit the dispersion effect of road pricing in a certain extent. When the toll level is 20 CNY, however, both employment and population deconcentration have emerged due to the decentralizing effect of road pricing being greater than the agglomeration effect of rail transit.

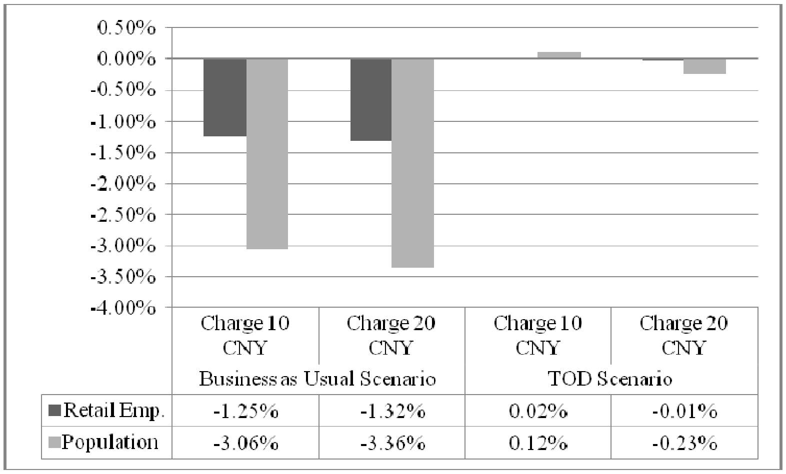

Figure 1. Changes of land use indicators under different scenarios

3.2 Traffic Impact Analysis

The modal splits under different development scenarios are provided in the following table, we can observe that:

- Look at the difference between Scenario A and C, we can find that the proportion of the travelers who use private car decreased dramatically with the increase of toll level. On the contrary, the ridership of walking and public transportation increased with the increase of road pricing level. This indicates that travelers are more likely to choose public transit or foot instead of driving, following the implementation of road pricing. In addition, the number of cycling trips affected little by the road pricing.
- Due to the introduction of a rail transit system, mode share for walking and public transit increased significantly under the TOD scenario. Moreover, the proportion of private car travel under the TOD scenario is much lower in comparison with the BAU scenario. This means that TOD stragety (especially rail transit) is much more effective than road pricing to change the structure of travel choices.

Table 1. Modal splits under different regional development scenarios

Travel Mode	Modal split					
	BAU Scenario			TOD Scenario		
	A	C		T	D	
		Charge 10 CNY	Charge 20 CNY		Charge 10 CNY	Charge 20 CNY
Walk	12.0%	14.0%	15.1%	34.5%	35.3%	35.9%
Bike	30.9%	30.2%	30.2%	15.7%	15.6%	15.7%
Public Transit	9.5%	11.4%	12.1%	24.3%	25.0%	25.3%
Private Car	47.6%	44.4%	42.5%	25.5%	24.0%	23.1%

3.3 Analysis of Vehicle Emissions

Figure 2 demonstrates the impacts of different regional development scenarios and road pricing schemes on regional vehicle emissions, we can see that:

- Compared with the Scenario A, the 10 CNY pricing scheme (Scenario C) can reduce the total amount of all types of exhaust emissions by more than 2%, the 20 CNY scheme (Scenario C) can decrease the vehicle exhaust emissions by about 4%, and the exhaust emissions are reduced by 6%~10% under the Scenario T. This indicates that when considering reducing vehicle emissions of the whole region, TOD strategy is better than road pricing policy. Furthermore, A combined strategy (Joint implementation of road pricing and TOD strategy), as simulated in Scenario D, leads to much better results, it can reduce the emissions by 10%~15%.
- It is also interesting to note that, for the same congestion toll rate, (D-T)/T is larger than (C-A)/A. This means that, for the entire region, road pricing and TOD strategy can play mutually reinforcing roles in reducing vehicle emissions. The underlying mechanism needs further research.

4 Conclusions

The important practical implications on the basis of this study are as follows:

First of all, road pricing may have a negative impact on both retail employment and population. Rail transit can promote the commercial development and population concentration. Therefore, in order to avoid the negative effects of road pricing on land use, road pricing and TOD strategy should be used together. Secondly, the TOD stragety (especially rail transit) is much more effective than road pricing to change the structure of travel choices. Thirdly, the results in this article also show that road pricing and TOD strategy can play mutually reinforcing roles in reducing vehicle emissions of the whole region. The underlying mechanism of this phenomenon is worthwhile of further study.

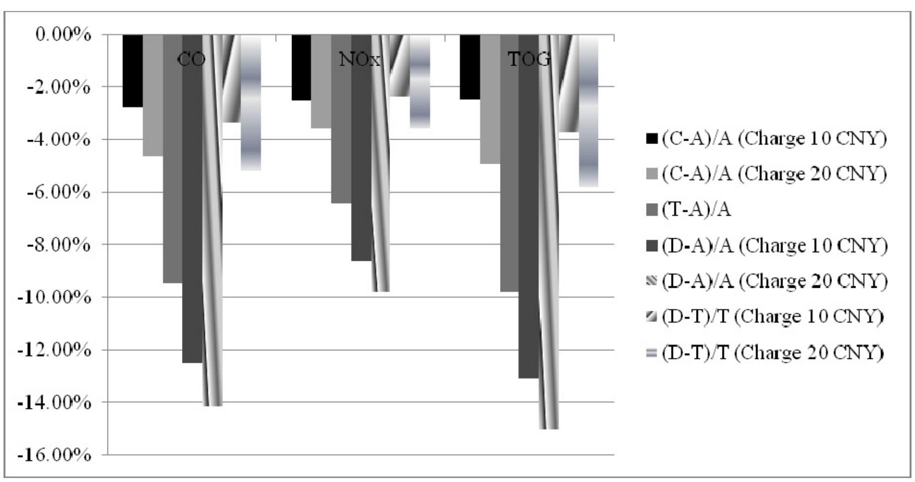

Figure 2. Changes of vehicle emissions under different scenarios

Acknowledgement

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References

Abraham, J., and Hunt, J. (2000). "Parameter Estimation Strategies for Large-Scale Urban Models." *Transport. Res. Record: J. Transport. Res. Board*, 1722, 9-16.

Bandeira, J.M., Coelho, M.C., Sá, M.E., Tavares, R., and Borrego, C. (2011). "Impact of land use on urban mobility patterns, emissions and air quality in a Portuguese medium-sized city." *Science Total Envir.*, 409(6), 1154-1163.

Banister, D. (2002). "The Integration of Road Pricing with Land Use Planning." Proceedings of essay for the second seminar of the IMPRINT-EUROPE thematic network: "Implementing reform on transport pricing: identifying mode-specific issues", Brussels.

De La Barra, T., Pérez, B., and Vera N. (1984). "TRANUS-J: putting large models into small computers." *Envir. and Plan. B: Planning Design*, 11(1), 87-101.

Tillema T., van Wee B., and Ettema, D. (2010). "The influence of (toll-related) travel costs in residential location decisions of households: A stated choice approach." *Transport. Res. Part A: Policy Practice*, 44(10), 785-796.

Zhong S., Zhang L., and Max B. (2013). " Reliability-Based Marginal Cost Pricing Problem Case with Both Demand Uncertainty and Travelers' Perception Errors." *Mathematical Problems in Engineering*, 1-13.

Zhong S., Deng W., and Max B. (2015a). "Reliability-based congestion pricing model under endogenous equilibrated market penetration and compliance rate of ATIS." *Journal of Central South University*, 22(3): 1155-1165.

Zhong S., Wang S., Jiang Y., Yu B., and Zhang W. (2015b). "Distinguishing the land use effects of road pricing based on the urban form attributes." *Transport. Res. Part A: Policy Practice*, 74, 44-58.

Hazard and Operability Analysis on Risk Factors of Railway Dangerous Goods Transport

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Abstract: In order to identify risk factors in the process of the railway dangerous goods transport, decrease the risk index, based on the work flow of rail dangerous goods transport, this paper made a deviation analysis according to the three working links of railway dangerous goods transport (sending work, work on the way, arriving work) by using hazard and operability analysis (HAZOP), determined the reasons of the deviation, the consequences and the corresponding measures, at the same time, made an idea to determine the degree of deviation quantitatively. Finally, took yellow phosphorus as an example, analyzed risk factors in the process of transport comprehensively and systematically, provided reference and recommendations for safety management of railway dangerous goods transport.

Keywords: Dangerous goods; Railway transport; Risk factors; Hazard and operability.

1 Introduction

There are so many kinds of dangerous goods which behave different characteristics, serious accident might happen if workers operate carelessly, which could result in loss of security and property. Many of the freight transport accidents are caused by dangerous goods. To make the railway dangerous goods transport safe and dependable, decrease the risk, there is a crying need to discuss the risk situation of railway dangerous goods transport and to analyze the risk factors. Researches (B. Fabiano, 2005) indicated: to evaluate and assess the railway dangerous goods transport had an important significance to safety guarantee. Some scholars offered a proposal to enhance the safety management and the development of railway station by analyzing the problems exiting in the safety management of the railway station (ZHANG Lan, 2005), the other analyzed the necessity and feasibility of the safety monitoring of the railway dangerous goods transport, the safety monitoring is beneficial to safe operation(WANG Zhe, 2010). And some scholars found the main problems in the dangerous goods transport process of handling station in China and puts forward countermeasures (YANG Zhanjun, 2000). Above researches investigated related problems of railway dangerous goods transport such as safety evaluation, operation management, terminal yard study and so on, which have a reference role for subsequent study. But most of the research methods are qualitative, that is to say they are pretty traditional and short of innovation. While the research consequences were not used to practical application, which remain to deepen.

So the author studies deeply on risk factors in every link of the railway dangerous goods transport by using an innovative and cross-domain method. Hazard and operability analysis method (HAZOP) was used in chemical sector widely, it can find all of the risk factors by analyzing every point of technological process and provide reference to improve security. Railway dangerous goods transport is a complicated and dangerous process, which can be regarded as a technological process. So we can add the idea of HZAOP into it and take yellow phosphorus as an example, to avoid risk factors, to ensure operability safety, which has important reference significance to the railway dangerous goods transport.

2 Application of HAZOP in Railway Dangerous Goods Transport

HAZOP was used to railway dangerous goods transport, its meaning should be redefined: it is a kind of structured analysis method which is used to identify equipment problem, technical defects and human error in the process of the railway dangerous goods transport. Its nature is to identify deviation degree of every point, possible accident and influence by analyzing the process of railway dangerous goods transport, partitioning analysis points, choosing guide words, finally achieved the harm identification of risk factors.

The analysis step of HAZOP of railway dangerous goods transport includes partition analysis point, determine and analyze deviation and record consequences, the HAZOP flow chart as shown in Figure1.

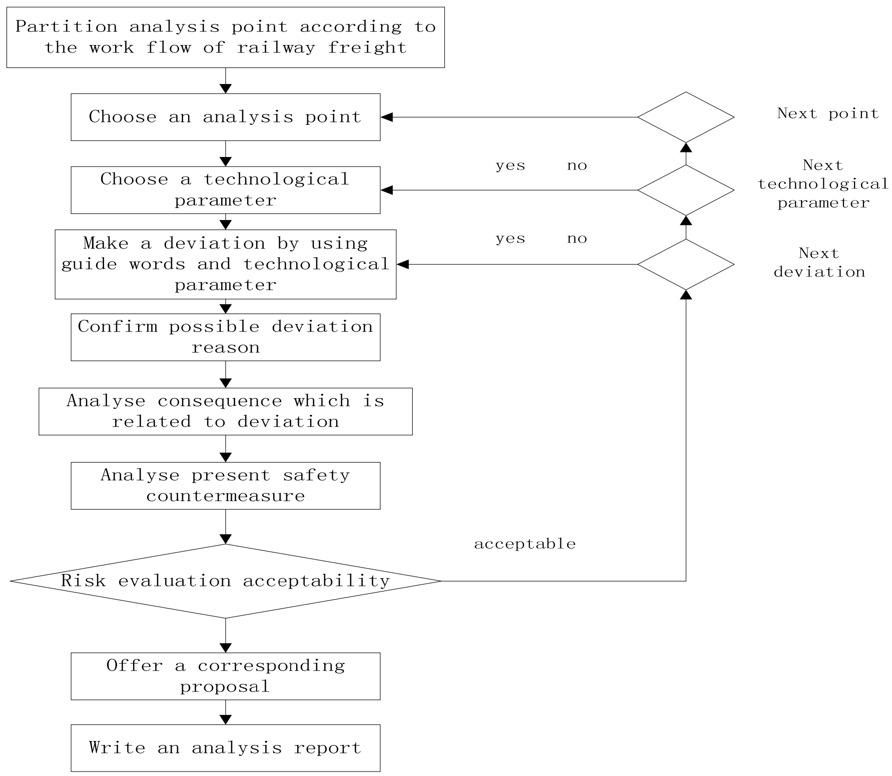

Figure 1. HAZOP flow chart of railway dangerous goods transport

Railway workers of different trades and departments constitute analysis group, analyze the whole process according to the HAZOP analysis method comprehensively. Firstly, partition points and determine deviations according to the process of railway dangerous goods transport. Secondly, analyze points and deviations, deviations are usually combined by guide words and parameters, Finally, analyze reasons, consequences, present measures and suggestions, then record analysis consequences.

3 HAZOP of Railway Dangerous Goods Transport

3.1 The partition of points

The process of railway dangerous goods transport is a continuous safety chain, in which the analysis points refer to key points of operation and equipment. Points partition shown as black, italic and underline in Figure2.

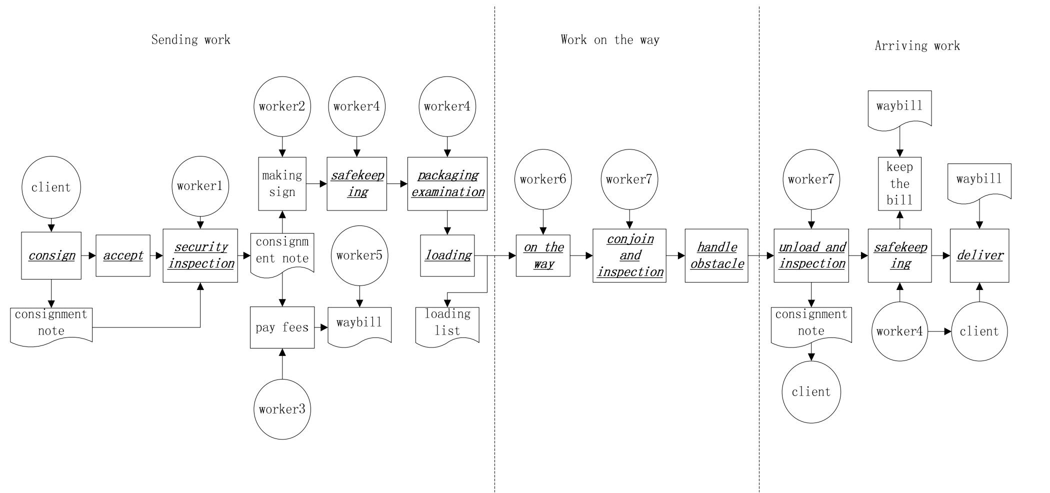

Figure 2. Analysis points of HAZOP

3.2 The analysis of deviations and consequences

The deviations are the main parts of the analysis (ZHANG Lingwan,2012), by analyzing deviations, we can find all of hidden danger in the every analysis point. The HAZOP deviations and their descriptions of the railway dangerous goods transport shown as Table 1.

Table 1. HAZOP deviations and descriptions

Number	Deviation	Description
1	Wrong name	point1)：record goods name wrongly
2	Wrong waybill	point2)：record waybill information wrongly
3	Useless safety check	point3)：security inspection did not avoid hidden danger
4	Damaged goods	point4)：keeping goods carelessly leads to goods damage
5	Useless packaging	point5)：wrong appliance, material and operation lead to packaging useless
6	Damaged packaging	point4) 6) 7) 10) 11)： operate improperly leads to packaging damage in the process such as loading
7	Goods losing	point4) 6) 7) 8) 10) 11) 12)：goods losing happens in the process of keep, deliver and so on
8	Operating fault	point6) 10) 8)：delivery and loading goods improperly
9	Unusual parameter	point7-9)：check and find unusual parameter
10	Handling fault	point9)：handle obstacle improperly
11	Dereliction	point7)：workers neglect duty on the way

For railway dangerous goods transport, the specie of dangerous goods is various, which is divided into 9 big kinds, 25 small classes. Different kinds of dangerous goods have different properties, this paper provides an unified model for analysis, when you analyze one kind of dangerous goods, you should have different emphasis point. For example, when we study on the inflammable and explosive materials, the risk factors may exist in the consign and accept link, except that, we should consider the sealed packing, temperature control and so on.

3.3 The analysis of deviation degree in HAZOP

After we got the deviation analysis consequences (ZHOU Shuai,2014), to make a unified standard for qualitative parameters and quantitative parameters, to make it easy to count data, the author used deviation degree to measure the degree of deviation. It shows that how far do the measured parameters away from the standard parameters. For quantitative parameters, we presume the maximum allowable positive deviation isa_{max}^{+} , and the maximum allowable negative deviation isa_{max}^{-}, so the deviation degree of parameters can be recorded as:

$$f = \frac{|t-s|}{a_{max}^{+}-a_{max}^{-}}\beta \qquad (1)$$

Which the t refers to measured parameters, the s refers to standard parameters, the β refers to risk parameters.

When the positive deviation and negative deviation exist respectively, the β should be calculated as:

$$\beta = 1-\frac{a_{max}^{-}}{a_{max}^{+}} \qquad \beta = 1-\frac{a_{max}^{+}}{a_{max}^{-}} \qquad (2\text{-}3)$$

Thus, the reasonable range of deviation degree for quantitative parameters is [0,1], if f=0， then deviation is 0, if f=1, then it is maximum allowable deviation, if f>1, then the parameter is transfinite。

For qualitative parameters, the deviation degree is divided into 5 levels, the f can be [standard, pretty standard, general, pretty eccentric, eccentric] ≤[0.2，0.4，0.6，0.8，1.0].

4 HAZOP of Yellow Phosphorus Transport by Railway

Yellow phosphorus is a kind of translucent white or yellowish waxy solid, its ignition point is 30 ℃ and melting point is 44.1 ℃. It is stable when it can not contact air, but it will spontaneous combustion in the air, when it is burning, there will be white poisonous smoke(WANG Bowei,2007). So in the process of yellow phosphorus transport by railway, the most key link is the packaging inspection, the concrete analysis process and consequences are shown as Table 2.

Table 2. HAZOP analysis process and consequences

Number	Deviation	Description	Possible reason	Consequence	Present countermeasure	Proposal
1	Wrong name	record goods name wrongly	1misstatement 2mistake	1accidents 2equipment damage 3increased cost	inspect before accept goods	1emphasize and avoid 2strengthen training and inspection power
2	low height of water on yellow phosphorus	the height of water on the yellow phosphorus is lower than 15cm	1original quantity deficiency 2leakage	1yellow phosphorus spontaneous combustion 2hidden trouble of spontaneous combustion	inject water according to the standard	1strengthen safety inspection after injection 2test equipment
3	sealing differential	containers had not been sealed well	1priming negligence2sealing differential on the way	1yellow phosphorus spontaneous combustion2hidden danger	seal rigorously	1seal rigorously 2ensure equipment quality
4	overloading	the weight of yellow phosphorus boxes is more than 10kg	1operation against rules 2negligence	1accident 2equipment damage	limit weight	1limit weight rigorously 2increase punishment
5	temperature of container does not reach the standard	temperature of container does not reach 44.1℃	1did not preheat before priming 2preheated but not enough	1yellow phosphorus condensation 2hidden danger	heating layers and thermometer are design	1preheat before priming 2inject equipment
6	the quantity of nitrogen	the quantity of nitrogen is less than	1negligence 2equipment damage	yellow phosphorus spontaneous combustion	Use container equipment to fill	1periodic inspection 2ensure seal

	is deficiency	0.15Mpa			nitrogen	
7	improper isolation of train vehicle-body	the isolation material is not wet mat	1shortage of professional quality 2negligence	1leakage and accident 2equipment damage	wet mat isolation	1inject after loading 2more advanced material
8	overloading	the number of yellow phosphorus tub is more than 240	1operation against rules 2negligence	1accident 2hidden danger	inject after loading	strengthen training and inspection power

The Table 2 shows the whole process of HAZOP clearly. We took the quantitative parameter: the quantity of nitrogen as an example, calculated the degree of deviation. From Table 2 we can know that the standard parameter s is 0.15Mpa, according to the practical experience we presume the maximum allowable positive deviation a_{max}^{+}, is 0.25Mpa and the maximum allowable negative deviation a_{max}^{-}, is 0.05Mpa, now the measured parameter t is 0.20Mpa,. Then substitute values into formula (1) and (2), the calculation process shown as formula (4) and (5).

$$\beta = 1 - \frac{0.05}{0.25} = 0.80 \tag{4}$$

$$f = \frac{|0.20-0.15|}{0.25-0.05} \bullet 0.80 = 0.20 \tag{5}$$

Thus, the degree of deviation f is 0.20, between the reasonable range [0,1].

5 Conclusions

Here we may draw the following conclusions.

（1）Research shows that HAZOP can get all of the risk factors of railway dangerous goods transport comprehensively, the analysis results can be used in the process of practical operation to avoid the appearance of risk factors, as a result, the safety degree can be promoted and it can promote the development of railway dangerous goods transport. So we can say, the HAZOP is effective for analysis of railway dangerous goods transport. Also, this paper shows the calculation method of deviation degree.

（2）Takes yellow phosphorus as a case to show how to analyze factors by using HAZOP, provides railway dangerous goods transport with a reference

（3）Through HAZOP, railway workers can identify all of the hidden danger in the process of railway dangerous goods transport, increase operability, avoid accident or decrease consequences, finally ensure railway dangerous goods transport operate safely, placidly and economically.

Acknowledgement

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References

B.Fabiano(2005).”Dangerous good transportation by road: from risk analysis to emergency planning.” Loss Prevention in the Process Industries, 18(4-6):403-413.

WANG Zhe(2010).”Safety information monitoring for railway dangerous goods transport based on cybernetics.” Railway Freight,5:32-37.

WANG Bowei(2007).”Study on yellow phosphorus transport by rail.” Railway Freight,10：38-41.

YANG Zhanjun(2000).”safety analysis and suggestion for railway dangerous goods station in China” China Safety Science,10(8): 16-20.

ZHANG Lan(2005).”Management and suggestion for dangerous goods station.” China Rail,(2):45-47.

ZHANG Lingwan(2012).” Early-warning of railway dangerous goods transport based on fuzzy comprehensive evaluation.” China Safety Science,22(5):119-125.

ZHOU Shuai(2014).”Application of HAZOP-deviation degree in risk analysis.” China Safety Science,8(24):92-96.

Bayesian Belief Net Model-Based Traffic Safety Analysis on the Freeway Environment

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Abstract: The short-time crash risk measurement on the freeway has been catching much attention of government and management authorities. Due to recent advanced development in information systems and traffic sensor technologies, the real-time crash prediction models are getting more practicality. Critically, crash frequency analysis is the most important step for traffic safety studies. The paper makes two major contributions. Firstly, a multi-level Bayesian framework has been researched to identify risk factors towards the urban expressway by modeling unprocessed traffic data and roadway geometric topology data. Secondly, the paper utilized Bayesian belief net to build the real-time crash prediction model for the basic freeway segments. The objective is to predict the formation probability of a hazardous traffic condition in 4-9minuts in a 250-meter-long freeway road section. Results obtained can be used for the urban freeway management departments to understand the risk factors and take immediate actions in advance to avoid traffic accidents on the freeway.
Keywords: Urban expressway; Risk factors; Real-time crash prediction model; Multi-level Bayesian framework; Bayesian belief net.

1. Introduction

Road safety is a primary priority of transportation engineering. Up until now, lots researches have been carried out at both the macro- and micro-levels. Micro-level traffic safety studies research motor-vehicle crashes in specific locations, such as roadway segment, intersection) with the need of with a small number of occurrences but a great deal of detailed traffic information. Studies in this area concentrate on the aggregate analysis (including crash frequency analysis, crash rate analysis) and disaggregate analysis (including real-time crash prediction).

Conventional road crash predication models employ traffic flow variables, such as speed limits, AADT and others, to identify hazardous locations. According to studies (Sabey and Staughton, 1975; Treat et al., 1977; Oh, C. 2005), road crashes occur due to the interaction of factors, and four major factors include the road geometry and environment, the motor vehicle, the human, and the traffic dynamics. Furthermore, the study (Oh, C. 2001) also indicates that road crashes will regularly occur because of sudden disrupted traffic conditions even on geometrically correct roads and under right driving conditions. Motivated by the above study, some researches began studying road crash predication in real-time with the help of high-resolution detector data (Lee et al., 2006; Pande and Abdel-Aty 2007; Abdel-Aty et al., 2008). However, existing crash predication models have some major shortcomings and are limited to the location of detectors, variable traffic variables and the modeling method efficiency.

In order to solve the above shortcomings and limitations, this paper proposes a Bayesian belief net (BBN) based framework to design a real-time crash prediction model. The research simulates an urban expressway equipped with uniformly but packed detectors, and uses BBN to conduct the evaluation.

2. Simulated Scenario and Data Preparation

The simulated scenario needs to consider quality of detector data, accuracy in reported crash time and sample size. We use VISSIM to simulate one expressway with two lands in each direction, and the expressway has 210 detectors within 25.4 kilometers with an inter detector space about 250 meters. The simulated scenario is used to experiment with different detector combinations and identify optimal detector layout plan for the surveillance of hazardous traffic condition formation in real-time. The data stored in the detectors include speed, vehicle count, occupancy and number of heavy vehicles per lane for each 8 milliseconds round the clock (24 h a day, 365 days a year). Data of all the lanes are collected once every 5mins. The crash data contain date, time in minutes, location (in nearest 10 meters), vehicles involved, type of crash, and others. This study divides the whole road length into 250 meters road sections in such a way that every section harbors one detector. Then, for every crash case, data from two upstream, two downstream and the detector with in the section are extracted from the detector database.

For every crash case, the data point contained information on 5-min cumulative vehicle count, number of heavy vehicle count, average speed and average occupancy from all five detectors. Furthermore, the study also introduces another variable called 'congestion index' (CI) at each detector position to get the combined impact of speed and flow. Diasetal. (2009) argued that level of congestion is a less biased representation of speed as the speed that can be considered low for a specific road section may emerge as too high for another road section due to the road geometry and other physical constrains. Motivated by this theory, this study includes CIatall5 positions to the previously declared variable space. The CI for any detector position can be calculated according to Equation (1):

$$CI = \frac{\text{FreeFlowSpeed-Speed}}{\text{FreeFlowSpeed}} \tag{1}$$

The free flow speed for each of the detector position is calculated based on the speed-flow, the speed-occupancy diagram and the observed value. The final variable space contains 65 predictors. Values for 25 predictors (5 variables for each detector position× 5 detector positions=25) are directly generated by detectors and the rest 40 are calculated via comparing the longitudinal difference of these predictors among different detector positions.

3. The Description of Bayesian Belief Net Method

Bayesian belief net (BBN) is a relatively new method in the artificial intelligence (AI) probability and uncertainty community with multifarious usage (e.g., reason in g under uncertainty, making predictions of highly uncertain phenomena, etc.).BBN based system can help researches understand a phenomenon or make predictions about events. BBN is highly effective in situations where inferences are not warranted logically but probabilistically. As a graphical modeling method, BBN is represented with a graph and a basic equation. The graphical part of the BBN consists of two types of elements–a set of nodes and a set of directed edge. To explain the numerical part, we can define a BBN over a universe of variable U={A1,...,An}. Then the BBN can be specified with a joint probability distribution P(U) that can be obtained according to Equation(2).

$$P(U) = \prod_{i=1}^{n} P(A_i \mid pa(A_i)) \quad (2)$$

Where, $pa(A_i)$ represents the parents of A_i.Now, if new findings e1,..., ek on some variables with in U are obtained and joint probability distribution P(U) has been known, we can re-write Equation(2) as Equation(3):

$$P(U,e) = \prod_{i=1}^{n} P(A_i \mid pa(A_i)) \prod_{i=1}^{n} e_j \quad (3)$$

Via marginalizing $P(U,e)$, we can obtain the probability of any variable A within U, according to Equation (4).

$$P(A \mid e) = \frac{\sum_{U/A} P(U,e)}{P(e)} = \frac{\sum_{U/A} P(U,e)}{\sum_{A} P(A,e)} \quad (4)$$

4. Model Design

In this section, we propose and evaluate the BBN based real-time crash prediction model in three interlinked phases with three datasets. Firstly, the variable selection contains 189 crash data and 6478 traffic condition data. Secondly, the paper constructs and simplifies the model according to parent divorcing technique and then yields the conditional probability tables for each variable. Thirdly, the model performance is evaluated using a separate dataset.

4.1 Data Extraction

Random multinomial log it (RMNL) method was employed on the dataset for variable selection to decide and rate the most important variables. A step-wise iteration method has been followed in which at each step 100 logistic regression trees were grown by randomly selecting 4 variables at a time. Figure 1 represents the top ten most important variables. Figure 2 presents the cumulative importance of detectors in each location which has been calculated by summing the importance of all five variables (e.g., for detector in position 2, d2 is the summation of the importance of d2q, d2p, d2v, d2o, d2i). Figure 3 shows the importance of detector combination based on their spatial variation (e.g., for the spatial variation between positions 2 and 4, d24 is the summation of the importance of d24q, d24p, d24v, d24o and d24i). It should be further noted that in the form $d\alpha X$, d represents the detector, α means the position of the detector (e.g., 24 means the location between 1 and 4), and X is the variable, where "q" means 5-min cumulative vehicle count, "p" means 5-min cumulative count of heavy vehicles, "v" is the average speed over 5mins, and "o" stands for the average occupancy over 5mins. From these three figures, we can draw the following conclusion that detector positions 2 and 4 should be chosen to maximize the prediction success when the real-time crash prediction model employs a combination of detectors in two locations.

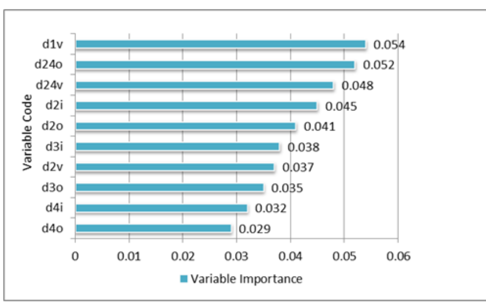

Figure 1. Top Ten Variables within the Variable Space

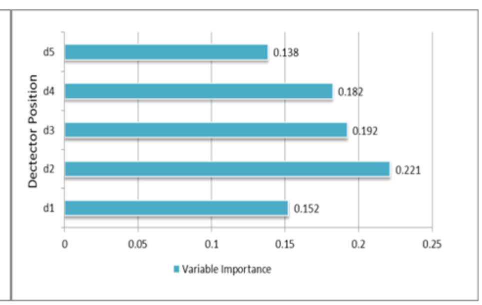

Figure 2. Each Detector Location

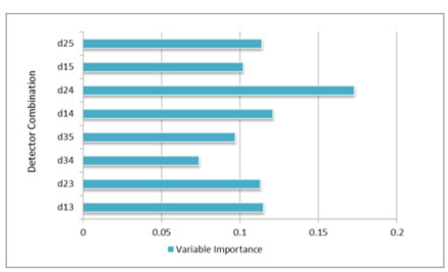

Figure 3. Detector Combinations

4.2 Model Design Principles

Subsequently, we extract data from the combined dataset for all the crash cases with complete information on variables generated by 2 and 4 detector locations. The dataset contains 622 crash cases and corresponding 25,899 normal traffic condition data points. Furthermore, the dataset is further divided into the dataset for the model design purpose and the one for the evaluation purpose. The dataset for model building includes 545 crash cases (including the 119 crashes employed for variable selection) and 22,204 normal traffic condition data. Of these 362(69.5%), 68 (10.1%), 83(13.6%) and 3(<1%) are respectively rear-end, side-swipe, single vehicle and tipping over crashes.

The determination of the BBN graphical structure follows the data extraction. And 'crash' is chosen as a child node to the parent nodes. Furthermore, two new intermediate variables 'risk ratio A' and 'risk ratio B' are introduced in order to decrease the complexity of the conditional probability table for 'crash'. Based on the above methods and corresponding independent variables, we can obtain the probability of potential crash traffic conditions.

In order to establish BBN model, we use the information variables, the outcome variable along with their states and conditional probability tables as input and computes and provides the BBN as output. The resulting model is illustrated by figure 4. From figure 4, we can observe the node d2i suggests that 23.72% of the samples (crash and normal all together) have congestion index at detect or location 2 to be less than 0.04; 7.16% of the samples have congestion index at the same location between 0.04 and 0.06 and soon.

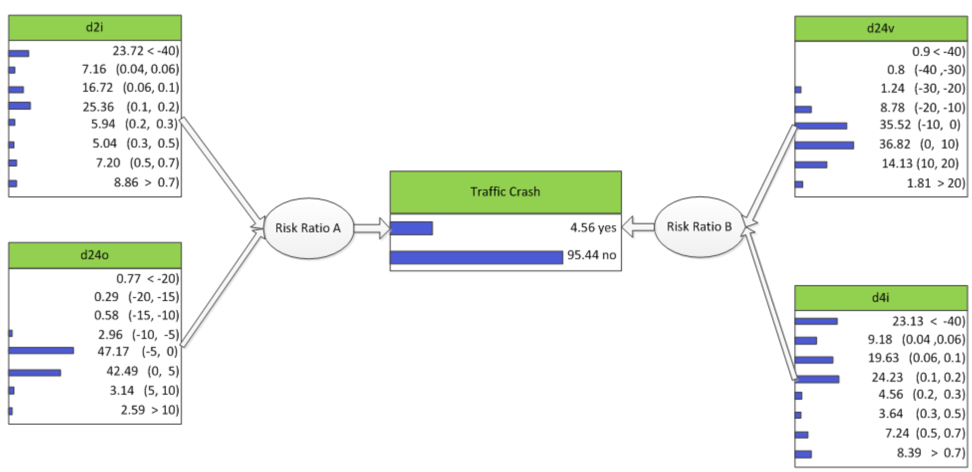

Figure 4. The BBN-based real-time crash prediction mode

4.3 Model Evaluation

The simulated crash data is used for evaluating our proposed BBN model. The dataset contains 90 crash cases and 2795 normal traffic condition cases. Among these normal traffic condition data points, 450 have been randomly selected to evaluate the model. Based upon Figure 4, we can observe that the average probability of the crash traffic condition equals to 4.56% for the unavailability of new evidence entered. We use this value as the minimum threshold for evaluating the performance of the model. The threshold value has been raised up to 15% and the classification accuracy have been fathomed and presented in Figure 5.

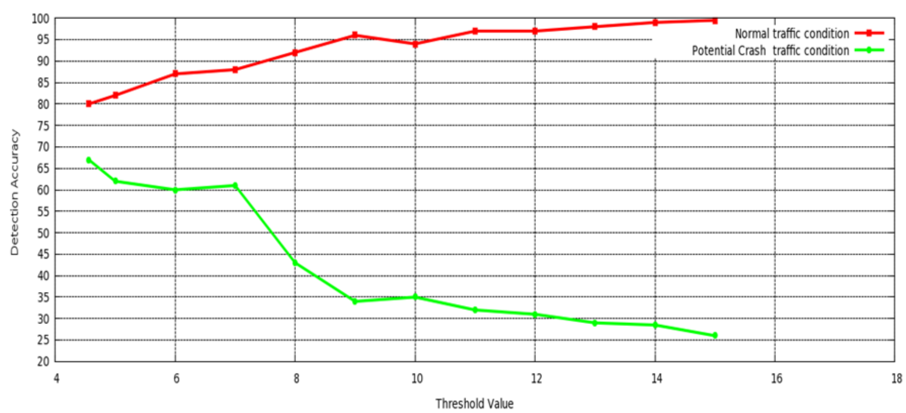

Figure 5. Performance evaluation

The results reflect that at a threshold value of 4.56% the model is able to successful classify 66% of the crashes with a false alarm rate less than 20%. If the threshold value is raised up to7% then the model still can predict 58% crashes and 87% normal traffic conditions with an overall classification accuracy of 82%. And in case of a threshold value as high as 14%, the model classifies 30% of the crash cases with only less than 3% false alarm.

5. Conclusion

The paper offers an improved framework and modeling method to predicate the real-time traffic crashes. The paper also solves the problem of large variable space with small sample size with the introduction of random multinomial logit model to identify and rank the most important variables. Furthermore, the Bayesian belief net (BBN) has been introduced. Simulation results show that the model can predict the chance of a traffic condition of a 250 meter long section under consideration in the basic freeway segment to become hazardous within then ext4–9mins.

References

Abdel-Aty, M., Pande, A., Das, A., Knibbe, W.J., 2008."Assessing safety on Dutch freeways with data from infrastructural-based intelligent transportation systems." *Transport .Res. Rec. 2083, 153–161.*

Dias,C.,Miska,M.,Kuwahara,M.,Warita,H.,2009."Relationship between congestion and traffic accidents on expressways: an investigation with Bayesian belief networks."In: *Proceedings of 40th Annual Meeting of Infrastructure Planning (JSCE), Japan.*

Lee,C.,Abdel-Aty,M.,Hsia,L.,2006."Potential real-time indicators of sideswipe crashes on freeways." *Transport. Res. Rec. 1953, 41–49*

Oh,C.,Oh,J.,Ritchie,S.,Chang,M.,2005."Real time hazardous traffic condition warning system: framework and evaluation.*"IEEE Trans. Intell. Transp. Syst. 6 (3), 265–272.*

Oh,C.,Oh,J.,Ritchie,S.,Chang,M.,2001."Real-time estimation of freeway accident likelihood."In: *Proceedings of the 80th Annual Meeting of Transportation Research Board, Washington, DC.*

Pande,A.,Abdel-Aty,M.,2007."Multiple-model framework for assessment of real time crash risk." *Transport. Res. Rec. 2019, 99–107.*

Sabey,B.E.,Staughton,G.C.,1975."Interacting roles of environment, vehicle and road user in accidents." In: *Proceedings of the 5th international conference of the International Association for Accident and Traffic Medicine, London.*

Treat,J.R.,Tumbas,N.S.,McDonald,S.T.,Shinar,D.,Hume,R.D.,Mayer,R.E.,Stanisfer, R.L.,Castellan,N.J.,1977."Tri-level study of the causes of traffic accidents." *Report No. DOT-HS-034-3-535-77 (TAC)*

Impact of Speed Guidance on Vehicle Exhaust Emissions at Signalized Intersections Based on Microscopic Simulation

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Abstract: When reaching the intersection, driving conditions of vehicles always change among acceleration, deceleration, idling, resulting in increasing fuel consumption and emissions dramatically. This paper proposes a vehicle speed guidance system to make consumption and emission become the minimum based on real-time signal state, vehicle location and speed when vehicles through the intersection. A simulation study is implemented for the intersection of Caoan Road and Lvyuan Road in Shanghai and the study results show that there is a significant effect under different traffic flow. Better results can be obtained in high saturation.
Keywords: Speed guide system; Emission; Microscopic simulation.

1 Introduction

With the rapid development of urbanization and motorization, motor vehicle exhaust pollution is more and more serious in cities. Because driving conditions of vehicles always change among acceleration, deceleration, idling at the intersection, fuel consumption and emission will increase dramatically (Cherchas, D.B,1979). Because drivers cannot obtain the information of intersection in the front of vehicles, the driver cannot make judgments in advance and only rely on experience to determine the driving speed. In this case, the fuel consumption and emission are relatively large (Guohua Song, 2010). Therefore, this paper proposes vehicle speed guidance based on real-time signal state vehicle location and speed, so that realizing the target of decreasing exhaust emission.

2 Strategy of Speed Guidance

To sharpen the research problem, we make the following assumptions:

(1) The study area is a single intersection without considering the impact of adjacent intersections.

(2) Assume that vehicles obey speed guidance strictly.

(3) Without considering interference of pedestrians and non-motorized.

(4) Lane speed limit is 60 km/h.

(5) Acceleration is $3.04 m/s^2$ when vehicles accelerate; driver's reaction time is 1s.

(6) Packet loss rate is 0, that is to say, sending and receiving information are accurate.

(7) Delay is in the acceptable range, that is to say, information is passed in a timely manner.

In this paper, a sensing line is disposed at the place that the distance between the sensor line and the stop line is 100m. Speed guidance will start when vehicles pass the sensor line. We will consider when the vehicles are given speed guidance according to speed of the vehicles and remaining green time. We regard the distance that vehicle can drive as judge distance. Vehicles start to accelerate to maximum speed when reaching the sensor line, and vehicles pass intersection at the maximum speed. The equation is given as follows.

$$L = \begin{cases} v + \frac{16.7^2 - v^2}{2*3.04} + 16.7 * (t - \frac{16.7 - v}{3} - 1); \frac{16.7 - v}{3.04} + 1 \leq t \\ v + v(t-1) + 0.5 * 3.04 * (t-1) \wedge 2; \frac{16.7 - v}{3.04} + 1 \geq t \geq 1 \\ vt; t \leq 1 \end{cases} \tag{1}$$

Where V is speed when vehicle pass sensing line, t is the sum of remaining green time and remaining yellow time. L compares with 100, if L is greater than 100, then we calculate the distance S that vehicle can drive at the current speed; if S is greater than 100, the driver is notified to drive at the current speed; otherwise vehicle will increase fuel consumption by accelerating. If S is less than 100, then informing the driver accelerate to 60 km/h through the intersection immediately; if L is less than 100, informing the driver slow down, not only decreasing fuel consumption and emissions, while improving throughput and traffic safety.

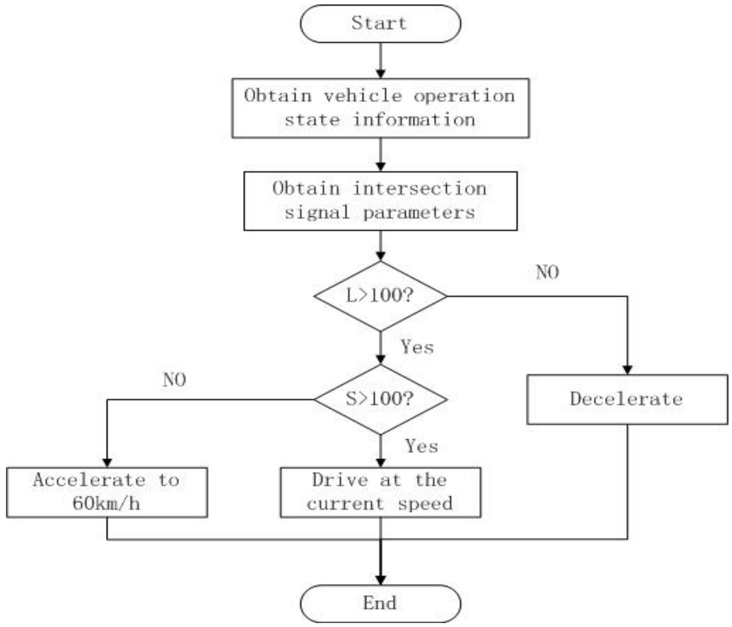
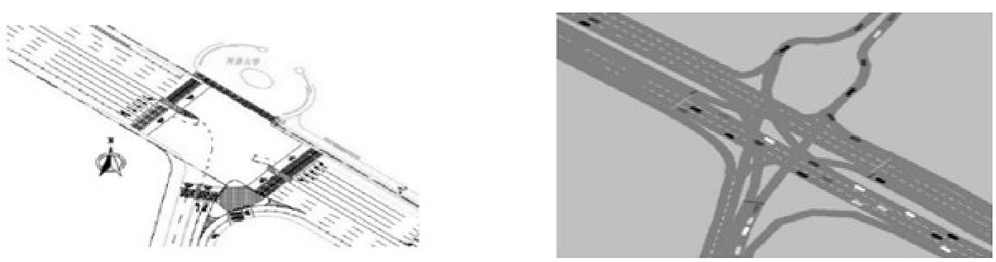


Figure 1. Flow diagram of speed guidance

3 Simulations and Analysis

(1) Experimental design

Selecting the intersection between Caoan Road and Lvyuan Road as empirical research, the current situation of road network and CAD diagram are shown in Figure 2. The lane functions are shown in Table 1.



(a) Situation of Intersection (b) Intersection simulation

Figure 2. Situation and Simulation of Intersection between Caoan Road and Lvyuan Road

Table 1. Lane function

	Lane function	Lane number
East entrance	Left-lane	1
	Straight	3
	Right-lane	1
West entrance	Left-lane	1
	Straight	3
	Right-lane	1
South entrance	Left-lane	1
	Straight	1
	Right-lane	1
North entrance	Left-lane	
	Straight	1
	Right-lane	

Considering various factors, West entrance of the intersection is selected as the research object. The signal timing control scheme adopts two phase control. The cycle is 90s and the green ratio is 0.5. And yellow light time is 4s. In order to demonstrate adaptability of speed guide model in various traffic states, we select different traffic conditions, corresponding traffic flow are 300 puc/h, 1500 puc/h and 2700 puc/h, and saturation are 0.1, 0.5 and 0.9. They cover different traffic saturation such as low, medium and high.

(2) Simulation

Taking Vissim4.3 software as simulation platform, and we will have an redevelopment using Visual Basic 2012 and Vissim.COM interface.

The total time of each simulation is 3600s, simulate accuracy is 2-step / s. Speed, trajectory and corresponding time signal status are recorded in 0.5s intervals during simulated process, so that we can facilitate results. Because data exists to large errors at initial stage of simulation, the paper selects 1000-3600s period of simulation to analyze.

4 Vehicle Exhaust Emission Model

We use VSP model to estimate vehicle emission. The paper determines calculation formula of VSP by selecting the relevant parameters accord with the characteristic of vehicles. VSP region is divided by selecting appropriate step size. We get the unit interval emission rate in VSP interval from measured data and emission model, finally establishing vehicle emission model based on VSP.

(1)Vehicle specific power(VSP)

Vehicle specific power is defined as the instantaneous power per unit mass of vehicle, unit is kw/t. VSP is independent of weight; it can describe this variation by combing driving conditions and vehicle emissions.

VSP formula considers several ways of doing work; its value is related to speed and acceleration. The formula is given as follows.

$$VSP = v*(a*(1+\delta)+g*grade+g*f)+0.5\rho*C_D*A*v^3/m \quad (2)$$

Where v is spot speed, unit is m/s ; a is instrument acceleration, unit is m/s^2; δ is factor of merit; g is acceleration of gravity, and generally its value is 9.8 m/s^2 ; $grade$ is road slope, dimensionless; f is coefficient of rolling resistance, dimensionless; ρ is air density, Celsius take 1.2kg / m^2 at 20 degrees; f is drag coefficient, dimensionless; A is front cross-sectional area, unit is m^2; m is vehicle mass, unit is kg.

Here vehicles are divided into light trucks vehicles (cars) and heavy-duty vehicles (buses and trucks). For light trucks, empirical values of the coefficients are given, C_D*A/m takes 0.0005, δ takes 0.1, f takes 0.0135, ignoring wind speed and road gradient. Finally the formula of light vehicles is given as following.

$$VSP = v*(1.1a+0.132)+0.000302v^3 \quad (3)$$

For heavy vehicles, C_D*A/m takes 0.00028, δ takes 0, f takes 0.00938, ignoring wind speed and road gradient. Finally the formula of heavy vehicles is given as following.

$$VSP = v*(a+0.09199)+0.000169v^3 \quad (4)$$

(2)Interval division of VSP

As can be seen from the above equation, VSP is closely related with traffic conditions, it represents the utility of spot speed and acceleration. We can calculate instantaneous VSP for per second according to the formula, but there is a large dispersion of the same VSP value accord with emission rates when we calculate emission based on VSP. In order to ensure a more accurate calculation of emissions based on VSP, VSP value is divided according to certain interval unit. We took average value of instantaneous emission rate as release rate under the Bin, thus it reduced the discreteness of data effectively. Interval division size of VSP Bin is directly related to accuracy of estimated results. At present, there are different ways to divide VSP interval depending on the vehicle type and data acquisition. VSP interval is classified according to the following principle.

$$VSP\ Bin = n,\quad \forall VSP \in [n-0.5, n+0.5) \quad (5)$$

Where n is integer.

(3)VSP interval emission rate

VSP Bin emission rate is determined by calculating VSP Bin emission based on second driving data and emission data. First, we calculate each kind of vehicle emission rate of VSP Bin by collecting a large number of various types of vehicles. Then we calculate emission rate that can represent light vehicles and heavy vehicles according to the proportion of models and other information.

1> Data collection

In this paper, light vehicles are divided into 5 types according to the national emission standards, ie. country 0, country I, country II, country III and country IV. Heavy vehicle includes passenger carriage and goods van, we have obtained data that includes all of the above types in the test. Real-time data includes testing time, speed, acceleration and other indicators.

2> Calculation of VSP interval emission rate

First, we put data into (3) and (4) after performing initial processing of data based on emission data. VSP values of light duty gasoline vehicle ranged from -20 kw / t to 20kw / t by analyzing data. Its emission accounted for more than 98%, while VSP values of heavy-duty diesel vehicle ranged from -15 kw / t to 15kw / t, its emission accounted for more than 98%. We can calculate emission rate according to the formula (6).

$$ER_{in} = EF_{in} / N_n \qquad (6)$$

Where ER_{in} is emission rate of the i-th effluent in the n-th VSP interval, unit is g/s; EF_{in} is total emission of the i-th effluent in the n-th VSP interval, unit is g; N_n is total time in the n-th VSP interval, unit is s.

We will calculate emission rate of light vehicle corresponding VSP interval according to national standards. The proportion of vehicle types l that come from Caoan road and Lvyuan road are foundation that calculates emission rate of light vehicle in VSP interval. According to statistics, National stage 0 emission standard accounted for 3.0% of the total number of road traffic, National stage I emission standard accounted for 6.3%, national stage II emission standard accounted 25.1%, National stage III emission standard accounted 44.1% State, National stage IV emission standard accounted 21.6%. According to the proportion coefficient of vehicle types and vehicle emission rates in each VSP interval, emission rate of light vehicles can be calculated in various VSP interval. The formula is given as following.

$$E_k = \sum_i ER_{ki} * \lambda_i \qquad (7)$$

Where ER_k is interval emission rate of the k-th effluent, unit is g/s; ER_{ki} is interval emission rate of the k-th effluent of the i-th vehicle type, unit is g/s; λ_i is proportion of vehicle type which is the i-th emission standard.

We will put the result into formula (7) according to formula (6), we can get emission rate of CO2, NOx, HC and CO in different VSP interval, they are regarded as basis in the paper.

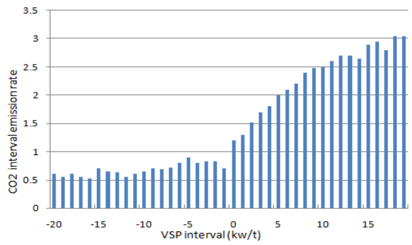


Figure 3. CO2 emission rate of light gasoline in each VSP interval

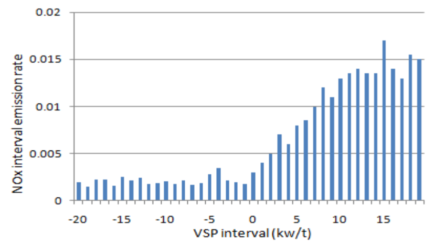


Figure 4. NOx emission rate of light gasoline in each VSP interval

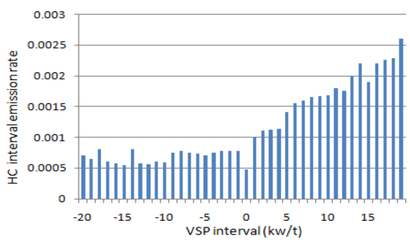


Figure 5. HC emission rate of light gasoline in each VSP interval

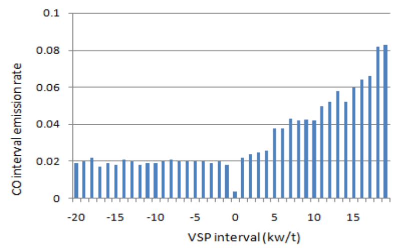


Figure 6. CO emission rate of light gasoline in each VSP interval

5 Impact of Speed Guidance on Vehicle Emission

To facilitate the analysis, all cars are light gasoline vehicles in simulation, and vehicle emission analysis range from the sensor line to stop line of import road. According to the simulation and emission model, results can be obtained as follows.

In the case where saturation is 0.9, average emissions of CO2, NOx, HC and CO were 1208.39 ml, 2.7939 ml, 0.9184 ml and 20.664 ml. In the case of speed guidance average emissions of CO2, NO x, HC and CO were 1064.39 ml, 2.5339 ml, 0.8224 ml and 19.064 ml.

In the case where saturation is 0.5, average emissions of CO2, NOx, HC and CO were 642.77 ml, 1.554 ml, 0.502 ml and 11.53 ml. In the case of speed guidance average emissions of CO2, NOx, HC and CO were 590.17 ml, 1.41 ml, 0.4565 ml and 10.59 ml.

In the case where saturation is 0.1, average emissions of CO2, NOx, HC and CO were 148.3 ml, 0.362 ml, 0.113 ml and 2.732 ml. In the case of speed guidance average emissions of CO2, NOx, HC and CO were 139.4 ml, 0.334 ml, 0.107 ml and 2.502 ml.

6 Conclusions

By analyzing the above results, when speed limit is 60 km/h, average emissions decreased significantly in different saturation with speed guidance, and the higher the saturation, the effect is more evident. When the saturation is 0.9, average emissions decreased by 10%.

Speed guidance will make different effect on emissions because of different speed limited, lane number and signal phase and other factors. These also need further study.

References

Cherchas, D.B. (1979). “A dynamics simulation for a high speed magnetically levitated guided ground vehicle.” Transactions of the ASME. Journal of Dynamic Systems,Measurement and Control,v 101, n 3, 223-9,Sept. 1979.

Graefe, V. Kuhnert, K. D. (1988). “A high speed image processing system utilized in autonomous vehicle guidance.” Proceedings of IAPR Workshop on Computer Vision: Special Hardware and Inddustrial Applications, 10-13, 1988.

Guohua Song. (2010). “The model for microscopic measurement of fuel consumption and exhaust on road traffic.” The transportation of energy saving and environmental protection, 28-31.

Juanjuan Liu. (2010). “The study for the model of velocity correction of fuel consumption and exhaust emission based on distribution of VSP.” Beijing Jiaotong University, 4-94.

Kumar S., Singh, R. (2011). “Advanced Speed Control of an Automated Guided Vehicle.” International MultiConference of Engineers and Computer Scientists 2011, 964-9.

Makino T., Oizumi J., Hashimoto N. (1992). “High-speed driving control of an automatic guided vehicle using an image sensor.” Transactions of the Society of instrument and Control Engineers, 28(5), 595-603.

Rao Kethireddipalli S. Krammes, Raymond A. (1994). “Energy-based fuel consumption model for FREFLO.” Transportation Research Record, n 1444, 36-43.

Yousry, Magdi.,Johnson, John H.,Pandit, Sudhakar M. (1978). “A statistical approach to determining the effects of speed, load, oil and coolant temperature on diesel engine specific fuel consumption.” SAE Technical papers, 1978, International Fuels and Lubricants Meeting, 4-17.

Impacts of Vehicle Information on Reaction Time Based on Driving Simulations

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Abstract: Recently, as the rapid development of electronic information and wireless communication technologies, Communication and information shared between the vehicles become possible. In the case of vehicle communication, driver can know the information of vehicle in front of it, so the reaction time will be different with tradition. The vehicle information of this paper includes headway, acceleration and speed. Firstly, the experiment without vehicle information on driving simulator was done to verify the driving simulator. Then, the experiment with vehicle information on driving simulator was done and the data was analyzed. Finally, the results show that the reaction time with vehicle information obviously less than without vehicle information. The difference of reaction time caused by age increases, however the difference of reaction time caused by gender decreases.
Keywords: Vehicle information; Reaction time of car-following; Factor; Model.

1 Introduction

Reaction time is the duration from the front vehicle shifting to the following vehicle begin reacting during car following process(including perception and operational phase). With the development of communication technology, car communications have become achieved which will become the future direction of transport development(YANG Fan,2012). Therefore, the study of reaction time under vehicle information is the basis of car following theory under information environment. Also, it has practical value for safe driving.

There are many factors impacting the reaction time which has been deeply studied. Dabbour and Easa thought the reaction time depends on the task of driving and personal characteristics of driver(Dabbour, E. and Easa, S.,2009). Broen and Chiang thought the reaction time of elderly driver are more than young in some cases (Broen, N., & Chiang, D, 1996). But Lerner found that age has little impact on reaction time (Lerner, N,1994). Green found several causes for different conclusions: sample bias, the elderly who have better driving habits, experience and more practice make up the defects of perceiving and moving slowly(Green, M.,2000). Chang et al. found when the speed increases from 25mph to 40mph, the reaction time reduces 0.5s. But when the speed increases from 40mph to 55mph, the reaction time reduces no longer (Chang, M., Messer, C., and Santiago, A,1985). Atif Mehmood and Said M.

Easa found acceleration and deceleration size of the front vehicle and personal characteristics of driver have significant impacts on reaction time(Mehmood Atif; Easa; Said M, 2009). At home, XU Ting, CAO Shili, MA Zhuanglin and ZHU Tong et al studied the reaction time and headway in car following based on driving simulator (XU Ting, 2013). ZHANG Zhiyong, HUANG Yi, REN Futian found the average reaction time is 0.97s in deceleration following state. Also, the reaction time changes as the speed changes. Fujita Motohiro found response delay is an independent variable of car following. It is affected not only by personal characteristics of driver and traffic situation, but also vehicle type(Zheng Jian, 2013).

But all the study mentioned above is the environment without vehicle information. Although Kong has optimized the model of car following based on the car-road network, the factors of impact on reaction time hasn't been deeply studied.

The reaction time has been divided into reaction time under deceleration and reaction time under acceleration in this article. Firstly, the feasibility of driving simulator has been certified through the experimental data under environment without vehicle information. Then, the traditional factors on reaction time has been analyzed and corresponding computational model has been achieved under environment with vehicle information.

2 Experimental Program

2.1 Experimenters and Equipment

This paper uses world-class driving simulator as an experimental platform which has simulation vehicles with sensor, computers, projectors and audio output device.

Factors on reaction time include personal characteristics of driver and driving conditions. Personal characteristics of driver include age, sex, age of driving and driving strength. Driving conditions include headway, speed and acceleration of front vehicle. Sixty drivers(32 men and 28 ladies) have been selected for this experiment. Their ages range from 22 to 67 years old and have been divided into three grades(22-28, 29-54, 54+). Driving ages begins from getting the license and have been divided into three grades(0-5, 6-20, 20+). Driving strength is measured by driving time weekly and has been divided two grades(0-20, 20+). In order to ensure comparability, the distribution of age and sex is same as the distribution in particle of Atif Mehmood and Said M. Easa. Specific information is mentioned in table 1 and table 2:

Table 1. Information of test people

Sex	Age					
	22-28		29-54		54^+	
	number	proportion	number	proportion	number	proportion
Man	4	6.7%	18	30%	9	15%
woman	4	6.7%	17	28.3%	8	13.3%

Table 2. Levels for categorical variables

Variable	Level and range		
	1	2	3
Age	young(22-28)	wrinkly(29-54)	old people(54+)
Sex	man	woman	
Age of driving	novitiate(0-5)	commonly(6-20)	skilled(20+)
Intensity of driving	commonly(0-20)	strong(20+)	

2.2 Program Design

The experiment road imitates the Beijing Lotus Pond Road. Reaction time is divided into acceleration and deceleration. There are two degrees based on deceleration of vehicle in front in deceleration circumstance. One is normal that the deceleration is ranging from $2.5m/s^2$ to $3.5m/s^2$. Another is urgent that the deceleration is ranging from $4m/s^2$ to $7.5m/s^2$(ZHANG Zhiyong, 2009).

The following vehicle travels at a rate of 60,80 and 100km/h respectively from a starting point in driving simulator. The front vehicle travels at the same rate from a point which is 1.5km away from starting point at a moment under deceleration circumstance. But different spacing between following vehicle and front vehicle are set up under different circumstance. The spacing is 20m, 30m and 40m respectively under normal deceleration. The spacing is 10m, 20m and 30m respectively under urgent deceleration. The front vehicle decelerates at a point which is 2km away from starting point. The front vehicle travels at a rate of 60km/h from a point which is 1.5km away from starting point at a moment under acceleration circumstance. The spacing is 20m under acceleration. The front vehicle accelerates at a point which is 3km away from starting point.

As mentioned above, every driver experiments 9 times respectively under normal and urgent deceleration. However every driver experiments one time under acceleration. Of course the same experiment will be done under circumstance with vehicle information. Therefore every driver experiments 38 times altogether and 2280 sets of experimental data will be obtained. Every driver will be trained one hour before experiment.

2.3Vehicle Information Provided and Data Acquisition

A lot of vehicle information were given for driver through voice and text. The information includes acceleration, speed, spacing and so on. The function achieves through program.

Data acquisition system of driving simulator is very powerful. All the necessary data can be achieved through driving simulator by program. The necessary data include acceleration of front vehicle, speed of following vehicle, reaction time of following vehicle, spacing and so on.

3 Data Analysis

3.1 Circumstance without Vehicle Information

3.1.1 Following under Deceleration

Data analysis software SPSS is used to analyze data received from driving simulator. Histogram of reaction time without vehicle information under different speed and spacing is showed in fig.1. The result in fig.1 shows that reaction time has significant difference between normal and urgent deceleration. The reaction time under normal deceleration is longer than urgent deceleration. The reaction time is longer as spacing increasing at a same rate under the same circumstance.

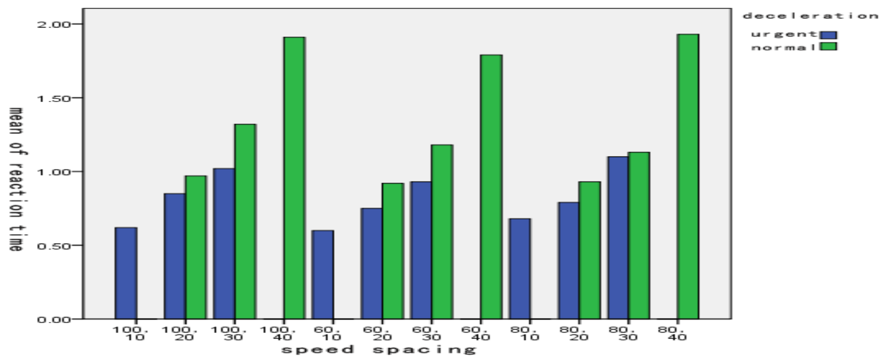

Fig.1 Reaction time under different speed and distance

The relation between reaction time and age, sex, age of driving and intensity of driving are analyzed respectively. The relation between reaction time and sex is showed in fig.2.

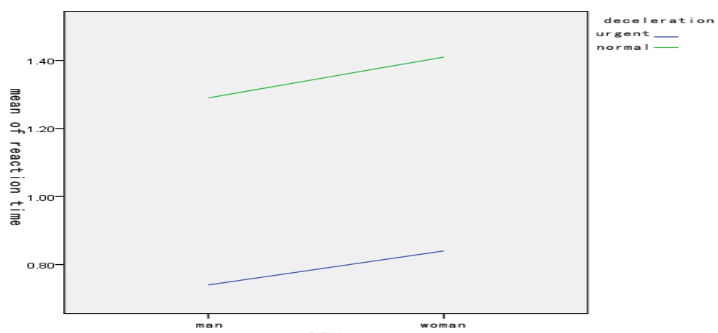

Fig.2 Comparison of Reaction time based on gender

The result in fig.2 shows that the reaction time of man is shorter than woman under two circumstances. The reaction time has little difference caused by age under the same circumstance. This is because that the old people is skillful at driving. The reaction time of novitiate is shortest under normal deceleration. The reaction time of commonly is shortest under urgent deceleration. The impact on reaction time by driving intensity is different under different age and sex.

In summary, the reaction time is taken as dependent variable. Spacing, speed, sex, age, age of driving and driving intensity are taken as independent. The model is achieved by SPSS as following.

$$T_N^{-} = 0.081G\text{-}0.003V + 0.052D \qquad (R^2 = 0.93) \tag{1}$$

$$T_S^{-} = 0.002A\text{+}0.107\text{G+}0.002\text{V+}0.025\text{D} \qquad (R^2 = 0.89) \tag{2}$$

T_N^{-} is reaction time under normal deceleration; T_S^{-} is reaction time under urgent deceleration; G is the sex of driver, man is 0, woman is 1; V (Km/h) is the speed of following vehicle; D (m) is spacing; A is age of driver.

3.1.2 Following under Acceleration

The data are received from driving simulator under acceleration without vehicle information. The reaction time is taken as dependent variable. Age, sex, age of driving and driving intensity are taken as independent variable. The relationship between reaction time and age, sex, age of driving and driving intensity are received by SPSS.

The result shows that reaction time of man is shorter than woman under acceleration. The reaction time is increasing as the age growing. The reaction time is reducing as the driving intensity increasing, but the difference is little obvious. The relationship between reaction time and age of driving is little obvious.

The model is achieved by SPSS as following:

$$T^{+} = 0.026A + 0.27G \quad (R^2 = 0.78) \tag{3}$$

T^{+} is reaction time under acceleration; A is age of driver; G is the sex of driver(man is 0, woman is 1).

The result is conformed to the conclusion of Atif Mehmood and Said M. Easa as mentioned above which certified the driving simulator is feasible(Mehmood Atif; Easa; Said M, 2009).

3.2 Circumstance without Vehicle Information

3.2.1Following under Deceleration

Histogram of reaction time with vehicle information under different speed and spacing is showed in fig.3.

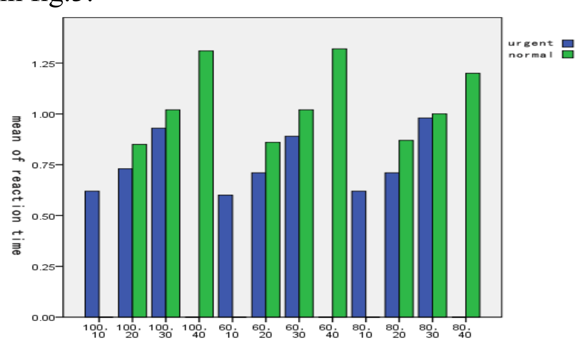

Fig.3 Reaction time for different speed and distance

Comparing the data under deceleration between circumstance with and without vehicle information, then we put forward hypothesis testing: the mean of reaction time under deceleration is same between circumstance with and without vehicle information. The confidence is 0.95. The t test is done by SPSS. The result is showed in table 3.

Table 3. Result of test

	The mean of reaction without vehicle information(s)	The mean of reaction with vehicle information(s)	t	result
Normal	1.23	1.04	-13.2	refuse
urgent	0.79	0.74	-3.2	refuse

T is -13.2 under normal deceleration which is within the range of refusal, so we reject the null hypothesis. The result is that the vehicle information has obvious impact on reaction time. T is -3.2 under urgent deceleration which is within the range of refusal, so we reject the null hypothesis. The reaction time decreases 15.44% under circumstance with vehicle information in normal deceleration. The reaction time decreases 6.33% under circumstance with vehicle information in urgent deceleration.

This is because that the vehicle information has warning function for driver. While the information of deceleration is offered to driver, the driver will have a feel of alertness.

The result in fig.3 shows that reaction time is different between normal and urgent circumstance. The reaction time under normal circumstance is longer than urgent circumstance. However, the difference between normal and urgent circumstance is minor under circumstance with vehicle information. Reaction time is increasing as spacing increasing while driving at the same rate under the same circumstance. However, the growth is minor under circumstance with vehicle information. This is very important for safely driving.

The relation between reaction time and age, sex, age of driving, intensity of driving is analyzed respectively by SPSS. The relationship between reaction time and sex is showed in fig.4.

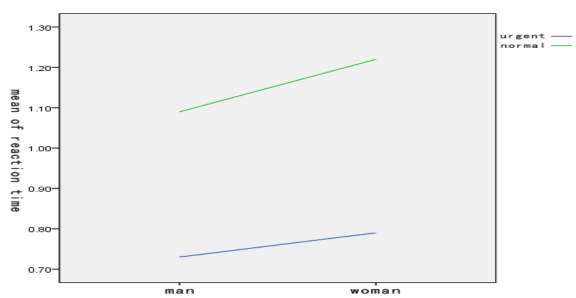

Fig.4 Comparison of Reaction time based on gender

The reaction time of man is shorter than woman under two circumstances showed in fig.4. The reaction time of woman is shorter with vehicle information than without vehicle information under two circumstances. The result shows that the vehicle information is valuable for women. The reaction time is increasing as age growing which is little different with circumstance without vehicle information. There is few impact on reaction time caused by age of driving and driving intensity under circumstance with vehicle information.

In summary, the reaction time is taken as dependent variable. Spacing, speed, sex, age, age of driving and driving intensity are taken as independent. The model is achieved by SPSS as following.

$$T_N^- = 0.003A + 0.056G - 0.001V + 0.031D \quad (R^2 = 0.92) \tag{4}$$

$$T_S^- = 0.001A + 0.105G + 0.002V + 0.019D \quad (R^2 = 0.94) \tag{5}$$

T_N^- is reaction time under normal deceleration with vehicle information; T_S^- is reaction time under urgent deceleration without vehicle information; G is sex of driver(man is 0, woman is 1); V is following speed(Km/h); D is spacing(m); A is age of driver.

3.2.2 following under acceleration

Comparing the data under acceleration between circumstance with and without vehicle information, then we put forward hypothesis testing: the mean of reaction time under acceleration is same between circumstance with and without vehicle information. The confidence is 0.95. The t test is done by SPSS. The result is showed in table 4.

Table 4. Result of test

	The mean of reaction without vehicle information(s)	The mean of reaction with vehicle information(s)	t	result
Acceleration following	1.17	0.92	-17.5	refuse

T is -17.5 under acceleration, so we reject the null hypothesis. The reaction time decreases 21.4% under acceleration with vehicle information. The result is very important for improving the capacity of road.

The relationship between reaction time and age, sex, age of driving, driving intensity are analyzed by SPSS showed in fig.5.

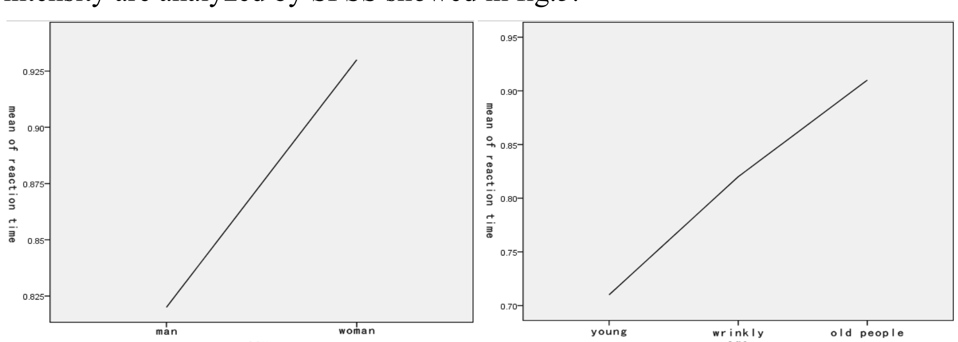

Fig.5 Effect of driver factors on reaction time based on vehicle communication

The reaction time of man is shorter than woman under acceleration. However, the difference is minor under circumstance with vehicle information. The reaction time is increasing as age growing. The reaction time is increasing as age of driving growing which is different from the circumstance without vehicle information.

In summary, the reaction time is taken as dependent variable. Spacing, speed, sex, age, age of driving and driving intensity are taken as independent. The model is achieved by SPSS as following.

$$T^{+} = 0.024A + 0.09G + 0.002E \qquad (\mathrm{R}^2 = 0.84) \tag{6}$$

T^{+} is reaction time under acceleration with vehicle information; A is the age; G is the sex(man is 0, woman is 1); E is the age of driving.

4 Conclusion

This paper do the experiment by driving simulator. We analyze the data received from driving simulator under different circumstances and achieve the conclusion.

(1) No matter under acceleration or deceleration circumstance, the reaction time is different between circumstance with and without vehicle information. However, the difference is more obvious under acceleration circumstance. The reaction time decreases 21.4% under acceleration with vehicle information than without vehicle information. There is 15.44% under normal deceleration and 6.33% under urgent deceleration. This shows that vehicle information is important for improving capacity and safe driving.

(2) The difference caused by sex is minor under vehicle information than without vehicle information. The mean of reaction time of woman is reducing under vehicle information. The result shows that the vehicle information is important for women driver.

(3) The reaction time is little impacted by age of driving under vehicle information.

(4) The reaction time is impacted mainly by age, sex and spacing under vehicle information.

This paper doesn't consider the impact of vehicle information itself. For example, the way of offering information, the amount of information and the content of information. of course the traffic flow doesn't been considered in this paper. So further research is needed to analyze the reaction time under vehicle information.

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References

Broen, N., & Chiang, D, (1996). "Braking response times for 100 drivers in the avoidance of an unexpected obstacle as measured in a driving simulator. In Proc. of the Human Factors and Ergonomics Society, 40, 900–904.

Chang, M., Messer, C., and Santiago, A, (1985). "Timing traffic signal change intervals based on driver behavior". Transportation Research Record Vol. 1027:20-32.Transportation Research Board, Washington, D.C., USA.

Dabbour, E. and Easa, S. (2009). "Perceptual framework for a modern left-turn collision warning system". International Journal of Applied Science, Engineering and Technology, 5(1): 8-14.

Green, M., (2000). "How long does it take to stop? Methodological analysis of driver perception-brake times.". Transportation Human Factors, 2:195– 216.

GONG Ming, SHEN Dangyun, LIU Xiaoming. (2011). Research for parameter calibration of directional sign on driving simulator. Journal of Highway and Transportation Research and Development(Applied Technology Edition), 04:254-257.

Kong, D.Y; Xu, H.Y. (2014). An improved car-following model in vehicle networking based on network control. Mathematical Problems in Engineering.

Khodayari Alireza; Ghaffari Ali; Kazemi Reza; Manavizadeh Negin. (2010). ANFIS based modeling and prediction car following behavior in real traffic flow based on instantaneous reaction delay. IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC ,599-600

Lerner, N, (1994). "Brake perception–reaction times of older and younger drivers". In Proc. of the Human Factors and Ergonomics Society, 38, 206–209.

Mehmood Atif; Easa; Said M. (2009). Modeling reaction time in car-following behavior based on human factors. World Academy of Science, Engineering and Technology, v 33, 10-718.

WANG Yizhi. (2012). Research on Driver's Emergency Reaction Facing to the Vehicle-Pedestrian side impact accident Based on the Driving Simulator. Tsinghua University.

XU Ting, CAO Shili, MA Zhuanglin, ZHU Tong, WANG Weili. (2013). Reaction Time and Headway in Car-Following Flow. South West Jiao Tong University,01:173-177.

YANG Fan, YUN Meiping, YANG Xiaoguang. (2012). Microscopic Traffic Flow Model Based on Multi-agent in CVIS Circumstance. Journal of Tongji University (Natural Science Edition) , 08:1189-1196.

ZHANG Zhiyong, HUANG Yi, REN Futian. (2009). The study of reaction time of following vehicle under deceleration state. Journal of Beijing university of technology,09:1220-1224.

Zheng, Jian; Suzuki, Koji; Fujita, Motohiro. (2013). Car-following behavior with instantaneous driver-vehicle reaction delay:A neural-network-based methodology. Transportation Research Part C-EMERGING TECHNOLOGIES, 339-351.

Analysis of Long-Distance Passenger Transportation Based on a Highway Network Using the SWOT-AHP Method

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Abstract: Nowadays the process of urbanization in China is rapid, so the demand of city-to-city transportation or downtown-to-suburb transportation is massively increasing. The traditional ways of passenger transportation cannot meet the passengers' requirements gradually and have some related safety problems. So this paper put forward the concept and the definition of long-distance passenger transportation based on highway network. At the same time this paper analyze the long-distance passenger transportation's advantages and disadvantages qualitatively and quantitatively by the SWOT-AHP method. We also found that the lack of theory support is the main disadvantage of long-distance passenger transportation based on highway network while it also confronts the strong competition of high-speed railway transportation, however the advantages like higher comfort level and higher coverage rate still demonstrate its development potential. The competitiveness of long-distance passenger transportation will be enhanced during its rapid developing if we strengthen its advantages.
Keywords: Long-distance transportation; Highway network; Passenger transportation; The SWOT-AHP method.

1 Introduction

With the economy rapid developing, the urbanization is speeding up in China. At the same time, with improving of the transportation capacity and the developing of the information network, the cooperation between cities to cities becomes more and more important. As a result that the passenger transport demand is constantly increasing. Passenger transport also has effect on the urbanization and the economic integration. So a new environmentally friendly passenger transport mode is asked to meet the demand（Mao, Zhang, Zhou,2004 and Xie, Zong, Wang ,2005）

At the end of the year 2011 long-distance transportation had been applied into to the passenger transport line which is between the Dalian and Lvshun. At year 2012 the intercity passenger transportation became a new mode and had been adopted in many cities like Shanghai, Hangzhou and so on (Ling, 2012). All the fact has shown that the long-distance passenger transportation is a growing trend in China. But the academic research of this type of transportation is not well developed. So establishing research methods for long-distance passenger transportation is very necessary.

Although the long-distance transportation has a good prospect, the studies of long-distance passenger transportation are few. Now many studies focus on the high speed railway passenger transportation, and some of the studies choose the intercity railway as the subjects and find out the problems of operation management (Zeng, 2013）. The studies of the long-distance passenger transportation are main about the rural passenger transportation (Cao, 2011) and intercity passenger transportation (He, Zhang, Bie, Zhou, 2011). So the researches on the long-distance passenger transportation is based on the highway network is significant.

2Long-distance passenger transportation

2.1The problems of traditional transportation modes

The features of the traditional transportation modes in China are high driving speed, overload and so on .The lack of planning and safety management brings so some risks (Li, Zhou, Si ,2008)such as the following problems.

(1)Unsuitable timetable plan. In the traditional long-distance transportation modes the drivers need to drive for a long time so it is easy for the drivers feeling tired and obviously it is not safe.

(2)Driving with high speed and vehicle overload. The drivers drive fast in order to arrive in least time. In addition the vehicle overload will bring some economic profit to the drivers but also bring many safety problems.

(3)There are two or more drivers are responsible for driving so the constraint of each driver is less. Under this condition the driver sometimes stops on the shoulders of highway to pick up the passengers. It is very dangerous.

2.2 Definition of long-distance passenger transportation system

The long-distance passenger transportation system is based on the city road network and highway network. It has been used in the city-to-city passenger transportation system and the long-distance passenger transportation system is consist of bus stations, service area, facilities of the road. The development of economic integration is the background of the long-distance passenger transportation and the target is improving intercity bus public service system of long-distance passenger transportation.

3. The properties of long-distance passenger transportation system

Passenger transportation is a concept which has been put forward in integration of urban and rural public transportation, high speed railway passenger transportation and long-distance passenger transportation. These three systems have the similarities so in table 1 these three systems are compared and the features of long-distance passenger transportation is concluded (Fang, 2011 and Zhou. Li, Yang, 2011)

Table1. The features of long-distance passenger transportation and the differences between urban public transportation, long-distance passenger transportation and high speed railway passenger transportation

NO		urban public transportation	high speed railway passenger transportation	long-distance passenger transportation
1	Service object	Towns and rural residents	The residents who are going out of the city	The residents who are traveling from one economic region to others
2	Passenger type	Visiting relatives, business, work, commuting	Visiting relatives, business, work, commuting and traveling	Visiting relatives, business, work, commuting and traveling
3	Length of route	Less than 20km	Inner city traveling :l80~400km；	Inner city traveling :20~400km；
4	speed	25km/h	200km/h-250km/h	On the highway the speed is 100km/h， on the national road the speed is 60-80km/h
5	Rush time	Morning rush: 7:30am-8:30am Evening peak: 5:15pm-6:15pm	On workday，morning rush is 7:00-8:30， Evening peak of commuting is 6.pm-8.pm，	January, February, May and October； Morning rush: 7am-9am Evening peak: 6pm-8pm
6	Line type	Backbone line and regional line	City to city	City to city
7	Departure interval time	10min-25min	10min-20min	Average 30min

8	Average distance between station to station	800m-1000m	Developed area is 20km-35km; Others are 40km-50km	20km-30km
9	price	2 to 8 RMB	0.4 RMB /km;	0.1 to 0.15 RMB /km
10	Coverage rate	If the urban-rural integration has been come true in all the area, the coverage will be over 95%	Low coverage rate	Higher than the rate of high speed railway, but need the cooperation of urban public transportation

From the table1 we can find out that high speed railway passenger transportation and the long-distance transportation system have the same service range. But the high speed railway passenger transportation is faced with two problems ---high price and low coverage rate. After optimizing the driving routes and stations as shown in the following, the long-distance passenger transportation system will not have these two problems.

4 Analysis of long-distance passenger transportation using the SWOT-AHP method

4.1 SWORT matrix of long-distance passenger transportation.

SWOT analysis, which is also called the situation analysis method, is the basic method of competitiveness research. Using this method to analysis, all the elements can be considered comprehensively and the best solution can be found out through systemic review (Guo,Wang, Jiang, 2009 and Ji,2013). The superiority, weaknesses, opportunities and threats of the long-distance passenger transportation system can be found out using SWOT analysis. AHP (the analytic hierarchy process) is used to find out the main factors, then these factors constitute the ladder hierarchical model and finally determine the total ordering of evaluation object (Han, 2006).

The SWOT analysis method is only qualitative analysis, so its result is only a qualitative description, but the AHP can simulate the procession of thinking and use the quantitative analysis to deal with the data. As a result the combined SWOT-AHP method has both advantages from qualitative analysis and quantitative analysis. Compared with other methods like Boston Consulting Group Matrix, Ansoff Matrix and SPACE Matrix (Strategic Position and Action Evaluation Matrix), SWOT-AHP method can analyse the influencing factors qualitatively and quantitatively (Jiang, Xu, Song,2013).

(1) Superiority (s)

1) Faster---- Because the long-distance passenger transportation system is based on the highway network, the coach is driving with high speed to meet the demand of

passengers

2) Convenient----The long-distance passenger transportation has the characteristics like many transfer stations, high coverage rate and so on. These features make passengers convenient.

3) Standardization----In the long–distance passenger transportation model all the operation of the programs have been planned and the price will not change without limited.

4) Comfortable----The vehicles of this system are air-condition coaches and there are service centers, urban commercial and leisure centers along the each route.

(2) Weaknesses (W)

1）The lack of theoretical analysis----As a result of the lack of theoretical analysis the price will perhaps not be reasonable and transport management perhaps not be well organized. As to the authors' knowledge, there are few researches of the long-distance passenger transportation.

2）The lack of facilities----The traditional transportation modes has few stations so the facilities cannot meet the demand of the new mode. To apply the long-distance passenger transportation system the transfer condition needs to be improved.

3）Management issues----Now the long-distance passenger transportation system are run in small scale and low efficiency. The government invests less because they do not notice the potential.

(3)Opportunity (O)

1）The demand is increasing----Because the urbanization is accelerating rapidly, so the demand of city to city transportation is increasing. The passenger transportation has been studied and applied on the town bus and high speed railway widely.

2）The application of long--distance passenger transportation is increasing. The passenger transportation has been studied some problems have been found out. But the demands for convenient and fast are obvious. If we can solve the problems the long-distance passenger transportation will have a good future.

(4)Threat (T)

1）Competitor—high speed railway transportation system is the main competitor to the long –distance passenger transportation system. The high speed railway network has been enlarged quickly in recent year, at the same time its travel speed and condition is improving. Therefore the long –distance passenger transportation system has much pressure.

2）Traffic fees---based on the regulation during the travel the vehicles need to pay for some kinds of fee. It is as same as the coaches. If we want to ensure the reasonable prices we need to reduce some traffic fees for long-distance coach.

4.2 Application of analytic hierarchy process to quantify the influence factors

(1)Based on the analysis and the degree of effect to construct the matrix (Huang, Wu, Huang, 2007)

Table 2. The analysis of long-distance passenger transportation using SWOT method

Internal conditions		External conditions	
Superiority (s)	Weaknesses (W)	Opportunity (0)	Threat (T)
High speed	The lack of the theory	Demanding is increasing	Competition of high speed railway transportation
high frequency	Facilities are not complete	the need of diversified development	difficulty of unified management
Transit conveniently	The lag of system software	this model has been tried	difficulty of traffic fee decreasing
regulatory management	lack of money		
divers services			

(2) Using the analytic hierarchy process to quantify the influence factors which have been listed in table 1

1）Comparing each factor of SWOR group, which is shown at table 3

Table 3. The comparisons on the weights of each group's elements

	S_1	S_2	S_3	S_4	S_5
S_1	1	1/2	1/2	3	3
S_2	2	1	1/3	2	5
S_3	2	3	1	2	6
S_4	1/3	1/2	1/2	1	3
S_5	1/3	1/5	1/5	1/3	1

	W_1	W_2	W_3	W_4
W_1	1	2	5	3
W_2	1/2	1	2	1/3
W_3	1/5	1	2	1/3
W_4	1/3	3	2	1

	O_1	O_2	O_3
O_1	1	4	2
O_2	1/4	1	1/3
O_3	1/2	3	1

	T_1	T_2	T_3
T_1	1	5	5
T_2	1/5	1	3
T_3	1/5	1/3	1

（2）Comparison of each group

Table 4. The comparisons on the weights of each group

	S	W	O	T
S	1	5	3/5	7/3
W	1/5	1	3/7	1/3
O	5/3	7/3	1	5/2
T	3/7	3	2/5	1

（3）Using the eigenvalue method to sort each group, the results are shown in Table 5

Table 5. The weight analysis of each group

SWOT group	Priority	CR0	SWOT factor	CRi	Priority of each group's factors	Total Priority
S	0.3425	0.0792	S1:high speed	0.0680	0.2013	0.0689
			S2:high frequency		0.2422	0.0830
			S3:Transit conveniently		0.3717	0.1273
			S4: regulatory management		0.1298	0.0444
			S5: divers services		0.0550	0.0188
W	0.0949		W1: the lack of the theory	0.0862	0.4800	0.0455
			W2:facilities are not complete		0.1672	0.0159
			W3: The lag of system sof tware		0.0947	0.0090
			W4: lack of money		0.2581	0.0245
O	0.3822		O1:demand of passengers	0.0176	0.5571	0.2129
			O2: the need of diversified		0.1226	0.0469

		development			
		O3: this model has been tried		0.3202	0.1224
T	0.1804	T1:the competition of high speed railway transportation	0.0176	0.6864	0.1238
		T2: difficulty of unified management		0.2114	0.0381
		T3: difficulty of traffic fee decreasing		0.1022	0.0184

CR is called random consistency ratio. When CR<0.1, the matrix is judged as acceptable consistency. When CR≥0.1, the matrix needs to be adjusted.

From table 5, the Cri<0.1 the matrix is judged as acceptable consistency, therefore the result is acceptable.

4.3 Analysis of the competition tendency.

(1)In the level of S/W/O/T, the opportunity of the long-distance passenger transportation system has the highest priority (0.3822), the priority of the threat and the weakness is relatively low (They are 0.1804 and 0.0949). These results show that the superiorities of the long-distance passenger transportation system such as comfortable, high speed and so on, which provide the opportunities of developing.

(2)The competition of high speed railway transportation system is the main threat. (The total priority is 0.1238). But the superiorities (S3) (The total priority is 0.1273) like high coverage rate, strong adaptability can help the long-distance passenger transportation system to compete with the high speed railway.

(3)In the analysis of weakness and threat, the priority of lack of the theory(W1) and the competition which comes from the high speed railway(T1) is the highest(they are 0.4800 and 0.6864).It means that we need to pay attention to the advantages of high speed railway to improve the competitiveness.

5. Conclusions

This paper compared the long- distance passenger transportation and high speed railway transportation and finds out the advantages and disadvantages of the long-distance passenger transportation system. Combined with analysis of economic integration, traffic integration and service integration, this paper concluded the definition of long-distance transportation. And the SWOT-AHP method was used to analysis the superiority, weakness, opportunity and threats of long-distance passenger transportation and finally confirm its potential. However this paper mentioned little about the operation research of the long-distance transportation system. Actually there are many problems, for example the lack of facilities. All the problems show that the operation of long-distance passenger transportation is still needed to be studied. With more and more facilities completed, the long-distance passenger transportation system will service for the passenger much better.

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References

CAO.H.N (2011)"Study on Pricing Method of Rural Passenger Transportation Route Based on Urban-rural Public Traffic Integration". *JiLin University*

FANG.H (2011)"Study on Passenger Station Equipment Configuration in the Condition of HSR Bus-type Operation". Southwest Jiaotong University,

GUO.X.CH, WANG.D, JIANG X.H (2009). "General Frames Construction of Integrative Planning of Urban and Rural Public Transit". Research on Modern City, 2.24-2.28.

HAN. X.J. (2006) "The Application of Analytic Hierarchy Process in SWOT method" Intelligence Explore, 05.119-5.122.

HE.D, ZHANG.W, BIE.J.R, ZHOU.Y.A (2011) "Research on the Operation Mode of Intercity Passenger Transportation". Highway and Automotive Application. 142.43-142.45.

HUANG.F, Wu. X, HUANG.X.M (2007) "SWOT Analysis of the Public Transport Operation of Inter-city Rail Transit", City Railway Traffic Study, 10.48-10.51.

JI.Y.B (2013)"SWOT Analysis of University Information-Based Teaching Management and Development Strategies: A Case in Sichuan International". Foreign Language and Literature.6.208-6.211

JIANG.Q.Z, XU.Y.M, SONG.Q.Q (2013)" Research on the Development Strategy of KunLun Industrial Lubricants Based on SWOT-AHP Model". Journal of China University of Petroleum (Edition of Social Sciences).29(5), 7-11

Li.C, ZHOU. W, SI.J.P. (2008) "Problems and solutions of highway long-distance transportation". Highway and Automotive Applications, 6.44-6.47.

Li.H.L (2012) "Study on Public transport of the Intercity Road Passenger Transportation in Urban Agglomeration". Chang'an University

MAO. M, ZHANG. J, ZHOU.H.W (2004). "Passenger Volume Forecasting of Guangzhou-Zhuhai Intercity Rapid Mass Transit". Journal of Southwest Jiaotong University, 2.195-2.198.

XIE.R.H, ZONG.Y, WANG.R.H (2005). "Comprehensive evaluation of the inter-city railway passenger transport". Journal of Guangzhou University (Nature Science Edition), 1.58-1.64.

ZENG.R.T（2013）"Discuss Some Related Problems of Public Transport Operation For Intercity Dedicated Passenger Line ". Southwest Jiaotong University

ZHOU.Y.L. LI.P.F. YANG. C. (2011) "Characteristic of Bus Line and Passenger Flow of Urban-Rural Transit". Traffic Engineering, 21.59-21.63

Highway Landscape Planning Based on "3S" Technologies
—Taking the Sichuan-Tibet Highway (Kanding Section) as an Example

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Abstract: With the implementation of promoting ecological civilization and green transportation construction process, the importance of highway landscape is increasingly recognized and more sustainable and innovative approaches are needed for planning and managing landscapes in China. Based on 3S techniques (Remote Sensing, Geography Information Systems, Global Positioning System),the study proposes a transdisciplinary method combines remote sensing interpretation, field reconnaissance and spatial analysis to delimit the range of visibility for highway and identify landscape resources in Sichuan-Tibet Highway. We also develop a landscape assessment by partitioning the highway landscape and discuss some planning solution to configure the networks of highway landscape and optimize the geographical layout of tourism facilities. We believe that this method proposed in this case can effectively assist highway landscape planning and will contribute to the formation of the tourism synthesis with Sichuan-Tibet highway as development axis and social, economic and ecological construction of Kangding in east Tibet Plateau.
Keywords: Sichuan-Tibet highway; Landscape planning; GIS; GPS; RS; Kangding.

1 Introduction

Over the last few decades, a 4.24 million-km network of highways has been superimposed on the west of China and it is the world's biggest road system.. Transportation planning has traditionally focused on economic and technical problems but not paid enough attention to landscape planning along the highway leading to monotonous design style and insufficiency of the regional features, even causing damages of local picturesque scenery for some highway construction. With the implementation of promoting ecological civilization and green transportation construction process, highway should meet the needs of ecology and the tourism simultaneously. And highway landscape planning plays an increasingly important role in construction of an ecological civilization. Highway landscape planning, taking the highway features, the natural circumstance and the social environment into comprehensive account, is considered to an ‘artistic creation’ for highways displays from the whole to the detail, which emphasizes overall grasp of the highway landscape taste and the tourism services . Xiong(1990) studied highway landscape systematically and put forward the basic theory of highway aesthetics. Zhang(1999) summarized components and characteristics of the highway landscape. Cai(2004) discussed the engineering factors and ecological factors of highway landscape from such perspectives as the alignment design, service area location, highway classification, horizontal and vertical curves, highway facilities, views borrowing, ecological planting landscape, etc. Li et al (2008) explored the theories of ecological restoration and reconstruction. Li and Cai (2011) give a general analogy of ecological landscape design based on the theory of scenic byway of USA. Zhang et al (2012) use CARD_1 software applications in landscape planning and design scheme of visual simulation. Sheng et al (2012) put forward the compensation design method of highway landscape involving the road side slop, the central dividing strip, the intercommunication grade separation and the service area. Marcucci et al (2013) examined the potential benefits and challenges of linking landscape-level green infrastructure planning and implementation with integrated transportation planning and highway project development in the United States policy context. Yang et al (2013) put forward the theoretical basis for highway landscape design method namely "ecological, artistic, secure". The Hawaii Statewide Highway System Sustainable Landscape Master Plan provides comprehensive guidance on how to bring Hawaii’s highway system into alignment with the Hawaiian principle of Pono – of being environmentally sustainable and in harmony with place (Charles et al, 2015). According to the analysis of previous research and relevant information, however， most of researches on highway landscape limits to highway slope ecological restoration, plant community arrangement, plant landscape design and highway environmental pollution and still need to be strengthened in depth and wideness. On the other hand，less researches has been done to focus on highway landscape in landscape planning design terms.. Meanwhile, landscape outside of the scope of the highway was often omitted, and the relationship between highway and highway landscape has not been studied, which causes visual intrusion and ecosystem damage. Generally speaking, theoretical basis for the planning, design and evaluation of the road system have not been established, which would not provide comprehensive guidance to highway landscape construction. Conception of researchers from different disciplines should be upgraded and innovated with the aim of further researches from different perspectives.

“3S”, the combination of Geographic Information System (GIS), Globe Position System (GPS) and Remote Sensing (RS), is a popular technology in the field of geo-statistics and has been gradually applied into landscape planning and design in recent years. RS has incomparable advantage over usage of long-sequence monitoring of land surface changes on multiple scale with cheap cost. GPS have become powerful tools for fieldwork along the highways with the ability to locate precisely. GIS has powerful ability of geospatial analysis, information integration of vector and raster data and map exported, which is superior to the traditional landscape layout methods by CAD mapping (Cai and Lu, 2009; Tian et al (2010). Therefore, “3S” technology can resolve the problems which is difficult to solve for traditional methods in highway landscape studies and develop a new way for highway landscape planning.

We took the impact range of highway as the scope of research and applied “3S” technology into highway landscape design under the guidance of landscape ecology and road ecology theory. We also explored the strategies to help plan Tibet Plateau highway landscape design and tried to suggest a new way of thinking about highway landscape constructions.

2 Profile and Landscape Planning Theme of the Study Highway

Sichuan-Tibet road entersinto Qinghai-Tibet Plateau in Zheduotang, Kangding County and is divided into south and north section in Dongeluo village, Xinduqiao town. What we study here is the Kangding section of Sichuan-Tibet Highway(in the west of Zheduotang), which consists No. 318 national highway in the east and west and No. 215 provincial highway in the south and north in the length of 125.8km.It connects 4 towns, nearly30 natural villages and many scenic regions such as Mount. Zheduo, Waze ecological valley, Xinduqiao, Mount. Gaoersi and Tagong Grassland, which is the main roads of Sichuan tourism west wing line and to travel ecologically on the ring road in Kangding County Meanwhile, it also can be an organic component of ‘2-hour tourism circle surrounding Mount. Gongga’ which is centered on Kangding airport (Figure 1).

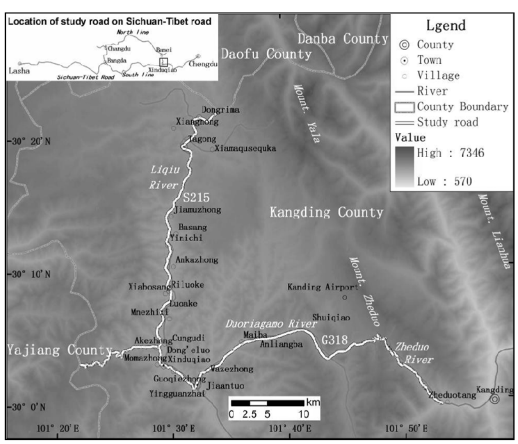

Figure 1. The location of the study road

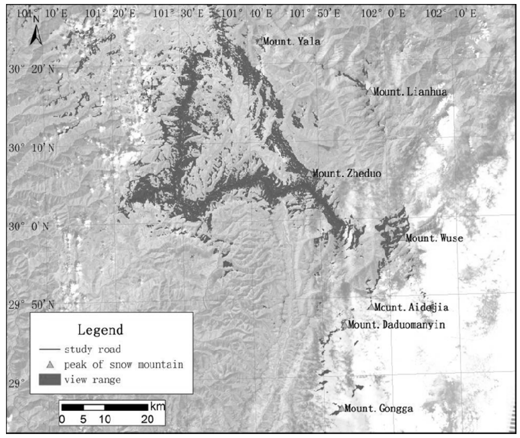

Figure 2. Visible analysis of the study highway

The region of planning section has a continental plateau climate with acute topographic undulation in the altitude interval 3250-4298 m and complex belt spectra of vegetation, but many ecological environmental problems such as weathered soil, degradation of vegetation and water and soil erosion. Meanwhile, the past road constructions fails to focus on ecology protection of slope for highways and spoil ground, the scenery inside the region has been largely affected. . Moreover, past highway constructions doesn't have special landscape design and lacks transformation to landscape outside road boundary line, which leads to obvious discordant phenomenon on landscape along the highway. These landscape defects have already been important factors that restrain the development of local tourism and an overall highway landscape plan needs to be effectuated eagerly

According to the researches on natural and cultural characteristics of Kangding section of Sichuan-Tibet highway, we can find that it is this section's geographical basis to be in the east of Qinghai-Tibet Plateau and at the intersection of south and north sections of Sichuan-Tibet highway. Shangri-la tourism zone and Gongga western slopes circular tour expand its tourist environment, and Muya culture which integrates the culture of Tangut qiang tribesmen and Tibetan constitutes its cultural connotation. Based on analysis on tourism resources and visitors' needs and requirements, this plan proposes two themes: 'Plateau Valley Ecotourism' and 'Muya Tibetan Cultural Tourism' which intend to build an exemplary landscape highway which embodies local characteristics, reflects natural and cultural truth and integrates ecological protection, tourism and socioeconomic performances.

3 Content of Landscape Planning

3.1 Definition of highway visible range and landscape resources investigation

The most significant factor of highway tourism is line-dependent tour, that is, the scenery can be seen on the highway. Therefore, visible area of the highway needs to be confirmed and landscape resources should be filtrated as the basis of landscape planning.

3.1.1 Viewable area of section planning

According to Digital Elevation Model (DEM) provided by International Scientific Data Service Platform, view field of planning section is obtained from ArcGIS platform (Figure 2). We can see that that the viewable region can cover 1167km^2, most of which is both sides of road and sectional high mountains, including Mount. Gongga, Mount. Daduomanyin, Mount. Aidejia, Mount. Wuse, Mount. Zheduo, Mount. Lianhua, Mount. Yala, etc.

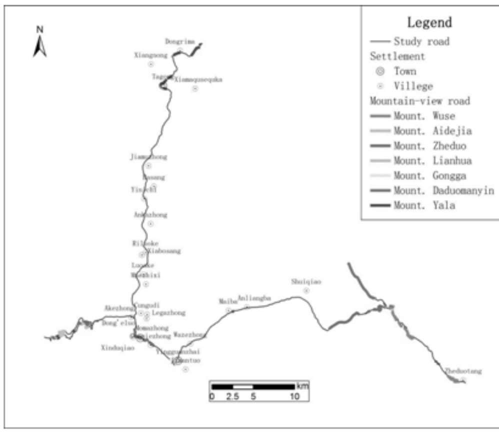

Figure 3. Viewable sections of snow mountain

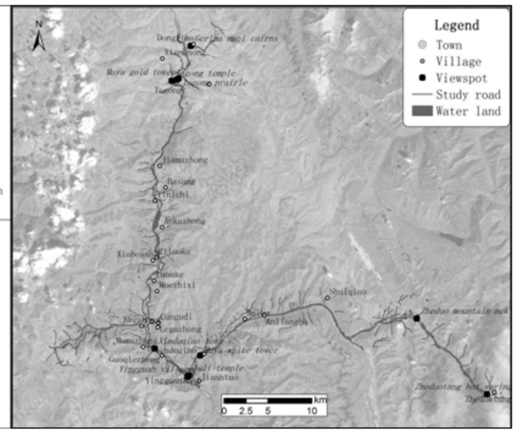

Figure 4. Distribution of villages and existing tourism scenic spots

3.1.2 Distribution of landscape resources

(1) Viewable sections of snow mountain

As the special part of the plateau, snow mountain are of fine scenery and occupy a hallowed status in local religion and customs. Through visible analysis, we get the section distribution of Snow Mountains as the basis of landscape district and arrangement of viewpoints.. The results (figure 3) shows that visible sections of Mount. Yala are distributed on Tagong Grassland and Gaoersi Peak with a length of 8.5km. Visible sections of Mount. Gongga are distributed on Waze Township and Mount. Zheduo with a length of 1.9km, while that of Mount. Zheduo are dispersedly distributed in No.2 section of Gongbuka Bridge and fractional sections of Mount. Gaoersi with a length of 9.0km. Visible sections of Mount. Aidejia peak are distributed on Mount. Zheduonek with a length of 1.5km, and visible sections of Daduomanyin near Xinduqiao town and the nek of Mount. Zheduo with a length of 3.4km. Visible sections of Mount. Lianhua at are distributed on ridge and peak of Mount. Gaoersi with a length 4.8km. Visible sections of Mount. Wuse are distributed from Mount. Zheduo nekto fractional sections of Zheduotang with a length 8.5km.

(2) Distribution of surface water resources

According to Landsat TM remote sensing image and on the basis of ERDAS 9.2, the distributions of surface water resources is decoded within 5 km of both sides of planning landscape through supervised classification. The results show that there are rich water resources near Kangding sections of Sichuan-Tibet Highway except Mount. Zheduo, Mount. Gaoersi and the Peak of Mount. Xiangpi. Nearly all the sections are along rivers. Various kinds of river landscape form the framework of natural scenery of plateau valleys. Meanwhile, there are two areas with wider river and moderate terrain, distributed fromXinduqiao to the middle section of Tagong and the west of Waze Township. These two places are fit for making wetland landscape and wetland view point.

(3) Distribution of villages and existing tourism scenic spots

Residential areas and tourist attractions near 5km of the planning highway are filtrated on the basis of ArcGIS 9.3, including 2 towns, 18 administrative villages, 36 natural villages, 5 road maintenance gang and 8 sight spots. We can see that Tibetan Villages are mainly distributed on the section from Wazezhong toJiamuzhong village which is the center of Muya culture. Road maintenance gang is distributed near Mount. Zheduo, Mount. Gaoersi and Songlingkou, forming unique culture of plateau highway maintenance squad. Meanwhile, existing tourist attractions are mainly distributed on 3 districts: Xinduqiao -Yingguanzhai, Tagong, Zheduotang,which respectively symbolizes Muya Tibetan culture, grassland and Tibetan Buddhism, geological hot springs, three special tourism resources(figure 4).

3.2 Evaluation and Subsection of Highway Landscape

Highway landscape is sequential kind landscape. In the process of driving, tourists can only feel the change of landscape sequence and can hardly feel every detailed feature which forms the scenery. These significant obvious changes are caused by the change of landform and various land-use types. The division of the sequence spaces as a whole should be based on the distribution rule of road landscape types. Boundaries can be put on the intersection of shifting landscape and view changes of every section should have a landscape main axis in which the distribution of scenery is proper, thus tourists can get a good visual effect.. Based on requirements of landscape experience and safety requirements, the length of every section should be among 10-20km to get rid of hypo-wakefulness.

3.2.1 Division of basic investigation unit

The investigation and evaluation of landscape resources are the foundation of highway landscape planning. Firstly, we should take samples of landscape statistics in every section according to the planning section and take the length of the section and the number of statistics into consideration., Basic **investigation** unit should be made at a length of 2km and target sections can be divided into 63 basic survey units, because of which multi-criteria evaluation to every unit can be done.

3.2.2 Analysis of basic investigation unit

(1) Topography

The elevation and slope of each investigation unit can be extracted out using DEM data on GIS platform (figure 5). The results reveals that the altitude of target highways differs greatly and lowest part is Zheduotang, less than 3300m, while both the nek of Mount. Zheduo and the peak of Gaoersi are higher than 4200 m. Other places are mainly among 3400m to 3700m. The slopes of sections near Mount. Zheduo and Mount. Gaoersi are more than 3 degree, and the highest is7 degrees, which is the degree of obvious sky way. The slope of other places are among 1-2 degrees. Therefore, Zheduotang and Mount. Gaoersi should be be listed individually in landscape sections of highways.

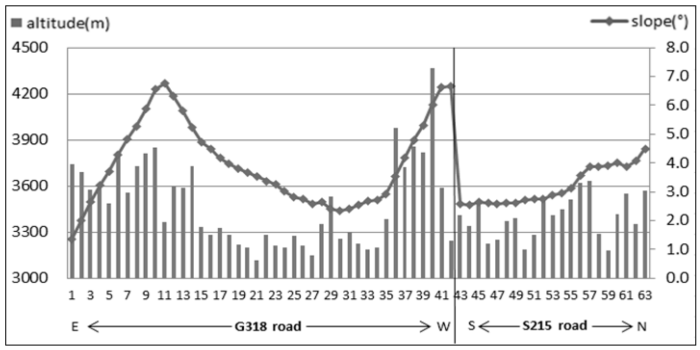

Figure 5. The altitude and slope of each highway section

(2) Land use types

We make artificial visual interpretation and divide planning section into several types: woodland, grassland, building land, water land and unused land on the basis of landsat TM images and ERDAS 9.2 platform (figure 6). The further analyses for proportion of different types of land use within 2km both sides of the planning section on the platform of ArcGIS(figure 6). We can see that that woodland besides both sides of Mount. Zheduo and Mount. Gaoersi occupies a large proportion; woodland and natural land form the majority of the land in 53-57 sections. The land of 31st section (Xinduqiao town) mainly used as building land, while grassland dominates other places. Because highways are built mainly besides the river, the water area is nearly 5 %. Thereby the areas near Xinduqiao and 53-57 sections can be listed as a category in landscape division.

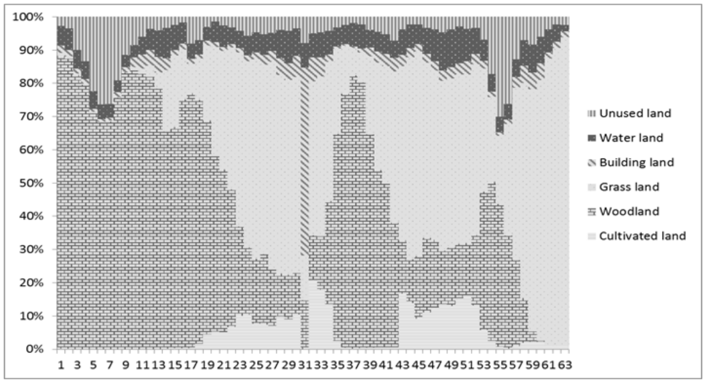

Figure 6. The land use structure of each highway section

(3) General evaluation on field and quality of vision

Visible area of each section is analyzed by viewshed model in ArcGIS and evaluation on field of vision is got through Equal Distance Visual Assessment by Expert Team (EDVAET) (Wu and Li, 2001), on the basis of natural and humane scenery in each section and aesthetic judgment of experts on landscape in real earnest. With figure 7, we can find that the maximum of visible areas occurring at the peaks of Mount. Zheduo and Mount. Gaoersi, while visible area in valley region is the smallest which is less than 30km^2 in each section. Area with the most beautiful scenery is the peak of Mount. Gaoersi and Mount. Zheduo peak and Tagong grassland. Scenery along No. 215 provincial road is better than along No. 318 national highway. In the following landscape section, field of vision and quality of vision should be taken into consideration and sections with large visible area and good scenery should be singled out..

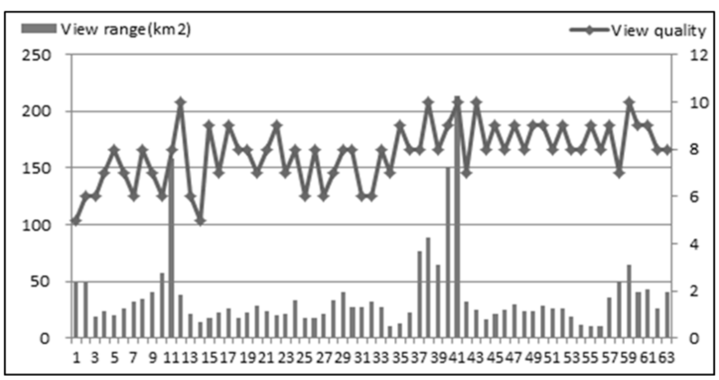

Figure 7. Evaluation of view range and quality in study road

3.2.3 Section of highway landscape

According to analysis to natural, humanistic scenery in basic investigation unit, we can divide the planning highway into 9 landscape sections (figure 8). Among them, No. 318 national highway is divided into 6 sections: Zheduotang valley section, Zheduo mountain meadow section, Waze broad meander valley section, Xinduqiao Muya Tibetain style section, Gaoersi alpine forest section and Gaoersi plateau meadow section. No. 215 provincial highway is divided into 3 sections: Baisang broad meander valley section, Songlinkou canyon torrent section and Tagong snow-capped plateau section.

3.3 Distribution of highway landscape nodes and tourist facilities

Based on the highway landscape section, the interval of landscape appreciation and focus of aesthetic experience is extracted according to the linear features and vision field features of the road, namely the landscape excitement, for satisfying tourists' requirements for appreciation and recreation.

3.3.1 Distribution of highway landscape nodes

There are 21 landscape nodes in this planning, including 16 ordinary viewing decks, 3 wet-land viewing decks and 2 service stations (figure 9). According to the planning, the average interval of the point of landscape service facilities is nearly 6km, relatively even in distribution, and the service stations are located in Mount. Zheduo nek and Tagong Gold Tower. The landscape facilities basically meets the tourists' requirements for rest, viewing and life service.

3.3.2 Distribution of bicycle paths

In order to improve the travel feeling of the road and satisfy the demand of riding backpacker, bicycle paths of three different types with a length of 7.5km are planned according to the terrain and road condition (figure 8), including the rural scenery bicycle path (out of the tree sides, connecting the Dong eluo and Menzhixi viewing deck), Muya elegant bicycle path (in side-ditch and cover-plate form, located near Waze Township) and forest greenroad bicycle path (the form of crossing the forest, near Niudi viewing deck).

3.3.3 Rural tourism-driven project

Due to reflect the support of landscape road to the tourist economy and promote the enthusiasm of local residents in the development of landscape road, the rural tourism-driven project is set for the viewing and tourist facilities. We set respectively the point of tourist facilities as 8km (service station), 5km (large-scale viewing deck), 3km (middle viewing deck), and 2km (small-scale viewing deck). The radius of bicycle path service is 2km. The results show that there are 4 villages including Luzhao Town, Waze Township, Xinduqiao Town, and Tagong Village, 23 administrative villages, 34 natural villages, 10 scenic spots an 7 other units along the bicycle path and all of them located in tourism scope of this planning. Each points of tourist service facilities correspond to 1 to 16 villages, scenic spots or other units (It may overlap), and it can provide basis for the operation in follow-up tourism development.

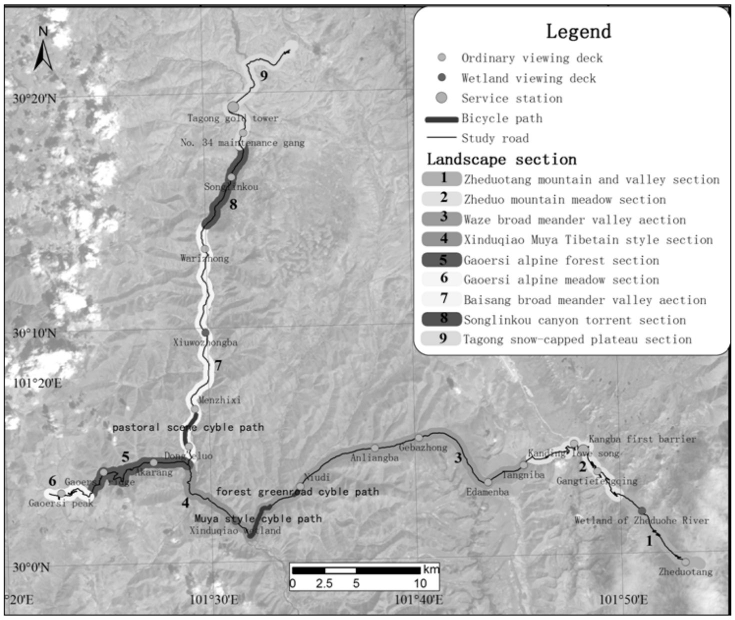

Figure 8. The landscape sections and node of the study road

4 Conclusions

This paper applies the methods of geographical space investigation and analysis represented by RS, GPS and GIS technologies (collectively referred to as "3S") into the landscape planning research of Kangding Section of Sichuan-Tibet Highway, which has yielded good results. Firstly, we employ such methods as visibility analysis, remote sensing interpretation and field reconnaissance to demarcate the visible highway field and study the landscape resources. Secondly, we employ GIS space analysis to make a comprehensive evaluation on the natural geographical characteristics including the elevation, slope, land use types and horizon along the highway and such humanistic landscape characteristics as visual quality. Based on this, we demarcate the highway sections in accordance with the changes of all landscape evaluation indexes. Thirdly, by employing the comprehensive analysis function and map output function of GIS, we formulate the landscape planning projects including landscape facilities layout and tourism-driven project and displays them on the map.

Eventually, the planning highway is divided into 9 landscape sections, and 21 lookouts and service stations of 3 types, 7.5km-long bicycle path of 3 types, the rural tourism-driven project are planned to help the landscape construction and tourism development of region. In addition, based on the landscape characteristics of highway sections, the planning researches into such fields as section planting configuration, slopes and borrow and disposal ground treatment project and ethnic culture displaying project.

By conducting landscape planning research on the Kangding section of Sichuan-Tibet Highway based on “3S”, it verifies the importance of “3S”in the highway landscape planning research and explores new methods of highway landscape planning; on the other hand, it realizes the joint development of the section landscape planning research and the tourism resources along the highway, which will not only make the tourists joyfully appreciate the plateau lakes, snow mountains and meadows and charming sceneries in Muya, Tibet but form an integrated tourism complex mode of ‘highway-scenic spots-tourism supporting-tourism services’, thus greatly promoting the development of the local society, economy and ecology.

References

Bai H., Jia S.W., Wu G. (2013). Planning and design of highway landscape based on spiral model architecture. *Journal of Chang'an University (Natural Science Edition)*, 33(4): 23-28.

Cai B.F., Lu R.S. (2009). Application of RS and GIS to road ecological effect assessment. *Journal of Changpan University(Natural Science Edition)*, 29(5): 54-48.

Cai Z.Z. (2004). Study of the highway landscape culture in China. *Journal of Chinese Landscape Architecture*, (4): 45-49.

Li J.C., Zhi Q.X., Yuan Y.X.(2008). Landscape greening design for expressway based on ecological intension in tropical rain forest. *Journal of Chang'an University: Natural Science Edition*, 28(1): 55-59.

Li L., Cai J. (2011). Ecological landscape design for scenic road. *Inner Mongolia Agricultural Science And Technology*, (3): 124-125.

Marcucci D.J., Jordan L.M.(2013). Benefits and challenges of linking green infrastructure and highway planning in the United States. *Environmental Management*, 51(1): 182-197.

Scott C., Kurokawa B. (2015). The Hawaii statewide highway system sustainable landscape master plan. *Transportation Research Board 94th Annual Meeting*. Washington DC, United States: 4813.

Sheng N.H., Qin D.F., Zhong H.H., Xin H.X. (2012). Compensation design of highway landscape. *Applied Mechanics and Materials*, 238: 507-509.

Tian L., Shen Y., Li Z.Y. (2010). Application of landscape ecology in road field environment variation based on 3S techniques. *Research of Soil and Water Conservation*, 17(2): 168-173.

Wu B., Li M.M. (2001). EDVAET: A linear landscape evaluation technique -- a case study on the Xiaoxinganling scenery drive. *Acta Geographica Sinica*, 56(2): 214-222.

Xiong G.Z. (1990). *City road aesthetics*. Beijing: Chinese Architectural Press, 1990.

Yang Y.X., Liu Q.F. (2013). Research on highway landscape design based on ternary theory. *Technology & Economy in Areas of Communications*, (6): 84-86.

Zhang Y. (1999). A few questions about the research of highway landscape. *Journal of Xi'an Highway University*, 19(S0): 26-28.

Zhang Y.J., Xu Q.J., Sun M.J. (2012). Planning and Design of Highway Landscape Based on Spiral Model Structure. *Advanced Materials Research*, 616: 1223-1226.

Vessel Behavior Analysis on a Narrow Waterway

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Abstract: The drivers are the main receivers and responders of the external environment while the ship navigation as well as the core of the maritime traffic systems. Their behaviors will direct influence the safety of the maritime traffic operation. However, maritime traffic models have only considered open sea without complex narrow channel traffic environment. Whereas the narrow channel performs various traffic characteristics with respect to its high density traffic flow; the narrow channel can efficiency describe the vessel behaviors under encounter situations including vessel following and near head on etc. The simulated area included a junction and a slight approach channel with high maritime traffic density within the YangShan port of Shanghai. According to use vessel handling simulator to gather throttle, rudder, DCPA (distance to closest point of approach), TCPA (time to closest point of approach) and others key parameters under following scenario when the vessels off the harbor. Furthermore, a microcosmic vessel behavior is analyzed combined with dynamic vessel factors (velocity and course) and external influence factors (wind and visibility). Analysis results can be insight into the real vessel behavior for each vessel category, meanwhile can improve current maritime traffic model.
Keywords: Vessel behavior; Narrow waterway; Following behavior.

1 Introduction

With the rapid increase in maritime traffic, maritime safety and capacity become more and more important. For the safety of navigation, the role of driver is essential to analyze. Drivers are the main receivers and responders of the external environment while the vessel navigation. Eighty percent of global maritime accidents were due to human error caused by the decision-making *(Coldwell,1983; Hazel,2007)*. Vessels' behavior research is an important part of the vessel traffic domain study and safety navigation area. By analyzing the behavior of the vessel driving characteristics, the collision avoidance aspects including ways, methods, features and discipline is captured at the microscopic perspective. Apparently, amounts innovative results are discovered *(Mou, 2010; Zhao-Lin W, 1984; Yang, 2013)*. So research on the vessel navigation and manipulation from the macroscopic view is the key to improve traffic safety on the sea, also can provide the data basis of traffic management strategy.

Vessel's behavior is determined by the brain thought, stimulate and judgment at significant degree *(Gerritsen,2010; Borgonovo,2001, Okura,2001)*. Whereas these intrinsic factors are unpredictable, only vessel navigation state can be used to investigate. Errors must be exit if different vessel behaviors were put together to analyze, because complete same states of two vessels has low possibility to occur. Now there are two main data collection methods to gather vessel behavior's data are direct observation and manipulation simulator respectively. Simulation method is easier on the data acquisition which can produce a variety of vessel traffic state according to the set and can be a recurring status. According to manipulate the vessel by bridge teams, simulated behavior data canbe directly collect including speed, distance, rudder etc.

2 Descriptions of Data

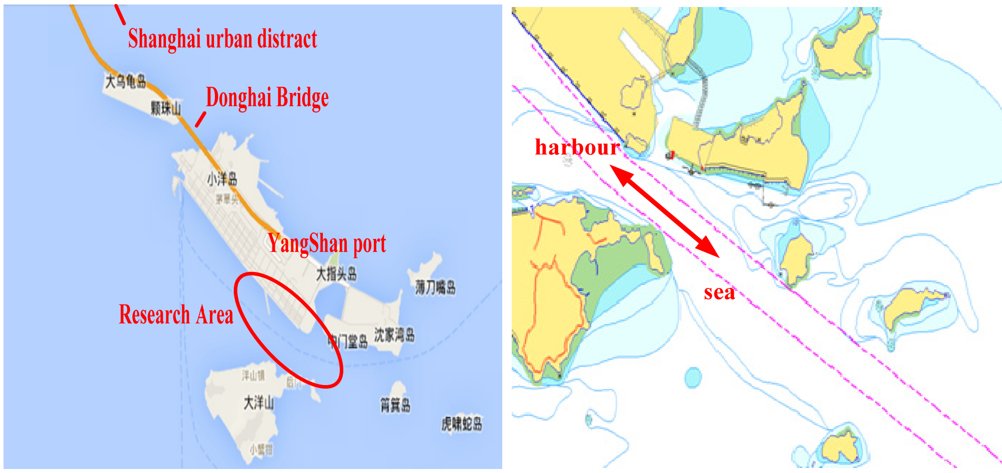
The data were obtained by vessel manipulation simulator, where 3 groups (20 in per group) shipmasters were selected to simulate the actual manipulation under departure port scenario for investigating their driving behavior. The data obtained by vessel manipulation simulator has obvious advantages. First of all, in the selection of the scene, it's easier to set port waters narrow waterway, avoid the observation data inaccuracies because of the higher density of the vessel traffic flow density. Secondly, that can also select the test object targeted, as ship master related by this paper, which can reflect the actual manipulation of the ship leader behavior more targeted

Simulated data is obtained through the Shanghai Maritime University Marine vessel simulator laboratory. The simulator is provided with a 3D scene and can be maximized consist with the actual situation of maritime traffic. Data is composed of 60 different sets of bridge teams on container vessel type. In the research area, the system accumulated simulated messages at 6-s intervals. And most vessels navigate with a speed of 0 to 14 knots (1 knot=1.852 km/h =0.514 m/s). Thus, a good way is needed to extract and compare relative speed, relative distance, DCPA, TCPA between tracks.

3 Data Analysis Method

Yangshan Deep-water Port has most containers handled and it is the largest container port in the world. It is connecting with the Shanghai area by the East China Sea Bridge. Harbor waters showed high traffic density, interference, narrow fairways and so on. Because of the requirements of complex traffic environment and high order, the transport behavior of typical research within the region is extremely important.

Research area as shown in Figure 1; Figure 1b zooms in on the area. The main vessel types are container vessels in the research area. Different container vessels have different vessel behavior because maneuverability and sensitivity to danger will differ. Container vessels have the largest vessel size, the gross tonnage is used to consider.



(a) (b)

Figure 1.Research area of Yangshan port: (a) overview and (b) close-up

The detailed data collection areas are proposed based on maneuvering simulator. Figure 2 shows the navigation direction sea to Yangshan port and Figure 2b shows the opposite navigation for Yangshan port to sea. Width of waterway is 300m, two-ways, and each way width is 150m. That is to say, there is significant influence of the objective vessel by the leading vessel or encounter vessels no matter what navigate from port to sea or sea to port in this narrow waterway.

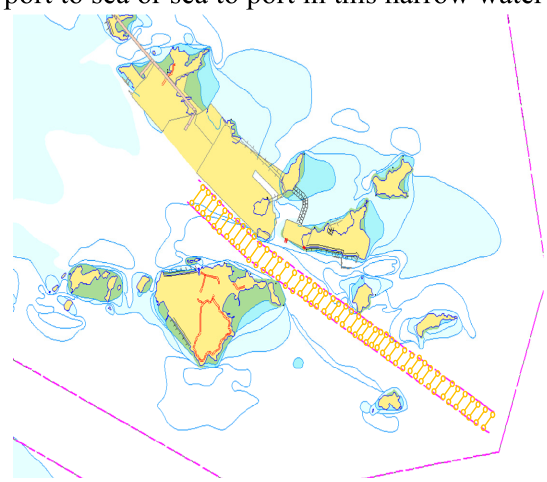


Figure 2. Study area navigation port to sea

4 Vessel Following Behavior

Due to the Yangshan Port hydrological conditions are semidiurnal tide, which means there are twice fluctuations of the tide one day. Vessels are required against stream during departure the berth. So the moment before the tug pull the vessel in channel won't be considered.

Figure 3a shows the probability of relative distance distribution when the vessel navigate from harbor to sea. Here, the x-axis, relative distance between the objective vessel and the former vessel, indicates the longitudinal distance along the consecutive vessel central position. The results show these simulated bridge teams tend to keep the following distance between 600 m to 900 m to maintain a respond arena. The simulated vessel set length is 290m and the draft is 15m. That means the relative distance between the consecutive vessels is about 2-3 times than a single vessel length. Also it apparently that a part of bridge teams choose a larger following distance more than 6 times as a vessel length, which can be pay more caution along the narrow waterway. This means that most ship masters prefer a reasonable following distance less than 3 times vessel length when they off the berth, meanwhile the relative distance is influenced by waterway geometry and vessel size.

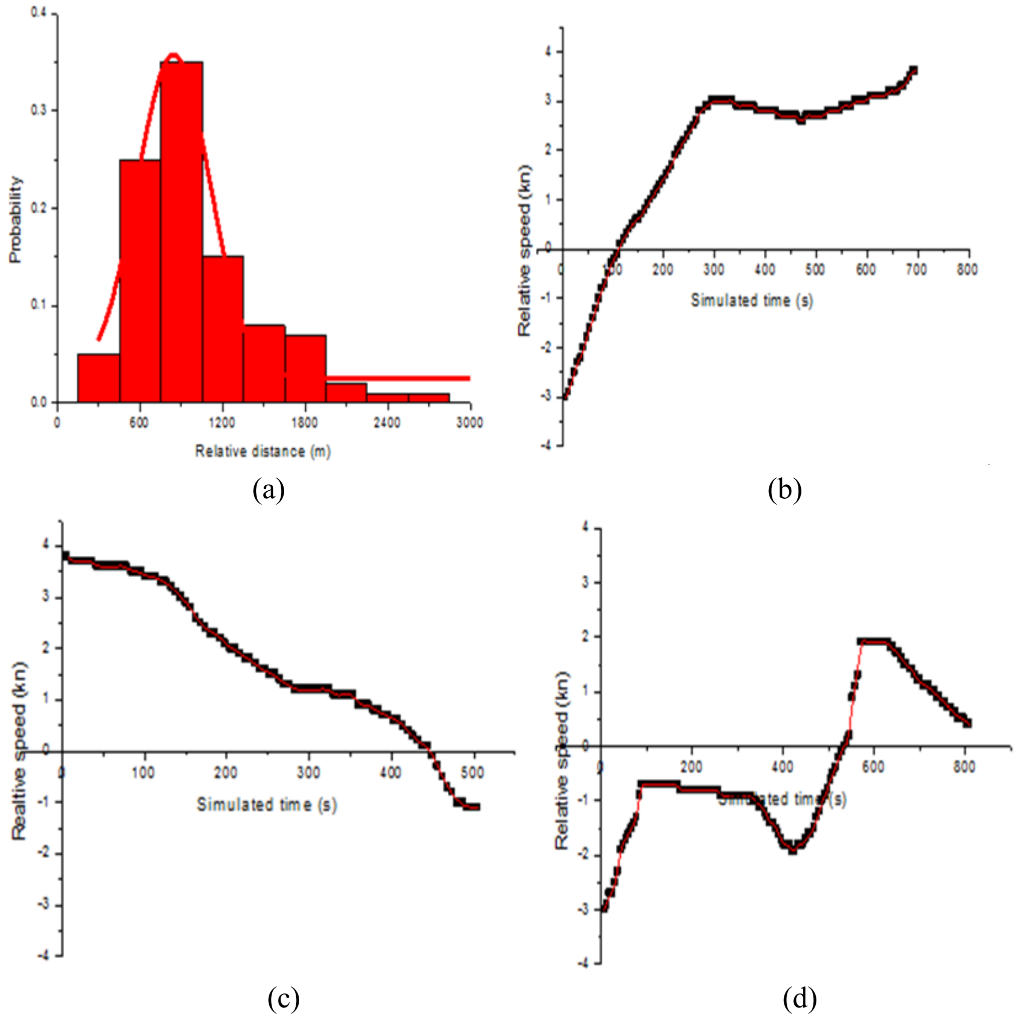


Figure 3.Vessel following behavior: (a) probability of relative distance, (b)-(d) relative speed

For better to describe different vessel behaviors, bridge teams were divided into 3groups, represent by Fig 3b, 3c, and 3d respectively.

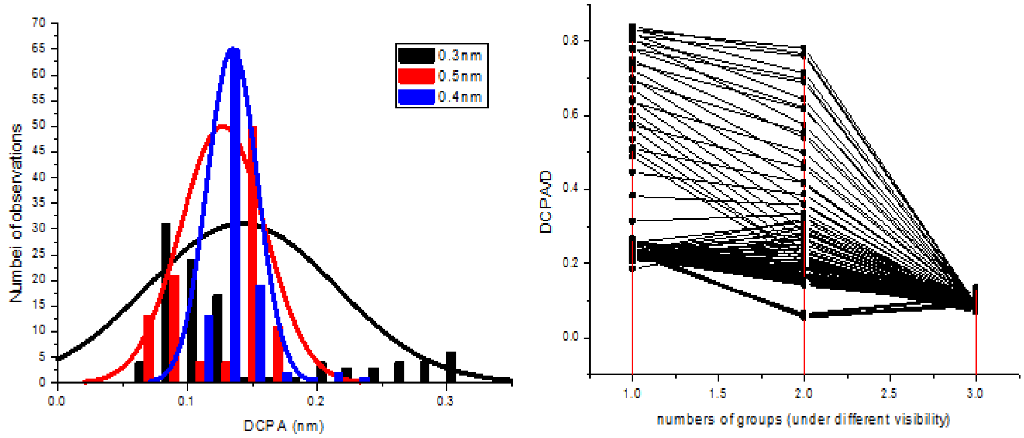
Figure 3b shows the relative speed between the objective vessel and leading vessel is gradually increasing from negative to positive. That indicates the objective vessel is in a accelerated state. This kind of situation demonstrates our objective vessel's speed was lower than the leading one before navigated in waterway. And then the objective chose to accelerate. It was can be seen from the Figure 3b, the objective vessel near the entrance of sea and keep a stable speed interval after simulated 300s while the leading one has already depart from harbor for a while. This figure illustrate that vessel speed is closely related with the leading ones'.

In Figure 3c the objective vessel speed shows a decline tendency which opposite with Fig 3a. It is certain that the objective vessel speed was decreasing from full speed for safety unlike the relative distance is enough large to keep high speed at the beginning. The leading vessel speed was decline due to the uncertain condition at 450s, so the objective one adopt same action to down their speed lower than the leading for keep away from the leading vessel's domain.

Different in Fig 3d, the relative speed appeared three inflection points. A reasonable explanation about objective vessel speed keep changing is that vessels have lower speed in a narrow waterway and adjusting throttle accompanying the leading vessel behavior.

5 Analysis of DCPA under Influence of Visibility

With reference to the literature *(Zhao-Lin, W. 1984)*, the DCPA were calculated. Figure 4a shows the DCPA distribution. Different colors represent different visibility which was set as 0.3nm, 0.4nm and 0.5nm respectively. Mean values of DCPA are 0.200nm, 0.134nm，0.127nm,respectively. It is easier to see that bridge team kept a lesser DCPA from the leading vessel in higher visibility scenario. The value of DCPA is decreasing with the visibility decreasing. And 0.3nm is a significant threshold, which the vessels were influenced under this threshold. It is forbidden to navigate when the visibility lower than 200m in China.



(a) (b)

Figure 4.Effect of visibility: (a) DCPA distribution and (b) DCPA/D distribution

Generally, shipmasters both consider the distance between objective and leading vessel and DCPA in order to judge if take collision avoid action or not. Figure 4b shows the values of DCPA / relative-distance under different visibility. With reference *(Zhao-Lin, W. ,*1984*)*, the smaller the value , the probability of take action to avoid collision is bigger. It's equally in Fig 4b that the third group data of DCPA/D is lesser than other groups, that means the possibility of bridge team tend to take action is increasing.

6 Conclusions and Recommendations

This paper presented the results of an analysis of simulated data for behavior of vessels while navigating from port to sea, and the influence of external factor as visibility in the YangShan port in Shanghai. Vessel behavior was characterized by relative distance, relative speed, and DCPA values.

The results show the different vessel behavior for different groups of ship masters. The safety following distance between the objective vessel and leading vessel usually maintain twice or three times than a vessel length while navigating to sea. That is to ensure the efficient reaction time to manipulate vessel state. Secondly, the speed of objective vessel is closely related with the leading vessel and companying with the changing of the relative distance. At last, the external influence factor was analyzed under different visibility. The experiments show that visibility has a significant impact on vessel relative distance. A bridge team decreases a vessel's speed and increase the following distance when visibility decreases. Meanwhile, values of DCPA are increasing with the visibility decreasing. Consequently, vessel adopt action possibility of collision avoidance is increasing.

Acknowledgement

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References

Borgonovo, E. (2001). “A new importance measure for risk-informed decision making”. *Reliability Engineering & System Safety*, 72(2), 193-212.

Coldwell, T. G. (1983). “Marine traffic behaviour in restricted waters”. *Journal of Navigation*, 36(03), 430-444.

Gerritsen, H. (2010). “Integrating vessel monitoring systems (VMS) data with daily catch data from logbooks to explore the spatial distribution of catch and effort at high resolution”. *ICES Journal of Marine Science: Journal du Conseil*, fsq137.

Hazel, J. (2007).” Vessel speed increases collision risk for the green turtle Chelonia mydas”. *Endangered Species Research*, 3, 105-113.

Mou, J. M.(2010). “Study on collision avoidance in busy waterways by using AIS data”. *Ocean Engineering*, 37(5), 483-490.

Okura, H. (2001). “Impact of pre-interventional arterial remodeling on subsequent vessel behavior after balloon angioplasty: a serial intravascular ultrasound study”. *Journal of the American College of Cardiology*, 38(7).

Yang, Z. S. (2013). “APF-based car following behavior considering lateral distance”. *Advances in Mechanical Engineering*, 2013.

Zhao-Lin, W. (1984). “An alternative system of collision avoidance”. *Journal of Navigation*, 37(01), 83-89.

Zhao-Lin, W. (1984). “Quantification of action to avoid collision”. J*ournal of Navigation*, 37(03), 420-430.

Ability Measurement of Urban Traffic Sustainable Development in China

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Abstract: China is one of the countries with fastest speed of development of urbanization and mechanization in the world. There are many problems, including serious traffic jam, aggravating environmental pollution, increased exhaust emission, lack of resources, increased gap between rich and poor, etc., affecting sustainable development of economy, society and environment. Meanwhile, these universal problems of 21st century have attracted wide attention of international society. Traffic, as the base and guidance of urban development, plays a decisive role in urban development. Consequently, attention has been paid to both urban sustainable development and sustainable development of urban traffic. In the work, evaluation index system of urban traffic sustainable development was built based on urban traffic sustainable development theory, and the weight of each index in evaluation was determined according to theoretical analysis and expert consultation. Extensional matter-element model was established using extension to evaluate urban traffic sustainable development condition, thus achieving the grade and possible development of urban traffic sustainable development in Beijing and providing scientific and rational basis for urban planning and construction department. The results show that urban traffic sustainability is in good condition, however, trending to common condition. Regulation and intervention should be carried out. In addition, evaluation index system and method of urban traffic sustainable development are scientific and rational, thus providing the relevant basis for decision of government department.

Keywords: Urban traffic; Sustainable development; Extension theory; Analytic hierarchy process; Comprehensive evaluation.

1 Introduction

China is one of the countries with fastest speed of development of urbanization and mechanization in the world. There are many problems, including serious traffic jam, aggravating environmental pollution, increased exhaust emission, lack of resources, increased gap between rich and poor, etc., affecting sustainable development of economy, society and environment. Urban traffic system, as a comprehensive system of all kinds of urban traffic modes, is the transport corridor of people flow, logistics and information flow. The development level of urban traffic system directly affects the improvement of residents' life quality, urban function and comprehensive competiveness. So, correct measurement and evaluation of development level of urban traffic system will have realistic meaning for solving traffic jam problems, achieving rapid, safe and efficient operation of traffic system, and promoting urban economic development(1).

Theoretic research of urban traffic sustainable development is focused on establishment of traffic sustainable index system at present (2). There have been a lot of achievements, where representative index systems are STPI in Canada (14 indices: freight volume, road network, travel mode structure, environment, energy, transportation cost, traffic casualties, etc.), COMPASS in German (15 indices: accessibility, transportation infrastructure, environmental impact, renewable energy utilization, transportation equity, etc.). Stockholm in Sweden has established evaluation index system through seven aspects including accessibility, environmental impact, health medical treatment, land use, housing condition, employment condition, etc. England has selected 21 indices including accessibility, crowded degree, infrastructure, travel mode structure, environment, energy, transportation satisfactory degree, transportation cost, etc (3-6).

Ability Evaluation of urban traffic sustainable development is a basic method of discovering and solving urban traffic problems. The point is not evaluation results but providing decision-maker with the information to solve traffic problems. Urban traffic sustainable development level is analyzed and evaluated to determine whether urban traffic system develops in accordance with society, economy, environment and resource, and the problems in the operation process of urban traffic system are revealed. It has an important realistic meaning for exploring limited factors, realizing early warning in bad state and promoting benign development of urban traffic.

Although lots of constructive studies have already been done on the ability measurement of urban traffic sustainable development by many scholars, relatively few studies fully consider its development potential, and point out its development trend to provide early warning and effectively control measures. Therefore, in the work, evaluation index system of urban traffic sustainable development in accordance with Chinese situation is established based on traffic problems, sustainable development and system theory. Combined matter-element analysis (7-12) with AHP, evaluation method of urban traffic sustainable development is researched to provide scientific and rational basis for urban traffic sustainable development in China.

The main chapters in the work are as follows. In Session 1, the meaning and research situation at home and abroad are introduced. In Session 2, combined with the present achievements, evaluation index system of urban traffic sustainable development in accordance with Chinese situation is established according to the actual problems of urban traffic development. In Session 3, the methodology is proposed. In Session 4, the system and method proposed in the work are verified and analyzed to get the conclusions by a case study of Beijing. The achievements in the work can provide scientific and rational direction for metropolitan traffic development in China.

2 Traffic Sustainable Development Measurement Index

2.1 Urban Traffic Sustainable Development

Sustainable development is one of the largest problems in the 21st century. The theory and thinking of sustainable development affects the process of world development and human civilization as an epoch-making thought. Urban traffic system is an organic whole composed of urban road system, traffic flow system and management system. The essence of urban traffic system is the development of urban traffic system in accordance with economy, society, resource and environment (3-6). It can satisfy the requirement of society to freedom of movement, access to opportunity, communication and commodity trade without damaging other basic or ecological value of human at present and in future. Urban traffic sustainable development should contain the following attributes.

(1)Sustainability

Sustainability means that natural resources will be sustainable for human use forever, and not affect the production and life of progeny because of resource exhaustion. It requires that human economy development cannot exceed the bearing capacity of natural resources and ecological environment. Because of limited resources for urban traffic development and certain bearing capacity of ecological environment, the following relations should be satisfied in urban traffic development: Development speed of vehicle should be adaptive to that of road resources; the traffic mode be adaptive to traffic need growth selected; the pollution caused by transportation not exceed self-purification of environment, thus meaning coordination between traffic development speed and bearing capacity of environment.

(2)Development

Development is the premise of sustainable development. To satisfy the growing traffic need of people, urban traffic system should be kept in certain growing speed, and the development quality be gradually improved. The advanced, safe, convenient and fast traffic means with low resource exhaustion should be applied to satisfy urban traffic development. Only in certain level can traffic system be provided with necessary material basis, thus achieving sustainable development and solving the present traffic environment problems.

(3)Equity

Equity contains interpersonal and intergenerational equity. Interpersonal equity is to compensate the welfare loss caused by traffic jam and decrease of ecological environment quality because of vehicle exhaust, noise, vibration, thus ensuring that members of the whole social group can have the fair right of using traffic resources and accepting transportation services. In addition, Intergenerational equity is to ensure the environmental pollution caused by urban traffic cannot exceed the self-purification and self-recovery ability of environment in order to make long-term use of ecological environment and not affect the production and life of progeny.

(4)Coordination

Coordination requires urban traffic system to change as follows: the pure economic growth is changed into the comprehensive development of economy, society and ecology; the present and partial benefits into long-term integral benefits; traditional material resources into nonmaterial and information resources; urban traffic system should focus on improvement of system structure to coordinate each subsystem with network.

2.2 Index Screening and Establishment

The purpose of urban traffic sustainable development is to achieve coordination of economy, society, resources, environment and transportation. In order to comprehensively evaluate the development level, a scientific and rational evaluation index system should be established. The system structure and elements of the object are analyzed, and the corresponding relation between sustainable development target and systematical elements established. Then the corresponding degree between quantitative index and target is researched to determine selection and set of index.

Table 1. Evaluation Index and Content of Urban Traffic Sustainable Development

<table>
<tr><td rowspan="8">Traffic Function Index B_1</td><td>[D1] Trip Time of 90% Residents (min)</td><td rowspan="4">Satisfaction of Residential Trip</td></tr>
<tr><td>[D2] Bus Number per Ten Thousand People (Buses/ Ten Thousand)</td></tr>
<tr><td>[D3] 300-meter Coverage Rate of Bus Station (%)</td></tr>
<tr><td>[D4] Traffic Congestion Coefficient</td></tr>
<tr><td>[D5] Road Network Density (km/ km^2)</td><td rowspan="4">Adaption to Traffic Function</td></tr>
<tr><td>[D6] Line Network Density of Public transport (km/km^2)</td></tr>
<tr><td>[D7] Supply-requirement Ratio of Center Parking Area</td></tr>
<tr><td>[D8]Average Vehicle Speed on Main Roads (km/h)</td></tr>
<tr><td rowspan="2">Economic and Finance Index B_2</td><td>[D9] Transportation Investment Coordination Coefficient (%)</td><td rowspan="2">Economic Support</td></tr>
<tr><td>[D10] Proportion of Public Transport in Infrastructure Investment (%)</td></tr>
</table>

Social Equity Index B_3	[D11] Road Area per Capita (m^2)	Traffic Equity
	[D12] Public Transport Share Rate (%)	
	[D13] Mortality per Ten Thousand Vehicles (People/ Ten Thousand vehicles)	Traffic Safety
	[D14] Direct Economic Loss of Accident (Ten Thousand Yuan/ ten thousand Vehicles)	
Ecological Impact Index B_4	[D15] Coordination Coefficient of Transportation Fuel Consumption	Impact of Environment and Energy
	[D16] Air Pollution Index (API)	
	[D17] Averages Traffic Noise of Traffic Trunk (dB (A))	
Government Management Index B_5	[D18] Management Capabilities of Urban Traffic System	Regulation Strength

In the work, based on the actual situation of China, the meaning of urban traffic sustainable development and relevant achievements at home and abroad, evaluation index system of urban traffic sustainable development level is divided into five aspects: traffic function index, economic and financial index, social equity index, ecological influence index and government management index. The structure is divided into several layers as follows: Top layer is abstract evaluation target, namely evaluation index of urban traffic sustainable development; second layer is the targets including society, economy, environment, resources, government management, etc.; middle is principle layer; last is index layer. Tab. 1 shows the concrete indices.

2.3 Index quantification

(1) Quantization of transport function index

D1：90%-level trip time consume of residents

Definition: 90%-level trip time consume of residents T (namely the trip time of 90% residents is less than T) is the acceptable maximum. The maximum tolerable (acceptable) trip time consume is different among cities with different scales and people with different trip purposes. People’s maximum tolerable trip time consume is relatively higher in cities of larger scale. Taking into account different sizes of cities, Chinese 90%-level trip time consume of residents should be: 60min in megalopolis; 50min in big cities; 40min in medium-sized cities; 30min in small cities.

D2: Bus number per ten thousand people

Definition: the average number of public transport vehicles of per urban ten thousand people (including temporary population). Bus number per ten thousand people is an index reflecting the level of development of urban public transport and traffic structural condition. Together with share rate of urban public transport, it is also a reference index that determines whether the transport development strategy is clear, and whether preferential policies and measures of public transport are implemented.

D3: 300-meters coverage rate of bus station

Definition: 300-meters coverage rate of bus station refers to the ratio of bus station coverage area (calculated as the radius of 300m) to the built-up area. This index can evaluate the status quo of urban transport systems to judge current situation of sustainable development of urban transport, thus providing a reference for making development plans. Meanwhile, it can also evaluate whether the urban transport planning has achieved requirements of sustainable development.

D4: Traffic congestion coefficient

Definition: traffic congestion coefficient is an evaluation index reflecting urban traffic congestion. According to operating conditions of network, congestion degree is divided into five grades: very smooth, smooth, mild congestion, moderate congestion and severe congestion.

D5: Road network density

Definition: Road network density refers to the ratio of road length to built-up area. (Road refers to that with pavement width of above 3.5m, not including sidewalks).Road network density is an index measuring of the constitutes feature of road network, the basic condition of road traffic management, and also an important index for making strategies of road traffic management, reflecting the construction level of urban transportation.

D6: Line network density of public transport

Definition: line network density of public transport refers to the ratio of total length of road centerline with public transport routes to built-up area, and the length of rail lines is directly included in the public transport line length. According to the sixth specification of the Five Cities Road Traffic Planning Design, the density of routes network of public transport should reach 3-4km/km2 in downtown area and 2-2.5km/km2 in urban fringe areas.

D7: Supply-requirement ratio of center parking area

Definition: supply-requirement ratio of center parking area is the ratio of parking capacity of central area to parking demand.

D8: Average vehicle speed on main roads

Definition: vehicle's average travel speed on the main road of built-up area.

(2) Quantification of economic and financial index

D9: Transportation investment coordinating coefficient

Definition: transportation investment coordinating coefficient, defined as the ratio of urban investment of transportation construction to total urban GDP, reflects the coordination of urban transport investment with economic growth.

D10: Proportion of public transport investment in infrastructure investment

Definition: the proportion of urban transport investments in the total public transport infrastructure investment.

(3) Quantification of social equity index

D11: Road area per capita

Definition: road area per capita refers to the ratio of road area in downtown area (road refers to that with pavement width of above 3.5m, not including sidewalks) to urban population (including agricultural population).

D12: Public transport share rate

Definition: public transport share rate refers to the ratio of public transport (including regular bus and rail) travel volume chosen by urban residents in recent years to the total amount of travel volume.

D13: Mortality per ten thousand vehicles

Definition: mortality per ten thousand vehicles refers to annual average number of traffic deaths per ten thousand vehicles (not including bike conversion). Mortality per ten thousand vehicles, as an important indicator to measure death situation of traffic accident under certain level of motorization, is also the comprehensive reflection of facilities construction of traffic safety and management effectiveness of traffic safety.

D14: Direct economic loss of accident

Definition: direct economic loss of accident refers to average direct economic loss of per million vehicles (excluding bicycles).

(4) Quantification of ecological impact index

D15: Coordination coefficient of transportation fuel consumption

Definition: coordination coefficient of transportation fuel consumption refers to the proportion of the growth of road traffic fuel consumption in travel demand growth.

D16: Air pollution index (Air Quality Index)

Definition: Air pollution index is a quantitative description of air quality. According to “Chinese ambient air quality index (AQI) technical regulations”(HJ 633-2012): air pollution index is divided into sixth gear, including 0 to 50, 51-100, 101-150, 151-200, 200-151 and more than 300. Correspond to the level of six, air quality index is larger, the pollution is more serious, and have the more obvious impact on human health.

D17: Averages traffic noise of traffic trunk

Definition: it refers to the average value of equivalent sound level weighted based on the length of monitoring data of urban traffic trunk road, reflecting the severity of the noise pollution on the environment caused by transport vehicles.

(5) Government management index

D18: Management capabilities of urban traffic system

Definition: it refers to whether comprehensive transportation—led by government leaders and coordinated by related departments—is established. Government should conduct transportation planning, construction and management based on traffic demand, road traffic safety situation and urban development requirements. Strategies for sustainable development should be made, with implementing public transport policy with priority, thus establishing countermeasures of people-oriented transport system.

3 Methodologies

In this stage, Matter-Element Analysis is mainly to describe the matter with three factors: matter, characteristics and magnitude. The three factors are then assembled orderly into one basic element, which is called matter-element. Given the evaluation standards for grades of index parameters of urban traffic sustainable development ability, the ability is judged by calculated values of each index parameters. The essence is an issue of identification. In this work, matter-element was composed of evaluation index, calculated value and grade. Evaluation index weight was determined synthetically with Analytic Hierarchy Process (AHP) and Entropy Method. The sustainable development evaluation model of urban traffic index parameters was established with the Matter-Element Analysis.

3.1 Matter-Element Method

Definition 1**:** In the following formula, R_0 is matter-element of urban traffic sustainable development evaluation; N_0 all of the grades; N_{0j} the j^{st} grade; C_i the i^{st} evaluation index; $(V_{0ij})_{nm}$ matrix of matter-element with same characteristics; N_j the value range of index C_i.

$$R_0 = \begin{bmatrix} N_0 & N_{01} & N_{02} & \cdots & N_{0m} \\ C_1 & V_{011} & V_{012} & \cdots & V_{01m} \\ C_2 & V_{021} & V_{022} & \cdots & V_{02m} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ C_n & V_{0n1} & V_{0n2} & \cdots & V_{0n3} \end{bmatrix} = \begin{bmatrix} N_0 & N_{01} & N_{02} & \cdots & N_{0m} \\ C_1 & \langle a_{011}, b_{011} \rangle & \langle a_{012}, b_{012} \rangle & \cdots & \langle a_{01m}, b_{01m} \rangle \\ C_2 & \langle a_{021}, b_{021} \rangle & \langle a_{022}, b_{022} \rangle & \cdots & \langle a_{02m}, b_{02m} \rangle \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ C_n & \langle a_{0n1}, b_{0n1} \rangle & \langle a_{0n2}, b_{0n2} \rangle & \cdots & \langle a_{0nm}, b_{0nm} \rangle \end{bmatrix} \tag{1}$$

Definition 2: Assuming that $<a_{pi},b_{pi}>$ means the allowed value scope of index C_i, membership degree of C_i and evaluation grade j can be expressed as $K_j(V_i)$.

$$\text{If } Vi \in [a_{0ij},b_{0ij}], \quad K_j(V_i) = \frac{-\rho(V_i, V_{ij})}{|V_{ij}|} \tag{2}$$

$$\text{Else, } V_i \notin [a_{0ij},b_{0ij}], \quad K_j(V_i) = \begin{cases} \dfrac{\rho(V_i, V_{ij})}{\rho(V_i, V_{pi}) - \rho(V_i, V_{ij})}, \rho(V_{i,} V_{pi}) \neq \rho(V_i, V_{ij}) \\ -\rho(V_i, V_{ij}) - 1, \rho(V_i, V_{pi}) = \rho(V_i, V_{ij}) \end{cases} \tag{3}$$

where

$$\rho(V_i,V_{ij}) = \left| v_i - \frac{1}{2}\left(a_{ij}+b_{ij}\right) \right| - \frac{1}{2}\left(b_{ij}-a_{ij}\right), \rho(V_i,V_{pi}) = \left| v_i - \frac{1}{2}\left(a_{pi}+b_{pi}\right) \right| - \frac{1}{2}\left(b_{pi}-a_{pi}\right)$$

Definition 3: If w_i is the weight coefficient of index i, the correlation of all evaluation indexes and grade j is shown as below.

$$K_j(p) = \sum_{i=1}^{n} w_i K_j(V_i) \tag{4}$$

$$\overline{K_j(p)} = \frac{K_j(p) - \min_j K_j(p)}{\max_j K_j(p) - \min_j K_j(p)} \tag{5}$$

$$j* = \frac{\sum_{j=1}^{m} j * \overline{K_j(p)}}{\sum_{j=1}^{m} \overline{K_j(p)}} \tag{6}$$

According to the principle of maximum correlation, eigenvalues of evaluation grade can be solved. J* is eigenvalues of evaluation grade, meaning the degree of tendency to a certain level of urban traffic sustainable development.

3.2 Weights determination

AHP is an approach for facilitating decision-making by organizing perceptions, feelings, judgments and memories into a multi-level hierarchic structure that exhibits the forces that influence a decision (13, 14). Saaty (14), further suggested AHP is about breaking a problem down and then aggregating the solutions of all the sub problems into a conclusion. AHP is used to determine the weight of controlling factors, and provides a structured framework for setting priorities on each level of the hierarchy using pair wise comparisons that are quantified using 1–9 scales (15).

Step 1: Establish decision matrix

$$A = \left(a_{ij}\right)_{n\times n} \tag{7}$$

Where: $a_{ij}=1$ (i=j), $a_{ji}=1/a_{ij}$. The 9-scale linguistic variables to compare the relative importance between any two dimensions are used. The linguistic variables to describe the importance comparison are shown in Table 5.

Step 2: Order and the consistent matrix

$$b_{ij} = \sqrt[n]{\prod_{k=1}^{n} a_{ik} \cdot a_{kj}} \tag{8}$$

$$B = \left(b_{ij}\right)_{n\times n} \tag{9}$$

Where: $b_{ij}=1(i=j)$, $b_{ji}=1/b_{ij}$, $b_{ij}=b_{ik}b_{kj}$.

Step 3: Calculate the weight

$$w_i = \frac{g_i}{\sum_{k=1}^{n} g_k} \tag{10}$$

Where: $g_i = \sqrt[n]{\prod_{k=1}^{n} b_{ik}}$

3.3 Calculation Procedures

(1) Matter-element of urban traffic sustainable development evaluation should be firstly determined with Formula (1), based on each measurement values evaluation indexes and the corresponding evaluation levels.

(2) Membership degree $K_j(V_i)$ of m evaluation grades corresponding to n evaluation indexes ($D_1, D_2, \ldots\ldots, D_n$) should be calculated, according to Formula (2) and (3).

(3) Weights W_i of C_i can be determined with AHP according to Formula (7-10).

(4) Correlation $K_j(V_i)$ of evaluation indexes and grade j can be calculated based on Formula (4).

(5) Eigenvalues of evaluation grade j and grade variable j^* can be solved with Formula (5) and (6). The grade variable can be used to judge the urban traffic sustainable development level.

4 Case Study

4.1Data

In this work, the relevant index data of Beijing mainly comes from the statistical literatures, such as Beijing statistical yearbook, China transportation yearbook, China urban construction statistics yearbook. With the statistical data, evaluation index values of sustainable development of Beijing urban traffic can be determined (see Table 2).

Table 2. Evaluation Indices of Urban Traffic Sustainable Development in Beijing

Code	Indexes	Situation Value
D1	Trip Time of 90% Residents (min)	42.72
D2	Bus Number per Ten Thousand People (Buses/ Ten Thousand)	21.56
D3	300-meter Coverage Rate of Bus Station (%)	75
D4	Traffic Congestion Coefficient	7.73
D5	Road Network Density (km/ km^2)	5.5
D6	Line Network Density of Public transport (km/km2)	4.1
D7	Supply-requirement Ratio of Center Parking Area	0.71

D8	Average Vehicle Speed on Main Roads (km/h)	19.4
D9	Transportation Investment Coordination Coefficient (%)	3.68
D10	Proportion of Public Transport in Infrastructure Investment (%)	43.6
D11	Road Area per Capita (m^2)	5.6
D12	Public Transport Share Rate (%)	34.5
D13	Mortality per Ten Thousand Vehicles (People/ Ten Thousand vehicles)	3.78
D14	Direct Economic Loss of Accident (Ten Thousand Yuan/ ten thousand Vehicles)	7.3
D15	Coordination Coefficient of Transportation Fuel Consumption	1.45
D16	Air Pollution Index (API)	147
D17	Averages Traffic Noise of Traffic Trunk (dB (A))	69.9
D18	Management Capabilities of Urban Traffic System	5

4.2 Results

Based on the reality of social and economic and historical data of Beijing, matter-element of urban traffic sustainable development evaluation was set up as Table 3, with the evaluation standards of expert research results and provisions of *Urban road traffic planning and design specification GB50220-95* and *Evaluation index system of urban road traffic management (2007 edition)*.

Membership degree $K_j(V_i)$ of m evaluation grades corresponding to evaluation indexes C_i can be calculated and listed in Table 4. Weight of indexes are determined by AHP and listed in Table 5. Grade correlation can be calculated and listed in Table 6. Table 7 shows eigenvalues of evaluation grade of urban traffic sustainable development. The grade of each index can be clarified with the screening of maximum of $K_j(V_i)$ (See Table 6). Combined with the eigenvalues, urban traffic sustainable development can be comprehensively analyzed. The classification can be achieved (See Table 7).

According to the eigenvalue j* evaluating the level of urban-traffic sustainable development, Beijing is in a general level in the sustainable development of urban traffic. However, the urban-traffic sustainable development of Beijing is getting better and better with more efforts from the government. Table 7 explains the current situation of urban-traffic sustainable development in Beijing.

Firstly, it introduces some important indexes belonging to level 1 or level 2, including the number of standard public-buses shared by every ten thousand people, public-transportation investment and sharing rate. It manifests the significant achievements and improvements of public transport reform in Beijing.

Secondly, relevant departments have attached great importance to traffic safety, and developed good management plans regulating static transportation systems. Therefore, there are some other indexes in level 1 or level 2, such as direct economic loss from traffic accidents, supply and demand ratio of parking in center area, mortality rate per ten thousand cars, management capability of urban traffic systems.

However, Table 7 also shows some negative results. For example, some evaluation indexes are in a general level, such as air pollution, noise, road-network density and road area per capita. Thus, more efforts should be made to improve ecological environment and traffic equality in Beijing.

Finally, some level-four indexes include residents travel time, traffic congestion coefficient and average speed of buses on main road. Those indexes indicate that Beijing still has severe traffic congestion and a low citizen-travel efficiency and satisfaction. Considering the overall traffic system, it can be seen that Beijing government has relatively strong control and regulation ability, making significant progress in transportation investment, public transportation development and traffic safety. However, Beijing government still needs to improve its environmental pollution control, citizen travel satisfaction and transportation functions.

Table 3. Matter Element of Urban Traffic Sustainable Development Evaluation

Index	Value	Excellent	Good	Normal	Bad	Worse	Joint Domain
D1	42.72	<0,20>	<20,30>	<30,40>	<40,50>	<50,100>	<0,100>
D2	21.56	<20,30>	<17,20>	<14,17>	<11,14>	<0,11>	<0,30>
D3	75	<90,100>	<80,90>	<70,80>	<50,70>	<0,50>	<0,100>
D4	7.73	<0,2>	<2,4>	<4,6>	<6,8>	<8,10>	<0,10>
D5	5.5	<7,9>	<6,7>	<5,6>	<4,5>	<1,4>	<1,9>
D6	4.1	<6,7>	<5,6>	<3,5>	<2,3>	<1,2>	<1,7>
D7	0.71	<0.8,1>	<0.7,0.8>	<0.6,0.7>	<0.5,0.6>	<0,0.5>	<0,1>
D8	19.4	<28,33>	<25,28>	<22,25>	<19,22>	<0,19>	<0,33>
D9	3.68	<5,8>	<4,5>	<3,4>	<1.5,3>	<0,1.5>	<0,8>
D10	43.6	<25,60>	<18,25>	<14,18>	<5,14>	<1.5,5>	<1.5,60>
D11	5.6	<10,15>	<7,10>	<5,7>	<3,5>	<0,3>	<0,15>
D12	34.5	<35,60>	<30,35>	<25,30>	<20,25>	<0,20>	<0,60>
D13	3.78	<0,3>	<3,8>	<8,12>	<12,16>	<16,20>	<0,20>
D14	7.3	<0,9>	<9,15>	<15,25>	<25,35>	<35,50>	<0,50>
D15	1.45	<0,1>	<1,1.5>	<1.5,2>	<2,2.5>	<2.5,10>	<0,10>
D16	147	<0,50>	<50,100>	<100,200>	<200,300>	<300,500>	<0,500>
D17	69.9	<0,60>	<60,65>	<65,70>	<70,75>	<75,110>	<0,110>
D18	5	<5,6>	<4,5>	<3,4>	<2,3>	<1,2>	<1,6>

Table 4. Degrees of Membership of Every Evaluation Index

	Excellent	Good	Normal	Bad	Worse
D1	-0.347	-0.229	-0.060	0.272	-0.146
D2	0.156	-0.156	-0.351	-0.473	-0.556
D3	-0.375	-0.167	0.500	-0.167	-0.500
D4	-0.716	-0.622	-0.433	0.135	-0.106
D5	-0.300	-0.125	0.500	-0.125	-0.300

D6	-0.396	-0.237	0.450	-0.275	-0.420
D7	-0.237	0.100	-0.033	-0.275	-0.420
D8	-0.387	-0.292	-0.160	0.133	-0.029
D9	-0.264	-0.080	0.320	-0.156	-0.372
D10	0.256	-0.531	-0.610	-0.643	-0.702
D11	-0.440	-0.200	0.300	-0.097	-0.317
D12	-0.014	0.100	-0.115	-0.216	-0.296
D13	-0.171	0.156	-0.528	-0.685	-0.764
D14	0.189	-0.189	-0.513	-0.708	-0.791
D15	-0.237	0.100	-0.033	-0.275	-0.420
D16	-0.398	-0.242	0.470	-0.265	-0.510
D17	-0.330	-0.196	0.020	-0.005	-0.202
D18	0.000	0.000	-0.500	-0.667	-0.750

Table 5 Weights of Evaluation Indexes Determined by AHP

Criterions	Weight	Indexes	Weight
B_1	0.439	D1	0.043289
		D2	0.051208
		D3	0.046718
		D4	0.057629
		D5	0.071075
		D6	0.066905
		D7	0.050411
		D8	0.051477
B_2	0.113	D9	0.044816
		D10	0.068521
B_3	0.211	D11	0.044629
		D12	0.051983
		D13	0.058026
		D14	0.05629
B_4	0.161	D15	0.050411
		D16	0.049991
		D17	0.06095
B_5	0.076	D18	0.07567

Table 6 Interrelated Values of Levels

$K_1(P)$	$K_2(P)$	$K_3(P)$	$K_4(P)$	$K_5(P)$
-0.21934	-0.11134	-0.14027	-0.2962	-0.44434

Table 7 Levels of Evaluation Indexes

	Level 1	Level 2	Level 3	Level 4
Indexes	D2, D10, D14	D7, D12, D13, D15, D18	D3, D5, D6, D9, D16, D17	D1, D4, D8

5 Conclusions And Discussion

The method evaluating urban-traffic sustainable development is developed by matter-element method and AHP. The eigenvalues can be figured out through the level of each evaluation index and the relevancy of evaluation levels. Then, multi-parameter evaluation will be converted to single-factor evaluation to quantitatively work out the overall level of urban-traffic sustainable development. Besides, the advantages and deficiencies of urban-traffic sustainable development can be clearly determined through analyzing the level of each evaluation index, thus providing a scientific and rational basis for promoting the sustainable development of urban transportation.

The accuracy of weighting coefficient is also significant to determine the sustainable development level of urban transportation. With the knowledge and experience from many experts, the work applied AHP to determine the weight of evaluation indexes, objectively and comprehensively reflecting the importance of each evaluation index and the actual situation of existing problems. When evaluating urban-traffic sustainable development, several aspects were paid relatively more attention, such as transportation functions, social equality and ecological environment. It can be seen that Chinese government not only emphasizes on constructing urban traffic but also attaches much importance to the social equality and ecological protection of environment in social and economic development. Such efforts are significant to the sustainable development of urban traffic.

This method was also applied to systematically analyze the sustainable development capability of urban traffic in Beijing. The evaluation results imply that Beijing government has a strong control and regulation ability. Beijing has achieved significant outcomes in the development of public transportation, traffic safety and transportation investment. However, Beijing government should make greater efforts to improve traffic environment management, transportation functions and citizen travel satisfaction. Besides, the analysis manifests the practical situation of urban-traffic sustainable development in Beijing, proving the effectiveness and practicality of this method. However, different cities emphasize on different aspects of urban-traffic sustainable development due to some complex and changeable influential factors. Therefore, government should consider the practical situation of urban development when applying this method in order to reasonably select indexes and scientifically describe the practical situation of urban-traffic sustainable development.

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References

Congpan Li. Research on the evaluation of urban transportation sustainable development based on extension method.Beijing: Beijing Jiaotong University.2009.

Chunyan Yang, Wen Cai. Extension engineering. Science Press, Beijing, 2007.

Dong Du, Qinghua Pang. Modern comprehensive evaluation methods and featured case. Tsinghua University Press, Beijing, 2006.

Gumus, A. T. Evaluation of hazardous waste transportation firms by using a two step fuzzy-AHP and TOPSIS methodology. Expert Systems with Applications, Vol.36, 2009, pp.4067-4074.

Hao Yang, Peng Zhao. Transit sustainable development. China Railway Press, Beijing, 2001.

Jianlin Fan, Zhang Sun. Study on index system and assessment method for urban transit sustainable development [J]. Journal of Shanghai Tiedao University, vol.20(8),1999, pp.57-59.

Jianyou Zhao, Lijun Yu. Quantitative assessment method of sustainable development state for urban transport system. Journal of Chang'an University (Natural Science Edition), vol.24(4), 2004, 63-66.

Junjuan Liu, Wei Wang, Lin Cheng. Evaluation of urban traffic development based on press-state-response and composite matter-element and extension method. Journal of highway and transportation research and development, vol.24(10),2010, pp.136-141.

Lijun Yu, Jianmin Xu. Fuzzy assessment method of sustainable development for urban traffic system. Computer and Science, vol. 1(26), 2008, pp.1-4.

Liqiong Dong. Comprehensive evaluation on urban transit sustainable development in Kunming. Shanghai Maritime University, Shanghai, 2006.

Saaty, T. L. The analytic hierarchy process. McGraw-Hill, New York, 1980.

Wei Wang, Xuewu Chen, Jian Lu. Study on urban transit system sustainable development. Science Press, Beijing, 2004.

Wen Cai. Extension set and extension data mining. Science Press. Beijing, 2008.

Wenya Xu. Study on comprehensive evaluation of Wuhan urban transport sustainable development. College of urban and environmental science central china normal university. Wuhan, 2009.

Xingyu LV. Comprehensive evaluation study on urban transit sustainable development in Shenyang.Dalian University of Science and Technology.2003.

Carbon Emissions of Chengdu Road Passenger Transport Based on LMDI

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Abstract: By calculating Chengdu carbon emissions of road passenger transport per capita daily from 2008 to 2013, found that the carbon emissions per capita daily increased year by year and began to stabilize. Using LMDI method to analysis the factors of Chengdu road passenger transport carbon emissions, found that trip structure has increasingly become a major factor inhibiting Chengdu road passenger transport carbon emissions, motorized trip rate and residents daily trip distances increased carbon emissions. Chengdu should further improve the relevant policies, inhibiting the growth rate of private car ownership, and develop public transport and bicycles and other public transport modes to further reduce carbon emissions.
Keywords: Road passenger transport; Carbon emission; LMDI; Energy conservation and emissions reduction.

1 Introduction

With the deterioration of the environment and global warming, energy-saving and environmental protection and the development of low-carbon traffic has become the mainstream around the world. State Council issued *2014-2015 energy saving low-carbon development action plan* on May 26, 2014, which requires China 2014-2015 carbon dioxide emissions per unit of GDP fell by 4% and 3.5%.On November 12, 2014, the Asia-Pacific Economic Cooperation Organization meeting, the two countries jointly issued the *U.S.-China Joint Announcement on Climate Change* is mentioned about 2030 China plans to reach a peak of carbon dioxide emissions, and non-fossil energy accounted for an increased to about 20% of the total energy consumption.

In addition to the part of the natural causes of climate change, a big part is caused by human activities, especially the use of fossil fuel energy. According to the projections of the International Energy Agency, 23% of global carbon emissions from energy consumption in 2007 was from the transport sector, and by 2030 this proportion will increase to 41%, traffic has become a focus of carbon emissions in the developed countries to reduce emissions. Currently, most of the documents are given to calculate the total urban carbon emissions of road passenger transport, but ignore the impact of population growth to the carbon emissions.

2 Road passenger transport status of Chengdu

According to *2013 Chengdu Transportation Development Annual Report*, road passenger transport is divided into taxis and private cars, buses, rail transportation, non-motor vehicles and others. In order to facilitate the calculation, non-motor vehicles and other transportation options are collectively referred to as others. Because the carbon emissions of walking and cycling is zero, they are not included into the scope of statistics.

The recent Resident Trip Survey in Chengdu was investigated by Parsons Brinckerhoff Company in 2009. Through the survey to the central city of Chengdu 4700 households, we obtained the travel needs of 22000 residents. Due to various reasons, in recent years, there has been no large-scale resident travel survey in Chengdu. The data of 2008 and 2009 are from Transportation Committee of Chengdu and *Chengdu urban and rural comprehensive transportation planning studies*. The data of taxi, bus and the subway from 2010 to 2013 are from *2012 Chengdu "traffic ahead" strategy Statistical Monitoring Report*, *2013 Chengdu "traffic ahead" strategy Statistical Monitoring Report* and *Chengdu Transportation Development Annual Report 2013*. In the absence of the data of the proportion of private car travel in residential structures from 2010 to 2013, in reference to the car ownership over the years from *2013 Chengdu Transportation Development Annual Report*, based on the car ownership and the proportion of residents' travel structure in 2008 and 2009, we get 2008-2013 Chengdu residents travel structure and per capita daily travel distance (excluding walking) shown in Figure 1.

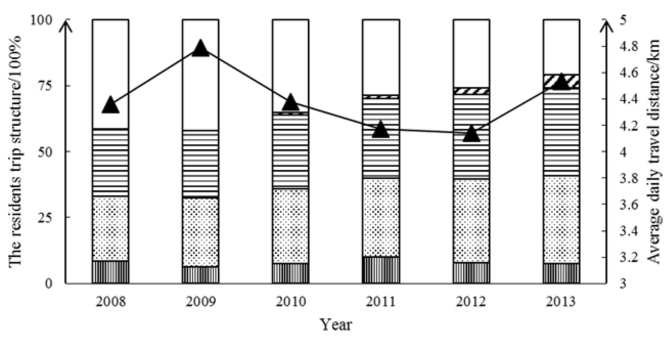

Figure 1. The resident trip structure and the distance of everyday travel in Chengdu from 2008 to 2013 (without walk)

As shown in Figure 1, the travel distance per capita daily began to recovery after experienced a reduction of three years. Bus and rail travel structure ratio increased year by year, and the proportion of cars is steadily. The increasing of the vehicle on the road in the city caused urban congestion, while it also increasing the carbon emissions of urban road passenger transport.

Assume that the average time travel a certain distance, carbon emission factor is calculated with reference to the various modes of transportation standards of the US Energy Foundation, as shown in Table 1:

Table 1. Emission factor standards by US Energy Foundation (g/km· per capita)

	emission factor
Taxi	140.2
Car	116.9
Bus	19.8
Subway	7.5
Others	19.8

3 LMDI model building and decomposition

In order to analyze the factors influencing Chengdu road passenger transport, this paper uses logarithmic mean Divisia index method for carbon decomposition.

Assume that C is the daily road passenger transport carbon emissions per capita in Chengdu, i is the type of transportation (car, taxi, bus, rail transportation and other modes of transport). The daily road passenger transport carbon emissions per capita in Chengdu decomposed into four factors (various carbon intensity of transportation, travel structure, motorized travel rates and average daily travel distance).

$$C=\sum_i C_{it}=\sum_i \frac{C_{it}}{M_{it}\times m}\times\frac{M_{it}\times m}{N_t\times m}\times\frac{N_t\times m}{S_t\times m}\times\frac{S_t\times m}{P_t} \quad (1)$$

C_{it} is the carbon emission of transportation i per day in year t; M_{it} is the amount of passengers of transportation i per day in year t; m is the distance of every travel; N_t is the amount of passengers by motor vehicle per day in year t; is the amount of passengers per day in year t; S_t is the population of Chengdu in year t. Let:

$$e_{it}=\frac{C_{it}}{M_{it}\times m},r_{it}=\frac{M_{it}\times m}{N_t\times m},p_t=\frac{N_t\times m}{S_t\times m},q_t=\frac{S_t\times m}{P} \quad (2)$$

e_{it} is the carbon emission intensity of different modes of transportation, r_{it} is the resident trip structure, p_t is the residents travel motorization rate, q_t is the distance of every travel in year t, then:

$$C=\sum_i e_{it}\times r_{it}\times p_t\times q_t \quad (3)$$

Use LMDI method decompose the factors of formula (3). Let the carbon emissions of period 0 is C_o, C_t is the carbon emissions of year t, then:

$$\Delta C = C_t - C_0 = \Delta C_{ei} + \Delta C_{ri} + \Delta C_p + \Delta C_q \quad (4)$$

ΔC_{ei} is the effect of carbon emissions caused by the carbon emission intensity of different modes of transportation; ΔC_{ri} is the effect of carbon emissions caused by the residents trip structure; ΔC_p is the effect of carbon emissions caused by the residents travel motorization rate; ΔC_q is the effect of carbon emissions caused by the distance of every travel. Then the equation (4) can be showed as below:

$$\Delta C_{ei} = \sum_i \frac{C_i^t - C_i^0}{\text{In}C_i^t - \text{In}C_i^0} \text{In}\left(\frac{e^{it}}{e^{i0}}\right) \quad (5) \qquad \Delta C_{ri} = \sum_i \frac{C_i^t - C_i^0}{\text{In}C_i^t - \text{In}C_i^0} \text{In}\left(\frac{r^{it}}{r^{i0}}\right) \quad (6)$$

$$\Delta C_{p} = \sum_i \frac{C_i^t - C_i^0}{\text{In}C_i^t - \text{In}C_i^0} \text{In}\left(\frac{p^{t}}{p^{0}}\right) \quad (7) \qquad \Delta C_{q} = \sum_i \frac{C_i^t - C_i^0}{\text{In}C_i^t - \text{In}C_i^0} \text{In}\left(\frac{q^{t}}{q^{0}}\right) \quad (8)$$

Assuming the carbon emission intensity of different modes of transportation is constantly, then $\Delta C_{ei} = 0$.

4 Chengdu daily road passenger transport carbon emissions per capita calculation and decomposition analysis

According to the formula mentioned in *Calculation of Urban Passenger Transport Carbon Emissions and Carbon Development Strategy*, which is written by Zheng Dayong (2011), considering the days and the population, the formula of Chengdu daily road passenger transport carbon emissions is:

$$C_t = \sum_{i=1} q^t r_i^t e_i^t \quad (9)$$

q_t is the distance of every travel in year t; r_{it} is the residents trip structure; e_i^t is the carbon emission intensity of different modes of transportation, which is constantly. By calculation, the result is shown in Figure 2:

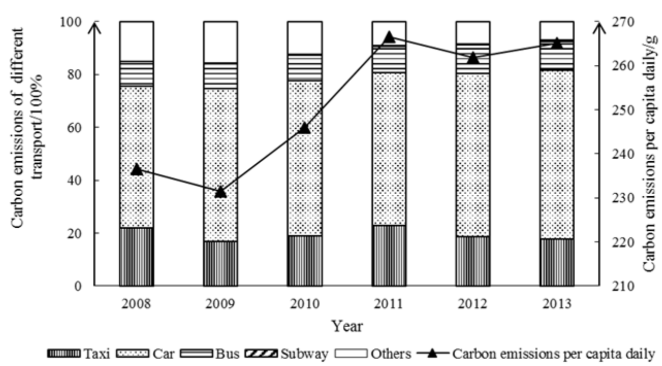

Figure 2. the daily per capita carbon emissions and the proportion of different of transport in total emissions from 2008 to 2013

Combined with Figure 1 and 2, although the proportion of cars in the traffic structure is not the largest, but the largest carbon emission is the car. Based on the data in 2008, decompose the factors, the result is shown in Table 2 and Figure 4.

Table 2. The decomposition results of the factors

	ΔC_{ri}	ΔC_p	ΔC_q	ΔC
2008	0	0	0	0
2009	-24.99	-2.53	22.38	-5.14
2010	12.66	27.34	-25.53	14.47
2011	22.8	9.92	-12.1	20.62
2012	-12.82	10.26	-2.14	-4.7
2013	-37.33	16.9	23.65	3.22

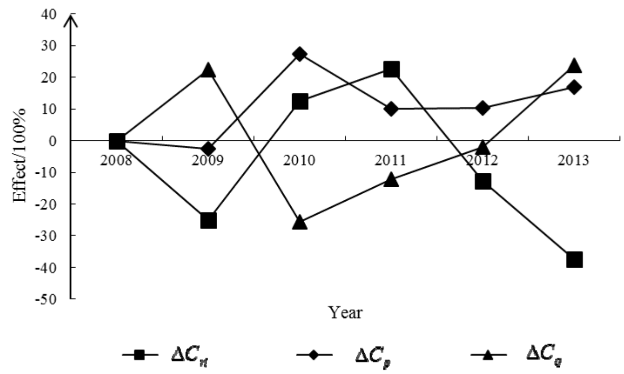

Figure 3. The trends of the contribution of the factors

Because the data of the residents trip structure is without walking, so this three factors are independent of each other. Although Figure 1 shows the factor impact the carbon emissions of Chengdu road passenger transport, we cannot see the relationship between them.

From Table 2 and Figure 3, the main factors of the increasing of the carbon emissions per capita daily are the resident trip structure and the residents travel motorization rate, which the impact of residents travel motorization rate is higher than the resident trip structure. While after 2011, the residents trip structure became the factor inhibited carbon emissions. The daily travel distance gradually became the factor increasing carbon emissions, which is related with the expansion of Chengdu and the construction of Tianfu New Area, Many people's workplace began to move south with the construction of Tianfu New Area and the residents travel distances increase year by year. The residents travel motorization rate from Figure 3 can be seen is an important factor increasing carbon emissions, which suggests that maintain the current level if the motorization rate is difficult to reduce. The resident trip structure in the past two years largely inhibited the growth of carbon emissions, which indicated that with the implementation of the "Traffic Ahead" and the development of public transport played a very important role in reducing carbon emissions. With the continuous growth of car ownership, it is recommended to take draw lots in Beijing to reduce the number of cars increasing. It's also very important to develop public transport and optimize the structure in further.

5 Countermeasures

5.1 Structural reduction

Chengdu should accelerate the development of subway. Deeping the study of modern tramcar at the same time, accelerate the construction of tramcar. Chengdu should also accelerate the planning and construction of bus station, and the integration of two spheres of public transportation, achieving the integration of the central city and suburban transit. By the end of 2013, Chengdu vehicle population reached 124,000, an increase of 10.9% over the previous year. Chengdu should take actions such as take draw lots in Beijing to inhibit the growth of cars.

5.2 Technical reduction

Chengdu should speed up the optimization of intelligent transportation system, start the development of intelligent transportation integrated information service platform, and gradually build a platform which integrated public transportation, real-time traffic and park driving system. Developing renewable energy or other new energy, accelerating the progress of Chengdu taxi “Oil to Gas” project. Meanwhile, optimize the structure of buses, increase the proportion of pure electric vehicles, LNG vehicles and dual-fuel vehicles to reduce carbon emissions radically.

5.3 Policy reduction

Sichuan Provincial Communications Department, Chengdu Municipal Government, Municipal Energy Saving and Reduction Office have released documents about low-carbon city construction or energy saving. Apart from it, we should also enhance the propaganda of low-carbon transport, protect the implementation of the policies.

6 Conclusion

In this paper, using LMDI method to analysis the factors affecting the carbon emissions of Chengdu road passenger transport, the following are conclusions:

(1) From 2008 to 2013, carbon emissions of Chengdu road passenger transport per capita daily increase gradually and being stabilize.

(2) Residents travel structure is becoming a major factor inhibiting the growth of carbon emissions. The development of public transport in Chengdu optimized residents travel structure, effectively easing the growth of urban road passenger transport carbon emissions.

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References

International Energy Agency (2009).CO2 Emissions from Fuel Combustion 2009.Paris:IEA Publication,117-180

Organisation for Economic Cooperation and Development (2007).Cutting Transport CO2 Emissions:What Progress? . Paris: OECD Publications, 76-153

TANG Baojun, SHEN Danjin. (2014). The Study of Carbon Emissions of Road Passenger Transport in Beijing and Its Scenario Analysis, Journal of Beijing Institute of Technology (Social Science Edition), Aug, 16(4), 8-12

ZHEN Dayong(2011). Calculation of urban passenger transport carbon emissions and carbon development strategy. Southwest Jiaotong University

HE Caihong(2012). Research on low-carbon development of urban traffic in Shanghai based on LMDI model. Hefei University of Technology.

Green Inland Navigation Developing Path of Zhejiang Province

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Abstract: The researches and practices of green inland navigation are comprehensively investigated. Based on the national oceanic economic strategy that Zhejiang provincial party committee proposed, the dynamic mechanism of green inland navigation development are made deep research, and the current status and problems of Zhejiang province inland navigation are systematically discussed. The development thoughts and key tasks of Zhejiang province green inland navigation are further studied and the policies of development of Zhejiang province green inland navigation are put forward.
Keywords: Green; Inland navigation; Zhejiang.

1 Introduction

Zhejiang province is famous for water resources. Water is the base of ecology and the source of life. Under China's New Normal，Zhejiang province has been speeding up the building of green inland waterway transport. It is the strategic choice of Zhejiang adjusting and optimizing the structure, energy conservation and emissions reduction and building an upgrade regional economy. In March, 2012, Zhejiang provincial government officially approved "Zhejiang province inland waterways Renaissance action and plan". This indicates that the Zhejiang inland waterways recovery action plan had begun comprehensively. The 4th plenary session of the 13th Zhejiang provincial party committee put forward "five water treatment" in November 2013. "Five water treatment" indicates the treatment of sewage, flood control, drainage, water supply security and water conservation. It is the fundamental policy that Zhejiang provincial government has recently introduced. It is the key to promote the development of a new round of reform in Zhejiang. Water conservancy has been regarded as the breakthrough to promote industrial transformation and upgrading. The 5th plenary session of the 13th Zhejiang Provincial Party Committee introduced the decisions about developing beautiful Zhejiang to create a better life. It is the guidance document that Zhejiang province has been promoting ecological civilization construction and improve people's livelihood in the current and future period. It is the strategic task for the future development of ports and shipping in Zhejiang province of revival of inland waterway transport, guiding the optimization configuration of inland port resource, reasonable adjustment of inland water transportation structure, promoting the green development, low carbon development, cycle development of inland waterway transport, realizing the win-win situation of Inland waterway transport development and improving the water environment in Zhejiang province under China's New Normal.

2 The Current Situation of the Development of Inland Waterway Transport in Zhejiang Province

Zhejiang province is full of rivers with Butiao River, Qiantang River, Caoer River, Yong River, Jiao River, Ou River, Feiyun River, and Ao River from north to south. With abundant water resources, Zhejiang province ranks as the top province of inland water transport. The inland navigation is an engine of economic development in Zhejiang province. In Zhejiang province, the inland waterway has the navigation mileage of 9748 kilometers, with high-grade waterway of the fourth and above rank 1398 kilometers. There are seven important inland ports in Zhejiang province as are Hangzhou port, Huzhou port, Jiaxing inland port, Shaoxing port, Ningbo inland port, Jinhualanxi port and Lishuiqingtian port with 4535 berths. At the end of 2013, Zhejiang province inland port cargo throughput reached 375 million tons, and the container throughput reached 231 thousand TEU. The year navigation ships is 1.74 million.

Table 1. Zhejiang province inland port cargo throughput (Unit:10 thousand ton)

year / port	2013	2012
sum	**37458.7593**	**39171.1994**
Hangzhou port	9381.6092	9097.0459
Jiaxing inland port	11106.9621	10855.5495
Huzhou port	15311.8033	17840.4484
Shaoxing port	1344.5611	1205.1643
Ningbo inland port	52.4946	52.3883
Lanxi port	69	20.2
Lishui port	3.8	3.22
Qingtian port	188.489	97.183

3 Dynamic mechanism of Zhejiang green inland water transport development

3.1 The requirements of the transformation and upgrading of Zhejiang inland waterway transport

Waterway transport is regarded as the green transportation mode. Inland waterway transport has the comparative advantage of large capacity, low cost, less land, small energy consumption, light pollution and high comprehensive efficiency. Enhancing rapid and accurate emergency response capacity and ability to dispose of the sudden water pollution accident of ships, improving supervision and regulatory capability of inland waterway transport water pollution, building smooth, efficient, safe and green inland waterway transport system of Zhejiang province are important contents of implementation of major policy decisions of Zhejiang provincial party committee and provincial government "five water treatment" and "beautiful Zhejiang". Speeding up the building of green inland waterway transport, and realizing the sustainable coordination development between inland waterway transport and ecological environment not only effectively relieve the contradiction between economic development and traffic resources in Zhejiang province, but also are of great significance for construction of Zhejiang Marine ecological civilization demonstration area, transformation of economic development patterns and the transformation and upgrading of inland waterway transport.

3.2 Reversed transmission of the pressure from ecological environment

With the rapid development of inland waterway transport, there is serious lag about shore handling and treatment of inland ships garbage and watercraft oil-contaminated water and water pollution prevention and control of inland waterway transport. Under China's New Normal，Zhejiang inland waterway transport development mode faces many adjustments. Ecological environment problems formed reversed transmission mechanism for the transformation and upgrading of inland waterway transport in Zhejiang province. If Zhejiang transformation and upgrading of inland waterway transport is not in place, not only the goal of promoting the transformation of regional economy of Zhejiang province in short time will not be achieved, but also the sustainable development of Zhejiang economy will be seriously restricted. The transformation and upgrading of Zhejiang inland waterway transport has become the basic needs of "five water treatment" and "beautiful Zhejiang province" in Zhejiang province, as well as the practical basis of the long-term stable development of regional economy in Zhejiang.

4 The path of the development of Zhejiang green inland waterway transport

4.1 To foster green inland waterway transport market subject with positive guidance

It is advisable to make financial support and introduce favorable policies to develop green inland waterway transport. The marketization of shipping resources allocation should be operated. The merger and reorganization of inland port and shipping enterprise should be encouraged. The small and medium-sized enterprises of inland port and shipping should be encouraged to make scale operations. The partnership of inland port and shipping enterprise should be explored. The contract mechanism and equity alliance mechanism, etc should be gradually made to strengthen business market competition.

4.2 To strengthen the construction of ecological channel

Based on the harmony between man and nature, ecology protection, and the characteristics of humanities and the natural environment, ecological environmental and reusable materials should be made use of to the greatest extent in order to reduce the consumption of natural resources and social resources, improve ecology self-healing of channel and network of rivers and capacity of flood discharge along channels. The construction of ecological waterway and arterial waterways greening should be actively explored. The waterway maintenance work should be made further perfection to ensure that the channel intact and clear by enhancing funds in waterway maintenance.

4.3 To strengthen the overall process management

It's suggested to establish the cooperation mechanisms on information sharing and communication, and to form working resultant force of shipping water pollution prevention and control. Vessel inspection departments should strengthen the inland water transport ship anti-fouling structure and equipment design drawing review and inspection. The waterway transportation management department should actively lead water transportation operator to eliminate backward non-environmentally friendly equipments. The structure of inland navigation must be adjusted to meet the demands of economical development.

Ship standardization should be vigorously promoted. Local maritime administrative institutions should enforce better supervision and administration of ship pollution in inland water transport. The environmental protection consciousness of the inland river crew should be enhanced. The port enterprises should, in accordance with the requirements of the laws and regulations, constantly perfect port security facilities under the supervision of port administrative department, and the latter should carry out supervision and inspection on a regular basis.

4.4 To enhance the supervision over dangerous goods transportation in inland navigation

It's to strictly implement reporting system of dangerous goods and ships in port operation. Those who conceal, falsely report and have berthing operation of non-compliances should be sanctioned. The intensity of the cruise should be increased in order to improve navigation order. It's to use the advanced information methods and tools, such as comprehensive supervision system of the ship, AIS and GPS, to regulate inland navigation ships of dangerous goods have dynamically, comprehensively and effectively.

4.5 To strengthen prevention and control of inland port water pollution

The sustainable development of port means to build the port that is of safe transport, quality-beneficial, scientifically and technically pioneering, energy saving and environmental friendly. The existing inland port shoreline resources should be integrated. Those inland ports that are of small scale and causing serious environmental pollution should be relocated, transformed or removed. Inland ports should be aimed at being of large scale, intensified, and modern. According to the types of loading and unloading of goods, inland ports should gradually establish water retaining devices of land frontier and yard spray dedusting facilities. It’s better to build dock depot sewage collection sedimentation facilities. It's to speed up the renovation of ship garbage receiving facilities of the existing port to meet the requirements of environmental protection standard. According to the opinions that the environmental protection department approved, new port project is to carry out the measures of prevention and control of pollution, the same must be designed, constructed and put into use as main body project.

4.6 To speed up the standardization of inland ship

It's to takes enterprise as the main, government guidance as the supplementary to speed up the renewal and reconstruction of the existing nonstandard, old environmental protection facilities of ships by using economic incentives methods and improve technical standards of inland ships. It's to actively promote the use of standard ship. It's to establish and improve the coordination mechanism of ship standardization work.

Newly built ships should be strictly equipped with corresponding oil pollution and garbage prevention facilities, and obtained corresponding vessel inspection certificate. For existing ship, the oil pollution and garbage pollution prevention equipments should be transformed as quickly as possibly. If the ships can not meet the requirements, ship inspection department should mot issue the inspection certificate, the maritime administration department should not issue port entry and exit visas of the ship. According to the requirements of national energy conservation and emissions reduction, the principle of overall planning, a step-by-step implementation, easiest first and steady progress, new energy ships such as LNG is to be actively promoted.

4.7 To strengthen the regulation about receiving ashore of the ship rubbish and oil sewage and the pollutants collection and disposal of ship pollutants

Port and shipping administration departments should enhance the regulation and supervision over the oil sewage recycling place and garbage receiving place. The port enterprises should be supervised to establish the necessary waste receiving place and ship oil sewage receiving place. In conditioned ship anchoring service area and ship visa points, it’s better to set up the public ship waste receiving and oil sewage receiving place. It's to establish and improve the mechanism of ship pollutant collection and treatment and operational management.

4.8 To strengthen the inland navigation supporting and safeguarding system

The four supporting and safeguarding systems of the inland navigation safety, salvage, pollution prevention and emergency treatment should be strengthened. The long-term mechanism on prevention and control of water pollution of inland navigation should be established and improved. First of all, the inland navigation safety-guarding system should be enhanced. A variety of water traffic safety facilities should be built. Provincial and municipal monitoring platform and terminals should be established. Visualization and control of main channels and ships should be fully achieved so as to improve the capacity of water traffic safeguarding. The inland river salvage system should be set up. What’s more, it's to be equipped with the rescue ships, salvage ships, towing ships, fire fighting and other professional equipments as a whole. It's to have a professional and part of the rescue team in order to develop water salvage ability. In addition, the prevention and control system of water pollution in inland navigation should be strengthened. It's to plan and set up emergency rescue base of dangerous goods in the north of Zhejiang province planning and construction. Finally, it's to reasonably reserve pollution prevention emergency supplies, be equipped with specialized clean-up ships. It's to promote shipping water pollution accident emergency rescue capabilities. The emergency treatment system should be set up in order to make the risk assessment of inland shipping area, hazard monitoring and early warning.

4.9 To strengthen rules and regulations of water pollution prevention and control as well as publicity work in inland waterway transport

The rules and regulations of water pollution prevention and control in inland waterway transport should be introduced immediately. The delivery management regulations of garbage and oil water of ships and the plan for the implementation of supervision on ship garbage delivery should be studied and made as soon as possible in order to provide legal safeguard for shipping pollution of water prevention and control. There should be more publicity of water pollution prevention and control of inland navigation. The shipping personnel should be actively guided and supervised to conscientiously implement the relevant laws and regulations, and the ship pollution prevention facilities should be properly equipped with and used. It's high time to raise the water protection consciousness of personnel, port and wharf enterprises. The ship pollution damage liability insurance should be actively carried out. The ship pollution accident should be preceded efficiently and quickly.

5 Conclusion

It is observed that developing green inland navigation will be a complex and systematic project. It needs having a whole list of design issues and taking overall consideration of. It should have the corresponding complete supporting system including mechanism, policy and evaluation. The research proposes the supporting system of the mechanism, path and policy of Zhejiang green inland navigation. It provides access to the transformation and upgrading of Zhejiang inland navigation. It better explore the coordination development path of "five water treatment", beautiful Zhejiang and inland navigation industry. It also provide theoretical support of the policy on a powerful province of marine economy and the sustainable development of Marine economy.

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References

J.Craig Fisehenich, Jos Van Alphen.(2002).Guidelines for Sustainable Inland Waterways and Navigation. Proceedings on CDROM of the 30th PIANC-AIPCN Congress. Sydney, 25-38.

David Schaaf, Lisa Pierce.(2002).Sustainable Development of an Inland Waterway-An Overview of the Ohio River Main stem Systems Study. In: R J Cox. eds. Proceedings on CDROM of the 30th PIANC-AIPCN Congress. Sydney, 18.

The People's Government of Zhejiang Province. "Inland water transportation Renaissance actions plan in Zhejiang province from 2011 to 2015." http://www.zj.gov.cn/art/2012/4/17/art_12461_8856.html(Mar 14, 2012).

ZHAO Yapeng.(2014)."Ningbo-zhoushan Ecological Port Development and Innovation under the National Oceanic Economic Strategy." Regional Economic Review. (5):113-118.

Method of Selecting the Fault Detection Point for the Onboard Power Controller of a Maglev Train

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Abstract: The principle of selecting test points is that the number of test points is as less as possible and faults that can be isolated should be as much as possible. Firstly, the structure and function of the system is described by using the logical model. According to the principle, two matrixes with the criteria of the fault detection and the fault isolation are built by combining the Boolean matrix in order to obtain the global testing point sets. Then the global testing point sets is optimized with the evaluation index of the amount of test information and the test cost, and the best global test point sets and the test sequence are obtained. Finally, the onboard power controller of maglev train is taken as an example to validate the model. The result shows that the method is effective and can be used for faults detection and measurability design of analog circuits
Keywords: The test point; Logical model; Boolean matrix; The best global test point set.

1 Introduction

As the fastest ground transportation in our country, the maglev train is a kind of transport system with fully dispersed power. It has many characteristics such as numerous electric equipment, complicated structure, the diversity of electrical characteristics, and a large number of large scale integrated circuit and so on. However, as an imported equipment, maglev trains lack of much information, such as the complexity of circuit data and the schematic diagram, which is unconventional to repair the equipment when faults occur. Therefore, equipment only has to be sent to foreign factories to repair, causing long maintenance time and big cost, which have serious influence to the operation of maglev train. So there is an urgent need to carry out the research of the fault diagnosis methods and the diagnosis system for maglev electrical equipment.

But almost all of the fault diagnosis methods rely on the acquisition of data from the test point samples. Only chose the best test points, it can guarantee the information and representativeness of samples, which can ultimately achieve good diagnosis.

There have made certain achievements at home and abroad in selecting the test point. In the some papers, the optimization of the test point in the different board-level circuits is studied respectively by graph theory and the fault tree method.in order to solve the problem, such as complicated types of signal ,the optimization principles of the biggest fault characteristic information entropy is built based on the correlation matrix model. The validity and feasibility of this method is verified by actual circuit, but the process is complex, large amount of calculation.

However, in the other papers, topology problem of test engineering is studied. The graph theory model is used to describe the topology structure, and the optimization method of the test points is given based on graph theory model from the Angle of the concurrent design engineering requirements; there are many algorithm of selecting the test points in the papers. Varghese come up with a kind method of selecting the test points, which is called "faith level"; Hatchway and Bastian put forward the concept of fuzzy sets; Stenbakken and Souder sit put forward a method , which is used to decompose QR factorization of the circuit sensitivity matrix; Abdurrahman and others generate the test point set with continuous quadratic equation method; Wang Peng and Yang Shaquan describe the fault distinguish ability of the test point by the fault isolation degree and conditional fault isolation degree, and choose the test point according to distinguish ability. These methods above are only local optimization method, can't guarantee the global minimum point sets. Although the exhaustive search algorithm can find global optimal solution, but it is a NP-complete problem, the system with medium size is not applicable.

Therefore, this paper describe the structure and function of the system by using the logical model, and build the matrix with the criteria of the fault detection and the fault isolation combining the Boolean matrix. Then optimize the global testing point sets with the evaluation index of the amount of test information and the test cost, the best global test point sets and the test sequence are obtained.

2 The Optimization Model Of The Test Points Based On Boolean Algorithms And Logic Model

Logical model is put forward by American scholar Ralph De Paul Jr., which can describe the correlation and causation between function modules and test on the basis of through the form of a directed graph to diagnose the reason and have the test analysis.

The logical model is mainly composed of functional flow diagram and correlation chart. The functional flow diagram is built based on the function of the system and the information of the test points, which has an overall description about the dissemination path of the system functions information by directed graph. Directed graph mainly includes the following elements: the functional test point set $T_0 = \{t_1, t_2, \cdots t_b\}$, is the set

mof all test position in a level; the set of fault modules $M = \{m_1, m_2, \cdots m_a\}$, Refers to the set of all the components; the set of the directed edge is represented by $E = \{e_{ij}\}$, where e_{ij} is the edge from m_i to m_j

Because the logical model mainly describes the relationship between the fault mode and the test points, and ignore the testing methods and means, which can't reflect the correlation of the detection and the specific fault mode. Meanwhile, because the fault mode is not clear, the location of the test point is primarily determined. Therefore, On the basis of the logical model, the introduction of Boolean matrix can describe the causal relationship between the fault unit and the test point in detail.

Boolean algorithms can be used for fault detection and fault isolation with the logic "or", "and" as well as "exclusive or".so the test point sets in the guideline of fault detection and fault isolation can be got, which is represented by T_D, T_I .if the global test point set is represented by T:

$$T = \left\{ T_n \middle| T_n \subset T_D, 且 T_I \subset T_D \right\} \quad (1)$$

2.1 The Choice Of the Global Test Point Set

2.1.1 The optimization of the test point set in the Standard that the number of the fault isolated is the most

Generally, assuming that there is only a fault at a certain moment for a system, which is a typical binary pattern recognition problem. Therefore, it is necessary to combine the output of different tests to judge the possibility of faults. m_0 represents the system has no fault, and $M = \{m_i, i = 0,1,\cdots a\}$ represents the state set of the system. So the correlation matrix of the state as follows:

$$MT_{(a+1)\times b} = \begin{matrix} \\ m_0 \\ m_1 \\ \cdots \\ m_a \end{matrix} \begin{matrix} t_1 \quad t_2 \quad \cdots \quad t_b \\ \begin{Bmatrix} h_{01}, h_{02}, \cdots\cdots h_{0b} \\ h_{11}, h_{12}, \cdots\cdots h_{1b} \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ h_{a1}, h_{a2}, \cdots\cdots h_{ab} \end{Bmatrix} \end{matrix} \quad (2)$$

In the correlation matrix above, The element in the first line is special, $h_{0j} = 0$, $j = 1,2,\cdots n$.

The condition that two faults can be isolated is that the corresponding row vector of two faults must be different, and the logical "or" represents the corresponding test can isolate two faults. $T_I(m_i, m_k)$ is used to represented the test point set that can isolate

m_i and m_k :

$$T_I(m_i, m_k) = \sum_{j=1}^{b} \left[(h_{ij} \bullet h_{kj}) t_j \right] \quad (3)$$

In the formula (3), $\bullet$ represents"Exclusive or", and $i \neq k$.

According to the formula (3), the test points that can isolates any two faults can be got. The accumulation of these test combinations is the set that can isolate all faults. Which is represented by $T_I(M)$:

$$T_I(M) = \prod_{i,k=0,i\neq k}^{a} T_I(m_i, m_k) = \prod_{i,k=0,i\neq k}^{a} \left\{ \sum_{j=1}^{b} \left[(h_{ij} \bullet h_{kj}) t_j \right] \right\} \quad (4)$$

However, With the fault modes and the quantity of the test points increasing, T_D is not the only one, which causes that the global test point set is not the only one, $T = \{T_1, T_2, \cdots T_n\}$. Therefore, it is necessary to optimize the test point sets.

2.1.2 The optimization of the test point set in the Standard that the number of the fault test points is the least

First, construct the incidence matrix in accordance with the relationship between fault and the test points:

$$M'T_{a\times b} = \begin{matrix} & t_1 \quad t_2 \quad \dots \quad t_b \\ \begin{matrix} m_1 \\ m_2 \\ \dots \\ m_a \end{matrix} & \left\{ \begin{matrix} h_{11}, h_{12}, \cdots\cdots h_{1b} \\ h_{21}, h_{22}, \cdots\cdots h_{2b} \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ h_{a1}, h_{a2}, \cdots\cdots h_{ab} \end{matrix} \right\} \end{matrix} \quad (5)$$

This matrix is Boolean matrix, $M' = \{m_1, m_2, \cdots m_a\}$ represents the faults set. $T = \{t_1, t_2, \cdots t_b\}$ represents the primary test point. The matrix element h_{ij} represents the correlation between the test point t_j and the fault mode m_i, when t_i can detect m_i, the value of h_{ij} is 1, otherwise the value of h_{ij} is 0.

Assuming that $D(m_i)$ represents the total test point sets that can test the fault m_i:

$$T_D(m_i) = \sum_{j=1}^{b} (h_{ij} \bullet t_i) \quad (6)$$

In the formula (6), $\sum$ represents the accumulation of "Logic plus". When $T_D(m_i) = 0$, there is no test point detecting the fault m_i.

Therefore, $T_D(M')$ is used to represent the test point sets that can simultaneously detect different faults:

$$T_D(M') = \prod_{i=1}^{a} T_D(m_i) \quad (7)$$

In the formula (7), $\prod$ represents the accumulation of "Logic multiply ", which can simultaneously detect different faults.

2.2 The optimization of the global test point set in the guideline that the test cost is the lowest

Each of the test point has the different amount of information, so the test efficiency will be different. At the same time, differences in the location of the test point results in the different test cost. Under the same conditions, it is easier and lower test cost to measure the output test point than the test points in the internal circuit. Therefore, this article will be further screened the best global test point set based on the test cost and the amount of information contained in the test point.

The set $C=\{c_1,\cdots,c_b\}$ represents the test cost of the test points; The failure rate of each fault mode in the circuit is represented by $P=\{p(m_0),p(m_1),\cdots,p(m_b)\}$, and $p(m_0)$ represents the rate of the circuit without fault; The global test point set of the system is $T=\{t_j \mid t_j\in T_0\}$, the test point t_j divides the fault of the system into the detect fault set M_{jp} and undetectable fault set M_{jf}. $M_{jp}=\{m_1,m_2,\cdots m_{jp}\}$， $j\geq 1$。 $M_{jf}=M-M_{jp}$ .The probabilities of detect fault set and undetectable fault set $P(M_{jp})$, $P(M_{jf})$ can be respectively got:

$$P(M_{jp})=\sum\left[1-h_{ij}\right]p(m_{jp}) \quad (8)$$

$$P(M_{jf})=1-P(M_{jp}) \quad (9)$$

The test information $L(M,t_j)$ of the test point t_j can be obtained according to information entropy theory:

$$L(M,t_j)=-\left\{P(M_{jp})Log_2P(M_{jp})+P(M_{jf})Log_2P(M_{jf})\right\} \quad (10)$$

The test efficiency of the test point t_j is α_j, which the ratio of the test information is and the test cost:

$$\alpha_j=\frac{L(M,t_j)}{c_j} \quad (11)$$

The test efficiency of the global test point set as follows:

$$A=\prod_{j=1}^{|T|}\alpha_j=\prod_{j=1}^{|T|}\left(\frac{L(M,t_j)}{c_j}\right) \quad (12)$$

The larger the value of A, the higher the test efficiency of the test point set which has the maximum value is the best global test point set.

Therefore, the flow chart of the preferred fault detection point set as shown in figure 1.

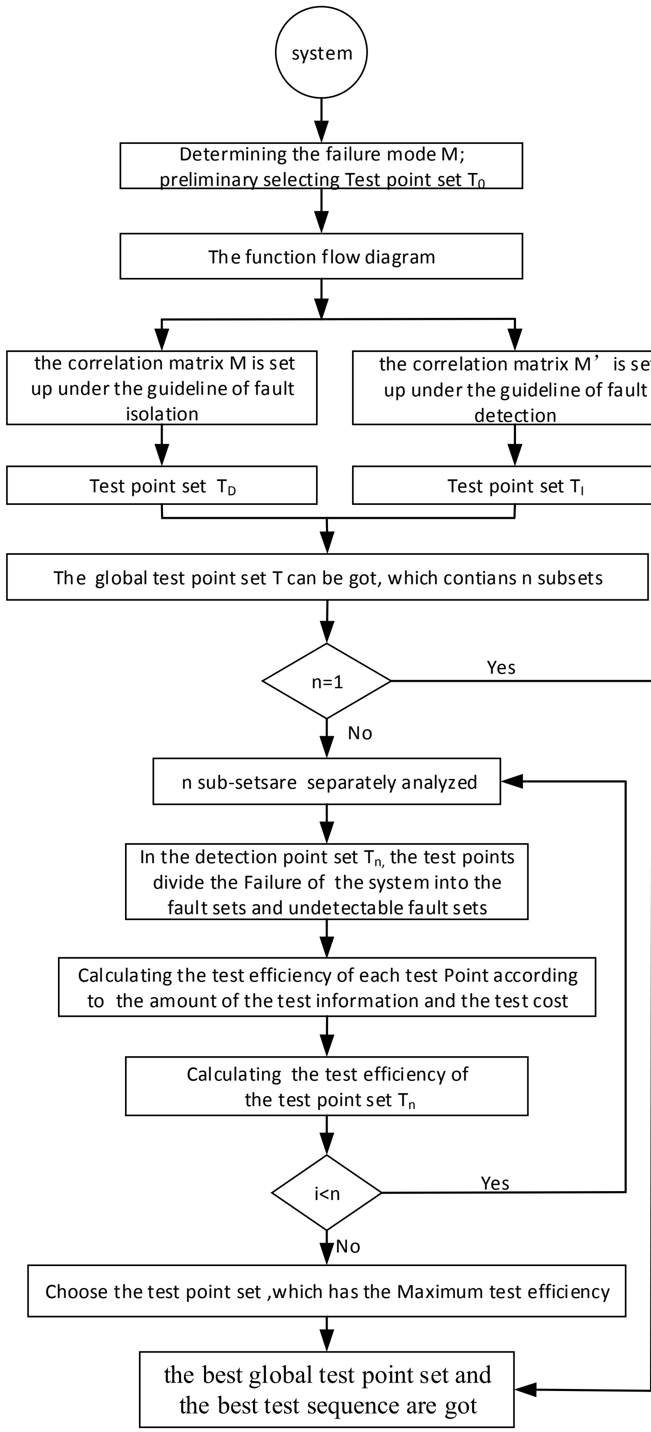

Figure 1. The flow chart of the preferred fault detection point set

3 The Optimization Of The Test Points For The Onboard Power Controller Of Maglev Train

The onboard power controller of Maglev train is referred to as "BNS, which is mainly controlling and monitoring the main vehicle power supply equipment of train. The system contains a large number of integrated circuits, and the analog circuit occupy the main part, as shown in figure 2.

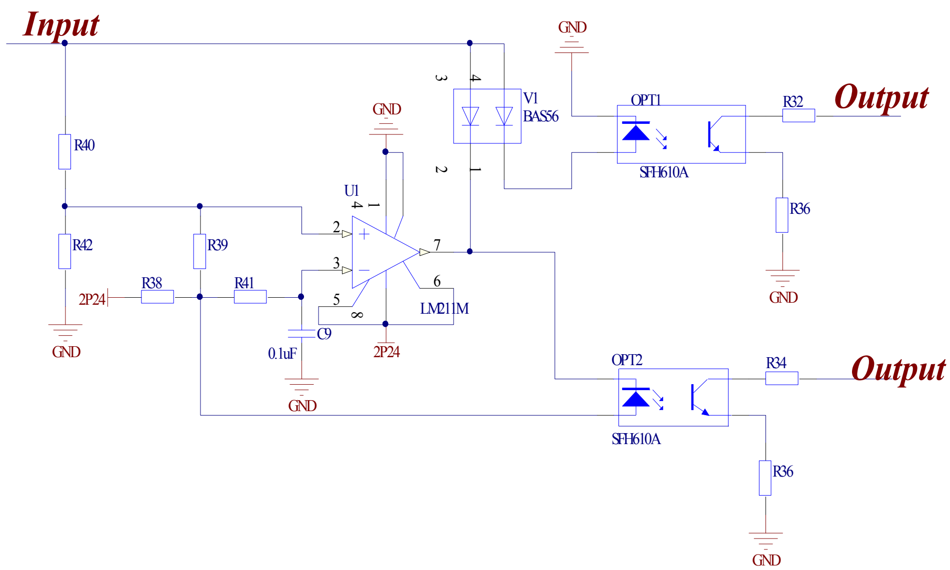

Figure 2. The analog circuit of the onboard power controller of Maglev train

There is introducing the application of the optimization method of the test point in analog circuit, where take the onboard power controller of Maglev train as an example, specific steps are as follows:

(1) The circuit is divided into five modules, as shown in figure 3.

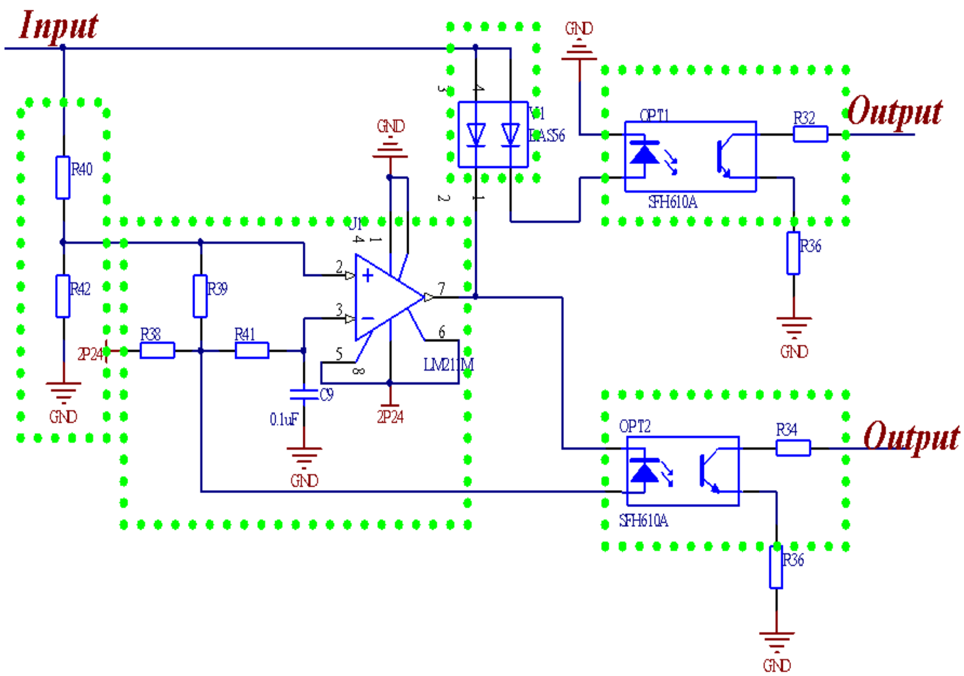

Figure 3. The partition of circuit module

(2) Drawing the function flow diagram of the analog circuit, as shown in figure 4.

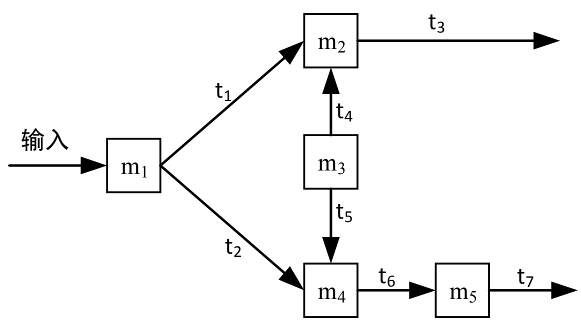

Figure 4. The function flow diagram of the onboard power controller of Maglev train

(3) According to the function flow diagram of analog circuit, the correlation matrix is set up under the guideline of fault isolation. And the corresponding test point set can be obtained according to the formula (3), (4).

$$M'T = \begin{bmatrix} & t_1 & t_2 & t_3 & t_4 & t_5 & t_6 & t_7 \\ m_0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ m_1 & 1 & 1 & 1 & 0 & 0 & 1 & 1 \\ m_2 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ m_3 & 0 & 0 & 1 & 1 & 1 & 0 & 1 \\ m_4 & 0 & 0 & 0 & 0 & 0 & 1 & 1 \\ m_5 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$T_I(m_0, m_1) = t_1 + t_2 + t_3 + t_6 + t_7$， $T_I(m_0, m_2) = t_3$， $T_I(m_0, m_3) = t_3 + t_4 + t_5 + t_7$

$\ldots\ldots T_I(m_4, m_5) = t_6$

$$T_I(M) = \prod_{i,k=0,i\neq k}^{a} T_I(m_i, m_k) = T_I(m_0, m_1) \bullet T_I(m_0, m_2) \bullet \cdots \bullet T_I(m_4, m_5) = (t_1 + t_2 + t_3 + t_6 + t_7)(t_3)\cdots(t_6)$$

$$= t_3t_4t_6 + t_3t_4t_7 + t_3t_5t_6 + t_3t_6t_7 + t_1t_3t_4t_6 + t_1t_3t_4t_7 + t_1t_3t_5t_6 + t_1t_4t_6t_7 + t_1t_5t_6t_7 + t_2t_3t_4t_6 + t_2t_3t_5t_6 + t_2t_4t_6t_7 + t_3t_4t_5t_6$$
$$+ t_3t_4t_6t_7 + t_3t_5t_6t_7 + t_1t_2t_3t_4t_6 + t_1t_2t_3t_4t_7 + t_1t_2t_3t_5t_6 + t_1t_2t_3t_6t_7 + t_1t_2t_4t_6t_7 + t_1t_3t_4t_5t_6 + t_1t_3t_4t_6t_7 + t_1t_3t_5t_6t_7 +$$
$$t_1t_4t_5t_6t_7 + t_2t_3t_4t_5t_6 + t_2t_3t_4t_6t_7 + t_2t_3t_5t_6t_7 + t_2t_4t_5t_6t_7 + t_3t_4t_5t_6t_7 + t_1t_2t_3t_4t_5t_6 + t_1t_2t_3t_4t_6t_7 + t_1t_2t_3t_5t_6t_7 + t_1t_2t_4t_5t_6t_7$$
$$+ t_1t_3t_4t_5t_6t_7 + t_2t_3t_4t_5t_6t_7 + t_1t_2t_3t_4t_5t_6t_7$$

Therefore, when the guideline is the fault isolation, the test point set is $\{t_3t_4t_6\}$， $\{t_3t_4t_7\}$， $\{t_3t_5t_6\}$， $\{t_3t_6t_7\}$。

(4) According to the function flow diagram of analog circuit, the correlation matrix is set up under the guideline of fault detection. And the corresponding test point set can be obtained according to the formula (6), (7).

$$M'T = \begin{bmatrix} & t_1 & t_2 & t_3 & t_4 & t_5 & t_6 & t_7 \\ m_1 & 1 & 1 & 1 & 0 & 0 & 1 & 1 \\ m_2 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ m_3 & 0 & 0 & 1 & 1 & 1 & 0 & 1 \\ m_4 & 0 & 0 & 0 & 0 & 0 & 1 & 1 \\ m_5 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$T_D(m_1) = t_1 + t_2 + t_3 + t_6 + t_7$， $T_D(m_2) = t_2$， $T_D(m_3) = t_3 + t_4 + t_5 + t_7$， $T_D(m_4) = t_6 + t_7$

$T_D(m_5) = t_7$

$$T_D(M) = \prod_{i=1}^{a} T_D(m_i) = T_D(m_1) \bullet T_D(m_2) \bullet T_D(m_3) \bullet T_D(m_4) \bullet T_D(m_5)$$
$$= (t_1 + t_2 + t_3 + t_6 + t_7)(t_2)(t_3 + t_4 + t_5 + t_7)(t_6 + t_7)(t_7)$$
$$= t_3t_7 + t_1t_3t_7 + t_2t_3t_7 + t_3t_4t_7 + t_3t_5t_7 + t_3t_6t_7 + t_1t_3t_4t_7 + t_1t_3t_5t_7 + t_1t_3t_6t_7$$
$$+ t_2t_3t_4t_7 + t_2t_3t_5t_7 + t_2t_3t_6t_7 + t_3t_4t_6t_7 + t_2t_3t_4t_6t_7 + t_2t_3t_5t_6t_7$$

Therefore, when the guideline is the fault detection, the test point set is $\{t_3 t_7\}$ 。

(5)The best global test point set can be got by the formula (1),which is $\{t_3,t_4,t_7\}$, $\{t_3,t_6,t_7\}$.

(6) According to the test efficiency, the global test point set t can be optimized, and the best test point set can be got, as well as the test sequence can be determined.

For the test point set $\{t_3,t_4,t_7\}$, the failure mode is divided into pass subsets and failure subsets, "P" is said that the detection pass, "F" said the test is failed. As shown in figure 5.

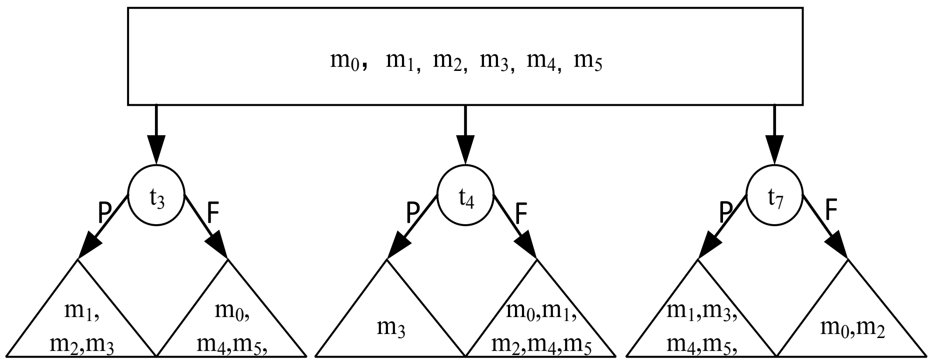

Figure 5. The classification figure 1 of failure mode

There are assumes that the normal probability of the circuit is 0.8, the failure probability is 0.2, five kinds of fault state probability is same, which is 0.04; because t_3 and t_7 are the output test point, which facilitates testing, so There are assumes that the testing cost of the test point t_3 , t_7 is 1, the testing cost of others is 2. The detection efficiency of each testing point can be got by the formula (8), (9), (10), (11), (12), the results are shown in table 1.

Table 1.The detection efficiency of each testing point in the test point set $\{t_3,t_4,t_7\}$

project	t_3	t_4	t_7
M_{jp}	$\{m_1,m_2,m_3\}$	$\{m_3\}$	$\{m_1,m_3,m_4,m_5\}$
$P(M_{jp})$	0.12	0.04	0.16
M_{jf}	$\{m_0,m_4,m_5\}$	$\{m_0,m_1,m_2,m_4,m_5\}$	$\{m_0,m_2\}$
$P(M_{jf})$	0.88	0.96	0.84
$L(M,t_j)$	0.5294	0.2423	0.6343
c_j	1	2	1

$\alpha_j = \dfrac{L(M,t_j)}{c_j}$	0.5294	0.1212	0.6343
$A = \prod_{j=1}^{\vert T\vert} \alpha_j$	0.0407		

In the test point set $\{t_3, t_6, t_7\}$, figure 6 shows the classification figure of the failure mode, table 2 shows the detection efficiency of each testing point in the test point set.

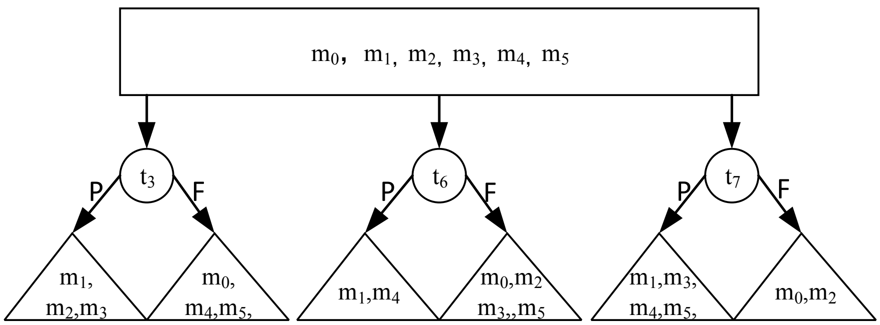

Figure 6. The classification figure 2 of failure mode

Table 2.The detection efficiency of each testing point in the test point set $\{t_3, t_6, t_7\}$

project	t_3	t_6	t_7
M_{jp}	$\{m_1, m_2, m_3\}$	$\{m_1, m_4\}$	$\{m_1, m_3, m_4, m_5\}$
$P(M_{jp})$	0.12	0.08	0.16
M_{jf}	$\{m_0, m_4, m_5\}$	$\{m_0, m_2, m_3, m_5\}$	$\{m_0, m_2\}$
$P(M_{jf})$	0.88	0.92	0.84
$L(M,t_j)$	0.5294	0.4022	0.6343
c_j	1	2	1
$\alpha_j = \dfrac{L(M,t_j)}{c_j}$	0.5294	0.2011	0.6343
$A = \prod_{j=1}^{\vert T\vert} \alpha_j$	0.0675		

Because $A\big|_{\{t_3,t_6,t_7\}} > A\big|_{\{t_3,t_4,t_7\}}$, the best global test point set is $\{t_3, t_6, t_7\}$.

In the best set of the global testing point $\{t_3, t_6, t_7\}$, $\alpha_j\big|_{t_7} > \alpha_j\big|_{t_3} > \alpha_j\big|_{t_6}$, so the best test sequence is t_3, t_6, t_7. As shown in figure7.

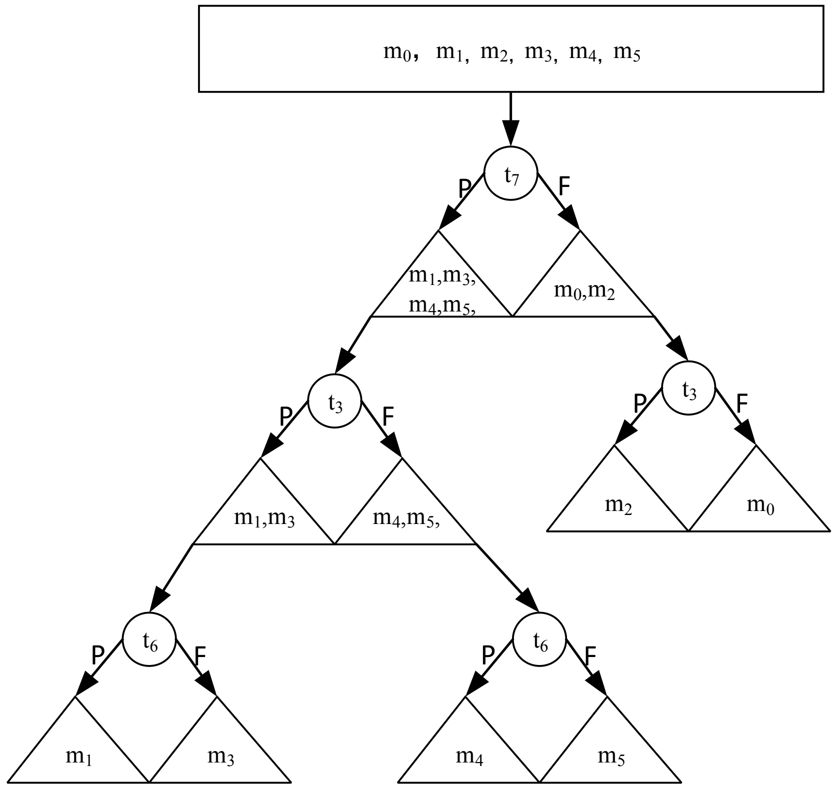

Figure 7. The best test sequence

4 Conclusions

Here we may draw the following conclusions.

(1) The method of selecting test point makes full use of the test cost and failure probability information without exhaustive all fault diagnosis tree, which makes the algorithm simple, fast, and reduces the amount of calculation;

(2) The related model of the strategy takes the test cost of each test point into account, which is more accord with the actual system;

(3) The instance shows that the strategy is effective and can be applied to fault detection of analog circuits.

5 Recommendations For Future Research

In this paper, the method of selecting test point requires the users draw the function flow diagram of the system according to the composition module and information flow of the system. And when the number of the test units is large, there are large amount of calculation, and needs to further selecting test point of complex systems test points.

Acknowledgement

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References

Abderrahman, A., Cerny, E., Kaminska, B. (1996). Optimization-based multi frequency test generation for analog circuits. Journal of Electronic Testing: Theory and Applications, 9: 59-73.

Cai, J.Y., Chen, G.T., Zhang, H.W. (2003). A method of selecting nodes for fault Diagnosis. Journal of ordnance engineering college, 14(1): 7 -10.

Huang, J.L., Cheng, K.T. (2000). Test Point Selection for Analog Fault Diagnosis of Unpowered Circuit Boards. IEEE Transaction on Circuits and Systems Ò: Analog and Digital Signal Processing, 47(10): 977 -987.

Hu, Z., Li Q.W., Wen X.S. (2000). Two topological problems and their solutions in testability. Journal of National University of Defense Technology, 22(6):105-110.

Hochwaldw, Bastian, J.D. (1979). A dc approach for analog fault dictionary determination. IEEE Trans. Circuits Sys.t, CAS-26: 523-529.

Liu, B.D., Hu, C.H. (2006) .Testability analysis of analog circuit fault based on graph pattern. Journal of Projectiles, Rockets, Missiles and Guidance, 27(4):257-260.

Prasad, V.C., Babun, S.C. (2000).Selection of test nodes for analog fault diagnosis in dictionary approach. IEEE Trans In strum. Meas., 2000, 49: 1289-1297.

Starzyk, J.A., Liud, Liuzhh. (2004).Entropy-based optimum test nodes selection for analog fault dictionary techniques. IEEE Trans In strum Meas., 2004, 53: 754-761.

Stenbakken, G.N., Souders, T.M. (1987). Test point selection and test ability measure via QR factorization of linear models. IEEE Transaction on Instrumentation and Measurement, IM-36(6): 406-410.

Varghese, X., Williams, J.H., Towill, D.R. (1978). Computer-aided feature selection for enhanced analog system fault location. Pattern Recogni.t, 10:265-280.

Wang, P., Yang, SH.Y. (2006). New algorithm for test node selection for analog circuits' diagnosis. Chinese Journal of Computers, 29(10): 1780-1785.

Yang, CH. L., Tian, SH. L., Long, B. (2001) Application of heuristic graph search to test point's selection for analog fault dictionary techniques. IEEE Trans In strum Meas. 42: 1139-1143.

An Augmented ε-Constraint Algorithm to the Hazardous Waste Location-Routing Problem

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Abstract: This paper investigates the location-routing problem arising in the context of hazardous waste (HW) management. The problem is to identify the location of recycling center, treatment center and disposal center, and determine the allocation and route plan of HW and waste residue. By incorporating various operational and capacity constraints, especially the link risk tolerance capacity constraints, we formulate the problem as a multi-objective mixed integer linear programming model to minimize the total cost and the total risk simultaneously. An augmented ε-constraint algorithm is customized to approximate the non-dominated frontier to the problem. Finally, a realistic example is used to test the proposed approach. Computational results show that the augmented ε-constraint algorithm is a suitable multi-objective optimization approach to handle the problem.
Keywords: HW management; Location-routing problem; Multi-objective optimization; Augmented ε-constraint approach; Non-dominated solution.

1 Introduction

Hazardous waste (HW) is the waste material which is corrosive, toxic, flammable, reactive or infectious and so on. With the advancement of China's industrialization process, a large amount of HW is produced nowadays. Compared with the conventional waste, the biggest feature of HW is that it is dangerous, if not properly managed; it may be harmful to the ecological environment and human health, and even to the sustainable of economic development. HW management including collection, transportation, recovery, treatment and disposal, and complex decision-making is needed in all process, and all parts together affect the quality and safety of the HW management. This paper discusses the management of hazardous waste location-routing problem (HWLRP), its decision-making process is shown in Figure 1.

HWLRP is a difficult multi-objective combinatorial optimization problem. In the recent twenty-five years, the academic societies conducted a lot of research works for solving this problem. Zografos first proposed the location-routing problem for a single type of HW (Zografos, 1989), the author constructed a multi-objective optimization model which minimizes the risk and time at the same time, and designed a goal programming algorithm. After that, many papers studied a similar problem, and their differences are the location centers, risk assessment methods and multi-objective optimization algorithms. Discussing about the algorithms, Revelle designed a linear weighted sum algorithm (Revelle, 1991), while Giannikos chose a goal programming algorithm (Giannikos, 1998). List first studied the location-routing problem for many types of hazardous materials/wastes (List, 1991), the author built a multi-objective optimization model which contained cost, risk and risk equity objectives at the same time, and presented a linear weighted sum algorithm. After that, Alidi discussed a similar problem, and developed a goal programming algorithm (Alidi, 1992). Alumur first took into account the compatibility constraint between the HW and the treatment technology, and he solved this model with a linear weighted sum algorithm (Alumur, 2007). Shuai extended the cost and risk objectives and built a new multi-objective optimization model by taking recycling center location problem into the decision-making process, and then designed a TOPSIS algorithm to solve the model (Shuai Bin, 2011). Recently, Samanlioglu built the most comprehensive model that encompassed the recycling center, treatment center and disposal center location at the same time, as well as the allocation plan of the wastes and waste residues to the corresponding centers. The author designed a lexicographic weighted Tchebycheff algorithm to solve the model (Samanlioglu, 2013).

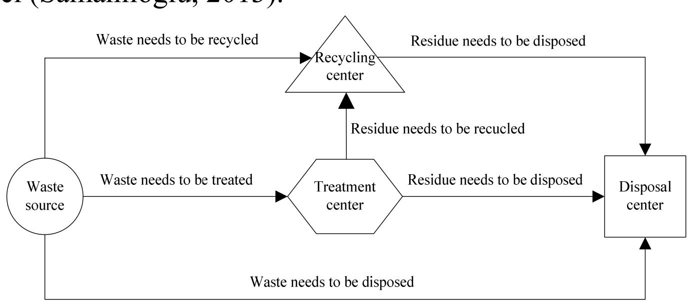

Figure 1. Process of HW management

In summary, the methods of the existing literatures have the following two drawbacks. On the one hand, no literature has considered the link capacity in their approach. On the other hand, HWLRP is a mixed integer multi-objective programming problem, the linear weighted sum algorithm that the existing literatures commonly used is affected severely by the weighting factor, and it is possible to return weakly non-dominated solutions. Therefore, this paper studies multi-objective optimization model and algorithm for HWLRP. On the basis of fully analyzing HW management processes, we build a new multi-objective mixed integer linear programming model which minimizes both systematic cost and risk, and contains link capacity constraint, and then design an augmented ε-constraint approach for the model. Finally, we use an example to test the ability of the proposed algorithm.

2 Model Formulation

2.1 Problem Description

This paper mainly answers the following questions: (1) where to locate HW recycling centers; (2) where to locate HW treatment centers, and what treatment technology to use; (3) where to locate HW disposal centers; (4) how to distribute and transport the recyclable HW (and HW needs to be treated and disposed) among the recycling centers (treatment centers and disposal centers); (5) how to distribute and transport the recyclable residues (and residues need to be disposed) among the recycling centers (and disposal centers); (6) how to distribute and transport the residues which need to be disposed among the recycling centers.

2.2 Model Assumption

Our model is based on the following assumptions:

(1) The research area could be described as a transportation network consisting of nodes and links; (2) transportation cost is linearly related to distance, and location and operation costs are respectively unrelated and linearly related to process amount; (3) transportation risk and location risk are respectively linearly related to transportation amount; and process amount;; (4) a type of HW is compatible with at least one kind of treatment technology; (5) The detail transportation, recycling, treatment and disposal processes of HW and waste residues are not considered.

2.3 Optimization model

The following notations are used in our model.

Sets:

$N(V,E)$: HW transportation network，where V is the set of nodes, and E is the set of links.

$R \subseteq V$,$T \subseteq V$ and $D \subseteq V$: set of candidate recycling centers, treatment centers and disposal centers, indexed by r , t and d ,respectively.

$O \subseteq V$: set of other kinds of nodes.

L : set of treatment technologies, indexed by l .

W : set of the kinds of HWs, indexed by w .

H : set of HWs, indexed by h .

Parameters:

$c_{\text{HR},ij}$ ($r_{\text{HR},ij}$): unit transportation cost (risk) of transporting recyclable HW using link $(i,j) \in E$.

$c_{\text{HT},wij}$ ($r_{\text{HT},wij}$): unit transportation cost (risk) of transporting HW $w \in W$ which needs to be treated using link $(i,j) \in E$.

$c_{\text{HD},ij}$ ($r_{\text{HD},ij}$): unit transportation cost (risk) of transporting HW which needs to be disposed using link $(i,j) \in E$.

$c_{\mathrm{TR},ij}$ ($r_{\mathrm{TR},ij}$): unit transportation cost (risk) of transporting recyclable waste residue from treatment center using link $(i,j)\in E$.

$c_{\mathrm{TD},ij}$ ($r_{\mathrm{TD},ij}$): unit transportation cost (risk) of transporting waste residue which needs to be disposed from treatment center using link $(i,j)\in E$.

$c_{\mathrm{RD},ij}$ ($r_{\mathrm{RD},ij}$): unit transportation cost (risk) of transporting waste residue which needs to be disposed from recycling center using link $(i,j)\in E$.

$f_{\mathrm{R},r}$ ($v_{\mathrm{R},r}$): fixed cost (variable cost) of operating a recycling center at node $r\in R$.

$f_{\mathrm{T},tl}$ ($v_{\mathrm{T},tl}$): fixed cost (variable cost) of operating a treatment center at node $t\in T$ using technology $l\in L$.

$f_{\mathrm{D},d}$ ($v_{\mathrm{D},d}$): fixed cost (variable cost) of operating a disposal center at node $d\in D$.

$s_{\mathrm{R},r}$ ($s_{\mathrm{D},d}$): location risk of operating a recycling (disposal) center at node $r\in R$ ($d\in D$).

$s_{\mathrm{T},tl}$: location risk of operating a treatment center at node $t\in T$ with technology $l\in L$.

o_h , τ_h , q_h : origin node, type and volume of HW $h\in H$.

α_h (β_h , γ_h): percentage of the part needs to be recycled (treated, disposed) of HW $h\in H$.

η_{lw}: percentage of mass variation of HW type $w\in W$ after being treated using technology $l\in L$.

κ_{lw} (σ_{lw}): percentage of the part needs to be recycled (disposed) of HW type $w\in W$ after being treated using technology $l\in L$.

δ_{lw} : 0-1 parameter, if HW type $w\in W$ could be treated using technology $l\in L$, $\delta_{lw}=1$, otherwise, $\delta_{lw}=0$.

λ_r : average recycling proportion of recyclable HW and waste residue at recycling center $r\in R$.

$b_{\mathrm{LR},r}$ ($b_{\mathrm{UR},r}$): minimum (maximum) recycling capacity of operating a recycling center at node $r\in R$.

$b_{\mathrm{LT},tl}$ ($b_{\mathrm{UT},tl}$): minimum (maximum) treatment capacity of operating a treatment center at node $t\in T$ using technology $l\in L$.

$b_{\mathrm{LD},d}$ ($b_{\mathrm{UD},d}$): minimum (maximum) disposal capacity of operating a disposal center at node $d\in D$.

$b_{\mathrm{UE},ij}$: maximum risk allowed on link $(i,j)\in E$, which is pre-determined by the decision maker of government.

θ_{iV} : 1, if $i\in V$. 0, otherwise.

ϑ_{ij} : 1, if node $i\in V$ is the same with node $j\in V$. 0, otherwise.

Variables:

$x_{\mathrm{HR},hij}$ ($x_{\mathrm{HT},hij}$, $x_{\mathrm{HD},hij}$): amount of the part needs to be recycled (treated, disposed) of HW $h \in H$ transporting on link $(i,j) \in E$.

$x_{\mathrm{TR},tij}$ ($x_{\mathrm{TD},tij}$): amount of waste residue needs to be recycled (disposed) from treatment center $t \in T$ transporting link $(i,j) \in E$.

$x_{\mathrm{RD},rij}$: amount of waste residue needs to be disposed from recycling center $r \in R$ transporting link $(i,j) \in E$.

$y_{\mathrm{HR},hi}$: amount of the recyclable part of HW $h \in H$ recycled at node $i \in V$.

$y_{\mathrm{HT},hil}$: amount of the treatable part of HW $h \in H$ treated at node $i \in V$ using technology $l \in L$.

$y_{\mathrm{HD},hi}$: amount of the disposable part of HW $h \in H$ disposed at node $i \in V$.

$y_{\mathrm{TR},ti}$ ($y_{\mathrm{TD},ti}$): amount of recyclable (disposable) part of waste residue from treatment center $t \in T$ recycled (disposed) at node $i \in V$.

$y_{\mathrm{RD},ri}$: amount of disposable part of waste residue from recycling center $r \in R$ disposed at node $i \in V$.

$y_{\mathrm{R},r}$: total amount of waste recycled at recycling center $r \in R$.

$y_{\mathrm{T},tlw}$: total amount of waste of HW type $w \in W$ treated at treatment center $t \in T$ using technology $l \in L$.

$y_{\mathrm{T},tl}$: total amount of waste treated at treatment center $t \in T$ using technology $l \in L$.

$y_{\mathrm{D},d}$: total amount of waste residual disposed at disposal center $d \in D$.

$z_{\mathrm{R},r}$: 0-1 variable, if a recycling center is operated at node $r \in R$, $z_{\mathrm{R},r}=1$, otherwise, $z_{\mathrm{R},r}=0$.

$z_{\mathrm{T},tl}$: 0-1 variable, if a treatment center using technology $l \in L$ is operated at node $t \in T$, $z_{\mathrm{T},tl}=1$, otherwise $z_{\mathrm{T},tl}=0$.

$z_{\mathrm{D},d}$: 0-1 variable, if a disposal center is operated at node $d \in D$, $z_{\mathrm{D},d}=1$, otherwise, $z_{\mathrm{D},d}=0$.

Using the notations, HWLRP can be formulated as the following multi-objective mathematical optimization model [P]:

$$\begin{aligned}\min z_1 = &\sum_{h\in H}\sum_{(i,j)\in E} c_{\mathrm{HR},ij} x_{\mathrm{HR},hij} + \sum_{h\in H}\sum_{(i,j)\in E} c_{\mathrm{HT},\tau_h ij} x_{\mathrm{HT},hij} + \sum_{h\in H}\sum_{(i,j)\in E} c_{\mathrm{HD},ij} x_{\mathrm{HD},hij} \\ &+\sum_{t\in T}\sum_{(i,j)\in E} c_{\mathrm{TR},ij} x_{\mathrm{TR},tij} + \sum_{t\in T}\sum_{(i,j)\in E} c_{\mathrm{TD},ij} x_{\mathrm{TD},tij} + \sum_{r\in R}\sum_{(i,j)\in E} c_{\mathrm{RD},ij} x_{\mathrm{RD},rij} \\ &+\sum_{r\in R}\left(f_{\mathrm{R},r} z_{\mathrm{R},r} + v_{\mathrm{R},r} y_{\mathrm{R},r}\right) + \sum_{t\in T}\sum_{l\in L}\left(f_{\mathrm{T},tl} z_{\mathrm{T},tl} + v_{\mathrm{T},tl} y_{\mathrm{T},tl}\right) \\ &+\sum_{d\in D}\left(f_{\mathrm{D},d} z_{\mathrm{D},d} + v_{\mathrm{D},d} y_{\mathrm{D},d}\right)\end{aligned} \tag{1}$$

$$\begin{aligned}\min z_2 = &\sum_{h\in H}\sum_{(i,j)\in E} r_{\mathrm{HR},ij}x_{\mathrm{HR},hij} + \sum_{h\in H}\sum_{(i,j)\in E} r_{\mathrm{HT},\tau_h ij}x_{\mathrm{HT},hij} + \sum_{h\in H}\sum_{(i,j)\in E} r_{\mathrm{HD},ij}x_{\mathrm{HD},hij} \\ &+\sum_{t\in T}\sum_{(i,j)\in E} r_{\mathrm{TR},ij}x_{\mathrm{TR},tij} + \sum_{t\in T}\sum_{(i,j)\in E} r_{\mathrm{TD},ij}x_{\mathrm{TD},tij} + \sum_{r\in R}\sum_{(i,j)\in E} r_{\mathrm{RD},ij}x_{\mathrm{RD},rij} \\ &+\sum_{r\in R} s_{\mathrm{R},r}y_{\mathrm{R},r} + \sum_{t\in T}\sum_{l\in L} s_{\mathrm{T},tl}y_{\mathrm{T},tl} + \sum_{d\in D} s_{\mathrm{D},d}y_{\mathrm{D},d}\end{aligned} \quad (2)$$

s.t.

$$\sum_{r\in R} y_{\mathrm{HR},hr} = \alpha_h q_h \quad \forall h\in H \quad (3)$$

$$\sum_{(i,j)\in E} x_{\mathrm{HR},hij} - \sum_{(j,i)\in E} x_{\mathrm{HR},hji} + \theta_{iR} y_{\mathrm{HR},hi} = \vartheta_{i,o_h}\alpha_h q_h \quad \forall h\in H, i\in V \quad (4)$$

$$\sum_{t\in T}\sum_{l\in L} y_{\mathrm{HT},htl} = \beta_h q_h \quad \forall h\in H \quad (5)$$

$$\sum_{(i,j)\in E} x_{\mathrm{HT},hij} - \sum_{(j,i)\in E} x_{\mathrm{HT},hji} + \theta_{iT}\sum_{l\in L} y_{\mathrm{HT},hil} = \vartheta_{i,o_h}\beta_h q_h \quad \forall h\in H, i\in V \quad (6)$$

$$\sum_{d\in D} y_{\mathrm{HD},hd} = \gamma_h q_h \quad \forall h\in H \quad (7)$$

$$\sum_{(i,j)\in E} x_{\mathrm{HD},hij} - \sum_{(j,i)\in E} x_{\mathrm{HD},hji} + \theta_{iD} y_{\mathrm{HD},hi} = \vartheta_{i,o_h}\gamma_h q_h \quad \forall h\in H, i\in V \quad (8)$$

$$\sum_{h\in H \mid \tau_h = w} y_{\mathrm{HT},htl} = y_{\mathrm{T},tlw} \quad \forall t\in T, l\in L, w\in W \quad (9)$$

$$\sum_{w\in W} y_{\mathrm{T},tlw} = y_{\mathrm{T},tl} \quad \forall t\in T, l\in L \quad (10)$$

$$\sum_{r\in R} y_{\mathrm{TR},tr} = \sum_{l\in L}\sum_{w\in W}\eta_{lw}\kappa_{lw}y_{\mathrm{T},tlw} \quad \forall t\in T \quad (11)$$

$$\sum_{(i,j)\in E} x_{\mathrm{TR},tij} - \sum_{(j,i)\in E} x_{\mathrm{TR},tji} + \theta_{iR} y_{\mathrm{TR},ti} = \vartheta_{it}\sum_{l\in L}\sum_{w\in W}\eta_{lw}\kappa_{lw}y_{\mathrm{T},tlw} \quad \forall t\in T, i\in V \quad (12)$$

$$\sum_{d\in D} y_{\mathrm{TD},td} = \sum_{l\in L}\sum_{w\in W}\eta_{lw}\sigma_{lw}y_{\mathrm{T},tlw} \quad \forall t\in T \quad (13)$$

$$\sum_{(i,j)\in E} x_{\mathrm{TD},tij} - \sum_{(j,i)\in E} x_{\mathrm{TD},tji} + \theta_{iD} y_{\mathrm{TD},ti} = \vartheta_{it}\sum_{l\in L}\sum_{w\in W}\eta_{lw}\sigma_{lw}y_{\mathrm{T},tlw} \quad \forall t\in T, i\in V \quad (14)$$

$$\sum_{h\in H} y_{\mathrm{HR},hr} + \sum_{t\in T} y_{\mathrm{TR},tr} = y_{\mathrm{R},r} \quad \forall r\in R \quad (15)$$

$$\sum_{d\in D} y_{\mathrm{RD},rd} = (1-\lambda_r)\, y_{\mathrm{R},r} \quad \forall r\in R \quad (16)$$

$$\sum_{(i,j)\in E} x_{\mathrm{RD},rij} - \sum_{(j,i)\in E} x_{\mathrm{RD},rji} + \theta_{iD} y_{\mathrm{RD},ri} = \vartheta_{ir}(1-\lambda_r)\, y_{\mathrm{R},r} \quad \forall r\in R, i\in V \quad (17)$$

$$\sum_{h\in H} y_{\mathrm{HD},hd} + \sum_{t\in T} y_{\mathrm{TD},td} + \sum_{r\in R} y_{\mathrm{RD},rd} = y_{\mathrm{D},d} \quad \forall d\in D \quad (18)$$

$$b_{\mathrm{LR},r}z_{\mathrm{R},r} \le y_{\mathrm{R},r} \le b_{\mathrm{UR},r}z_{\mathrm{R},r} \quad \forall r\in R \quad (19)$$

$$b_{\mathrm{LT},tl}z_{\mathrm{T},tl} \le y_{\mathrm{T},tl} \le b_{\mathrm{UT},tl}z_{\mathrm{T},tl} \quad \forall t\in T, l\in L \quad (20)$$

$$b_{\mathrm{LD},d}z_{\mathrm{D},d} \le y_{\mathrm{D},d} \le b_{\mathrm{UD},d}z_{\mathrm{D},d} \quad \forall d\in D \quad (21)$$

$$\sum_{h\in H} r_{\text{HR},ij} x_{\text{HR},hij} + \sum_{h\in H} r_{\text{HT},\tau_h ij} x_{\text{HT},hij} + \sum_{h\in H} r_{\text{HD},ij} x_{\text{HD},hij} + \sum_{t\in T} r_{\text{TR},ij} x_{\text{TR},tij} + \sum_{t\in T} r_{\text{TD},ij} x_{\text{TD},tij} + \sum_{r\in R} r_{\text{RD},ij} x_{\text{RD},rij} \le b_{\text{UE},ij} \quad \forall (i,j)\in E \tag{22}$$

$$y_{\text{HT},htl} \le b_{\text{UT},tl}\delta_{l\tau_h} \quad \forall h\in H, t\in T, l\in L \tag{23}$$

$$y_{\text{T},tlw} \le b_{\text{UT},tl}\delta_{lw} \quad \forall t\in T, l\in L, w\in W \tag{24}$$

In model [P], formulas (1) and (2) are the objectives, minimizing the systematic cost and the systematic risk, respectively. In formula (1), the first three items represent the transportation cost of recyclable, treatable and disposable of HWs from their origins to recycling centers, treatment centers and disposal centers, respectively. The fourth and fifth items correspond to the transportation cost of recyclable and disposable waste residuals from treatment centers to recycling center and disposal centers, respectively. The sixth item is the transportation cost of disposal waste residuals from recycling centers to disposal centers. The seventh to ninth items describe the fixed location cost and variable operating cost of recycling centers, treatment centers and disposal centers, respectively. The systematic risk in formula (2) could be understood following formula (1), but the only difference is location risks in the seventh to ninth items are only related with process amount.

Formulas (3) to (30) are the constraints. Specifically, constraints (3) and (4) represent the volume allocation requirement of the recyclable part of HWs among recycling centers and the associated flow conservation constraints in the transportation network. Similarly, constraints (5) to (8) specify the volume allocation and the flow conservation requirements of the treatable part and the disposable part of HWs, respectively. Constraint (9) determines the amount of HWs treated per technology and per type at treatment centers, while constraint (10) aggregates this amount of HWs per technology. Constraints (11) to (14) are the volume allocation and the flow conservation requirements of waste residuals from treatment centers, and Constraints (15) to (17) are those of waste residuals from recycling centers. Constraint (18) determines the amount of waste residuals coming from the HW origins, treatment centers and recycling centers disposed at disposal centers. Constraints (19) to (21) ensure the minimum and maximum capacity requirements of recycling centers, treatment centers and disposal centers, respectively. Constraint (22) guarantees the risk tolerance capacity of each link in the transportation network. Constraints (23) and (24) are the compatibility constraints between HWs and treatment technologies.

3 Augmented ε-Constraint Algorithm

It is not difficult to prove HWLRP is a NP-hard problem. Fortunately, the proposed model [P] is a multi-objective mixed integer linear programming model, and HWLRP is a tactical problem, it is often not sensitive to the solution time. Hence, we customize the augmented ε-constraint algorithm, a state-of-the-art multi-objective integer programming approach, to solve this problem efficiently.

In order to facilitate the description of the algorithm, we simplify the HWLRP as $\min z(x)=\{z_1(x),z_2(x)\}$ s.t. $x\in X$, where $z_1(x)$ and $z_2(x)$ represent the cost objective (1) and risk objective (2) respectively, and the feasible region X is composed of formulas (3) to (24). Firstly, normalization method are used to eliminate the dimension of objective such as $\overline{z}_i(x)=\left(z_i(x)-z_i^{\min}\right)/\left(z_i^{\max}-z_i^{\min}\right)$, $\forall i=1,2$. Suppose x_1 and x_2 be the optimal solution of minimizing only cost objective $z_1(x)$ and risk objective $z_2(x)$ of the original problem, respectively. Let $z_1^{\min}$ and $z_2^{\min}$ be the minimum value of cost objective $z_1(x)$ and risk objective $z_2(x)$, respectively, $z^{\min}=\left(z_1^{\min},z_2^{\min}\right)$ is named as ideal point, obviously, we have $z_1^{\min}=z_1(x_1)$, $z_2^{\min}=z_2(x_2)$. Let $z_1^{\max}$ and $z_2^{\max}$ be the maximum value of cost objective $z_1(x)$ and risk objective $z_2(x)$, respectively, $z^{\min}=\left(z_1^{\min},z_2^{\min}\right)$ is known as nadir point. There are many methods to determine the nadir point. In this paper, we use a method based on lexicographical order, namely:

$$\begin{cases} z_1^{\max}=\min z_1(x) \text{ s.t. } z_2(x)=z_2^{\min}, x\in X \\ z_2^{\max}=\min z_2(x) \text{ s.t. } z_1(x)=z_1^{\min}, x\in X \end{cases} \tag{25}$$

Now we discuss the augmented ε-constraint algorithm(Mavrotas, 2013). For the original problem, suppose i_2 and r_2 be the iteration number and the varying range of risk objective, where $r_2=z_2^{\max}-z_2^{\min}$. Let g_2 and e_2 be the equalized interval number and the current constraint level of risk objective. Initialize $i_2=1$, and set the constraint level $e_2=z_2^{\max}-i_2\,r_2/g_2$ at the current iteration number i_2. Introduce slack variable $s_2\geq 0$ of risk objective, the non-dominated solution of the original problem can be searched by solving the following model:

$$\begin{aligned} &\min \overline{z}=z_1(x)+\delta s_2/r_2 \\ &\text{s.t.}\begin{cases} z_2(x)+s_2=e_2 \\ s_2\geq 0 \\ x\in X \end{cases} \end{aligned} \tag{26}$$

If model (26) has an optimal solution $\{x^*,s_2^*\}$, then a non-dominated solution $\left(z_1(x^*),z_2(x^*)\right)$ is obtained. Update the iteration number $i_2=i_2+1$, and algorithm continues. If there is no feasible solution, algorithm terminates.

4 Illustrated Example

The illustrated example comes from the HW management practice of Sichuan province in China. Assume administrative cities are the source nodes of HWs, and they are also the candidate points of recycling centers, treatment centers and disposal centers. Let HWs could only be transported by highway, national or provincial road. A HW transportation network of Sichuan province containing 44 nodes and 164 links are constructed as shown in Figure 2, where nodes 1~21 are administrative cities, and other nodes are road intersections. Due to the length limitation of the paper, other parameter settings are not explained in detail.

The proposed algorithm is coded by MATLAB 8.0, and CPLEX 12.5 is used as the underlying optimization solver. All experiments are executed on a PC with Intel Core i5-2400 3.10GHz and RAM 8.00 GB.

For the test example, the solution procedures are as follows. Firstly, ideal point is obtained as (586732547.7, 240752.7) by minimizing the cost objective and the risk objective, respectively. Based on this result, using the lexicographic order method explained above, nadir point is solved as (673215755.1, 307891.5). Then, the augmented ε-constraint algorithm (AECA) is implemented where parameter δ is set as 10^{-3}. The non-dominated frontier with 11 non-dominated solutions is shown in Figure 3. As can be seen from figure 3, all 11 non-dominated solutions are distinguished with each other and uniformly distributed in the frontier, demonstrating AECA is an efficient algorithm to the multi-objective HWLRP.

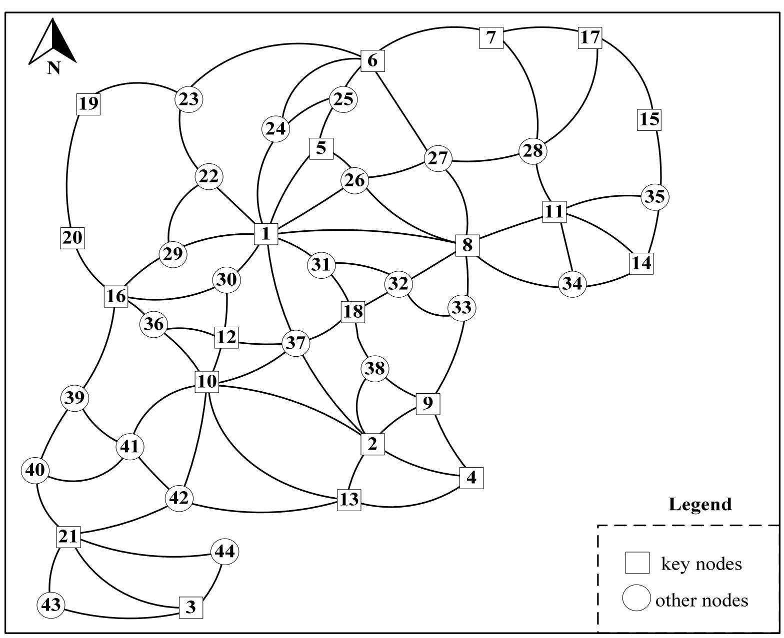

Figure 2. Test HW network

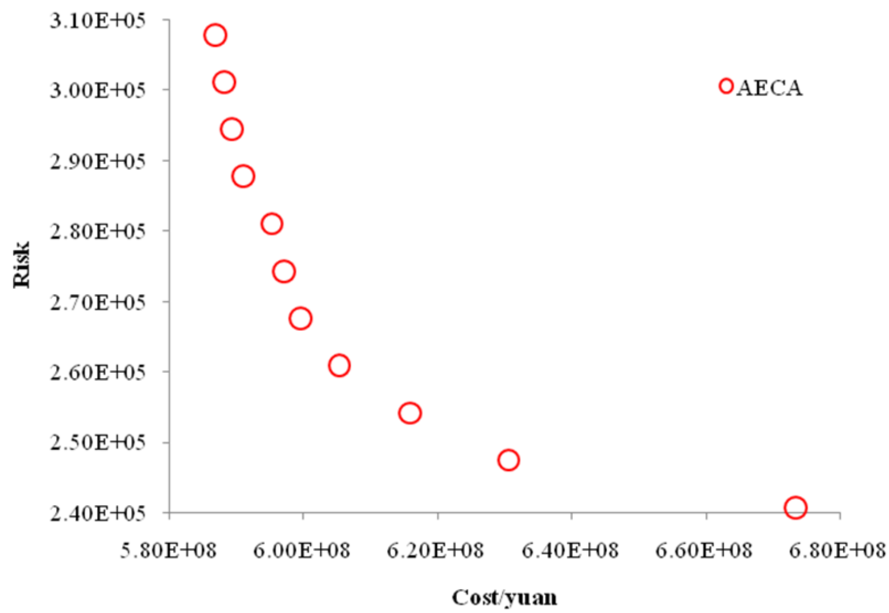

Figure 3. Non-dominated frontier of the test example

5 Conclusions

Location-routing problem is one of the key issues of HW management process, and the nature of the problem is a multi-objective optimization problem. In this paper, we first formulate the original problem as a multi-objective mixed integer linear programming model to minimize cost and risk simultaneously. The structure of the model is compact, and if only one objective exists, the model can be used to solve large-scale practical problems directly using commercial optimization software. In order to find effective non-dominated frontier, a state-of-the-art multi-objective integer programming algorithm, namely augmented ε-constraint algorithm, is customized. Finally, computational tests on a large-scale realistic example show that the augmented ε-constraint algorithm is suitable for solving the multi-objective HWLRP. The algorithm not only can ensure the uniform distribution of non-dominated solutions, but also avoid redundant computations effectively.

Acknowledgement

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References

Alidi A S(1992). An integer goal programming model for HW treatment and disposal. *Applied Mathematical Modelling*, 16(12): 645-651.

Alumur S, Kara B Y(2007). A new model for the HWLRP. Computers & Operations Research, 34(5): 1406-1423.

Giannikos I(1998). A multiobjective programming model for locating treatment sites and routing HWs. European Journal of Operational Research, 104(2): 333-342.

List G, Mirchandani P(1991). An integrated network planar multiobjective model for routing and siting for hazardous materials and wastes. Transportation Science, 25(2): 146-156.

Mavrotas G(2009). Effective implementation of the e-constraint method in multi-objective mathematical programming problems. Applied Mathematics and Computation, 213(2): 455-465.

Revelle C, Cohon J, Shobrys D(1991). Simultaneous siting and routing in the disposal of HWs. Transportation Science , 25(2): 138-145.

Shuai Bin, Zhao Jiahong(2011). Multi-objective 0-1 linear programming model for combined location-routing problem in HW logistics system. Journal of Southwest Jiaotong University, 46(2): 326-332.

Samanlioglu F(2013). A multi-objective mathematical model for the industrial HWLRP. European Journal of Operational Research, 226(2): 332-340.

Zografos K G, Samara S(1989). Combined location-routing model for HW transportation and disposal. Transportation Research Record, 1245: 52-59.

Estimation of the Carbon Emissions of Ningbo Port and Low-Carbon Emissions Solutions

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Abstract: In order to understand the level of carbon emissions of a port, a calculation model is constructed on the basis of fuel consumption, electricity consumption and consumption of ship activities, and this model has been applied to the estimation of carbon-emission of Ningbo Port. Results show that CO_2 emissions of Ningbo Port have increased by 144 percent from 2005 to 2013. Besides, carbon emissions from ship activities account for more than 50 percent and are still on the rise. Meanwhile CO_2 emissions of electricity and fuel consumption of Ningbo Port are 30 percent and 14 percent respectively, and they show a downward trend. Finally some countermeasures of technical innovation, fine management, regulations of legislation and cultivation of energy-saving concept, are put forward to promote low-carbon development of Ningbo Port.

Keywords: Port; Carbon emissions; Low-carbon development.

1 Introduction

Under the constraints of energy and environment, low-carbon economy is a must. According to China's “12th Five-year Plan”, energy consumption and carbon emissions per unit of GDP must be decreased by 16% and 17% respectively by 2015. In Ningbo-Zhoushan port, the top port throughout the world, large amount of energy is consumed and large amount of carbon dioxide is emitted every year. In Copenhagen meeting in December 2009, China committed to decrease greenhouse gas emissions per unit of GDP to 40%-45% in 2020 lower than that in 2005. Reducing carbon emissions of port is not only beneficial to the development of the whole economy but also conducive to sustainable development of ports. In this paper, the calculation frame of Ningbo Port is constructed for seeking the sources and the trends of carbon emissions in recent ten years, and some countermeasures of low-carbon development are put forward to promote the advancement of Ningbo Port.

2 Researches on carbon emissions

Currently there are mainly three kinds of framework document of carbon emissions. These are the Greenhouse Gas (GHG) Protocol, the Air Quality and Greenhouse Gas Toolbox, and the Carbon footprint guidance document.

Greenhouse Gas (GHG) Protocol is developed by World Resources Institute (WRI) and World Business Council on Sustainable Development (WBCSD). The global standard for how to measure, manage, and report greenhouse gas emissions is set in this document, and hundreds of companies and organizations are using GHG Protocol standards and tools to manage their emissions and become more efficient. Air Quality and Greenhouse Gas Toolbox is a tool system developed by the International Association of Ports, which raises some strategies to reduce carbon emissions and puts forward guidelines of the development of clean and low-carbon air project and climate protection program. Meanwhile, the tool system puts forward the corresponding solutions aimed at the air quality of ports, climate change and other issues. Carbon Footprint Guidance Document is developed jointly by the World Ports Climate Initiative Company and some ports, whose purpose is to provide technical guidance for those ports that commit themselves to designing their own methods to calculate carbon footprint.

The GHG protocol divides carbon emissions of enterprises into three categories, namely, the carbon emissions from production activities, power consumption and others activities of enterprise. As this model is easy to be applied to calculate the port's carbon emissions and is widely adopted throughout the world, it is adopted to construct the carbon emissions model of Ningbo Port in this paper.

3 Measure models of Ningbo Port's carbon emissions

3.1 Overview of Ningbo Port

Ningbo Port is located in Zhejiang Province, and is one of China's important ports of collective and distributive transportation of commodities such as liquid chemical, oil, ore and containers. In 2014, cargo throughput and containers throughput of Ningbo Port respectively amount to 5.26 billion tons and 18.7 million TEUs, growing 6.2 percent and 11.5 percent compared with the data in 2013. At present Ningbo Port's cargo throughput and container throughput respectively rank the first and the fifth in the world.

Since 2005, Ningbo Port's throughput has continued to increase, meanwhile the amount of fuel consumption, power consumption and arrived ships show a rising trend. Table 1 shows the facts, as following.

Table 1.Statistics of fuel, power and ships on Ningbo Port (2005-2013)

Year	Fuel consumption (t)	Power consumption (million kw/h)	ships (unit)
2005	25502.9	12708.4	5955
2006	29186.0	14088.0	6973
2007	31183.5	15571.0	9605
2008	35163.7	15692.7	11220
2009	33897.1	17313.4	12643
2010	37253.5	22528.5	14020
2011	39786.7	25030.4	15305
2012*	39129.5	24616.9	16610
2013*	41434.9	26067.3	18877

Data sources: Ningbo-Zhoushan Port (Ningbo Port) Production of energy consumption statistics, China Energy Statistical Yearbook, PMB Zhejiang Province, Ningbo Statistical Yearbook, Ningbo Maritime Bureau, with a "" year of the data according to the relevant data is calculated.*

3.2 Model design of the calculation of carbon emissions

3.2.1 Scope definition

This paper measures the carbon emissions of Ningbo port mainly from the following three categories:

(1) Fuel consumption of port

This category includes the consumption of gantry cranes (including door and cantilever type), the traditional rubber tired gantry cranes, forklifts and other mechanical equipment, and fuel consumption of trucks, trailers and other transportation vehicles, except the fuel consumption of ships in port.

(2) Electricity consumption of port

This part includes power consumption of tire cranes, rail cranes, quayside container cranes and other production equipments which consume electricity, such as lighting, office buildings, warehouses, container loading sites, work areas and other places. And it also includes electricity consumed in the process of machine repair, sewage treatment, ventilation, inspection car weighing, as well as electricity consumed in the daily management of port operations and other facilities. (3) Power consumption of ships

This part includes the carbon dioxide emitted from ships burning fuel to generate electricity to provide for their operation in the process of waiting or discharging in the harbor.

3.2.2 Formula of carbon emissions

(1) Carbon emissions of fuel consumption of port

$$E_F = \sum (C_{Fi} \times F_{Fi}) \quad (1)$$

In the above formula, E_F = amount of CO_2 emissions from total fuel consumption (t); C_{Fi} = i-class fuel consumption per year (t); F_{Fi} = i-class fuel emission factors（t CO_2/t）. Referring to the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, the author decides that the CO_2 emission factors of diesel and gasoline are 3.150 t.CO_2 / t and 3.045 t.CO_2 / t respectively.

(2) Carbon emissions of electrical power consumption of port

$$E_E = (C_E \times F_E) \div 1000 \tag{2}$$

In this formula, E_E = amount of CO_2 emissions from electricity consumption (t); C_E = Port in total power consumption (kw.h); F_E= CO_2 emission factor used electricity (kg CO_2/kw.h). Electricity power of Ningbo Port is mainly thermal power, and the CO_2 emission factor is 1.0523 kg CO_2 / kw. h.

(3) Carbon emissions of ship power consumption

$$E_s = (Q_s \times F_s) \div 1000 \tag{3}$$

In this formula, E_S = annual amount of CO_2 emissions from shipping activities in port (t); Q_S = annual amount of oil consumption of ships in port (L); F_S = factor of CO_2 emissions (kg CO_2 / L). According to the statistical data of Ningbo Port, the average time of ship in port is about 48h, the average tonnage is 30 thousand tons and the consumption of diesel is about 10092 liters / ship.

4 Data Analysis

4.1 Results of calculation

Overall, from 2005 to 2013, the amount of Ningbo Port's CO_2 emissions increases by 1.44 times, and the average annual growth rate reaches 11.8 percent. Meanwhile, the percentage of carbon emissions from fuel and power consumption decrease gradually in recent nine years, and the percentage from ship in port increases. See Table 2 and Figure 1 for the results.

Table 2.Amount of CO_2 emissions in Ningbo Port (2005-2013)

Year	Various sources of carbon emission						Total
	Fuel consumption of port		Electrical power consumption of port		Ship power consumption		
	Ton	Percent	Ton	Percent	Ton	Percent	Ton
2005	80334.4	21.5	133731.1	35.8	159079.0	42.6	373144.5
2006	91936.2	21.6	148248.2	34.8	186273.4	43.7	426457.8
2007	98228.2	18.9	163853.4	31.6	256583.4	49.5	518665.0
2008	110765.7	19.2	165134.3	28.7	299725.7	52.1	575625.7
2009	106776.0	17.0	182189.5	29.1	337739.1	53.9	626704.6
2010	117348.8	16.1	237067.9	32.5	374523.6	51.4	728940.3

2011	125328.3	15.7	263395.2	33.0	408850.5	51.3	797573.9
2012	123258.2	14.9	259044.6	31.4	443708.3	53.7	826011.1
2013	130520.3	14.4	274306.9	30.2	504276.6	55.5	909103.8

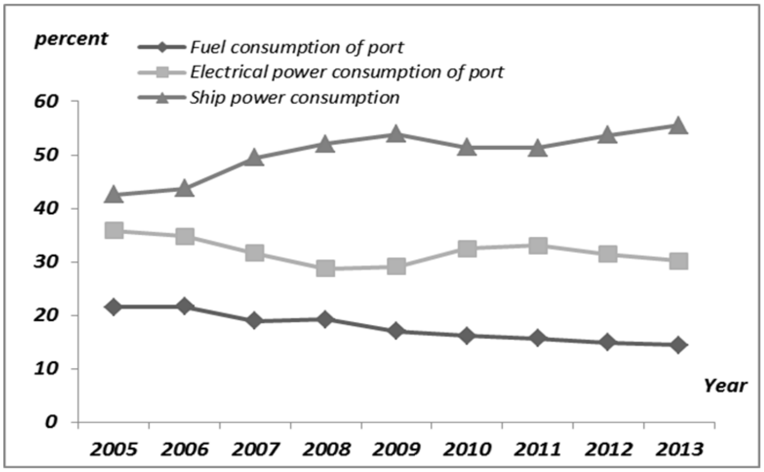

Figure 1.Trends of carbon emissions of Ningbo Port (2005-2013)

4.2 Analysis of results

(1)The proportion of fuel consumption has decreased due to promoting energy saving projects. The growth of CO_2 emissions from fuel consumption is relatively flat, and the proportion of fuel consumption has declined from 21.53 in 2005 to 14.36 in 2013, which is closely related to energy conservation and emissions reduction projects carried out in Ningbo Port. In recent years, the energy structure has been optimized by increasing the use of clean energy and gradually promoting the use of LNG trucks within Ningbo Port. Compared with conventional diesel-powered trucks, LNG trucks can be reduced by nearly 20 percent of energy cost and nearly 30 percent of CO_2 emissions. At the same time, gantry crane are powered by shore power instead of original diesel generator, hence the consumption of fossil energy is reduced. According to statistical data from Ningbo Port, the effect of these energy conservation and emission reduction projects is so significant that the port has saved the equivalents of 9,000 tons of standard coal, and has reduced 2400 tons of exhaust emissions and more than 20000 tons of CO_2 emissions.

(2)The growth speed of carbon emissions from electric power consumption has accelerated, but the proportion in total has declined. From 2005 to 2009, the increase of CO_2 emissions from electric power consumption in Ningbo Port is relatively flat and stable. But from 2009 to 2011, the increase is faster, which is mainly caused by the continuous promotion of the "Oil to Electricity" project. Through the use of cleaner electrical energy to replace fossil energy, CO_2 emissions of fossil fuel have been greatly reduced. Although the shore power consumption shows relatively fast growth, the CO_2 emissions from shore power consumption has decreased from 35.84 percent in 2005 to 14.36 percent in 2013 in total emissions.

(3)The proportion of energy consumption from vessels arriving at Ningbo Port has increased due to the growth of transport business. Over the past decade, owing to the benefits from the location advantages and the economic growth in foreign trade, the number of vessels arriving at Ningbo Port shows a sharp increase, consequently leading to a continuous growth of CO_2 emissions from arrived vesse1s. The proportion of CO_2 emissions from arrived vesse1s has also increased. From 2005 to 2013, the number of vess1s arrived at Ningbo has increased from 5955 to 18,877, in the meantime, the CO_2 emissions of arrived vess1s has increased from 160,000 tons to 500,000 tons. Although the proportion of CO_2 emissions from arrived vesse1s has slightly declined from that in 2009, it has showed a rising trend in general, that is, it has increased from 42.63 percent in 2005 to 55.47 percent in 2013.

5 Countermeasures of promoting low-carbon development of Ningbo Port

Here the author suggests the following countermeasures to reduce the amount of carbon emissions in Ningbo Port.

(1)The enterprises of port should improve the efficiency of port operations, shorten the stay time of vessels in port, and promote the use of shore power instead of ship power, so that the fuel consumption of ships will be reduced.

(2) Clean energy such as solar, wind, gas and other low-carbon energy should be developed through technical innovation. Thus the dependence on fossil energy will be reduced.

(3)Fine management of low-carbon development should be developed，in which the whole target of carbon emissions control should be broken into pieces and distributed to all the management units of the port, which should be controlled through budget. The enterprise should set up the fine management of low carbon development by dividing the whole target of carbon emissions into pieces, and control the amount of carbon emissions of management units through the budget.

(4)The authorities of government should develop standards and future legislation, and periodically evaluate the performance of enterprises’ carbon emissions, rewarding the good and punishing the bad.

(5) Working staff of enterprises should be guided to develop low-carbon awareness and energy-saving behaviors in their daily work and life. In this way the consumption of energy will be reduced and the level of carbon emission will decrease.

6 Recommendations for future research

Low-carbon development is a consensus in the whole world. The index of low-carbon must be included in evaluation of sustainability and quality of port economy. In this paper, a framework of port carbon emissions has been promoted and applied to the practice of Ningbo Port. More practical countermeasures to reduce carbon emissions need to be further proposed in future.

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References

Clare Taylor.(2009)."Greenhouse Gas Protocol and the printing industry." *Print China*, 27(8):35-37.

Jiang Ting.(2010)."Overview of Carbon Footprint Assessment Standards." *Information Technology & Standardizatio*n, 311(11):15-16.

Ningbo Municipal Statistics Bureau.(2014). "*Ningbo Statistics Yearbook of 2014*". Ningbo Municipal Statistics Bureau. Ningbo.

Peng Chuansheng.(2012). "Port Carbon Accounting Method—Case of 2010 Carbon Footprint Report of Singapore Jurong Port." *Port Economy*, 106(7):5-9.

Risk Assessment of Water Traffic Safety on the Wuhu Section of the Yangtze River

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Abstract: Systematical, reasonable and feasible water traffic safety evaluation is an important basic work to build a long-term effective mechanism of safety. In this paper, on the base of safety systems engineering, water transportation systems engineering and other theories, and traffic characteristics of Wuhu Section of the Yangtze River, we proposed a reasonable, exercisable and effective comprehensive evaluation method for water traffic risks—AREEAC, which estimates accident rates synthetically, environmental effects and accident consequences in waterways. And a comprehensive evaluation model basing on AREEAC is set up to estimate traffic risks of the busy waterways in the Yangze River apart from an empirical researching on Wuhu section of Yangze River. The researching results consistent with actual situation in general. Besides, the corresponding measures to control risks are proposed according to the results of safety risks assessment.
Keywords: Safety risk; Comprehensive evaluation; Busy waterway; The Yangze River.

1 Introduction

The trunk line of the Yangtze River has become China's largest inland shipping golden waterway. The Yangtze River water traffic safety evaluation is the foundation of the Yangtze River water traffic safety supervision, to strengthen research on traffic safety risk assessment of the Yangtze River, and to set up risk control strategy and corresponding measures, have great practical significance for the healthy development of the Yangtze River. Currently, the study on water traffic safety risk assessment at home and abroad has achieved abundant research results, derived a number of scientific, comprehensive and systematic evaluation methods, such as fault tree analysis, fuzzy mathematical analysis method, gray fuzzy theory, BP artificial neural network, FSA (ZHAO Jiani, 2005) and the like. But the strong comprehensive risk evaluation method(Fujii.Y,1974), that in view of characteristics of a busy section of the Yangtze River traffic flow, and to consider the consequences of environmental factors , the effects of the accident and strong operability is less. According to the characteristics of traffic flow and safety accident of the busy segment of Yangtze River; referring to the domestic and foreign existing research results of risk evaluation method, the article puts forward the comprehensive risk evaluation method based on accident rate, environmental factors and the consequences of the accident，three factors (referred to as AREEAC). A comprehensive evaluation model basing on AREEAC is set up and we will use it to access and analyze the traffic safety risk on Wuhu section.

2 Characteristics of Traffic Flow and Safety Accident on Wuhu

Wuhu maritime bureau covers the jurisdiction of the Five-step of Yangtze river main channel to head of the Old-continent on-line to Tzuhu river and Wujiang river, including the Yangtze trunk line of 13 main channels, 175 kilometers, 8 branch channels,157 km water areas, covering three level administrative area waters as Wuhu, Tongling, Maanshan(WANG Yuhong, 2003). The main characteristic of busy segment is large vessel traffic flow. During 2009 to 2013, daily traffic flow reached more than 1400 on Wuhu, but maintained at the average daily level of 400 on Wuhan and Threegorges. So we take Wuhu segment as typical characteristics to access and analysis the traffic safety risk in main busy segment of the Yangtze River. Combined with accident statistics of Wuhu section and the actual situation, safety accident characteristics of the Yangtze River main busy segment in 2008-2013 are as follows (LI Zhuo, 2013):

（1）From quantitative analysis of the general accident danger accidents, there is no obvious rules to follow. Except for 2001 the water traffic safety situation improved markedly, in the other five years the number of accident danger is 24 pieces or more every year. However, the number of accidents numerical rating shows a declining trend.（2）According to analyze the types of accidents, the largest, the number of ship collision accident is far higher than other types of accidents and collisions, and because of the characteristic of the collision accident, the three indicators, personnel missing death、 economic loss and wreck number caused by accidents, obviously higher than that of other types of water traffic safety accident. The second is the sink .The third category of multiple incidents is contact damage, partly because busy traffic flow of the large segment that frequent accidents section leads to the wreck more prone to loss of touch events.（3）Based on analysis of the circadian time of the accident , the night is the high incidence of accidents , especially between midnight to 6am.（4）From the point of the loss caused by accidents, With the loss of the number of accidents is declining, but the number of the death, missing people and ship wrecks as well as economic losses showed significant upward trend.（5）From the cause aspect of accidents , the crew improper operation , violation of sailing, fatigue driving, adventure sailing, manning missing, negligence lookout and other human factors and so on, these anthropogenic factors are the main causes of the danger accidents . Second factor is the ship, as the ship unseaworthy, electrical equipment aging and ship hull aging, adventure overload e and so on, all easily lead to accidents. Environment factors are the major cause leading to crew error, especially at fog navigation that seriously affecting the observed sight so extremely easy to cause the collision, rocks and g running aground accident。Moreover large traffic flow of the Yangtze River trunk busy segment and wreck accidents have caused the collision of multiple malignant events, the rocks and sank aground events occurred frequently.

3 Comprehensive Risk Assessment Model and Index System

3.1 AREEAC Assessment Model

According to the characteristics safety accidents of the Yangtze River trunk busy segment the paper proposes an integrated water traffic safety evaluation method --AREEAC. The comprehensive risk evaluation method is based on the accident probability, the environmental impact factors and consequences of accidents, the core design philosophy is calculated statistical probability of the accident the busy segment, the relative environmental harmony degree and accident consequence assessment, and then to obtain the value of a comprehensive accident risk assessment in the form of being multiplied by the three factor's value. That is, comprehensive risk evaluation of water traffic value（R_c） can be regarded as product of the accident rate（A_r）, relative environmental harmony degree（E_f）, the accident consequence assessment（A_c）.

$$R_{\mathrm{c}} = A_r \times E_f \times A_c \qquad (1)$$

Note: A_r is considered by the number of accidents and traffic flow; E_f is adjusted value by eight objective indicators of environmental factors considered; A_c is Calculated by four consequences considered. (ZHANG Shengkun, 2003)

AREEAC evaluation method has the following characteristics: （1）The AREEAC draws lessons from the domestic and foreign existing studies of water traffic safety evaluation method, and have been adjusted to make it more suitable for research of this paper. （2）The comprehensive consideration the incidence of the accident and objective environmental factors and the influence of accident consequence of water traffic safety. （3）The influence degree of each index and the evaluation standards are related to the various aspects of the topic research experts survey results. （4）The AREEAC is strong operability, suitable for practical application.

3.2 Accident Rate Evaluation and its Indicators

$$A_r(\mathrm{t}) = X(\mathrm{t})/T(t) \qquad (2)$$

In the format: $X(\mathrm{t})$--The total number of accident dangers in year t; $T(\mathrm{t})$--Traffic flow in year t; $A_{\mathrm{r}}(\mathrm{t})$--The occurrence rate of water traffic accidents in year t.

3.3 Environmental Impact Assessment and Its 1ndicators

Through objective environment and accident analysis of the Yangtze River busy segment, combined with expert opinion, eight kinds of objective danger rating of environmental factors are shown in the table (see Table 1). (HAN Yansheng, 2006)

Table 1. Risk Rating Standard of 8 Kinds of Objective Environmental Factors Danger Rating Criteria

Risk Class	5	4	3	2	1
Traffic flow (vessel/day)	>1000	750~1000	500~750	250~500	<250
Visibility (number of bad days / year)	>40	30~40	20~30	10~20	<10
Wind ((year-standard number of days)	>140	100~140	60~100	20~60	<20
Flow velocity (m/s)	>5	4~5	3~4	2~3	<2
Channel width (B0/B)	<2	2~3	3~5	5~8	>8
Curvature (steering angle)	>50	35~50	20~35	10~20	<10
Water depth (H/d)	<1.3	1.3~1.6	1.6~2.0	2.0~4.0	>4
Perfect rate of beacon Aids to navigation	<70	70~80	80~90	90~95	95~100

Note: This evaluation method selects quantity of ships a day for traffic flow evaluation index; Poor visibility is set within 2km horizon; Annual average standard wind days = (grade 4 ~ 5) the number of l average annual wind days + 1.5 * (level 6 and above) annual average wind days; The evaluation index of the channel width is channel width B0 / shipping maximum width B; Maximum angle of curvature that the ship steering required when through channel is selected as the evaluation index of Curvature; Water depth of risk evaluation indexes is H (channel)/d (ship draft); Navigation AIDS is perfect rate of beacon Aids to navigation as the evaluation standard, that is " the waters area / the whole channel waters area covered by the actual waterway navigation aids ", so as to improve the rate of 100% is denoted as 100. (HUANG Liwen, 2005; Nii Yasuo, 1992).

The risk value F_i of factor i can be regarded as the product of risk score and corresponding weight of environmental factor i, i.e.:

$$\mathrm{F}_i = F_0 \times w_t \qquad (3)$$

Adding risk value of the 8 single factors and get the objective environment risk value on the segment, i.e.:

$$F = \sum_{i=1}^{s} F_i \qquad (4)$$

Then the objective environmental risk value F of the segment /the objective environment risk value F_0 of the basis segment, get the relative environmental adjustment value E_f, i.e.:

$$E_f = F / F_0 \qquad (5)$$

3.4 The Accident Consequence Assessment and Its Indicators

Reference to the accident grading standards in “Statistics Approach of Water Traffic Accident”, as well as expert assessment, the accident consequence assssment standards are shown in the table (see Table 2). (HU Shenping, 2010)

Table 2. The Score Judgment Standard of Water Traffic Safety Accident Consequences Measure Indicators

Consequences measure indicators	Judgment standard	Score
Casualties （C）	Accident caused the death of people more than 30	1
	Accident caused the death of people from 3-30	0.8
	Accident caused the death of 1 or 2 people	0.6
	Accident caused serious injuries	0.4
	No one seriously injured in the accident	0.2
Economic loss （M）	above 100 million Yuan	1
	from 5 million to 100 million Yuan	0.8
	from 3 million to5 million Yuan	0.6
	from 500000 to3 million Yuan	0.4
	less than 500000 Yuan	0.2
Environmental pollution（E）	Widespread, long-term ecosystem destruction in the near waters	1
	Serious environment pollution	0.6
	Small scale, local environment pollution	0.3
Social influence （S）	a great influence both at home and abroad	1
	great influence in China	0.6
	Small effect	0.3

Note : If no casualties , economic loss or environmental pollution, the score is 0.

According to the project , " key security technology research on the golden waterway navigable segments of the Yangtze River " and the opinions of the experts, assessing the consequences of the accident in busy segment is based on comprehensive quantitative evaluation on casualties (C), economic losses (M), the pollution of the environment (E) and social impact (S) four indicators. So when calculating accident consequence assessment , first of all, getting the four measure indicators respectively on the basis of Table 2 ,then summing and then dividing by four we obtain the value of accident consequences , i.e.:

$$A_c = (C + M + E + S)/4 \tag{6}$$

4. Traffic Safety Risk Assessment on Wuhu Section Based on AREEAC

4.1 The Calculation of Accident Rate

This paper will use the evaluation method on Wuhu section of the busy 3 years 2011 to 2013 for traffic safety comprehensive risk evaluation of longitudinal water. First we collected traffic flow and accident data on Wuhu period of the Yangtze River from 2011 to 2013. Traffic flow: 554490 ships in 2011, 529830 ships in 2012, 518885 ships in 2013; accident data: 19 cases in 2011, 24 cases in 2012 and 30 cases in 2013.

According to the data in Table 3 and referring to the formula (2) we obtained accident rate on Wuhu segment for three years from 2011 to 2013: $A_c(2011)$=3.43; $A_c(2012)$=4.53; $A_c(2013)$=5.78 (unit :Thousand ships/year).

4.2 Calculation of Relative Environmental Adjustment Value

Getting score of 8 factors of the objective environment from the analysis of actual situation on Wuhu between 2011 to 2012, and in accordance with many experts studied of the relevant scientific project, scholars and the views of the crew, 8 the value of objective environmental factors of the Yangtze trunk busy segment statistics compiled are shown in the table (see Table3).

Table 3.Grading value and weight of objective environmental factors in the Yangtze Trunk busy part

environment all factor	traffic flow	visibil ity	wind	flow rate	course width	tortuosity	water depth	Aid to navigation
2011	5	2	3	2	1	5	4	3
2012	5	2	3	2	1	5	3	3
2013	5	3	3	2	1	5	3	3
Weight W_i	0.26	0.18	0.05	0.09	0.13	0.10	0.12	0.07

Reference formula (3), (4), (5), we calculate the relative environmental adjusted value on Wuhu for nearly 3 years 2011 to 2013: Environmental risk value (F):3.13 in 2011, 3.19 in 2012 and 3.37 in 2013. Take the objective environment risk value of 2011 as the baseline to calculate the relative environmental adjustment value (E_f):1 in 2011, 0.96 in 2011 and 1.02 in 2011.

4.3 Accident Consequence Assessment

According to the data required for this accident consequence assessment method for evaluating，then statistical sorting water traffic accident consequences detail in Wuhu section of the busy trunk line of the Yangtze River from 2011 to 2013, water traffic accident consequence assessment value calculated referring to the formula (6) of Wuhu section on the Yangtze trunk busy segment in the nearly three years are shown in the table (see Table 4).

Table 4. Water Traffic Accident Consequences Assessed Values of Wuhu Section in the Yangtze River from 2011 to 2013

Year	2011	2012	2013
Casualties C	4.6	4.2	3
Economic loss M	4.8	5.6	7
Environmental pollution E	0.3	1.5	0.3
Social influence S	5.7	8.1	9.6
The accident loss value A_c	3.85	4.85	4.93

4.4 The Analysis of Comprehensive Evaluation's Results

The above results are substituted into the formula (1) to get the water traffic comprehensive risk value on Wuhu section nearly 3 years as shown in the table (see Table 5).As can be seen from table 4, 2011 to 2013, water traffic accident risk appraisal of the busy trunk line of the Yangtze River in Wuhu section of AREFAC values were 13.21, 21.17 and 29.07. Water traffic safety situation nearly three years on Wuhu show the best in 2011, then in 2012, the worst in 2013.

Table 5. Risk Assessment of Water Traffic Based on AREFAC on Wuhu Section of the Yangtze's Busy Trunk Segment from 2011 to 2013

Year	2011	2012	2013
A_r	3.43	4.53	5.78
E_f	1	0.96	1.02
A_c	3.85	4.85	4.93
R_c	13.21	21.17	29.07

Analyzing the evaluation results, the reason is as follows:

(1)From the point of accident rates the maximum traffic flow on Wuhu section in 2011 is 554490, but the water traffic safety accidents number is 19 that at least in three years, all lead to the lowest accident rate in 2011. Traffic flow on Wuhu section in 2013 is the least the last three years, the corresponding water traffic safety accident is the most as 1.5 times the number of accidents in 2011, which all led to water traffic accidents in Wuhu section in 2013 significantly higher than the previous two years.

(2)From the analysis of relative environmental adjustment value, because the relative environmental harmony degree is mainly with large difference in the horizontal risk assessment comparison in different segment, but the relative environmental harmony degree of risk evaluation in the longitudinal in the same segment nearly 3 years has little difference so leading to small influence on the assessment results.

(3)From the analysis of accident consequence assessment in 2013, the number of accidents is largest in 2013 in Wuhu segment and four indicators of accident consequence assessment show as follow: 12 casualties just less than18 casualties in 2011, 5 sunken ships, the economic losses is as high as 630 ten thousand Yuan. All the above made the consequences of the accident to a corresponding maximum value in 2013.

From the above analysis, in combination with the status of water traffic safety supervision and management in the Yangtze River in recent years, it is not difficult to find water traffic safety management in the busy part of the Yangtze River still need to be improved in many aspects: (1)To promote technology innovation of safety navigation: The implementation building of AIS and VTS, CCTV in main busy segment, integrated use of GPS satellite positioning, electronic chart, wireless communication, radar, SMS group sending device and other scientific and technological means in order to explore and enrich the means of stereo Cruise etc. (2) Covering AIS (GPS) system in the busy segment of the Yangtze Rive, construction of the integration mechanism of electronic cruise for help, preparing plans database system, etc. that all can further improve the early warning management and emergency rescue mechanism; (3)Popularization of safety culture education can improve water traffic safety culture and we should improve navigation safety protection system.(XIONG Bing, 2011)

5 Conclusions

The AREEAC evaluation method considering the rate of accident, the consequences of objective environmental factors and the impact of the accident to the water traffic safety, the most obvious characteristics and innovation place are simple, strong operability and suitable for practical application.

While AREEAC risk evaluation method proposed in this paper has considered three aspects as the accident incidence, objective environmental factors and accident consequences and been on the quantitative processing. But the indicators of membership degree and weight given by the many are based on the expert's experience evaluation, which makes the conclusion of the evaluation is too subjective. Therefore using more objective scientific methods will be another main content of the future. That requires the government, research institutions and shipping companies and other multi persistent co-operate to ensure the water traffic's safety of the Yangtze trunk segment.

References

Fujii, Y. (1974). “Some factor safe affecting the frequency of Accidents in marine traffic”. Journal of Navigation, 27.

HAN Yansheng. (2006). “Research of the Yangtze River water traffic safety evaluation system”. Wuhan University of Technology.

HU Shenping. (2010). “Research on risk assessment of coastal traffic safety”. China navigation, 2010 (03): 50-55.

HUANG Liwen. (2005). “The index system research on water transportation safety evaluation of the Yangtze River”. Beijing: Institute of Navigation China, 2005(12): 88-91.

LI. Zhuo (2013). “The risk assessment of water traffic safety on the Yangtze River”. Wuhan University of Technology.

Nii Yasuo. (1992). “Effects of navigation safety evaluation in the natural environment conditions”. The Japanese maritime traffic engineering set, 145-152.

XIONG Bing. (2011). “The three gorges reservoir water traffic safety control and emergency management research”. Wuhan University of Technology.

Yuhong WANG. (2003). “The channel above Wuhu reopened seagoing waterway”. Yearbook of Wuhu.

ZHANG Shengkun. (2003). “Ship and marine engineering risk assessment”. Beijing: National Defense Industry Press, 12-13.

ZHAO Jiani. (2005). “Review of Comprehensive safety assessment (FSA) method”. Journal of navigation technology, 2005(2):77-78.

Lifeline Road Planning Method in Disaster-Prone Areas

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Abstract: Road system is one of important part of lifeline systems in disaster-prone areas. It is very significant to do the lifeline road planning in disaster-prone area to mitigate disaster loss and save lives. The paper borrowed ideas from developed countries about lifeline road's definition, planning methods, and planning experiences. After that, the definition of lifeline road in our country has been set. And several affect factors of lifeline road planning were found, they are: natural characteristics, type of disasters, spatial distributions, transportation system, and other lifeline system distributions. The planning object was set up to build a definite function, wide coverage, flexible and reliable, and smooth lifeline road system. According to the object, basic principles were suggested and the planning method was provided. By integrating node layout and dynamic programming with the guidance of planning objects, there are two paths to planning the lifeline road based on evaluating existing road network, the first one is to select critical links of road network, and the second one is to improve the road network structure.
Keywords: Lifeline road; Disaster-prone area; Planning method.

1 Introduction

Natural disasters such as flood, earthquake, debris flow, freezing rain and snow, occur frequently in China, which causes huge loss of life and property. Road system is one of important part of lifeline systems in disaster-prone areas. It is very significant to do the lifeline road planning in disaster-prone area to mitigate disaster loss and save lives. Till now, we do not have specific researches about lifeline road planning method in disaster-prone area. In disaster-prone area, it is not enough to repair road infrastructures after natural disasters occurred. The more important thing is to take preventive measures before natural disasters occurs. So it is necessary to operate the research on lifeline road planning method to strengthen the road network, improve the safety and reliability in disaster-prone area.

2 Literature Review

There are numbers of researches defined lifeline system in past years. Duke and Moran (1975) is one of the pioneering papers on lifeline system, which classified lifeline system as: Energy (Electricity, Gas, Liquid Fuel), Water (Potable Flood, Sewage and Solid Waste), Transportation (Highway, Railway, Airport, Harbor), and Communication (Telephone and Telegraph, Radio and Television, Mail and Press).

Hall (1991) states in his state-of-the-art report, “Within a broad definition lifelines can be defined as those utilities, facilities, structures and equipment that make up much, but not all, of the fabric of our infrastructure, whether it be in a rural or urban setting” . Platt (1995) defined transportation and communication lifelines as: among the critical networks required for moving material, people and information among locations distributed in geographic space. And Chang (2000) pointed out that “performance and recovery of transportation systems appear to play a major role in the development of long-term impacts. This arises in large part because transportation infrastructure often requires substantially lengthier repair times than other lifeline systems. ”

Some of researchers did studies on finding approaches to strengthen or improve lifeline road network. Sakakibara (2004) found that it is critical that individuals in each district have access to vital facilities in their local neighborhood so that no district is isolated. They used a topological index to quantify road network depressiveness/ concentration to evaluate the isolation of district in a city. Miller (2003) stated that many approaches have been used to measure lifeline roads' vulnerability but most can be grouped into two major categories: performance based indicators (network reliability and network performance) and user based indicators (accessibility).

Lifeline road planning is one of important part of disaster prevention in developed countries. In 1998, the American Lifelines Alliance (ALA) established to facilitate the creation, adoption and implementation of design and retrofit guidelines of lifeline system. In New Zealand, Transport Agency published the report titled *Engineering Lifelines and Transport- Should New Zealand be doing it Better?* The report examined New Zealand engineering lifelines activity, its level of integration in road controlling authority management practices, and its relationship to the resilience of roading networks to natural hazards.

3 Definition and Impact Factors of Lifeline Road

Based on definitions of previous researches, the definition of lifeline road in this paper is: critical roads with high resistance against natural disasters which connecting vital facilities inside districts and between districts.

Numbers of factors impact lifeline road planning, they are:

(1) Natural characteristics. Including topography, geology, and climate which are important impact factors of general road network planning;

(2) Type of natural disasters. It is the most important factor which impacts the demand of lifeline roads, road strengthen technologies chosen, and the location of new lifeline roads;

(3) Spatial distributions. The distribution of vital facilities such as residence districts, shopping malls, hospitals, and schools.

(4) Existing road network. Lifeline road planning should be based on existing road network by strengthen existing roads and construct new roads.

(5) Layout of railway, airport and harbors. Lifeline road planning should consider the connection of railway stations, airports and harbors. And they also impact the function of lifeline road when considering of the whole comprehensive transportation system.

(6) Layout of other lifeline systems. Lifeline road is the base and connection of other lifeline systems. Lifeline road planning should also consider the connection of energy system, communication system, water supply and drainage system, and sanitary system.

4 Objectives and principles

4.1Objectives

The planning object was to build a definite function, wide coverage, flexible and reliable, and smooth lifeline road system. Detailed objectives are:

(1) All districts in the region have at least two roads with enough capacity connecting with other regions, make no district is isolated after disaster occurred;

(2) There is at least one road with enough capacity connecting with railway stations, airports and harbors in the region;

(3) There is at least one road with enough capacity connecting with vital facilities including energy system, communication system, water supply and drainage system, and sanitary system.

4.2 Principles

(1) Consider the demand of economic and social development after fully satisfied the demand of personnel and material delivery when disasters occurred;

(2) Choose the road which could serve more people after connected basic nodes;

(3) Choose existing roads first, if there is no existing road, then build a new one;

(4) Fully consider the geography, geology and climate characteristics in disaster-prone areas, make the road construction coordinate with the environment.

5 Lifeline Road Planning Method

There are two paths to planning the lifeline road based on evaluating existing road network, the first one is to select critical links of road network, and the second one is to improve the road network structure.

The planning procedure could be summarized as following:

(1) Confirm planning area and set up planning objectives. It is the first and basic step of lifeline road planning.

(2) Collect related materials and analyze the demand. Related materials including: type, history, distribution and characteristics of natural disasters in the planning area and their impacts to roads; population, industry, and urbanization of planning area; geography, geology and climate characteristics of planning area; and the layout of vital infrastructures such as school, hospital, supply station, transportation system, urban street, metro system and pipelines.

(3) Choose connecting nodes. It is the pivotal step of lifeline road planning. Generally, we choose connecting nodes as residential areas, manufacturing districts, airports, railway stations, bus stations, harbors, energy bases, water bases, communication center, hospitals, and schools.

(4) Evaluate of existing road network about the ability of resistant disasters. The purpose of this step is to find out the pivotal roads and weakness of the road network by physical topology method. The physical topology of road network means the structure of a network, including device location and cable installation.

- The method of identifying critical links of road network. The definition of critical links of road network in the paper is: roads with high probability to make the district isolated after destroyed by disasters. There are some methods and indexes to identify pivotal roads based on previous researches such as the Mincuts Frequency Vector by Bulteau and Rubino (1997). The Mincuts Frequency Vector could compare two different topologies and point out edges make the network more vulnerable.
- The method of identifying weakness of road network. Sometimes we strengthen the road network by constructing new roads. The purpose of identifying weakness of road network is to decide which road contributes most to strengthen the network. The Topological Index (TI) proposed by Hosoya (1971) could be used to quantify road network depressiveness and compare the effect of adding a new road.

(5) Planning lifeline road. Lifeline road comes from two ways: one way is to strengthen critical roads of existing road network; the other way is to construct new roads to strengthen the whole road network. The planning procedure is shown as following:

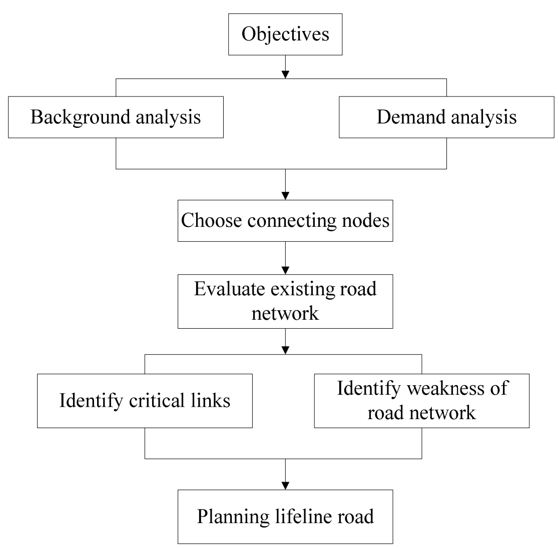

Figure 1. Lifeline road planning procedure

6 Conclusions

Lifeline road planning is more concern about connecting with critical nodes and avoiding isolated which is differing with regular road network planning. It is very significant to do the lifeline road planning in disaster-prone area to mitigate disaster loss and save lives. The paper borrowed ideas from developed countries about lifeline road's definition, planning methods, and planning experiences. After that, the definition of lifeline road in our country has been set. And several affect factors of lifeline road planning were found. The planning objectives were set up and basic planning principles were suggested. We found that there are two paths to planning the lifeline road based on evaluating existing road network. The lifeline road planning procedure was drawing out to guide the lifeline road planning in disaster-prone areas.

References

Bulteau S. and Robino G. (1997). Evaluating Network Vulnerability with the Mincuts Frequency Vector. *Publication Interne N^{o} 1089, Rennes: INRIA*, 3-20.

Chang S. E. (2000). Transportation Performance, Disaster Vulnerability, and Long-Term Effects of Earthquakes. *Second EuroConference on Global Change and Catastrophe Risk Management. Laxenburg*, Austria.

Duke C. M. and Moran D. F. (1975). Guidelines for Evolution of Lifelines Earthquake Engineering. *U.S. National Conference on Earthquake Engineering.* Ann Arbor,367-376.

Hall W. J. (1991). Lifeline Earthquake Engineering at the Turn of the Century. *3rd U.S. Conference on Lifeline Earthquake Engineering.* Los Angeles, 1-16.

Hosoya H. (1971). Topological Index. A Newly Proposed Quantity Characterizing the Topological Nature of Structural Isomers of Saturated Hydrocarbons. *Bull. Chem. Soc. Jpn.,* 44, 2332-2339.

Miller H. J. (2003). The Geographical Diensions of Terrorism. *Transportation and Communication Lifeline Disruption*, Routledge. 145-152.

Platt R. H. (1995). Lifelines: An Emergency Management Priority for the United States in the 1990s. *Disasters 15*, 172-176.

Sakakibara H., Y. Kajitani, et al. (2004). Road Network Robustness for Avoiding Functional Isolation in Disasters. *Journal of Transportation Engineering*, 560-567.

Research Review of Rail Transit and Urban Space Integration Development

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Abstract: As having the technical feature of rail transportation model，the urban rail transit is widely regarded as one of the effective ways to improve the current situation of urban public traffic and environmental problems. Especially at the background of adding the Megalopolis type in China, the construction of rail transit and urban space is facing increasing complex and intertwined problems, which relates to the engineering disciplines of traffic planning, traffic operation and management, urban planning and design, architecture and landscape design, as well as other disciplines of economy, anthropology, sociology and so on. So summarizing the Integrative development method of urban rail transit and urban space is of urgent significance. By concluding and reviewing the relating research and project, the research condense the trends of integration of urban rail transit and urban space, and furthermore the new key problems of Integrative development of urban rail transit and urban space.
Keywords: Urban rail transit; Transport planning methodology; Urban space; Integrative development; Review.

1 Introduction

In recent years transportation means have expanded from walking pedestrian routes to cars, buses, taxis and urban rail transit. Updating transportation methods not only directly changes the travel mode, but also has a marked impact on the urban space. Urban rail transit has been treated as a typical representative of the new development of urban public transport modes in recent years. As the urban public three-dimensional passenger transport system featuring in the main rail transport, urban rail transit has been generally accepted and welcomed for its large capacity, time efficiency, low pollution and low energy consumption. It has been widely researched by many countries, especially developing countries, and is generally seen as one of the most effective ways to improve the current situation of urban public transport and mitigate environmental issues.

Compared with other transit modes in the city, the underground rail transit improves the land utilization, and the degree of freedom of the city space layout to a certain extent. Rapidly developing rail transport lines and stations have become a new element in the urban space, leading to new phenomena, new features, new laws and new relations to the urban space under such influence. As rail transit construction and urban space are faced with ever more complicated and intertwined issues, it involves multiple engineering disciplines, such as transportation planning, transportation operation and management, urban planning and design, and architecture and landscape design, as well as integrated disciplines such as economics, anthropology and sociology. In recent years, under the guidance of important theories like the compact city, TOD, transit metropolis and smart growth, research scholars have made fruitful exploration into the theory and practice of rail transit and urban space integrative development from different perspectives. By sorting and reviewing the current situation of studies on the rail transit and urban space integrative development, targeted methodological guidance will be provided to address the practical problems in the process of building a sustainable city.

2 Summation and analysis of research status

After integrating into urban space, rail transit will impose impacts on the urban spatial form, urban transport system, social patterns and economic conditions, and some impacts are overt but some are covert, which take a long time to embody.

2.1 Aspect of city and architecture

As the main arteries through the urban area, the smooth operation of the transportation network is directly related with the urbanization process and effective solution of such issues. At present, there are some conflicts between the development of rail transit and the layout of the city development, but the problems are gradually improved with the overall planning more scientific. Rail transit development and the urbanization process affect and improve each other. The development backgrounds are different in Paris, London, Tokyo, Stockholm and Hong Kong, and the reason why such cities became globally recognized model cities for rail transit development is closely connected with the promotion of urbanization and guidance of orderly and compact city growth by developing the TOD mode（Tiwari R., Cervero R., Schipper L.，2011）.

As an important interface between city and transportation, the rail transit complex is the primary form of transport in the city center integrating into the city, and also an effective way to realize reasonable resource allocation within a limited space, having advantages of multifunctional synthesis, full service, integrative space and three-dimensional expansion. In the high speed development period of rail transit construction, the construction of station complexes became an important implementation method for the research on rail transit and urban space integration on the micro-level.

2.2 Aspect of transportation

Compared with the traditional local public transport system, urban rail transit has a more significant decisive effect on the spatial pattern, and introducing urban rail transit will recombine the accessibility in cities and push change of the urban structure（Huang Zhigang，Jin Zeyu，2010）. The development and construction of rail transit bring significant impact on surroundings along the lines and around the station mainly in aspects of integrated land use and urban spatial evolution, as well as space value and comprehensive benefits brought by stations.（Krause A L，2012）.

Different countries face different problems. Taking China as an example, it mainly faces the problems of poor accessibility to the destination, complicated paths and low space quality for travelers（Sohn K.& Shim H.，2010）. Facing practical problems, the urban builder and administrator put forward specific optimization strategies usually by integrating resources related to rail transit construction, and strictly controlling the nature of land-use and building density of the land along rail transit lines and around stations. Rail transit construction also impacts on the type and development mode of surrounding land by changing location conditions of the area along the lines and around the station.（Ratner K. A.，2013）.

2.3 Aspect of society

In the rapid process of urbanization, the people-oriented social function of urban space cannot be changed, and the social aspects of rail transit become important. This is seen in many cities and is also a key issue in the process of rail transit and urban space integrative development（Ewing R., Handy S.，2009）. It remains highly meaningful for the sound development of cities, improving the attractiveness of public transport, and easing traffic and environmental pressure.

In recent years, the “transfer” problem has gradually become a focus after rail transit integrated into the urban system, and it is also a key link for realizing rail transit and urban space integration. Many studies show that a good connection quality is not only key as to whether rapid transit in large capacity is achieved and encourages more people to transfer to rail transit, but also one of the important foundations for the safety of passengers. From the sociology perspective, the discussion of rail transit and urban space integration at the level of physical perception and behavior pattern of pedestrians is currently very lively.

2.4 Aspect of economy

Benefits generated from rail transit and urban space integrative development are various and remarkable, mainly including space benefits, social benefits, environmental and economic benefits. The influence of rail transit on the real estate market embodies the value of rail transit’s influence on the urban space. A specific influence is to change the original land price distribution by enhancing the accessibility of the surrounding area, reducing travel costs and improving the original urban spatial pattern, but there are different perspectives in studies on the specific influence level（Fang Jing，Chen Rongqing，2013）.

Land use plays an extremely important role in rail transit construction and urban space creation. Good interaction should be kept between them. Studying the influence on land use has important implications for improving the density of land use, researching rail transit and urban space integration and realizing the urban sustainable development（Zhao Yanjing，2007）. At the level of specific implementation, urban rail transit can promote high-density and high-strength development and use of land along the lines, increase the efficiency of land use, and increase the economic and social vitality of the area along the lines（Bian Jingwei，2009）.

3 Trends of research and Practice

(1)Diversification of research disciplines

Statistics show that globally, the highest proportion of studies concentrate on engineering and transportation, and keep increasing, although of course all areas are comprehensively discussed and new fields such as urban studies are developing. In China specifically though the main focus comes from the angles of “resource sharing” and “land utilization” and most discussions are from a macro perspective. From the macro and micro perspective, the ratio of studies on the key link of “transfer” in transportation and urban space integration is low all the time, but having an increasing trend.

(2)Complication of existing problems

Many studies show that problems in rail transit and urban space integration in China at present are getting more and more complicated and are no longer just problems at the level of operations management and transportation planning. As a complex and gigantic system as a whole, the comprehensive effectiveness of cities is closely related to the matching degree of various subsystems. The actual operation efficiency of the rail transit system has to rely on the participation and coordination of subsystems in other relevant cities, and higher rail transit efficiency is crucial for the orderly development of urban space.

(3)Integration of solutions

Since existing problems are complicated, the “transportation-city-building” integration-design theory system and method shall be established by synthesizing problems and integrating multiple disciplines like transportation planning, urban planning, urban design, architectural design and landscape design from a comprehensive perspective. Taking transport efficiency and space quality evaluation in studies on rail transit stations and urban space integration as an example, we will leave out the traditional single simulation for passenger flow around rail transit stations and the evaluation of urban sustainability. Meanwhile, simulation and evaluation of rail transit and urban space integration is an important way to solve transportation and urban problems（Figure 1）.

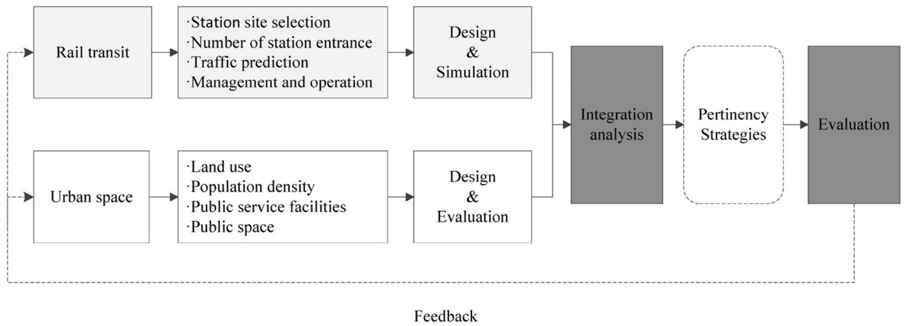

Figure 1.Integrated optimization idea of rail transit and urban space

4 Conclusions

After gradually planted into city built area, urban rail transit lines and stations have been fusing development with original city space, which resulting in a series of new space, new phenomena, new problems, new rules need to research deeply and optimizing. By combining relevant urban practices and research, the following two key conclusions were extracted:

(1) Establishing scientific contact among "Traffic mode - Behavior rules - Urban space". Through studies on rail transit and urban space integration, taking "Behavior rules" on transportation as the medium and link, we can reveal the relating principle. We can break through the limitations of discipline classification, clarify the scientific contact and the coupling properties among the "Traffic mode - Behavior rules - Urban space", find the objective principle of comprehensive connection in Influenced Urban Realm around Station, and provide corresponding theoretical support for precise studies on urban space from an intensive, systematic and synergic perspective.

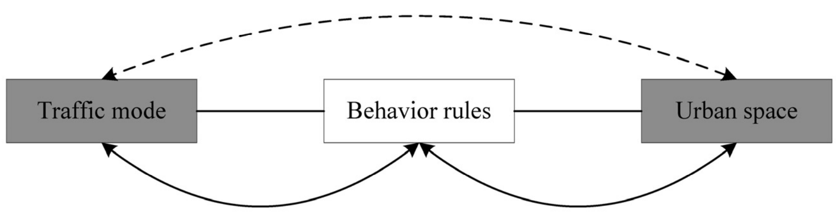

Figure 2.Integrated optimization idea of rail transit and urban space

(2) Forming the "transportation-city-building" integration design theory and method system under the influence of urban rail transit. Based on the solution of key issues at the first level, relevant achievements and academic ideas in fields of transport planning and design, urban planning and design, architectural design, and landscape and public design ought to be integrated effectively, and new theories, new tools and new methods should be sought.

The aim should be to ultimately improve urban transport efficiency, urban living quality and urban space quality, and to deliver results which are both theoretically credible and have practical meaning.

5 Recommendations for Future Research

Firstly，as the carrier of event, precise definition of radiation realm of rail transit station which has the character of complex function, diverse behavior, sensitive ecology and technology complex is very basic to in-depth knowledge and optimization to the space whose health is directly related to the city traffic, travel mode, image of city, city disaster prevention and so on. Secondly，selecting the most suitable method to solve the problems in the radiation realm of rail transit station. Thirdly，building integration development guidance to rail transit and urban space in different levels of point，line and plane in order that lay a solid foundation to progressive solving the problems in different levels and the whole urban environment sustainable development.

Acknowledgement

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References

Bian Jingwei. (2009). “Development Patterns of Urban Rail Transit and Spatial Structure.” *URBAN TRANSPORT OF CHINA*, 5. 40-44.

Ewing R., Handy S. (2009). “Measuring the Unmeasurable：Urban Design Qualities Related to Walking.”J*ournal of Urban Design*,14.65-84.

Fang Jing，Chen Rongqing. (2013). “The review of influence of rail transit domestic to housing price .”*Economic Research Guide*,19.220-221.

Huang Zhigang，Jin Zeyu. (2010).“Traffic Terminal's Impact on Urban Spatial Structure Evolution .”Urban Mass Transit,10.10-13.

Krause A. L，Bitter C. (2012). “Spatial econometrics, land values and sustainability: Trends in real estate valuation research.” *Cities*, 29.S19-S25.

Ratner K. A., Goetz A. R. (2013). “The reshaping of land use and urban form in Denver through transit-oriented development .” *Cities*, 30. 31-46.

Sohn K., Shim H. (2010). “Factors generating boardings at Metro stations in the Seoul metropolitan area .” *Cities*, 27. 358-368.

Tiwari R., Cervero R., Schipper L. (2011). “Driving CO2 reduction by Integrating Transport and Urban Design strategies .” *Cities*, 28.394-405.

Zhao Yanjing. (2007). “Sustainable Urban Land Use Planning .” *Planners*, 6.74-76

Problems and Improvement Measures of Highway Traffic Safety Facilities

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Abstract: As to improve road traffic safety and traffic efficiency, this paper focused on the study of highway traffic safety facilities. By investigating the currently basic application of highway traffic safety facilities, combining with the traffic accidents statistics and the setting regulation of highway traffic safety facilities, the problems of each kind of safety facilities were described in detail. Result shows that the main problems existing is caused by the lack of traffic safety facilities and unreasonable traffic safety facilities' setting. Finally, this paper analyses the causes of the problems from the planning, design, construction and maintenance management of highway safety facilities and puts forward the improvement measures.
Keywords: Traffic safety; Traffic safety facilities; Setting problems; Improvement measures.

1 Introduction

With the development of the socio-economic level, the road transport developed rapidly, road accidents' number is also increasing, which becomes the focus of attention. After a lot of research, Treat and Sabey found that people, vehicles, road-related accidents showed as Table 1, where road-related accidents accounted for 28% to 34%, which is an important factor affecting traffic safety.

Table 1. The proportion of people, vehicles, road-related accidents

The reason	Only Road	Only people	only Vehicles	Road & People	People & Vehicles	Vehicles & Road	People , Vehicles & Road
Sabey conclusions /%	2	65	2	24	4	1	3
Treat conclusions /%	3	57	2	37	6	1	3

US had settled up multiple vehicle crash test site, has accumulated a lot of experience in setting fence, has a large number of experiments on the material, form and structure of the fence system from experiment, developed a series of standards in guardrail's design, selection and installation and maintenance (Yan Xinping, 2009). European countries researched the type and structure of highway guardrail, forming a complete experimental system and procedures, and combining the characteristics of each country's road traffic environment to develop a appropriate barrier (He Xinyun, 1999). Japan focus on simple and practical, amended several times, making the road traffic safety facilities' settings is more simple and practical (Cheng Binsheng, 1989). Chinese traffic safety measures were mostly in traffic management, mainly from training of security awareness (Wang, Y. J, 2009), relying on rules and regulations for the management, little research of the engineering technology. In recent years, research on the security facilities has made some results (Shi Maoqing, 2005), but there are still some unreasonable conditions in traffic safety facilities' setting (Fan, X, 2006)).

2 Highway Traffic Safety Facilities

2.1 Fence

Fence is an important part of Traffic safety facilities, plays an important role in preventing traffic accidents. It can effectively prevent the vehicle crossed the median strip to prevent the vehicle left the road, it can absorb energy through the deformation of the fence to lessen the severity of the accident, at the same time, induce a driver's view of the road to make contour and linear be clearly observed.

2.2 Traffic Sign

Traffic sign, with a predetermined pattern, symbol, or text, transfer traffic information to pedestrians, drivers and other traffic participants.

Its role is to organize, manage and guide traffic to run, to provide allowable route to road users, to protect the vehicle safe and smooth operation, but also the specific measures of road traffic organization design implementation.

2.3 Road Marking

Road marking is a kind of transportation facilities installed on the road with in a variety of lines, arrows, text, graphics and facade marks entity tag, protruding signs or outline standard. Its role is to inform users of road traffic passing rules, warning, guidelines and other information. It can be used alone or in conjunction with the sign.

2.4 Glare Facilities

Glare facility is used to improve night driving environment and prevent drivers suffer nighttime glare interference of structures. Glare facilities usually set in the center median strip of road, the main purpose is to eliminate the moving car headlights at night causing the driver glare interference. Setting glare facility can make nighttime driving conditions more favorable, increases driver's line of sight, thus weakening the tension of driver, effectively reducing the probability of road traffic accidents and improve traffic safety.

2.5 Sight Inducing Facility

Sight inducing facility is provided along the road, for identifying the road line shape, direction, roadway and the dangerous road. it can expand through the line of drivers' sight, thereby to make protection of secure driving.

2.6 Other Safety Features

It include isolation facilities, lighting, crash facility, crosswalk, hedge lane, anti-wall, cooling pool, convex reflector and other facilities in order to improve road safety.

3 The Situation of Highway Traffic Safety Facilities

Nearly half of China's traffic accidents occurred on secondary and below roads. The low standard level of these roads, poor road conditions and traffic safety facilities lack or unreasonable, lead to highlighting security risks and easily traffic accidents.

A large number of statistical data shows that about 30% traffic accident is concerned to the vehicle outside the outlet, about 10% caused by the collision of vehicles and roadside hazards (including the bridge pier, railings, tree, lighting fixtures, mark column and other road infrastructure).

Road safety facilities plays an indispensable role in reducing traffic accidents. Table 2 showed the relationship of roadside protection and traffic accidents (LIU Jing-hui., 2011). It can be seen from the table, no protection facilities conditions, traffic accidents has a big number and most serious harm. No protective facilities condition the traffic accident is 4.1 times of the protective facilities, and casualties reached 5 times as much.

Table 2. The Relationship of Roadside Protection and Traffic Accidents

protective facilities	Accidents number		Deaths number		Injured number	
	number	Proportion (%)	number	Proportion (%)	number	Proportion (%)
Waveform guardrail	17990	7.55	8243	12.16	23880	8.68
Collision walls	3613	1.52	1237	1.83	4401	1.60
Protective pier	7151	3.00	2361	3.48	8530	3.10
Other protective facilities	38711	16.24	9037	13.34	43390	15.77
no protective facilities	170886	71.69	46881	69.19	194924	70.85

4 Problems and Analysis of Traffic Safety Facilities

4.1 Plan

Highway traffic safety facilities system in China carried out in recent years. In terms of planning, there is a systematic approach and lack of planning. Safety facilities did not get attention, more not considered together in the plan with other facilities of highway engineering, often tended to consider safety facilities after completion of other engineering facilities, which makes the entire road system poor coordination and influence the highway traffic function (LI Fu-yong, 2006). Evaluation on the safety, reliability and environmental aspects of the planning scheme of safety facilities little to consider even is not involved, due to the lack of planning, traffic safety facilities application cannot form a complete system, thus causing traffic safety facilities system a lot of problems in the overall application.

4.2 Design

In spite of the design in accordance with national standards and foreign examples, consider the characteristics, the geographical information, climate conditions and the factors of highway construction investment of the road, select the appropriate structure and materials, reasonable setting of highway safety facilities. But as a result of the planning of safety facilities system in China on the issue, has not formed on the design norms of traffic safety facilities, lack of safety facilities for the software design, the vast majority of the design of safety facilities are based on personal experience, this caused the subjective factors become the main factors influence in the design, it led to poor safety facilities.

4.3 Construction

Construction safety facilities are usually started after the road construction, there will often be in a not good situation in safety facilities and the main project. The construction unit of safety facilities is most important to guarantee the quality, but in order to shorten the construction period, some construction units had not set the safety facilities with the requirements of the construction.

More seriously, there is a construction unit Jerry situation, it bring that safety facilities set did not adopt the design requirements of the process and materials are not strictly construction, which makes the construction quality of safety facilities not to meet the design requirements, which greatly reduced safety performance, so that the overall decline in road safety.

4.4 Management

The maintenance work of safety facilities is to protect the safety of facilities can play an important role of security protection in normal for a long time. But now the traffic safety facilities maintenance has not been taken that of attention like highway pavement maintenance, which caused that the setting and updating of the highway safety facilities haven't meet the demand of road. The lack of traffic safety facilities maintenance equipment of advanced technology, make the maintenance work more difficult, and impact the capacity of highway traffic. On the other hand, because of the inadequate propaganda and supervision of highway management department, there are many security facilities man-made damage, seriously affecting the normal use of safety facilities.

5 Measures to Improve Road Traffic Safety Facilities

5.1 Technical measures

There are only two traffic-related laws "People's Republic of China on Road Traffic Safety Law" and "People's Republic of China on Road Traffic Safety Law Implementing Rules", although there is some provisions related to traffic safety facilities, but the operability of the law and regulations for the safety facilities' planning and management is not strong. Should make the law of traffic safety facilities through its planning, construction and management, implement safety responsibility, strengthen the planning, construction and management of traffic safety facilities, and make it more authority and operation.

5.2 Management Measures

5.2.1 Material Procurement Supervision

In material procurement, relevant departments should formulate corresponding management mechanism, prevent the materials safety facilities which cannot meet the standard requirements (Xiao Dian-liang, 2007). Rigorous testing of material properties, relevant departments should promptly notify the unqualified safety facilities purchasing department for rectification, accept the safety facilities materials which meet the requirements, and allow it to be input in construction.

5.2.2 Construction Supervision

The safety facilities of construction is carried out by the construction unit, safety facilities construction need to be synchronized with the road engineering to ensure the coordination of safety facilities and road facilities, in order to make the safety facilities to function properly, the traffic management department should supervise the construction unit of the road safety facilities, to ensure the safety of facilities construction is synchronized with the theme of the road engineering, to establish a good management mechanism to ensure the safety facilities engineering construction schedule, to prevent the jerry emergence, and to ensure the quality of safety facilities engineering.

5.2.3 Acceptance Supervision

After the highway safety facilities construction completed, organizing the relevant experts. Experts have to study the setting of safety facilities. If they found unreasonable situation, it means the safety facilities in a bad quality, it should not be accepted, but to inform the construction unit to rearrange the safety facilities, then check again until the entire road safety facilities to be acceptance of all. It should be avoided that road has been opened to traffic while the safety facilities are still setting.

5.2.4 Maintenance Management

There should establish a safety facilities inspection table, if not meet the requirements, the safety facilities should be promptly repair and rectification. In addition, the safety facilities maintenance also should strengthen the propaganda, strengthen the awareness of traffic safety facilities, advocate the masses care of traffic safety facilities, and supervise the destruction of traffic safety facilities, if traffic safety facilities found problems, timely to reflect to the relevant departments.

6 Summary

Through research discovery, lack of traffic safety facilities and unreasonable traffic safety facilities setting are the major problem in currently traffic safety facilities setting. In China, The main reason is the lack of long-term development planning, the lack of scientific design process, not deal construction effect, the relative lack of maintenance and management of the investment, the lack of necessary scientific management mechanism.

For these problems, our country should establish technology system of safety facilities in technology. In the management, our country should strength all aspects of supervision and management work, including materials procurement, construction, acceptance and maintenance management.

References

Yan Xinping, Huang Helai, and Ma Ming (2009). “American road traffic safety situation and research hotspot.” *Traffic information and safety*, 5, 1-9.

He Xinyun (1999). “Foreign road and traffic safety.” *Traffic and transportation*, 1, 011.

Cheng Binsheng, And Wang Shuhua (1989). “Application of traffic safety facilities on the highway.” *East China highway*, 3, 004.

Wang, Y. J. (2009) “The Optimization of Mountain Highway Traffic Signs and Deceleration Vibration Marking.” Chang'an University.

Shi Maoqing (2005). “Research and design of road traffic safety facilities.” Southwest Jiaotong University.

Fan, X. (2006). “Mountain Highway Safety Evaluation.” Chang'an University.

LIU Jing-hui. (2011). “Rural highway traffic safety status quo analysis and safety facilities improve countermeasures.” Chang'an University.

Li Fuyong (2006). “Evaluation of freeway traffic safety facilities system.” Chang'an University.

Xiao DianLiang, Chen Hong, and Jiang Feng (2007). “Feasibility Analysis of Selection of Safety Facilities on Rural Highways.” *highway*, 3, 152-155.

Transportation Security Assessment Method for a Mountainous Freeway Using a Bayesian Network

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Abstract: In order to solve the driving safety problem caused by the complicated terrain conditions and the changeable climate for mountainous freeway, it is necessary to construct assess index system to improve transportation security for mountainous freeway. The method used in this paper is: by taking the advantage of diagnosing and inferring the uncertainty of the knowledge of Bayesian network, we put forward a transportation security assessment model for mountainous freeway based on Netica. We use the model to evaluate a practical mountainous freeway and the result shows: the probability of the freeway section to keep in a safe state is 71.5%, and the safety grade of the road section of mountains freeway is 2.
Keywords: Mountainous freeway; Security assessment; Bayesian network (BN); Diagnostic reasoning.

1 Introduction

The geological and topographical conditions along the mountainous freeway are complicated, the overall geometric factors are poor and horrible weather often occurs, which is not conducive to vehicle operation, so transportation safety for mountainous freeway is a difficult problem in the traffic science research (Chen, 2013).

For improving highway safety, B. Φ .BABU Kov has been committed to research the relationship between the road condition and traffic safety since 1990, and had a study on safety evaluation of freeway section (Kov, 1990). Zheng Heng proposed to a method for roadside safety measurement using Bayesian network (Heng, 2008). Tian Yujia carried out an in-depth study on traffic safety of mountainous expressway bridge-tunnel sections and sets up the safety evaluation system of bridge-tunnel sections on mountainous expressway based on Bayesian network (Yujia, 2010). Yu Rongjie employed Bayesian inference method to evaluate Real-time weather and traffic variables, along with geometric characteristics variables (Rongjie, 2012). Meng Xianghai put forward a traffic safety evaluation method of the mountainous freeway section based on geometric alignment index by analyzing the relation between traffic accidents and geometric alignment (Xianghai, 2014). Up to now, few scholars conducted security assessment for mountainous freeway using the Bayesian network.

This paper presents a transportation security assessment model for mountainous freeway based on Netica. The model can effectively aggregation knowledge and experience of experts to update marginal probability of nodes, as well as flexibly conduct the diagnosis and sensitivity analysis of systems. Thus, the output of the safety assessment model can be used to compare the danger level for mountainous freeway. The model provides references for analysis on the safety hidden danger and making plan for improving the traffic safety for safety designers for mountainous freeway.

2 Bayesian Network

Bayesian Network (BN) has been widely-used approaches in probability theory at all times. A BN is a Directed Acyclic Graph (DAG) consisting of a set of nodes, representing variables with a finite set of states, and edges, which representing the probabilistic causal dependence among the variables (Yu, 2006).

Using Bayesian network method to establish traffic safety analysis model can do not only the accident probability prediction but also making accident diagnosis, thus finding out the weakest link of the system. As a traffic accident could be caused by multiple factors, in this paper, we give several main affecting factors of traffic safety for mountainous freeway; the precision of the model will increase along with other factors to be joined. Besides, other research results of transportation safety can also be used to improve conditional probability model in this paper, which making it more accurate.

3 Assessment Models of Traffic Safety Using BN

3.1 Topology structure of the BN of the traffic safety analysis

Due to the limitation of the special geographical conditions and nature environment of mountainous freeway, the horizontal curve radius, the longitudinal grade, the radius of vertical curve and the sight distance all have effect on traffic safety in the road factors for mountainous expressway. Meanwhile, lighting condition and ADT (average daily traffic) have intimate relationship with the driver's state. In addition, the accident occurrence has greatly close relation with environmental factors, therefore, the paper selects fault casualty number, weather condition as a measurement of the index of mountainous freeway.

In this paper, the analysis for mountainous freeway mainly to the driver's state, the road condition, and the environmental condition three aspects. Then, the paper will select eight observable variables and four latent variables to establish relations with the direct cause and the basic reason of accidents. The eight observable variables are “lighting condition (S_1)”, “ADT (S_2)”, “horizontal curve radius (S_3)”, "longitudinal grade (S_4)", "the radius of vertical curve (S_5)", "sight distance (S_6)", "fault casualty number (S_7)" and "weather condition (S_8)". The four latent variables are "the driver's state (B_1)", "road condition (B_2)", "environmental condition (B_3)" and "accident type (A)". For eight observable variables, this paper aggregates multi-group opinions of experts E (E_1~E_3) in traffic safety field to determine the marginal probability of nodes, and sets up the theory of Bayesian network model of bifurcate connection, as shown in Figure 1.

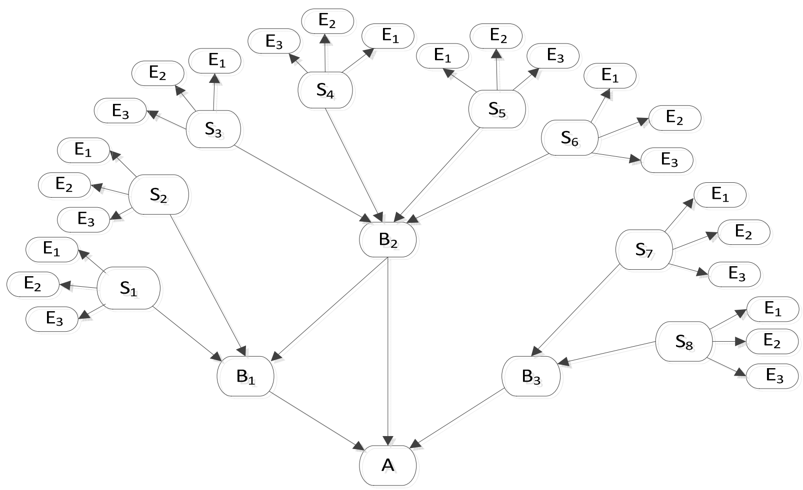

Figure 1.Topology structure of the Bayesian network

3.2 Marginal probability of node for aggregating experts' opinions via BN updating

For getting more objective evaluation results, we need to select a number of traffic safety experts to determine the judgment standard of every index. The 15 experts this article selected are equally distributed into three groups and every group of experts form a judgment standard after a deep discussion. Assuming that when the experts E_m (m=1, 2, 3) for a risk assessment of evaluation united, they would think the index S_i (i=1, 2, ⋯ ,8) as in a certain state E_{mn}, and the probability of the traffic accidents (refers to an accident in a month, the same below) is $P(S_i\!=\!Yes \mid E_{mn})$, where E_{mn} is the evaluation criterion of the expert E_m for index S_i. For the convenience of experts to evaluate index, the paper would use the appraisal interval values, as shown in Table 1, to divide the sensitivity extent of the index, and the medians of the appraisal interval values are used as the representative values to estimate $P(S_i \mid E_{mn})$.

Table 1. Appraisal interval values from the experts

Degree of sensitivity significance	$P(S_i \mid E_{mn})$（High）	$P(S_i \mid E_{mn})$（Low）
Very significant	1.0~0.8（0.9）	0.2~0.0（0.1）
Significant	0.8~0.6（0.7）	0.4~0.2（0.3）

Potentially significant	0.6~0.4（0.5）	0.6~0.4（0.5）
Low significant	0.4~0.2（0.3）	0.8~0.6（0.7）
Very low significant	0.2~0.0（0.1）	1.0~0.8（0.9）

Refer to the appraisal interval in Table 1, the evaluation criteria are listed on some indexes of different experts (Sulin, 2012),(Ahmed, 2011) as shown in Table 2.

Table 2. Assessment criteria of some factors from different experts

Index S_i	Expert 1		Expert 2		Expert 3	
	Criteria $P(S_i = Yes \mid E_{1n})$		Criteria $P(S_i = Yes \mid E_{2n})$		Criteria $P(S_i = Yes \mid E_{3n})$	
Horizontal curve radius S_3/m	(1) <2000	0.5	(1) <1500	0.6	(1) <2500	0.4
	(2) [2000,4000]	0.2	(2) [1500,3000]	0.25	(2) [2500,4000]	0.25
	(3) >4000	0.1	(3) >3000	0.1	(3) >4000	0.1
Sight distance S_6/m	(1) <165	0.4	(1) <165	0.5	(1) <150	0.6
	(2) [165,210]	0.3	(2) [165,300]	0.3	(2) [150,250]	0.3
	(3) >210	0.15	(3) >300	0.1	(3) >250	0.15
Weather condition S_8	(1) good	0.4	(1) good	0.6	(1) good	0.5
	(2) average	0.2	(2) average	0.25	(2) average	0.3
	(3) bad	0.1	(3) bad	0.1	(3) bad	0.15

According to the assessment criteria of index S_i, aggregated from different experts in Table 2, we can update the probability of index into each criterion under the premise of index $S_i = Yes$, and each node of $P(S_i = Yes)$ can be last updated based on the new evidence. Hence, they can be calculated using Bayesian theorem, which is shown as Eq. (1).

In Eq. (1), we can assume that $P(E_{m1})$=$P(E_{m2})$=, … ,=$P(E_{mk})$=1/k, as no information about the variable E_{mn} is provided yet. Then, We can calculate $P(E_{mn} \mid S_i = Yes)$ using Eq. (1), and calculate $P(S_i = Yes \mid E_{1n}, E_{2n}, E_{3n})$ using Eq. (2), so as to complete the modeling process of Bayesian network.

$$P\left(E_{mn} \mid S_i\right) = \frac{P\left(S_i \mid E_{mn}\right)P\left(E_{mn}\right)}{P\left(S_i\right)} = \frac{P\left(S_i \mid E_{mn}\right)P\left(E_{mn}\right)}{\sum_{n=1}^{k} P\left(S_i \mid E_{mn}\right)P\left(E_{mn}\right)} \quad (1)$$

$$P(S_i = Yes \mid E_{1n}, E_{2n}, E_{3n}) = \frac{P(E_{1n}, E_{2n}, E_{3n} \mid S_i = Yes)}{P(E_{1n}, E_{2n}, E_{3n})} \quad (2)$$

3.3 Model of reasoning and safety evaluation

Then we have established the Bayesian network model. For the road section with known influencing factor, we get the marginal probability of the root in the evaluation model by using aggregating experts' opinions via updating BN. Then we do the forward reasoning for the model by using the analysis model established by the BN analysis software packages-Netica, and we get the accident probability $P(A = Yes)$ for mountainous freeway. The paper will use the assessment criteria, as shown in Table 3, to evaluate the safety of mountains freeway using the probability $P(A=Yes)$.

Table 3. Assessment criteria of the mountains freeway safety

$P(A= Yes)$	Safety grade	$P(A= Yes)$	Safety grade
<0.1	1	0.1~0.3	2
0.3~0.5	3	>0.5	4

4 Applications

For a road section of mountains freeway with known influencing factor, the actual numerical values of influencing factor and the marginal probability updating are shown in Table 4.

Table 4. Marginal probability of root node via BN model

Index S_i	Actual numerical values	$P(S_i=Yes \mid E_{mn})$
Horizontal curve radius S_3	3500m	$P(S_3=Yes \mid E_{12},E_{23},E_{32})$=0.397
Sight distance S_6	230m	$P(S_6=Yes \mid E_{13},E_{22},E_{32})$=0.262
Weather condition S_8	average	$P(S_8=Yes \mid E_{12},E_{22},E_{32})$=0.353

We use BN analysis software packages-Netica to Figure 1 reasoning, finally the probability of system node A is "Yes": $P(A=Yes \mid B_1,B_2,B_3)$=0.285, as shown in Figure 2. Therefore, according to Table 3, the safety grade of the road section is 2.

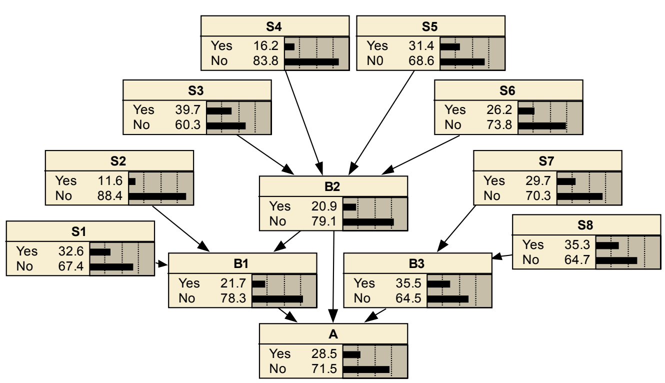

Figure 2. Final results of assessment

5 Conclusions

In this paper, based on past experience and the results of previous studies, the traffic safety analysis model is established using BN. The different views of different experts are reflected on the final results of the evaluation by BN. Meanwhile，we do the forward reasoning for the model by using the analysis model established by the BN analysis software packages-Netica, and we gets the accident probability of system, thus the security assessment for mountains freeway can be accomplished.

References

B.Φ.BABU Kov , Jing Tianran (1990). “Road conditions and traffic safety.” *Tongji University Press*, China, 42-58.

Liu Yu, Zheng Heng (2006). “Measuring Agility of Enterprise Using Analytic Hierarchy Process and Bayesian Beliefs Networks.” *Management Science and Engineering ICMSE'06. International Conference on. IEEE* (13th) ,551-556.

Meng Xianghai (2014). “An Accident Prediction Model for Expressway in Mountainous Hilly Area Based on Alignment Indexes.” *Journal of Highway and Transportation Research and Development*, China, 31(8),138-143.

Mohamed Ahmed, Huang, H., Abdel-Aty, M., & Guevara, B. (2011). “Exploring a Bayesian hierarchical approach for developing safety performance functions for a mountainous freeway.” *Accident Analysis & Prevention*, 43(4), 1581-1589.

Tian Yujia, Chen Hong (2010). “Safety Evaluation of Bridge-Tunnel Sections on Mountainous Expressway Based on Bayesian Network.” *10th International Conference of Chinese Transportation Professionals*, Beijing, China.

Wang Chen (2013). “Research on technology of transportation safety analysis and infrastructure assuring on mountain freeway.” *Chang' an University*, China.

Wang Sulin (2012). “Linear safetv evaluation of tunnel sections on mountain highway.” *Chongqing Jiaotong University*, China.

Yu Rongjie, Mohamed Abdel-Aty and Mohamed Ahmed (2013). “Bayesian random effect models incorporating real-time weather and traffic data to investigate mountainous freeway hazardous factors.” *Accident Analysis & Prevention*, 50 (2013): 371-376.

Zheng Heng, Li Changcheng (2008). “A Roadside Safety Assessment Method Based on Bayesian Network.” *Journal of Highway and Transportation Research and Development*, China, 25(2), 139-144.

Application of Fuzzy Set Pair Analysis in Poor Shunting Early Warning for a Track Circuit

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Abstract: Aiming at the problem of poor shunting failures in track circuit which seriously affect transportation safety, this paper proposes an early warning strategy based on fuzzy set pair analysis. For an example of 25 Hz electronic phase detecting track circuit, main influence factors are taken as early warning indexes through the failure mechanism analysis. In consideration of the effect of man-induced subjective factors during the index weight decision by Analytic Hierarchy Process, the grey relational analysis is applied to correct the weight to make the results more reasonable. The concept of fuzzy connection degree is applied to determine the value of discrepancy coefficient in set pair analysis theory. Measured samples and warning grades are used to compose a set pair and the connection degrees of the measured samples and the warning grades are calculated and ranked. Then through the farther same, difference and antagonism set pair analysis the poor shunting early warning for track circuit is achieved. The results and comparisons with other methods show that the fuzzy set pair analysis method is feasible and can provide a scientific basis for track circuit site maintenance.

Keywords: Track circuit; Poor shunting; Early warning; Grey relational analysis; Set pair analysis; Fuzzy connection degree.

1 Introduction

Track circuit is an important equipment in railway signaling system which is used for monitoring the position of the trains on the railway track. The performance of the track circuit which lay on the ballast bed is strongly influenced by its work environment. Especially for oil, coal and other cargo transport railway station the value of ballast resistance is rather changeable. The poor shunting failures frequently happen as a result. The poor shunting failures could lead to the wrong displays of the signal. So it is possible and necessary for us to find some methods for the fault early warning. The traditional method for early warning is achieved by setting several warning lines. It’s greatly influenced by human factors. Therefore, this paper proposes an early warning strategy based on fuzzy set pair analysis.

2 Set Pair Analysis

2.1 Definition of connection degree

The set pair analysis is a new quantitative analysis method about uncertainty theory. Its basic idea is to incorporate certainty and uncertainty into one system and describe the uncertainty of the system by the connection degree.

Given two sets A and B and assumes that the two sets form a set pair $H = (A, B)$. Then analyze the characteristic of the set pair H for a specific issue. Suppose that there are n characteristics in all and s characteristics are common to A and B. There are p characteristics that set A and B is antagonistic to each other. The ratios s/n, f/n (f=n-s-p), p/n are called the same, difference and antagonism degree (denoted as a, b, c for convenience) respectively. Therefore, the connection degree can be expressed as

$$\mu_{(A,B)} = \frac{s}{n} + \frac{f}{n} i + \frac{p}{n} j = a + bi + cj, \quad a + b + c = 1 \tag{1}$$

Where i is the discrepancy coefficient ($i \in [-1, 1]$), j is the antagonism coefficient and its specified value is -1.

In addition, a comprehensive connection degree analysis should be make based on the characteristics weights. Assumes that the connection degree of the index k is μ_k and its weight is ω_k. Then the connection degree of the set pair can be calculated using equation (2).

$$\mu = \sum_{k=1}^{n} \omega_k \mu_k \tag{2}$$

The warning grade of the poor shunting failure can be determined through sorting the connection degrees of the warning index value set and the warning grade set. The corresponding grade of the maximum connection degree is the warning grade of the poor shunting failure.

2.2 Determination of discrepancy coefficient

The determination of the discrepancy coefficient i is the key to calculating the connection degree. This paper applies the concept of fuzzy connection degree to determine the value of discrepancy coefficient i. So the fuzzy connection degree of the warning grades and the index values in the range of the adjacent warning grades should be confirmed. For example, assumes that the index value x is in the range of warning grade Ⅱ, that means $x \in [S_1,S_2]$. The fuzzy connection degree of index value x and the warning grade Ⅰ can be expressed as $\mu_{(x,\, b1)} = a + bi + cj$. Here a is the same degree, b is the difference degree, c is the antagonism degree. The closeness degree of x and S_1 is S_1/x. The closeness degree of x and S_2 is x/S_2. Then take the normalized results of the closeness degrees $S_1S_2 / [(S_1+S_2)x]$ as the same degree a and $x / (S_1+S_2)$ as the antagonism degree c. According to the equation $a + b + c$=1, the difference degree b can be expressed as $(S_1-x)(x-S_2) / [(S_1+S_2)x]$. Therefore, the fuzzy connection degree of x with the range of warning grade Ⅰ can be given by

$$\mu_{(x,b_1)} = \frac{S_1 S_2}{(S_1+S_2)x} + \frac{(S_2-x)(x-S_1)}{(S_1+S_2)x} i + \frac{x}{S_1+S_2} j \quad (3)$$

Substituting (3) into the discrepancy coefficient i in equation (1), it becomes

$$\mu_{(A,B)} = \left(\frac{s}{n} + \frac{f}{n}\frac{S_1 S_2}{(S_1+S_2)x}\right) + \frac{f}{n}\frac{(S_2-x)(x-S_1)}{(S_1+S_2)x} i + \left(\frac{p}{n} + \frac{f}{n}\frac{x}{S_1+S_2}\right) j \quad (4)$$

3 The model of poor shunting early warning for track circuit

3.1 Selection of early warning indexes

The factors affecting the magnitude of the voltage at receiving end of the track circuits include rail impedance, ballast resistance and the length of track circuit. Because the type and the length of track circuit are certain for a specific station, the ballast resistance is the main influence factor. The value of ballast resistance largely depends on the trackside temperature and humidity. Therefore, voltage at receiving end (V), cumulative number of failures (N), trackside temperature (T) and humidity (H) are used as the early warning indexes in this paper.

3.2 Partition of early warning grades

This paper establishes a set of sample data through the field survey data. The sample data set $\boldsymbol{Q} = [Q_1, Q_2, Q_3, Q_4, Q_5, Q_6, Q_7]$ is shown in table 1. In order to make the indexes comparable the sample data are normalized and the results are shown in table 2. In this sample data set the last 2 groups of data are test samples and the rest are reference samples which represent different degrees of fault tendency. According to the reference samples the early warning grades are divided into four grades which are green warning grade, yellow warning grade, orange warning grade and red warning grade. Four groups of early warning ranges are shown in Table 3. Here, S_1, S_2, S_3, S_4 are the threshold values of four warning grades.

Table 1. Sample data set

Serial No	U	H/%	T	N
1	24.2	25	24	1
2	22.4	40	30	2
3	21.2	56	38	3
4	19.6	70	45	4
5	18.0	95	56	5
6	24.0	30	40	2
7	1.2	60	20	2

Table 2. Normalized results of the sample data set

Serial No	U	H	T	N
1	1	1	1	1
2	0.933	0.818	0.833	0.75
3	0.533	0.527	0.567	0.5
4	0.267	0.273	0.333	0.25
5	0	0	0	0
6	0.992	0.819	0.844	0.75
7	0.833	0.455	1	0.75

Table 3. Early warning grades

Index	S_1	S_2	S_3	S_4
U	0.267	0.553	0.933	1
H	0.273	0.527	0.818	1
T	0.333	0.567	0.833	1
N	0.250	0.500	0.750	1

3.3 Evaluation of index weight

The AHP method is one of the most common methods to determine the index weight. The detailed process of AHP method is shown below.

1) Establish the comparison matrix ***A***. The determining principle of the element $\boldsymbol{a}_{ij}$ can be given by

$$\boldsymbol{a}_{ij} = \begin{cases} 0 & The\ j^{th}\ factor\ is\ important\ than\ the\ i^{th} \\ 1 & The\ j^{th}\ factor\ is\ as\ important\ as\ the\ i^{th} \\ 2 & The\ i^{th}\ factor\ is\ as\ important\ as\ the\ j^{th} \end{cases} \quad (5)$$

2) Calculate the significance index r_i, here

$$r_{max} = max\{r_i\},\quad r_{min} = min\{r_i\},\qquad r_i = \sum_{j=1}^{n} a_{ij} \quad (6)$$

3) Build the judgment matrix ***B*** whose element $\boldsymbol{b}_{ij}$ can be determined by

$$b_{ij} = \begin{cases} \dfrac{r_i - r_j}{r_{\max} - r_{\min}}\left(\dfrac{r_{\max}}{r_{\min}} - 1\right) + 1 & r_i \ge r_j \\ \left[\dfrac{|r_i - r_j|}{r_{\max} - r_{\min}}\left(\dfrac{r_{\max}}{r_{\min}} - 1\right) + 1\right]^{-1} & r_i < r_j \end{cases} \quad (7)$$

4) Establish the optimal transfer matrix ***C*** where

$$c_{ij} = \frac{\sum_{k=1}^{n}\left[lg\left(b_{ik}/b_{jk}\right)\right]}{n} \tag{8}$$

5) Build the consistent matrix ***D*** where .

$$d_{ij} = 10^{c_{ij}} \tag{9}$$

6) Solve the maximum eigenvalue and eigenvector of the consistent matrix ***D***.

In this paper the comparison matrixes are established using (5) based on the experience of three experts and then the AHP method is applied to calculate the index weight. The normalized results of the index weight are shown in table 4.

Table 4. Index weight

Expert	U	H	T	N
1	0.5636	0.2637	0.1177	0.0550
2	0.5898	0.1778	0.1778	0.0546
3	0.5638	0.1178	0.2634	0.0550

But, it's strongly influenced by man-induced subjective factors when determining the index weight using AHP. The grey relational analysis is used to correct the index weight in this paper. ξ_k is the correlation coefficient of index k which can be expressed as

$$\xi_k = \frac{\left(\Delta_{min} + \rho\Delta_{max}\right)}{\left(\Delta_{dk} + \rho\Delta_{max}\right)} \tag{10}$$

Where $\Delta_{\min}$ = minmin $|x_0(k) - x_d(k)|$; $\Delta_{\max}$ = maxmax $|x_0(k) - x_d(k)|$; $\Delta_{dk} = |x_0(k) - x_d(k)|$; ρ is the distinguishing coefficient whose value is 0.5 in this paper; $x_0(k)$ is the value at index k in standard model; $x_d(k)$ is the value at index k in testing model.

The vector X = [0.5898, 0.5898, 0.5898, 0.5898] is constituted by the maximum value of the index weight matrix shown in table 4 and it is used as the standard model. Three weight vectors given by the experts are used as three testing models. Using (10) the correlation coefficient matrix ξ can be denoted by

$$\xi = \begin{bmatrix} 0.7745 & 0.2163 & 0.1601 & 0.1440 \\ 1.0000 & 0.1793 & 0.1793 & 0.1440 \\ 0.7759 & 0.1601 & 0.2161 & 0.1440 \end{bmatrix} \tag{11}$$

Then calculate the correlation degree r_k of each index. r_k can be expressed as

$$r_k = \frac{1}{3}\sum_{j=1}^{3}\xi_{kj}\ (k = 1,2,3,4) \qquad (12)$$

Divide the correlation degree of each index by the sum of all the index correlation degree, and thus, the vector of the corrected index weight can be denoted by $\boldsymbol{\omega}$ = [0.6230, 0.1358, 0.1357, 0.1055].

4 Example verification

According to the above method the connection degree of the test sample Q_7 and each warning grade can be expressed as

$$\begin{aligned} &\mu_{(Q_7,S_1)} = \frac{1}{4}i + \frac{3}{4}j, \mu_{(Q_7,S_2)} = \frac{1}{4} + \frac{1}{2}i + \frac{1}{4}j \\ &\mu_{(Q_7,S_3)} = \frac{1}{2} + \frac{1}{2}i,\ \ \mu_{(Q_7,S_4)} = \frac{1}{4} + \frac{1}{2}i + \frac{1}{4}j \end{aligned} \qquad (13)$$

Take the determination of discrepancy coefficient i in $\mu_{(Q_7,S_2)} = \frac{1}{4} + \frac{1}{4}i + \frac{1}{2}j$ as an example. x_1=0.833， $x_1 \in [S_2,S_3]$， where S_2=0.553， S_3=0.933. Substitute these data into equation (3), it becomes

$$\mu_{(x_1,b_2)} = 0.4072 + 0.0246i + 0.5682j \qquad (14)$$

x_4=0.75， $x_4 \in [S_2,S_3]$， where S_2=0.5， S_3=0.75. Substitute these data into equation (3) too, it becomes

$$\mu_{(x_4,b_2)} = 0.4 + 0i + 0.6j \qquad (15)$$

Based on the vector of the corrected index weight $\boldsymbol{\omega}$=[0.6230,0.1358,0.1357,0.1055], the comprehensive fuzzy connection degree can be given as

$$\mu_{(x,b_2)} = \omega_1\mu_{(x_1,b_2)} + \omega_4\mu_{(x_4,b_2)} = 0.2959 + 0.0153i + 0.4173j \quad (16)$$

Substituting (16) into the discrepancy coefficient i in $\mu_{(Q_7,S_2)} = \frac{1}{4} + \frac{1}{4}i + \frac{1}{2}j$, it becomes

$$\mu_{(Q_7,S_2)} = 0.45865 + 0.00765i + 0.39795j \quad (17)$$

Now all information of the data is utilized and it can satisfy the requirement of the accuracy. Therefore, Substitute i=0，j=-1 into (17), it becomes $\mu_{(Q_7,S_2)} = 0.0607$. Similarly, it can obtain the results: $\mu_{(Q_7,S_1)} = -0.7559$, $\mu_{(Q_7,S_3)} = 0.54769$, $\mu_{(Q_7,S_4)} = -0.0607$.

The computed results of test sample 7 and test sample 6 are shown in table 5 and it can be seen that the maximum value of the connection degree of the 6th group of data is 0.7342 and it's in the range of the green warning grade. That means the track circuit is able to work well. Similarly, the maximum value of the connection degree of the 7th group of data is 0.5477 and it's in the range of the yellow warning grade. That means poor shunting failures are likely to occur and the surveillance for track circuit should be strengthened.

Table 5. Analysis and calculation of connection degree

Data	Expression of μ	Value of i	Calculation method of μ	Value of μ	Results
6	$\mu_{(Q_6,S_1)} = j$	i_a=0, i_b=0, i_c=0	$\mu_{(Q_6,S_1)} = j$	0	Green Warning
	$\mu_{(Q_6,S_2)} = \frac{1}{4}i + \frac{3}{4}j$	i_a=0.0432, i_b=0, i_c=0.0648	$\mu_{(Q_6,S_2)} = 0.0108 + 0i + 0.7662j$	-0.7554	
	$\mu_{(Q_6,S_3)} = \frac{1}{4} + \frac{3}{4}i$	i_a=0.4509, i_b=0.00036, i_c=0.4406	$\mu_{(Q_6,S_3)} = 0.588175 + 0.000272i + 0.33045j$	0.2577	
	$\mu_{(Q_6,S_4)} = \frac{3}{4} + \frac{1}{4}i$	i_a=0.2537, i_b=0.0153, i_c=0.354	$\mu_{(Q_6,S_4)} = 0.75 + 0.01055i + 0.015825j$	**0.7342**	
7	$\mu_{(Q_7,S_1)} = \frac{1}{4}i + \frac{3}{4}j$	i_a=0.0537, i_b=0.0049, i_c=0.0772	$\mu_{(Q_7,S_1)} = 0.0134 + 0.0012i + 0.7693j$	-0.7559	Yellow Warning
	$\mu_{(Q_7,S_2)} = \frac{1}{4} + \frac{1}{2}i + \frac{1}{4}j$	i_a=0.2959, i_b=0.0153, i_c=0.4173	$\mu_{(Q_7,S_2)} = 0.45865 + 0.00765i + 0.39795j$	0.0607	
	$\mu_{(Q_7,S_3)} = \frac{1}{2} + \frac{1}{2}i$	i_a=0.1105, i_b=0.0049, i_c=0.1512	$\mu_{(Q_7,S_3)} = 0.55525 + 0.00245i + 0.00756j$	**0.5477**	
	$\mu_{(Q_7,S_4)} = \frac{1}{4} + \frac{1}{2}i + \frac{1}{4}j$	i_a=0.2959, i_b=0.0153, i_c=0.4173	$\mu_{(Q_7,S_4)} = 0.39795 + 0.00765i + 0.45865j$	-0.0607	

5 Conclusions

This paper proposes a new early warning method for track circuit based on fuzzy set pair analysis. The grey relational analysis is used to correct the index weight determined using AHP, so the results become more reasonable. Compared with Radar Chart method the warning results are identical. It indicates that the method proposed in this paper is feasible. In addition, the Fuzzy Set Pair Analysis method has the advantages of strong operability and simple calculation.

References

Deng, J. L. (1990). "Grey - system theory tutorial." *Huazhong university of science press,* Wuhan.

Liu, J. H. (2012). "Comprehensive Evaluation of Power Quality Based on Fuzzy Set Pair Analysis." *Power System Technology,* 36(7), 81−85.

Mi, G. S. (2013). "Application of Radar Chart in Poor Shunting Early warning for Track Circuit." *Journal of The China Railway Society,* 35(11), 66−70.

Meng, X. M. (2009). "Application of set pair analysis model based on entropy weight to comprehensive evaluation of water quality." *Journal of Hydraulic Engineering,* 40(3), 257−262.

Zhang, B. (2001). "The method and thought of set pair theory treated with uncertainties information." *Fuzzy Systems and Mathematics,* 15(2), 89−93.

Zhao, K. Q. (2000). "Set pair analysis and its preliminary application." *Zhejiang Science and Technology Press,* Hangzhou.

Zhang, T. J. (2010). "Prediction of Coal and Gas Outburst Level Based On Improved AHP." *Journal of Xi'an University of Science and Technology,* 30(5), 536−542.

Zhang, W. W. (2010). "Fuzzy connection degree method for comprehensive evaluation of regional groundwater resources carrying capacity." *Journal of Sichuan University: Engineering Science Edition,* 40(6), 30−35.

Strategies for the Safety Management of Road Transportation Infrastructure under Severe Weather Conditions in China

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Abstract: Observed records provide clear evidence of global climate change, especially for severe weather events. The study presented addressed strategies for safety management of road infrastructure under Severe Weather Conditions (SWC), aims to consolidate transportation infrastructures' adaptation to severe weather change. On the basis of reviewing security and management strategy, we analyze the impact of Road Transportation Infrastructure (RTI) in severe weathers. Moreover, strategy development for managing highway safety under SWC is discussed based on the risk assessment, the precaution mechanisms, the emergency rescue and the traffic organization. Lastly, we briefly discusses guarantee measures for implementation. The study demonstrated that the reasonable adaptation strategy for safety management of RTI under SWC can effectively enhance the responsiveness of the traffic administrative department, in addition, which is of great social significance to reduce the loss of accidents to SWC, to maintain social stability and the protection of people's life and property safety.
Keywords: Adaptation strategies; Security; Management; Road transportation infrastructures; Severe weather conditions.

1 Introduction

Road Transportation Infrastructure (RTI) such as highways and bridges are exposed to exterior environments. Hence, they are vulnerable to extreme weathers. As modern RTI network extends continuously, the consequences and impacts of major disasters emergency (e.g., such as extreme weather) are becoming aggravate and complicate. In order to reduce the losses caused by traffic accidents, improving RTI management in extreme weather is the urgent need of the traffic safety.

According to the influencing degree of Severe Weather Conditions (SWC) on highway traffic safety, the biggest influence is caused by the heavy fog weather, ice and snow, rain and other weather followed behind. So it is a significant and long-term task to set up perfect major RTI crisis response mechanism, perfecting the traffic infrastructure and safety management strategy in extreme weather, strengthening emergency contingency ability in extreme weather and other major disasters,

According to the empirical findings, climate change related shifts in weather patterns might also cause RTI disruptions (Koetse, M. J., and P. Rietveld, 2009.). However, due to climate change, SWC may change positively or adversely in severity and frequency of occurrence, depending on the respective weather event and the location of its occurrence (Schweighofer, J., 2014.). More generally, it is concerned that the safety of RTI was closely related to the SWC (Eisenberg, D., 2004.; Barnes, P., and R. Oloruntoba, 2005.).

Climate change and SWC have impacted in the global, such as U.S.A (Karl, T. R., J. M. Melillo, et al, 2009.), Northern Canada (Koetse, M. J., and P. Rietveld, 2009.), E.U (Vajda, A., H. Tuomenvirta, et al, 2011.) and so on (Loosemore, M., V. Chow, et al, 2014.), which will affect several economic sectors including the hydroelectric, energy, marine, freshwater, and mining industries as well as RTI (Prowse, T. D., C. Furgal, et al, 2009.). Observations show that warming of the climate is unequivocal and the probability that SWC turns frequently.

Moreover, In response to cope with the climate change and set up management strategies, many local governments are directing agencies to utilize existing and traditional local government tools to adapt to climate change (Hirokawa, K. H., and J. D. Rosenbloom, 2013.). The United States governments and Canada governments (Selin, H., and S. D. VanDeveer, 2005.) have been working for environmental cooperation, in order to build the climate change networks and adaptation planning. Therefore, future RTI should be made more robust to possible changes in climate conditions, which includes three main parts: risk identification, risk ranking, and risk management. This aim implies that users of climate information must also change their practices and decision-making frameworks (Hallegatte, S., 2009.). Therefore, it is very necessary to study traffic risks and management measures of highway on the basis of SWC in order to develop effective early warning plans to improve usage and safety management level of infrastructures and equipment.

2 Analysis on Security Impact Factors of RTI In Extreme Weather

The impact of RTI on traffic safety is mainly reflected in the 3 aspects, such as lack of visibility, reduced road adhesion coefficient, unstable driving for motor Snow, slippery road conditions haze and low visibility weather has become one of the major incentives for traffic accidents (Ministry of Public Security Traffic Management Bureau). As shown (left) in Figure 1.

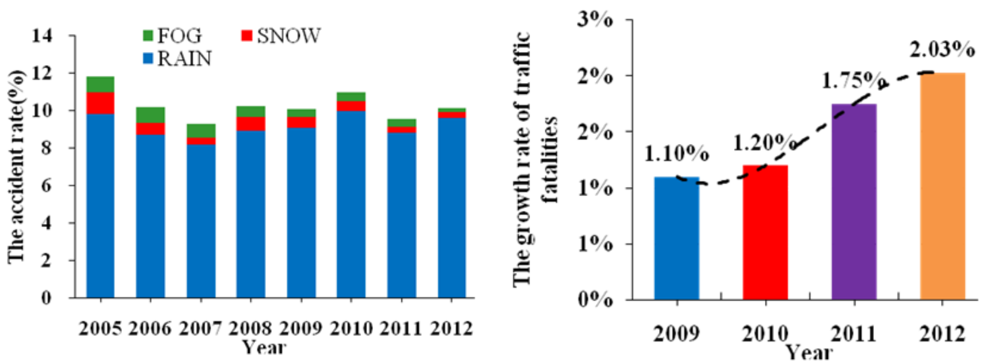

Figure 1. The accident rate statistics and growth rate of traffic fatalities in snow - ice in China

2.1 The Snow - Ice Impact on The Traffic Safety of The RTI

Table 1. The Influence in Ice - Snow and Foggy Condition

The braking distance for different types of speed on ice - snow condition							
Road conditions	Average speed (km/h)						
	50	60	70	80	90	100	110
Dry asphalt pavement	12.3	17.8	24.0	31.5	39.9	49.2	59.5
Ice and snow pavement	49.2	71.0	95.5	126.0	150.0	196.9	238.2

The highway fog speed limit recommended value in foggy condition					
Visibility distance	The maximum safe speed (km/h)				
	I < 1%	1 %≤ I < 2%	2% ≤ I < 3%	3% ≤ I <4%	4% ≤ I <5%
L ≥ 200	111	110	108	107	106
150 ≤ L < 200	92	92	91	90	89
100 ≤ L < 150	71	70	70	69	68
50 ≤ L < 100	44	44	43	43	43

Icy road will make road adhesion coefficient reaches the lowest point, causing the vehicle does not have sufficient capacity to resist lateral forces and unable to maintain a balance, leading the vehicle skidding drift out of control; when driving in snow, drifting snow will affect the driver's sight. Snow has a strong reflection of the sun, which prone to the snow-blind phenomenon (blinding) that damage to the driver's eyes and causing eye fatigue which is extremely detrimental to safe driving.

The braking distance for different types of speed on the ice and snow conditions is shown in Table 1.

According to the climatic conditions and traffic information, statistics in British, when snow falling the highway accident rate is 5 times as the dry road and the accident rate is 8 times as the dry road surface when freezing. The growth rate from 2009 to 2012 of traffic fatality statistics in China's snow and ice weather (right) is shown in Figure 1.

2.2 The Rain Impact on The Traffic Safety of The RTI

Traveling on the highway in rainy day would often have a "water slide" phenomenon. The coefficient of friction is significantly reduced on slippery roads, leading to reduced vehicle braking performance and increased risk of reduced visibility at the same time, which severely affected the sight and pavement marking visible distance. The relationship between surface water status and speed as well as adhesion coefficient is shown in Figure 2. H represents the water film thickness (mm).

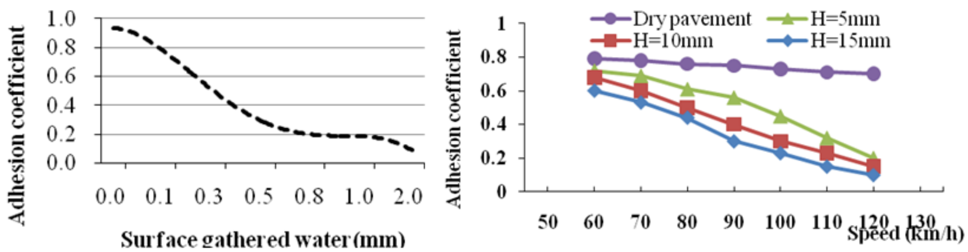

Figure 2. The relationship between surface water and speed as well as adhesion coefficient

According to accident statistics in Japan, Japanese highway fatalities associated with the rainy accounted for 42% (Ministry of internal affairs and communications - statistics bureau of Japan), however the number of rainy days throughout the year accounted for only 27%. The rainy growth rate of traffic fatality statistics from 2009 to 2012 is shown in Figure 3 (left).

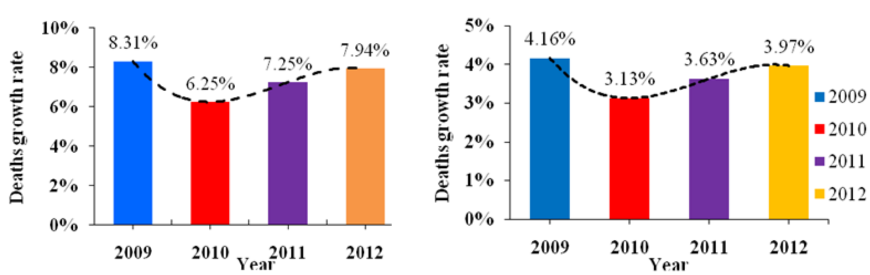

Figure 3. Traffic accident deaths growth statistics in rainy (L) and foggy (R)

2.3 The Fog Impact on The Traffic Safety of The RTI

Fog lead to low visibility and sight disorders and the driver's visual distance will be greatly shortened. Since it is difficult to discern the scene and traffic marking as well as front and rear vehicle, the driver is psychologically stressful and easier to have judge mistakes, which will lead to the front and rear car rear-end. Highway speed limits recommended values in fog condition are shown in Table 1. Due to fouling, dust and mist of water droplets in the air mixed in the water film formed on the road, the coefficient of adhesion between tire and road will become lower.

According to statistics in the annual report on road traffic accidents in 2010, traffic accidents caused by fog accounts for 3.51% of the total number of highway traffic accidents in China. The greater the fog, the more accidents will happen. The growth rate of deaths under accident in foggy weather from 2009 to 2012 is shown in Figure 3 (right).

3 Strategies For Addressing Security Managment

3.1 Risk Assessment

From the perspective of safety system engineering, risk assessment is based on analysis of past data loss, with system identification and security analysis of the safety or danger of the infrastructure, the level of risk is to be measured and graded according to certain standards, specifications, and safety indicators. So that combined with the existing conditions and the level of the security security, measures of the control system of a dangerous nature will be proposed. The flow chart of strategies for addressing security management was shown in Figure 4.

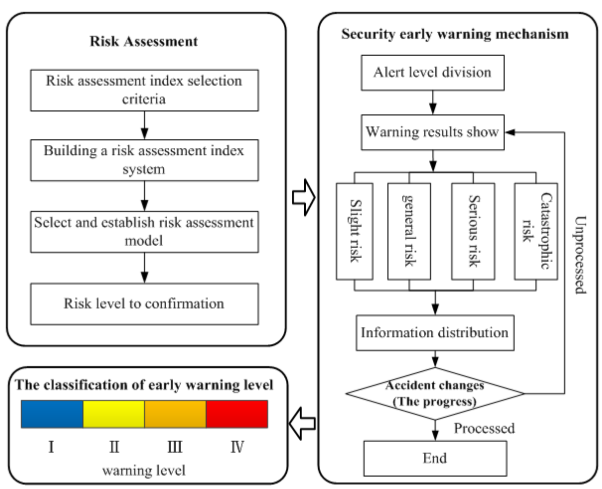

Figure 4. The flow chart of strategies for addressing security management

3.2 The Classification of Early Warning Level

In extreme weather, the warning classification of RTI was an insignificant risk (class I), general risk (class II), serious risk (class III) and catastrophic risks (class IV). In practical work, the precipitation, the disaster severity (the width, recovery difficulty and the length of the damaged roads and bridges), traffic congestion time, the development degree of the regional road network and highway rescue force are the basis of the warning classification. Meanwhile, the early warning level can also take local conditions, economic losses and casualties into consideration.

3.3 Early Warning Management

Development goals of traffic, whether in the meteorological development strategy research in china are: by 2020, the modern transportation meteorological monitoring, alert, early warning, integrated forecasting system will be established and improved; making great efforts in the detection and monitoring of the service conditions of the RTI in extreme weather to provide meteorological support services of international standards for smooth and safety transportation.

3.4 Emergency Rescue

It is a significant and long-term task to set up perfect major RTI crisis response mechanism, perfecting the traffic infrastructure and safety management strategy in extreme weather, strengthening emergency contingency ability in extreme weather and other major disasters, and guaranteeing the emergency response capacity of major disasters caused by extreme weather and other factors, as well as protecting the transport system as the lifeline of the national economy in all kinds of unexpected disasters remains safe operation. It is also an inevitable requirement for modern society to improve government management ability, and maintain social stability.

When extreme weather and other unexpected disasters happened, the following issues must be solved in the emergency rescue: Immediately understand the severity and the extent in extreme weather and other unexpected disaster events; enable the appropriate contingency plans and carry out disaster rescue and personnel evacuation in the shortest possible time according to established good procedures; simple, unified and efficient rescue organizations can reduce the blindness of the rescue by making full use of rescue supplies and time. Therefore, the scientific nature, timeliness and standardization of the emergency rescue are the key to the success of the emergency rescue work. Emergency plans library which has universal characteristics is summarized by traffic engineering prior knowledge, methods, and technology of road management and traffic flow states field. The dedicated plans library has highly pertinence and purpose. On the basis of profound knowledge and understanding of traffic conditions of a regional road network, road structural features, the characteristics and the severity of the traffic incident for managers, the dedicated plans library is summarized by the experience and the accumulation. Information (road infrastructure, traffic flow and other information) distribution, adjustment and release are carried out by the press, radio, variable information panels, variable speed limit signs, road network condition information site.

A reasonable emergency rescue engineering is based on previous crisis experience determine of the appropriate alert level and disposal procedures in accordance with the crisis category, size, extent, and grade. Once the crisis broke out, we can determine the corresponding level through the analysis of the situation immediately, then the appropriate contingency plans can be started and the best decisions can be made in the shortest possible time.

3.5 Traffic Organization Strategy

It is necessary to implement the corresponding management control strategy in order to ensure traffic safety and smooth flow. These management control strategies, which is corresponding to the weather type and its impact degree, should be embodied in the form of a plan or response program.

(1)The Recommendatory Strategy

This kind strategy is mainly used to provide real-time weather and traffic information for road users. The specific implementation method of the proposed strategies publishes information by variable information boards, temporary warning signs, road inspections, and Traffic Radio Ads, which ensure that road users can have immediate access to weather and traffic information.

(2)The Control Strategy

The main purpose of the control strategy is to control the travel speed of the traffic flow and running status on the road in extreme weather conditions. The specific implementation methods of the control strategy include publishing real-time speed limit information by speed limit signs or variable information boards; special sections may set up a temporary speed limit warning signs; publish warning information by the warning lights and Traffic Radio Ads.

(3)The Treatment Strategies

Treatment strategies can improve traffic safety and life safety with the use of rescue resources which the extreme weather and other major disasters required. Treatment strategies are mainly involved in internal and external coordination of the emergency department. Rescue resources required in rainy weather include pumps, steel bridge and others; rescue resources required in ice and snow weather include deicing salt, anti-slip agents, snow removal vehicles and others; rescue resources required in foggy weather conditions include anti-fogging agent, anti-fogging car and others. The primary duties of the treatment strategies for traffic management department prompt early warning notes for the relevant departments in extreme weather conditions.

4 Discussions

Strategic implementation safeguards include policy support and technical support, which can be divided into information gathering technical support, information dissemination, technical support, emergency rescue system, and space resources and data security.

(1)Information Gathering Technical Support

A collection of information includes traffic flow information and meteorological information. The weather information is obtained from meteorological, environmental monitoring equipment. Timely and accurate meteorological monitoring play an important role in developing reasonable response strategy, controlling and guiding vehicle to avoid risk, providing the driver with real-time traffic information and reducing the impact of highway traffic safety in extreme weather. Traffic flow information which is obtained by the information detectors (loop coil, video detector) includes traffic volume, density, speed and other data.

(2)The Emergency Rescue System

The emergency rescue system gives rapid response to traffic accidents and coordinate with all relevant departments to take emergency action through the information about traffic accidents prompt in extreme weather. It minimizes casualties and property losses caused by traffic accidents, restoring highway capacity as soon as possible and reducing traffic demand in the affected area of traffic accidents.

(3)Space Resources and Data Security

When taking a full account of the urban development planning, we should make urban development coordinate with emergency rescue and management development in sudden disasters. The basic conditions of emergency rescue work are applicable RTI. Therefore, the demand of the emergency rescue work should be given full consideration and leaves enough space of development for it in the construction of major transport infrastructure. The establishment of urban disaster risk assessment and disaster information database in line with the urban characteristics in China can provide a theoretical basis for the construction of the emergency rescue management system and data.

(4)The Policy Support

Urban RTI safety management requires a strong policy protection mechanism in extreme weather, especially for the continuity and security policy and financial investment, which are the basic guarantee for long-term development and construction of emergency rescue and management systems.

5 Conclusions

RTI is an important part of the transportation system. "The China's Twelfth Five-Year Guideline in the transportation field" makes great efforts to strengthen infrastructure construction, optimize the layout of the integrated transport infrastructure network and strengthen its traffic safety, which not only reflects the overall level of service of the transportation system, but also reflects the level of urban traffic management capabilities. With the continuous growth of RTI, traffic safety issues become increasingly prominent in china.

This paper reviews traffic accident status of ice, snow, rain and fog and summarizes domestic and international RTI security management strategy. Taking traffic fatalities number as indicators of road traffic safety operation, transportation infrastructure security of ice, snow, rain, and fog is analyzed from the visibility, sight, road adhesion coefficient, safe distance and other factors. The risk state of RTI facing disasters when a traffic accident happens is estimated and assessed. The early warning level together with publishing and management of early warning information are determined according to the analysis results of risk assessment. The emergency rescue system is studied from the accident detection and confirmation, command scheduling, resource optimization and configuration, and information dissemination etc. RTI safety management strategies and required rescue space of the strategy implementation, information database, policy and other strategic security in extreme weather are discussed from the recommended strategy, control strategy and treatment strategy these three aspects. The deficiency of this paper is that we only studied the influence of traffic safety of RTI in the ice, snow, rain, fog weather. However, in addition to the conditions mentioned above, more SWC have an impact on highway safety operations and further research is still needed.

Therefore, it is a difficult task for RTI safety management and security work in extreme weather. This requires formulating an emergency rescue and developed management strategy of appropriate transport infrastructure in sudden disaster, and carrying out the research on risk assessment, disaster warning, emergency response and management system. The safety management strategy of RTI needs to develop a scientific, rational, and sustainable strategic planning. With the dual support of the policy and technical support mechanisms, the expected target is completed in stages. Finally, safety management system of the RTI is established with urban characteristics in China.

Acknowledgements

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References

Barnes, P., and R. Oloruntoba (2005). Assurance of security in maritime supply chains: Conceptual issues of vulnerability and crisis management. *Journal of International Management,* 11 (4), 519-540.

Eisenberg, D. (2004). The mixed effects of precipitation on traffic crashes. *Accident Analysis & Prevention,* 36(4), 637-647.

Hallegatte, S. (2009). Strategies to adapt to an uncertain climate change. *Global Environmental Change,* 19(2), 240-247.

Hirokawa, K. H., and J. D. Rosenbloom. (2013). Land Use Planning in a Climate Change Context. *RESEARCH HANDBOOK ON CLIMATE ADAPTATION LAW, Jonathan Verschuuren, ed,* 12-33.

Koetse, M. J., and P. Rietveld (2009). The impact of climate change and weather on transport: An overview of empirical findings. *Transportation Research Part D: Transport and Environment,* 14(3), 205-221.

Karl, T. R., J. M. Melillo, and T. C. Peterson. (2009). *Global climate change impacts in the United States.* Cambridge University Press.

Loosemore, M., Chow V., and McGeorge D. (2014). Managing the health risks of extreme weather events by managing hospital infrastructure. *Engineering, Construction and Architectural Management,* 21(1), 2-2.

Prowse, T. D., C. Furgal, R. Chouinard, H. Melling, D. Milburn, and S. L. Smith. (2009). Implications of climate change for economic development in northern Canada: Energy, resource, and transportation sectors. *AMBIO: A Journal of the Human Environment,* 38(5), 272-281.

Selin H., and VanDeveer S. D. (2005). Canadian-US environmental cooperation: Climate change networks and regional action. *American Review of Canadian Studies,* 35(2), 353-378.

Schweighofer J. (2014). The impact of extreme weather and climate change on inland waterway transport. *Natural hazards,* 72(1), 23-40.

Vajda, A., Tuomenvirta H., Jokinen P., Luomaranta A., Makkonen L., Tikanmäki M., Groenemeijer P., Saarikivi P., Michaelides S., and Papadakis M. (2011). Probabilities of adverse weather affecting transport in Europe: climatology and scenarios up to the 2050s.

Motor Vehicle Crashes on the Sutong Yangtze River Highway Bridge

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Abstract: Bridges differ from surface streets and highways in terms of their physical properties and operational characteristics, which in turn, affect the risk of motor-vehicle crashes. This paper attempts to identify motor-vehicle crash patterns on Sutong Bridge and to compare differences between bridge-related crashes and all crashes. 459 crashes occurring on Sutong Bridge from May in 2008 to June in 2010 were collected and analyzed. Results reveal that bridge segment is involved in more fixed-object crashes and fewer rear-end crashes among total crash experience. And bridge-related crashes result in more serious consequences including higher fatality rate and longer crash duration.
Keywords: Bridge; Motor-vehicle crash; Crash type; Crash severity; Crash duration.

1 Introduction

The roadway system in China includes approximately 735,300 highway bridges (Statistical Report of Transport Development, 2013). Bridges differ from surface streets and highways in terms of their physical properties and operational characteristics. Bridges typically are narrower than approach roads, and often lack some safety features such as shoulders. And bridges as significant travel links over obstacles carry high traffic volume. The unusual physical properties and operational characteristics of bridges affect the risk of motor-vehicle crashes that occur on them (Retting, 2000).

Most existing studies about motor-vehicle crashes on bridges conclude that traffic crashes are more commonly associated with bridges than with comparable other roadways. Agent and Deen (Agent,1976)(Agent,1976) analyzed accident records on interstate routes and parkways from 1972 to 1973 in US and they found that bridge-related accidents were a significant percentage of the total accidents and their severity was generally higher than the severity of all accidents. Similarly, Brinkman and Mak (Brinkman,1986) also considered that bridge-related crashes constituted a high percentage of all crashes and were approximately twice as likely to result in fatality as a typical crash. Retting et al. (Retting,2000) studied 1,381 police-reported crashes of four highway bridges in the New York City and summarized that bridges had higher crash rates than their respective approach roads. However, in China, to date, little information regarding bridge-related crashes has been published. This paper attempts to identify motor-vehicle crash patterns on Sutong Bridge in China and to compare differences between bridge-related crashes and total crash experience.

2 Data Preparation

Sutong Bridge is a two-way and six-lane bridge located between Suzhou city and Nantong city in Jiangsu Province in China. Figure 1 describes a general view of Sutong Bridge. This bridge consists of two parts including bridge segment crossing the river and general highway segment. As a steel stayed-cable bridge with double towers, the bridge segment comprises main bridge, north bridge approach, and south bridge approach. And the general highway segment includes entrance/exit ramp and basic roadway segment. Thus, Sutong Bridge is divided into five parts: main bridge, south bridge approach, north bridge approach, entrance/exit ramp, and basic roadway segment. And main design parameters of the five segments on Sutong Bridge are listed in Table 1.

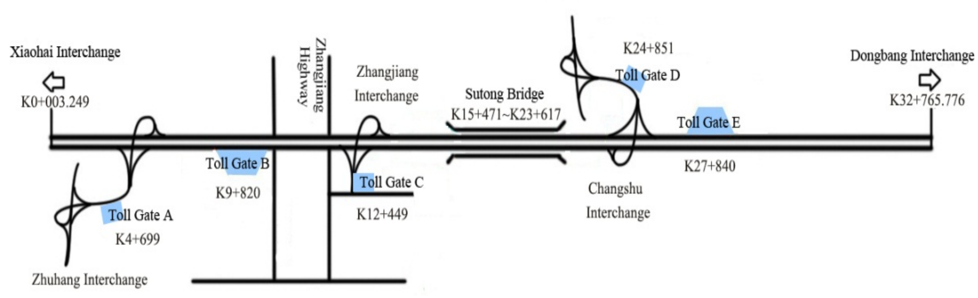

Figure 1. A general view of Sutong Bridge

Table 1. Road Parameters of Sutong Bridge

Segment Name	Length (m)	Minimum Curve Radius (m) and Length (m)	Maximum Slope (%) and Length (m)	Speed Limit (km/h)
Main Bridge	2,088		±1.5 / 2100	100
Bridge Approach (North)	3,485	7000 / 3417	+2.1 / 1795	100
Bridge Approach (South)	2,573	7000 / 3511	-2.4 / 1090	100
Entrance/Exit Ramp	17,080	55 / 226	+3.0 / 352	40
Basic Roadway Segment	24,277	5500 / 1716	-1.4 / 1540	120

There were 459 motor-vehicle crashes collected by Sutong Bridge Co. Ltd. from May in 2008 to June in 2010. Crash data from these crashes are available with specific information related to crash time, crash duration, crash location, weather conditions, crash vehicle, crash type and crash severity. Three distinct crash types plus an "other" category were defined. The three crash types are rear-end, fixed-object, and sideswipe/overtaking (Retting,2000). Regarding crash severity, these crashes were classified as fatal crash, injury crash and property damage-only (PDO) crash.

3 Data Analysis

To identify motor-vehicle crash patterns on Sutong Bridge, crash type, crash severity and crash duration were studied. Table 2 lists the distribution of crash types on Sutong Bridge. The three major crash types including rear-end, fixed-object, and sideswipe/overtaking crash account for more than ninety percent of all crashes. And there are similar conclusions in regard to bridge-related crashes. Moreover, there are eighty crashes occurring on the bridge segment that account for about seventeen percent of all crashes, which shows bridge-related crashes comprise a significant portion of total crash experience. In particular, the bridge segment involves more fixed-object crashes (43.75 percent) and fewer rear-end crashes (23.75 percent) associated with all crashes.

Table 2. Crash Types on Sutong Bridge

Crash Type	All Crashes		Bridge-related Crashes	
	Number	Percent of Crashes	Number	Percent of Crashes
Rear-end	154	33.55%	19	23.75%
Fixed-object	156	33.99%	35	43.75%
Sideswipe/Overtaking	118	25.71%	21	26.25%
Other	31	6.75%	5	6.25%
Total	459	100%	80	100%

Figure 2 illustrates the numbers of fatal, injury, and PDO crashes on Sutong Bridge and corresponding percent. PDO crashes account for almost ninety percent of all crashes, with similar results to bridge-related crashes. And there is no obvious difference in relation to the percent of injury crashes between bridge-related crashes and all crashes. But fatal crashes make up a higher percent of bridge-related crashes relative to all crashes.

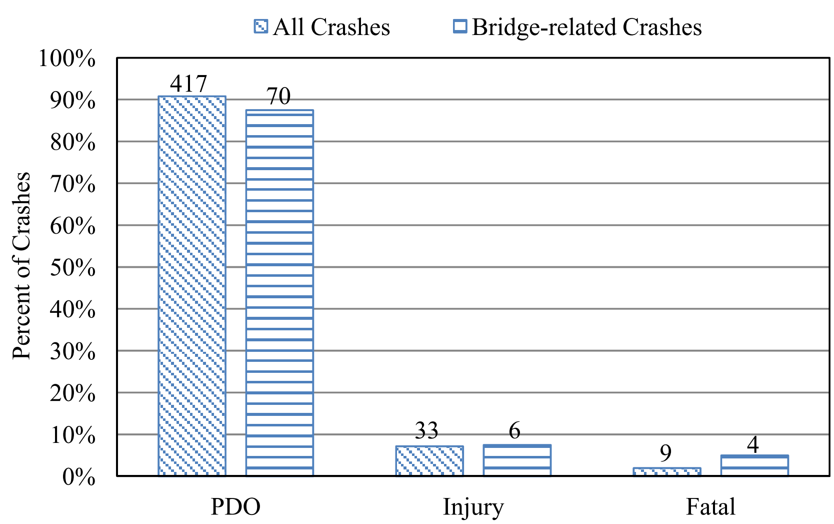

Figure 2. Crashes on Sutong Bridge by severity

In addition, crash duration is also regarded as an important factor to describe crash patterns. With crash duration increasing, negative impacts of crashes are becoming more and more serious. From May in 2008 to June in 2010, bridge-related crashes on Sutong Bridge in total cost 9,048 minutes that are about twenty-eight percent of the duration of all crashes. In Figure 3, a majority of crashes (89.85 percent in all crashes, 86.08 percent in bridge-related crashes) can be rescued and cleared within two hours (120 min). However, with respect to crashes lasting for more than six hours, the frequency of bridge-related crashes is much larger than one of all crashes. That is to say, in general, crashes occurring on bridge segment last more time than all crashes.

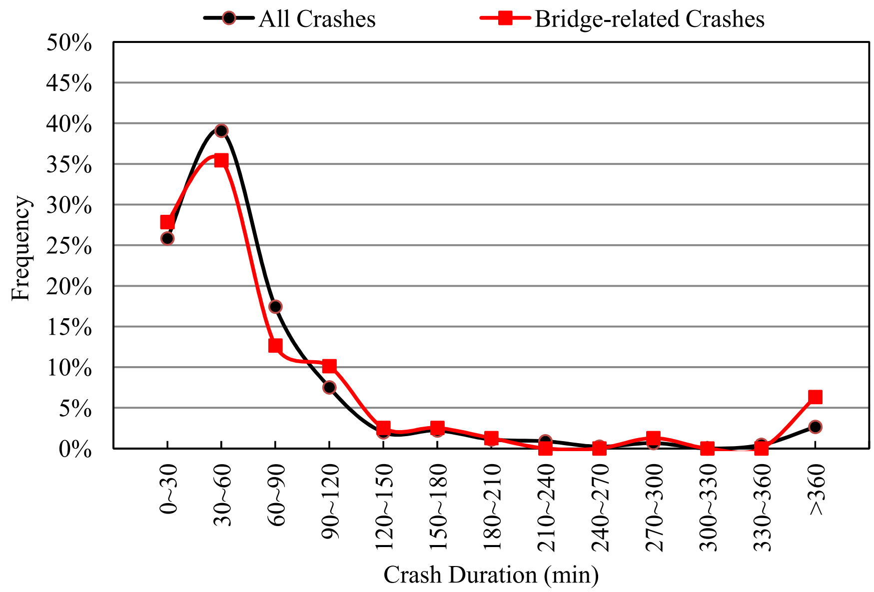

Figure 3. Crashes on Sutong Bridge by duration

4 Conclusions

In regard to Sutong Bridge, bridge-related crashes comprise a significant portion of total crash experience. And the three major types of bridge-related crashes is rear-end, fixed-object, and sideswipe/overtaking. In particular, the bridge segment involves more fixed-object crashes and fewer rear-end crashes than all crashes. Bridge-related crashes comprise a significant portion of severe accidents. Fatal crashes make up a higher percent of bridge-related crashes relative to all crashes. Moreover, although a majority of crashes can be rescued and cleared within two hours, bridge-related crashes take more time to be rescued and cleared than all crashes.

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Reference

Agent., K. R. (1975). “Accidents Associated with Highway Bridges.” Publication KYP-72-40; HPR-PL-1(10), Part III. Division of Research, Kentucky Bureau of Highways, Kentucky.

Agent., K. R., and R. C. Deen. (1976). “Highway Accidents at Bridges. Kentucky Transportation Center Research Reports.” Paper 872.

Brinkman, C. P., and Mak, K. K.(1986). “Crashes Analysis of Highway Narrow Bridge Sites.” In Public Roads: Journal of the Transportation Research Board, No. 4, Transportation Research Board of the National Academies, Washington, D.C., 127-133.

Retting, R. A., J. Williams, and S. I. Schwartz. (2000). “Motor Vehicle Crashes on Bridges and Countermeasure Opportunities.” *Journal of Safety Research*, 31(4), 203-210.

Statistical Report of Transport Development. (2013). Ministry of Transport of the People's Republic of China.

Fuzzy Comprehensive Evaluation on the Risk of Fatigue for Air Traffic Controllers Based on Improved AHP

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Abstract: With the rapid development of civil aviation, flights have increased dramatically. With the increasing flight density, the control interval has been narrowing constantly. Because of the heavy workload of the air traffic controllers (ATCs) in many regions, the risk of severe consequences due to ATCs fatigue becomes increasingly serious. Based on the analysis of the domestic events caused by ATCs fatigue in recent years, this paper investigates the fatigue of ATCs with using the SHEL model --- 'L' subsystem, 'L -L' subsystem, 'L -H' subsystem, 'L -E' subsystem and 'L-S' subsystem. It establishes the risk evaluation index system of ATCs fatigue. In the new approach, analytic hierarchy process (AHP) is used to determine the weights of evaluation index for ATCs fatigue. The method of decision making trial and evaluation laboratory (DEMATEL) is applied to revise indexes' initial weight at all levels and to effectively reduce the influence among evaluation indexes at all levels, so as to enhance objectivity and scientific degree of the indexes' weight. With the implementing of multilevel fuzzy comprehensive evaluation, each influence on fatigue is collected and corresponding measures are proposed according to the evaluation results to improve the aviation safety.
Keywords: Air traffic controller fatigue; AHP; DEMATEL; Fuzzy comprehensive evaluation; SHEL model; Aviation safety.

1 Introduction

According to the Federal Aviation Administration (FAA) statistics, about 21% of all aviation accidents associated with fatigue (Ji Q et al, 2006). The Confidential Human Factors Incident Reporting Programme (CHIRP) research data shows that 13% of the running error is directly related to controllers' fatigue (Allen, T. 2004). Controllers' responsibility is to prevent the collision of aircraft with aircraft, aircraft with obstacle, to sustain and accelerate the major task of air traffic order, their fatigue greatly increases the incidence of unsafe incidents. Fatigue is the most important factor that causes controllers "error, forgetting and leakage". With the rapid development of civil aviation, unsafe incidents caused by controllers fatigue have the increasing tendency year by year, fatigue has become the most important and unavoidable factor that affects ATC safety .

In general, most researches focused on the analysis of working pressure, control and scheduling system for the effects of fatigue, while ignored the quantitative management of the controllers' fatigue. The SHEL model is one of the most commonly used models that aim to analyze human factors. It can be used to analyze the factors that may affect controllers' fatigue from perspective of the man - machine - environment - management system engineering, so as to build controllers' fatigue risk evaluation index system, then to determine the controller's fatigue level with fuzzy comprehensive evaluation method.

2 To Build Assessment Index System of the Controllers' Fatigue Risk

The SHEL model was originally proposed by Edwards in 1972, and modified by Hawkins in 1987. It is now the research framework of human factor (Hongzhi Wang et al,2012). The controllers' fatigue is a combination of many factors, based on the SHEL model, the fatigue risk's research scope has been defined within the four interfaces of the SHEL model as well as the person's own factors. And the human and software interface mainly refer to some factors of management.

Based on the analysis of the related controllers' fatigue accidents, according to the feasibility of establishing index system, independent, comprehensive and scientific principles, from 'L' subsystem, 'L -L' subsystem, 'L -H' subsystem, 'L -E' subsystem and 'L-S' subsystem, the controllers' fatigue risk assessment index system has been established from the five dimensions based on expert experience (Table 1).

3 Controllers' Fatigue Risk Evaluation Method

3.1 The establishment of evaluation factor set and evaluation set

The factor set is an ordinary set, which is composed of the elements of various factors, usually expressed by $U = \{U_1, U_2, \cdots, U_n\}$. Here, $U_i = \{U_{i1}, U_{i2}, \cdots, U_{ij}\}$ is evaluation factors, it stands for number of single factor of the same hierarchy.

When evaluating sub-factors, determining the comment sets: $V = \{V_1, V_2, \cdots, V_5\}$. Here, V= {' less ', 'small', 'medium', 'high', 'higher'}is evaluation grades standard.

3.2 The determination of the weight sets

The analytic hierarchy process (AHP) is created by the T. L. Saaty professor in early1970s. It is assessing method which combines qualitative analysis , quantitative analysis and practical multi-objective decision analysis methods (Liu Lianxin,2014).

1-9 calibration method (Minhui Yan et al. 2014) is used for expert scoring to draw relevant judgment matrix, and square root method is used to calculate the consistency of judgment matrix. Steps are as follows (Kun P& Maoshan Q,2004):

1) To calculate the geometric mean of all the elements of judgment matrix X of each row: $\overline{W_i} = \sqrt[n]{M_i}$ where $M_i = \prod_{j=1}^{n} a_{ij} \quad i = 1,2,\cdots,n$.

2) To normalize $\overline{W} = \left[\overline{W_1}, \overline{W_2}, \cdots, \overline{W_n}\right]^T$: $W_i = \overline{W_i} \Big/ \sum_{j=1}^{n} \overline{W_j}$, $W = \left[W_1, W_2, \cdots, W_n\right]^T$ is the requested feature vector.

Table 1. evaluation index system of controllers' fatigue risk

Target layer	Index of first level	Index of second level
Controllers fatigue risk assessment	controllers U_1	sleep U_{11}
		Circadian rhythm U_{12}
		Control skills U_{13}
		Experience in control U_{14}
		The body health U_{15}
		Emergency and communication ability U_{16}
		Safety awareness and sense of responsibility U_{17}
	Controllers and Other staff members U_2	Control team U_{21}
		Pilots and other personnel U_{22}
		Members of the family U_{23}
	Controllers and equipment U_3	Equipment failure U_{31}
		Equipment can meet the demand of controllers U_{32}
	Controllers and the environment U_4	The weather conditions U_{41}
		The workplace environment U_{42}
		Sleep and rest environment U_{43}
		The military controls U_{44}
	Controllers and software U_5	Flight flow U_{51}
		Route structure U_{52}
		Business training U_{53}
		Crew resource management U_{54}
		The shift system U_{55}
		staffing U_{56}
		Site management U_{57}
		Operating procedures U_{58}

3) To calculate the largest eigenvalue of judgment matrix: $\lambda_{\max} = \sum_{i=1}^{n} \frac{(X \cdot W)_i}{nW_i}$

4)To determine the consistency index and the consistency ratio: $CI = \frac{\lambda_{\max} - n}{n-1}$, $CR = \frac{CI}{RI}$, where RI is random consistency indicator, its value can be obtained by look-up table (Feng C,2012). If $CR \le 0.1$, generally considered that the judgment matrix assign is reasonable.

3.3 The initial weights DEMATEL method

The DEMATEL is based on digraphs, which can separate involved factors into cause group and effect group (Mohsen Alvandi et al,2012).

1) The establishment of the direct-relation matrix: the direct- relation matrix is set by measuring the relationship between criteria in four levels: 0, 1, 2, 3 , where they respectively represent "no influence", "very low influence ", "low influence ", "high influence ".experts make sets of the pair-wise comparisons in terms of influence and direction between criteria. The direct- relation matrix:

$$A = \begin{bmatrix} 0 & a_{12} & \cdots & a_{1n} \\ a_{21} & 0 & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} = \left(a_{ij}\right)_{n\times n}, i = 1,...,n, j = 1,...,n;$$ in which a_{ij} is denoted as the degree to which the criterion i affects the criterion j.

2) To normalize the direct- relation matrix: $Y = A \Big/ \max_{1\le i\le n} \sum_{j=1}^{n} a_{ij} = (y_i)_{n\times n}$.

3) To calculate the total-relation matrix: $Z = Y + Y^2 + \cdots + Y^n = (z_{ij})_{n\times n}$, when $n \to \infty$, $Z = Y(1-Y)^{-1}$

4) To determine the influence weight: $W_b = \sum_{j=1}^{n} z_{ij} W_a \Big/ \sum_{i=1}^{n}\sum_{j=1}^{n} z_{ij} W_a$

5) To determine the new weight: $W = \frac{1}{2}(W_a + W_b)$

3.4 To establish the single-factor evaluation matrix

The ATCs fatigue factor set of risk assessment, from U_i to comment set V are regarded as a fuzzy mapping. The fuzzy evaluation matrix $R_i = \{r_{ijk}\}$ can be determined, where $r_{ijk} = d_{ijk}/d$, d_{ijk} is the number of experts that the evaluation factor U_i in the ij item evaluation index are made as evaluation V_k, d is the total number of experts who participate in the evaluation.

3.5 The fuzzy comprehensive evaluation

The fuzzy comprehensive evaluation method was founded by L. A. Zadeh in 1965, it is built on fuzzy mathematics based on a comprehensive evaluation method, the method is characterized by the use of fuzzy sets, some complex and difficult to quantitative, quantitative factors and then construct the fuzzy matrix, the use of fuzzy operator composite operator, to finalize the evaluation of the object level (Tao, J. C et al,2010).

1) The first level of comprehensive evaluation

According to FUZZY theory, the FUZZY matrix synthesis operation, to evaluate each child respectively to make comprehensive evaluation factor set, U_i of evaluation vector $B_i = W_i \circ R_i = (b_{i1}, b_{i2}, ..., b_{i5})$.

2) The second level of fuzzy comprehensive evaluation

Each child factors set U_i as a factor, B_i was used as the single factor evaluation, namely get factors set U to comment set V a fuzzy mapping. The secondary comprehensive evaluation: $B = W \circ R = (b_1, b_2, ..., b_m)$ .Here, R is fuzzy evaluation matrix. The W stands for weights of objects layer influence factors.

According to the quantitative value of V of the evaluation set , FUZZY comprehensive score of F is obtained by $F = B \cdot V^T$. The evaluation results would be analyzed according to the scores.

4 Controllers' Fatigue Risk Comprehensive Evaluation Example Analysis

Take a control center as an example, based on the evaluation index system and evaluation model, the controllers' fatigue risk instance has been analyzed:

1) To set up the evaluation factor $U = \{U_1, U_2, \cdots, U_5\}$, which $U_1 \sim U_5$ respectively controllers, controllers and other personnel, controllers and hardware, controllers and the environment, controllers and the environment; Second to set up the secondary evaluation factors: $U_i = \{U_{ij}\}(i = 1, 2, ..., 5; j = 1, 2, ..., 8)$.

2) To set evaluation set with the corresponding standards. According to controllers may happen fatigue risk, determine the evaluation sets of five levels: V = {v1, v2, v3 , v4 , v5} = {'less', 'small', 'medium', 'high', 'higher'}. In order to quantify the evaluation results, to make the results easy to understand, it is needed to clear the scale of the grade score interval, and the medium score would be taken as the quantitative score. The specific rating score interval and quantitative score are shown in table 2.

3) To determine the initial weights W_a. Using the expert investigation method, 15 experienced controllers have been consulted according to the rate of 1-9 scaling method to get the corresponding judgment matrix, the initial weight W_a, as shown in table3 has also been got.

Table 2. risk grade and risk level assessment

grade	I	II	III	IV	V
levels	less	small	medium	high	higher
score	[0，20]	(20，40]	(40，60]	(60，80]	(80，100]
score	10	30	50	70	90

4) To modify the initial weights. Through questionnaires to the expert panel, we can get influence matrix between the layers of index, through calculation, affect weight W_b can be set, with integrating the initial weights and improved weight, new weight W can be set .

Table 3. factor sets, evaluation index weights and evaluation results

index	weight			index	weight			Judging matrix data				
	W_a	W_b	W		W_a	W_b	W	V_1	V_2	V_3	V_4	V_5
U_1	0.4390	0.3022	0.3706	U_{11}	0.3135	0.1783	0.2459	0.4	0.4	0.2	0	0
				U_{12}	0.1215	0.1068	0.1142	0	0.3	0.5	0.2	0
				U_{13}	0.0651	0.2488	0.1570	0.1	0.3	0.3	0.2	0.1
				U_{14}	0.0500	0.0986	0.0743	0.1	0.2	0.5	0.2	0
				U_{15}	0.2595	0.1241	0.1918	0.3	0.5	0.2	0	0
				U_{16}	0.0385	0.1516	0.0950	0.3	0.4	0.2	0.1	0
				U_{17}	0.1522	0.0919	0.1220	0	0.1	0.6	0.3	0
U_2	0.0557	0.1516	0.1037	U_{21}	0.5396	0	0.5396	0.1	0.3	0.5	0.1	0
				U_{22}	0.2970	0	0.2970	0.1	0.2	0.5	0.2	0
				U_{23}	0.1634	0	0.1634	0	0.3	0.4	0.3	0
U_3	0.0545	0.1622	0.1083	U_{31}	0.3333	0	0.3333	0.5	0.2	0.3	0	0
				U_{32}	0.6667	0	0.6667	0	0.2	0.5	0.2	0.1
U_4	0.1661	0.2295	0.1978	U_{41}	0.4476	0.3205	0.3840	0	0	0.3	0.3	0.4
				U_{42}	0.1636	0.2265	0.1951	0.4	0.3	0.2	0.1	0
				U_{43}	0.1059	0.4530	0.2795	0.2	0.2	0.3	0.3	0
				U_{44}	0.2829	0	0.1414	0	0.4	0.5	0.1	0
U_5	0.2484	0.1545	0.2015	U_{51}	0.2424	0.0117	0.1270	0	0.4	0.3	0.2	0.1
				U_{52}	0.1216	0	0.0608	0.2	0.4	0.4	0	0
				U_{53}	0.0412	0.1283	0.0847	0	0.3	0.3	0.3	0.1
				U_{54}	0.0655	0.2276	0.1466	0	0	0.3	0.3	0.4
				U_{55}	0.2381	0.0947	0.1664	0	0.2	0.3	0.3	0.2
				U_{56}	0.1259	0.1706	0.1483	0	0.1	0.4	0.3	0.2
				U_{57}	0.0350	0.2340	0.1345	0	0.3	0.3	0.3	0.1
				U_{58}	0.1303	0.1331	0.1317	0.2	0.2	0.4	0.1	0.1

5) To determine the fuzzy evaluation matrix. In accordance with the above comment, 10 control experts are asked to evaluate the indexes to make the fuzzy evaluation matrix (table 3).

6) The first level of comprehensive evaluation.

$$B_1 = W_1 \circ R_1 = \begin{pmatrix}0.2075 & 0.3407 & 0.3211 & 0.1152 & 0.0157\end{pmatrix}$$
$$B_2 = W_2 \circ R_2 = \begin{pmatrix}0.0837 & 0.2703 & 0.4836 & 0.1626 & 0\end{pmatrix}$$
$$B_3 = W_3 \circ R_3 = \begin{pmatrix}0.1666 & 0.2000 & 0.4333 & 0.1333 & 0.0667\end{pmatrix}$$
$$B_4 = W_4 \circ R_4 = \begin{pmatrix}0.1339 & 0.1710 & 0.3088 & 0.2327 & 0.1536\end{pmatrix}$$
$$B_5 = W_5 \circ R_5 = \begin{pmatrix}0.0385 & 0.2153 & 0.3341 & 0.2427 & 0.1694\end{pmatrix}$$

Where "$\circ$" is a compound operator in fuzzy matrix. According to the evaluation factors, we select $M(\bullet,+)$ as the comprehensive evaluation function.

7) The second level of fuzzy comprehensive evaluation.

According to the first level of comprehensive evaluation results, the R can be stated as following matrix:

$$R=\begin{bmatrix}B_1\\B_2\\B_3\\B_4\\B_5\end{bmatrix}=\begin{bmatrix}0.2075 & 0.3407 & 0.3211 & 0.1152 & 0.0157\\0.0837 & 0.2703 & 0.4836 & 0.1626 & 0\\0.1666 & 0.2000 & 0.4333 & 0.1333 & 0.0667\\0.1339 & 0.1710 & 0.3088 & 0.2327 & 0.1536\\0.0385 & 0.2153 & 0.3341 & 0.2427 & 0.1694\end{bmatrix}$$

Make the second level of the fuzzy comprehensive evaluation:

$B=W\circ R=(0.1379 \quad 0.2532 \quad 0.3445 \quad 0.1689 \quad 0.0775)$

The vector B stands for object layer calculation results. Normalized as $B'=(0.1404 \quad 0.2578 \quad 0.3508 \quad 0.1720 \quad 0.0790)$. By fuzzy evaluation vector $V=(10 \quad 30 \quad 50 \quad 70 \quad 90)$ get comprehensive evaluation results:

$F=B'\cdot V^T=45.8251$

In the same way we can get $F_1\sim F_5$ as follows:

$F_1=37.8196$; $F_2=44.4952$; $F_3=44.6676$; $F_4=52.0206$; $F_4=52.0206$.

According to the evaluation results, the evaluation results of risk of fatigue can be stated by the following descriptions:

The grade of controllers' fatigue risk is "medium". The primary index score sorting is $F5>F4>F3>F2>F_1$, in addition to the ATC factor score of 37.8196, in a "small", the other factors in the "medium" level. Among them, the controllers and environmental factors, controllers and software factors score close to 60, namely "high" level, affects the overall score should be paid more attention. For the secondary indicators, among them, the weather conditions, the crew resource management, the shift system, personnel, equipped with 4 factor scores are more than 60, in a "high" level, are the higher rating reasons of the controllers and the environment, controllers and software. For this, the management and training should be strengthened, and the shift system should be optimized. Sleep, body health, emergency and communication ability, equipment failures, workplace environment, complex structure of six factors are in a "small" level; other factors are in the " medium", in which safety awareness and sense of responsibility, the equipment can meet the demand of controllers, business training, site management confusion, preference for 60 points, should be treated seriously to prevent the situation to become worse. Therefore, grading result has pointed out the direction for quantitative fatigue risk management.

5 **Conclusions**

Firstly, to establish the controllers' fatigue risk evaluation index system based on the SHEL model, factors of judgment matrix are obtained by expert grading, the weight of each influence factor is calculated by AHP. Secondly, the weights are modified with using DEMATEL that effectively reduces the interaction between various indicators, thus to improve the objectivity and scientific degree of evaluation index weight. Last, the fatigue quantitatively scores are set with the fuzzy comprehensive evaluation system. With the experiment, through the set model, the controllers' fatigue risk level has been determined as "medium". Verified by the relevant experts, the evaluation result accords with the basic control center's actual situation, which verified the practicability and validity of the evaluation system. At the same time, the various factors scores can provide the basis for fatigue risk management. This method, as a perfect combination of qualitative analysis and quantitative analysis, has provided a new method for the controllers' fatigue quantitative risk management.

6 Recommendations for Future Research

On the basis of the present study, combine with interactive programming software, it can develop tools of fatigue and risk assessment to the airline company's fatigue and risk assessment, provide a great reference of scientific management for the company.

Acknowledgement

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References

Allen, T. (2004). A report to the national consultative council occupational health and safety subcommittee on fatigue management within airservices Australia air traffic services. *AirServices Australia*.

Feng, C. (2012). The study on ERP system evaluation based on fuzzy analytic hierarchy process method. *International Journal of Digital Content Technology & Its Applic*,6(22),231-238.

Hongzhi Wang, Yang Zhao. (2012). Analysis on Mechanism of Human Factors and Complexity in Ship Transportation Management. *Journal of Theoretical and Applied Information Technology*, 609-614.

Ji Q., Lan P., Looney C. (2006). A probabilistic framework for modeling and real-time monitoring human fatigue. *Ym Man and Ybrn Ar A: ym and Hman Ranaon on*, 862 - 875.

Kun, P., & Maoshan, Q. (2004). Study on application of fuzzy-ahp in risk evaluation and bidding decision-making of Duber Khwar hydropower project. *Journal of Hydroelectric Engineering*, 23(3),44-50.

Liu Lianxin, Liu Yu, Shi Guangxia. (2014). Study on the analytic hierarchy process and fuzzy comprehensive evaluation on the quality of teaching. *Journal of Chemical and Pharmaceutical Research*, 6(2), 89-95.

Tao, J. C. A. J. (2010). Fuzzy comprehensive evaluation of drought vulnerability based on the analytic hierarchy process: —an empirical study from xiaogan city in hubei province. *Agrlr and Agrlral n roda*, 126-135.

Mohsen Alvandi, Safar Fazli, Leila Yazdani,et al. (2012). An Integrated MCDM Method in Ranking BSC Perspectives and key Performance Indicators. *Management Science Letters*, 2(3), 995–1004.

Minhui Yan, Xiuping Yao, Jinfeng Zhang, et al.(2014). Determining Weight Coefficients of Meteorological Service Evaluation Criteria with AHP. *Journal of Applied Meteorological Science*,25(04),470-475.

Humanized Transportation Design Research Based on the Sustainable Development of Urban Roads

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Abstract: Urban road plays a important task of carrying traffic flow in traffic system. The level of traffic design will directly affect the efficiency exerting of the whole urban traffic. Urban roads humanized transportation design bring humanized design ideas into the urban road traffic design, human centered and scale, to meet people's physiological and psychological needs, material and spiritual needs. In this paper, analyze the connotation of humanized transportation design of urban road. Then explore different levels of goals to humanized transportation design. Finally put forward the specific content of urban roads humanized transportation design, including humanized design of barrier-free facilities, sidewalk, crossing facilities, and temporary park. Through constantly integrate humanized ideas into the urban road design, ultimately achieve the harmony between humankind and nature.

Keywords: Urban roads; Humanized; Transportation design; Sustainable development.

1 Introduction

The sustainable development is the rational regression of think over about human traditional development model, social development translates from purely economic growth into coordinated development of economy, society and environment. Urban traffic sustainable development is the concrete embodiment of the concept of sustainable development in transportation field, and urban roads humanized transportation design is an effective means to achieve sustainable development of urban traffic. Through the use of humanized design ideas in the urban road traffic design, will maximum limit of traffic participants in the passage of time is not one's own internal force through, reduce road conflict between vehicular traffic and pedestrian traffic, protect personal safety of traffic participants, and promote the harmonious coexistence of people-car-road.

2 Connotation of Humanized Transportation Design

Humanized transportation design bring humanized design ideas into the urban road traffic design, optimize the design for transportation system and transportation infrastructure of human centered, to meet people's physical and psychological needs, material and spiritual needs. Through humanized transportation design can maximum limit traffic participants forced through the Places do not have the right of way, reduce the conflict between road traffic and pedestrian traffic, protect the personal safety of traffic participants, promote the harmonious coexistence of people-car-road, conducive to the sustainable development of urban traffic. In the humanized transportation design need to meet the following three requirements:

2.1 Centred round Traffic Participants

Centred round traffic participants, meet the traffic demand of the traffic participants. So-called humane traffic design is the design of traffic required to meet requirements of human. The so-called human traffic design is the traffic design need to satisfy the requirements of humanization. At present the development of urban traffic mode tend to be heavy vehicle light person, urban transportation infrastructure is car traffic system rather than the human system. In fact the ultimate goal of urban traffic is not in order to achieve the transfer of car, but with the help of the various traffic tools to realize transfer of people. In the final analysis is to serve the people.

2.2 Based on Traffic Planning

Taking traffic planning as the basis, play link role between traffic planning and road facilities construction. Traffic design is the intermediate link of traffic planning and road facilities construction. On the one hand through the traffic design makes transport planning concept to be realized, on the other hand road facilities construction need to be guided by the traffic design. Traffic design makes the road facilities construction follow traffic planning concept, to ensure the close linkage between traffic planning and road facilities construction.

2.3 Constrained by Transport Resources

Constrained by transport resources, ensure the effectiveness and feasibility of traffic design. Traffic resources refer to a series of elements of transport activities for the social and economic system, including market resources, technical resources, financial resources and space resources. In the traffic design, it is necessary to give full consideration to the existing transport resources, in order to ensure the effectiveness and feasibility of traffic design.

Humane transportation design based on the above three requirements, finally realize the traffic participants in the general process of traffic demand, included functionality, safety, convenience and comfort. Functionality is the most basic demand of traffic facilities, this is a prerequisite to let traffic participants make use of traffic facilities. Traffic participants in the use of transportation facilities need to consider the safety of transport facilities. After safety is met, traffic participants will pursue the convenience and comfort requirements. Elements of humanistic traffic design as follows.

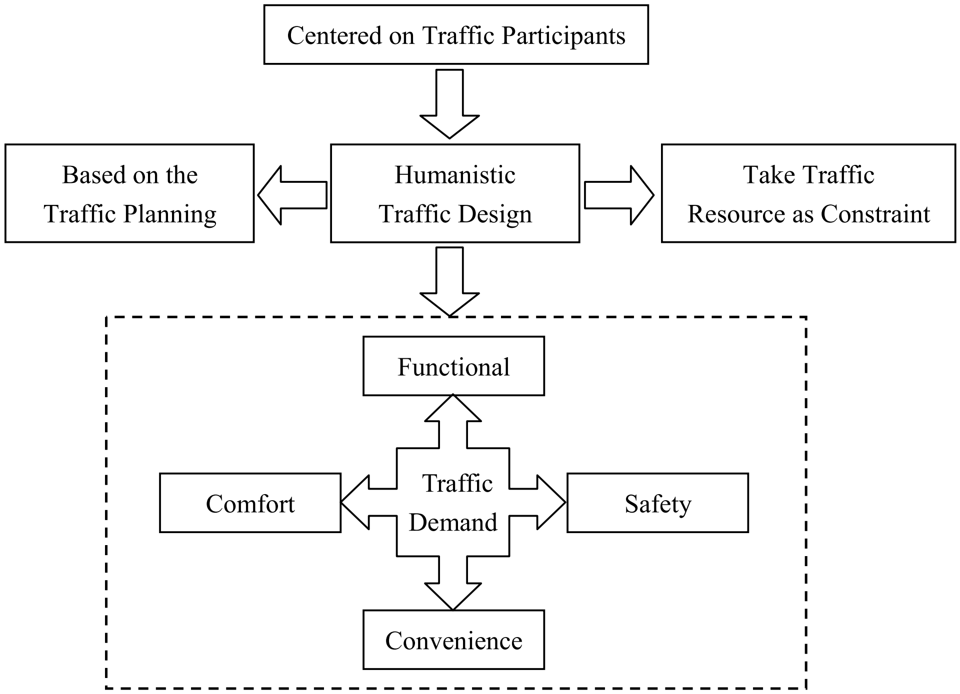

Figure 1. Elements of humanistic traffic design

3 Goals of Humanized Transportation Design

Humane traffic design's goal is to meet the traffic participants in turn different levels of traffic demand, let the traffic participants feel safe, convenient and comfortable in the traffic process. At the beginning of urban development, road system at an early stage, fewer roads and poor traffic quality, at this time traffic design goal is just to meet the basic needs of travel. With the continuous development of urban economy, road facilities gradually increase, traffic accident increased significantly, began to realize the importance of safety. Traffic safety as the main principle in traffic design; strengthen the construction of road safety facilities; ensuring the safety of travel. After the safety of traffic participants are protected, traffic design began to pursue the convenience of transportation. Through the road facilities construction to promote urban road system increasingly perfect. Traffic participants can quickly reach the destination by road infrastructure. When the traffic function, safety, and convenience of goals have been realized, people increasingly high to the requirement of the spiritual life, and humanization design concept more and more attention. Traffic design goal up to traffic comfort, emphasis on human-centered, ultimately achieve the maximum harmonization of people, car, road and environment. The relationship between the various levels goals of traffic humanization design as shown in Figure 2.

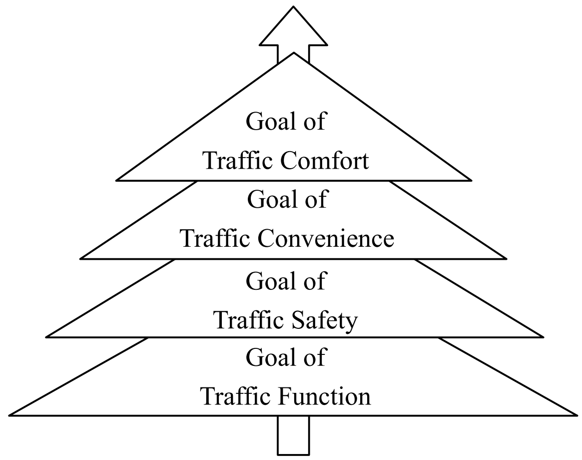

Figure 2. Goals of humanization traffic design

3.1 Goal of Traffic Function

Meet the traffic function is the primary goal of humane traffic design, traffic design if unable to meet the established traffic function, traffic participants would not have to use the traffic facilities, and the presence of the transport infrastructure is redundant. In all goals of humane traffic design, function demand is the most basic and important. Traffic design only meet the function of traffic, traffic participants will pursue a higher level of demand.

3.2 Goal of Traffic Safety

After the traffic design meet the established traffic function, traffic participants will pursue traffic safety in the travel process. Personal safety is the primary factor of traffic participants consider, this is the basic condition for people to survive. Traffic participants in the travel process, safety demand have risen to an irreplaceable position. On the road at any time and any place, people need a protected space. Traffic safety goal should be mentioned in an important position of the human traffic design, and fully consider the traffic participants for the safety of the psychological feeling.

3.3 Goal of Traffic Convenience

Convenience demand refers to traffic participants can easily choose the path in the travel process, eventually passed the road infrastructure to reach the destination. In the traffic design should take full account of this goal, road network is very complicated, when through the network node, traffic participants often encounter the problem of path selection, at this point the need for planning, decision-making, information processing, traffic participants need to have better spatial discrimination and psychological control ability, namely spatial cognition. Now people pay much attention to efficiency, we usually want the most effort, the most energy, the most time, the least cost way to achieve their own needs. So in the city humane traffic design, should fully consider the convenience of traffic participants needs.

3.4 Goal of Traffic Comfort

Comfort goal refers to traffic participants in the travel process of physical and mental pleasure, and enjoy the whole travel process. When the urban traffic design meets the function demand, safety demand and convenience demand of traffic participants, traffic participants becomes to pursuit of comfort goal. Urban traffic to ensure comfortable driving, traffic participants feel happy in the travel process, the quality of life is improved with the increase of, the quality of life increases. Comfort demand is a higher level of demand, can let people to get rid of the traffic negative impact, make the traffic participants physical pleasure in the travel process.

4 Humanized Designs of Urban Roads

4.1 Humanized Design of Barrier-free Facilities

Barrier-free design of urban roads can best reflect the level of humanized, from the blind road layout to curb ramp forms, reflects the love and care for people with disabilities. Currently most of the urban roads have barrier-free facilities, but there are some problems, such as curb ramps and crosswalk mutual dislocation, parking chaos on the blind, blind road brick loose, road barrier-free facilities and surrounding building barrier-free facilities not cohesion. In order to ensure safely travel and use for persons with disabilities, from design, construction to maintenance all needs to be strictly the quality pass. At the same time, the road barrier-free facilities linking to the surrounding entrances, to facilitate travel for the disabled.

4.2 Humanized Design of Sidewalk

Compared with road, city road pedestrian traffic volume is larger, sidewalk is an important part of city roads, establish and improve the pedestrian system is fully reflected humane. In the humanized design of the sidewalk, not only pay attention to the appearance design of pavement, pedestrians on the sidewalk of color and pattern is not very interested, Pedestrians are most concerned about safety and comfort. So traffic design should fully consider the smoothness of sidewalk and paving skid brick as far as possible, ensure that pedestrian can walk safely on the sidewalk.

4.3 Humanized Design of Crossing Facilities

Urban roads occupied large proportion of pedestrians and non-motor vehicles. If not fully consider the demand to across the street in the traffic design, then wait until after the completion of urban roads, they can only to find a suitable way out on their own arrangements, it will be prone to traffic violations such as crossing the road, not only affect the traffic order, and it is easy to cause traffic accidents. Therefore, during the humanized design of pedestrian crossing facilities, shall be detailed investigation of the engineering situation and planning, analysis of pedestrian demand scientifically, clear focus on the general location of crossing the street, and build reasonable crossing facilities.

4.4 Humanized Design of Temporary Park

Motor vehicle in urban road stop disorderly phenomenon is serious. Motor vehicle occupancy lane for parking, likely to cause congestion, reduce the traffic capacity of roads. Combined with urban land resources are very scarce, unable to build a large-scale parking for vehicle parking. In this case, can be wide sidewalks as a temporary parking of motor vehicle, combined with the specific circumstances of each road, sub-sections, sub-time to make scientific and reasonable regulations, formulate feasible charging standards, and increase the daily maintenance of these sections. It can not only make full use of the sidewalk resource, but also can relieve the pressure caused by parking in a certain extent, let parking chaos phenomena become orderly, thus to ensure the stability of the entire traffic order and smooth, thus to ensure the entire traffic order stability and smooth.

5 Conclusions

In summary, with the continuous development of china's national economy and the continuous improvement of people's living standards, urban residents on the construction of urban infrastructure and advance the level of awareness of a higher demand. For urban road, not only on the traffic function, but on the safety, convenience, comfort also has higher requirements. In response to deal with increasingly serious traffic pressure and environmental problems, need to constantly optimize the design of urban roads, integrate humanized ideas in the design, creating humanized space of city, and ultimately promote the sustainable development of society.

References

Du, R. B. (2008). "*Research on the methods of humanistic traffic design of urban road,*" Harbin Institute of Technology, Harbin.

Fu, L., and Yang, S. S. (2011). "*Urban transportation sustainable development strategies based on the conception of green traffic,*" China Population Resources and Environment, Jinan, 21(3), 367-370.

Han, Y. F., and Li, J. (2010). "*Discussion on urban road humanization design,*" Journal of Huazhong University of Science and Technology, Wuhan, 22(S), 164-168.

Lu, Z. R., and Qu, L. M. (2010). "*Humanization design idea of urban road,*" Communications Standardization, Beijing, (234), 114-116.

Zhang, Q. (2010). "*Evaluation on the humanization design of urban roads,*" Southwest Jiaotong University, Chengdu.

Analysis of Roadside Traffic Accidents on Arterial Highways and Roadside Security Protect

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Abstract: This article starting from the arterial highway traffic accident analysis, it analyzes "2010 Statistical Yearbook of road traffic accidents" and concludes the distribution law about the arterial traffic accident. Furthermore, the article analyzes the influence factors of arterial roadside accident, comparing the results of the roadside safety problem. According to the latest domestic and foreign roadside design ideas and methods, it analyzes the various design elements and understands the design content, so as to provide a reference to the later proposed improvement measures. Finally, from the side of road safety tolerance design concept and reasonable way the side net perspective, in order to enhance expressway roadside safety, optimize roadside safety facilities. It is of great significance to design roadside and take effective and practical measures to increase the safety level on arterial highway.

Keywords: Arterial highway; Traffic accident; Roadside; Protection; Tolerance design.

1 Introduction

Arterial highway is the main highway in long-distance travel and rapid transportation. But arterial highway traffic easily lead to accidents, due to high speed, complex road condition, complex vehicles and interference factors. Therefore, adopting all kinds of means to reduce off-road accident frequency and off-road accident severity, which has important significance to reduce the loss of people's lives and property and improve the level of road traffic safety.

By analyzing arterial highway accident, we find out the cause and characteristics of the accidents, and summarize the factors influencing arterial highway off-road accidents. Arterial highway roadside design improves road safety conditions and then put forward the main countermeasures of roadside accident.

2 Analysis of roadside accident statistics of arterial highway

This article starting from time, space, conditions and causes four angles, it analyzes "2010 Statistical Yearbook of road traffic accidents" and concludes the distribution law about the arterial traffic accident:

(1) Accident affected by season, from November to January is relative the peak, the number of accidents close to 10 %, while from September to

February's fatal accident rate is relatively high.

(2) The majority of arterial highway accidents occurred during the day, it formed the peak of accidents at 17-20.

(3) Arterial highway accident mainly occurred in the plain areas, accounted for 66%, but from the accident death rate angle, the area of mountain was significantly higher than the plains and hilly area.

(4) Arterial highway accidents mainly distributed in the straight section, the proportion of 90%, but the accident death rate is the lowest.

(5) Arterial highway accident black spot mainly distributed in the road.

(6) Arterial highway without protective measures is easy to cause accident, but inappropriate protective measures will increase the accident death rate.

(7) Arterial highway traffic accident is a collision between motor vehicles. The main form is head-on collision, side collision, following collision and scraping hit pedestrians, which side collision is more than 35%.

(8) The cause of arterial highway is varied, which the main factor is the driver's own, but also there are some objective factors leading to traffic accidents.

3 Analysis of influence factors of arterial highway roadside accident

Transportation system is consisted of people, vehicles and road, traffic accident is also the result of these three factors. The analysis of roadside accident's influence factors are also from the three points.

3.1 Roadside accidents and traffic participants

Traffic participant is driver, passenger and pedestrian, which the driver is the main factor. The driver's physiological; psychology, perception, analysis, judgment and reaction are not identical. While the perceived slow, inaccurate judgment, operational errors in the accident accounted for the majority, which is mostly due to the driver's body, physiological, mental, emotion ,experience and so on.

3.2 Roadside accident and vehicle

The vehicle performance is an important factor affecting traffic safety. Although in many accident statistics, the proportion of roadside accident caused by vehicle fault is not large, but once this kind of accident occurs, the consequences are more serious.

The reason caused by vehicle roadside accident is breaking failure, light failure, mechanical damage, vehicle overloading, goods lashing not solid and other reasons. In addition, because of many parts suffer repeated load, the vehicle will lead to accident after more than a certain number of fatigue.

3.3 Roadside accident and road

Traffic foundation is road. Road must meet its clients' characteristics and demand. The influence factors of road alignment to accident are: radius, curve frequency, corner, steep, linear combination, the horizon. These will affect the driver's driving to a certain extent. Studies have show that widening lane can reduce roadside accident.

Roadside protection measures are important influence factors of roadside accident, but improper protective measures may even lead to the roadside accident.

4 Arterial highway's safety protection design measures

4.1 Safety design concept and elements of arterial highway roadside

Roadside safety design includes tolerant design, flexible design and harmonious design. Tolerance design is the core of roadside safety design (YAO Xianghua, 2010). Based on the tolerant design, road must provide adequate roadside zone to off-road vehicle, in order to ensure the roadside safety and minimize the severity of the accident. The core of roadside tolerance design is the design of roadside zone. During the design of roadside safety facilities, flexible design should consider local economic conditions, the existing facilities, construction materials etc, which to select the most appropriate local scheme from a variety of options. The idea of harmonious design is to protect the local environment, the highway alignment in harmony with environment, giving a comfortable feeling (GAO Hailong, LI Changcheng, 2008).

Highway roadside accident is people, car and road in the traffic system which one or more of the factors' coordinate relationship have been destructed. According to the characteristics of roadside accident, this paper summarized the influence of highway roadside safety and environment factors.

Arterial highway design elements include: highway geometry alignment, road surface recognition, shoulder, side ditch, slope, traffic safety facilities, and other roadside safety facilities and the roadside environment.

4.2 Arterial highway roadside accident active preventive measures

Active guidance is to achieve interaction between driver and road, which install traffic safety facilities and improve road environment. The driver can consciously change operation behavior and driving direction, according to the information conveyed by running environment. Driving environment played an "active" leading role, who prevent vehicle from driving off-road and effectively reduce the possibility of vehicle off-road (LI Yang, 2008).

4.2.1 Line of sight guidance

Line of sight induced facilities set along the lane both of the road, indicating the direction of the road, roadway boundary and dangerous section. It can induce the driver's line of sight in the daytime and night, showing the outline of road and guiding or warning the change of the highway alignment, in order to promote safe operation. At present common sight induced facilities are outline sign, linear induction sign (PENG Wuxiong, 2007) and confluence induced sign. The facility's cost is low and the use is widespread.

Outline sign arrange on the edge of the road, indicating the road alignment outline and the right direction. Arterial highway often has vicious accidents in sharp and continuous steep place, where it is necessary to set up outline sign. The accident black spot should also set up a reflective outline sign or bigger size of reflector. When you set the outline sign, please pay attention to the transition between the straight line and curve, and maintain a smooth continuous line of sight guidance.

Linear induction sign used to show the outline of road and guiding or warning the change of the highway alignment, in order to promote safe operation. Linear inducing divided into the indicative linear inducing sign and warning linear inducing sign.

Confluence induced sign commonly is warning pile. Warning pile is to improve its recognition and warn driver road alignment, which usually are red and white. Warning pile is arranged on the side of roadside with a certain width and good horizon.

4.2.2 Cross-boundary reminder

Cross–boundary reminder has vibration line and shoulder rumble strip. Vibration line's surface spread over refractive index glass beads, which can slow down, prevent slippery and rainy night reflection. At the same time, it also can effectively avoid vehicle off-road according to vibration reminder which serve as a warning to the driver. Setting vibration line needs to have adequate zone providing "tolerance" space to off-road vehicle.

Shoulder rumble strip remind vehicle through the vibration and noise to return the normal lane. Reducing caused by driver fatigue and distraction off-road accident is very effective. It has low maintenance cost and high profit. It also can be used in existing or new pavement.

4.2.3 Pavement skid resistance

Pavement skid resistance mainly set skid resistance sideslip and change the pavement structure. Skid resistance sideslip usually arranged on sharp bends or steep sections, and its cost is low. Changing pavement structure aim to increase pavement skid resistance coefficient and improve pavement skid resistance. It includes changing pavement material, increasing the cover layer, increasing pavement texture, using pavement groove. Due to the high cost, it generally used in high grade highway.

4.2.4 Shoulder hardening

Shoulder hardening can be divided into shoulder widening and shoulder strengthening. In most cases shoulder widening involve widening roadbed. From the financial point of view, it is not very economical, compared with shoulder strengthening is more economical and efficient. Shoulder strengthening is one of the most effective means to increase the width of the road, especially highway pavement width is small in the mountainous area, which can increase traffic capacity and improve traffic safety.

4.2.5 Speed control

Speed control includes the following factors: Advisory, Speed feedback facilities, Deceleration mark, Illusion mark and Deceleration hump.

Advisory speed limit is different from the general speed limit. It does not have the force of law. In China there is not advisory speed limit, but many foreign countries began to use. Advisory speed limit is usually used in dangerous curve recommended together with warning sign.

Speed feedback facilities can detect vehicle speed passing a point and display on the screen. Once the vehicle speeding, it also can send out the alarm to the driver. In arterial highway, speed feedback facilities are suitable to frequent accidents sections caused by excessive speed.

Deceleration mark is used to remind the driver to slow down. It usually set in a small radius curve segment, long downhill, uphill convex vertical curve etc.

The principle of the illusion mark is making driver illusion that feeling the road is more and more narrow, causing the driver's psychological preparedness and involuntarily slowing down.

Deceleration hump is a mandatory deceleration measures which have a certain degree in the road. It usually sets at the chicane steep two-lane highway, the continuous long steep, road through the town or village. Next to the deceleration hump should set up corresponding deceleration sign and mark.

4.2.6 Change the alignment

Changing the alignment includes changing the horizontal curve and geometry. If changing horizontal curve and shoulder widening implemented together, it will greatly help to reduce arterial highway roadside accident. Change horizontal curve common methods are: increasing the horizontal curve radius, setting transition curve and avoiding negative linear combination. Changing road geometric alignment is high investment and long cycle, but is the most fundamental improvement method. Improving methods are the following three points: making the alignment consistency, straighter and eliminating the "dark concave".

4.3 Arterial highway roadside roll over and collision protective measures

Arterial highway roadside roll over and collision protective measures is to set up adequate roadside area and minimize roadside obstacles. It includes rational design of embankment slope, drainage facilities, removal of roadside hazardous materials, roadside hazardous material sign.

Embankment slope can be divided into three types: return slope, non-return slope and dangerous slope. Return slope's safety is best. Off-road vehicle usually can stop or slow back to lane in the return slope. Design had to be not apparent discontinuities dangerous goods and fence. If necessary, it can set the sight induced facilities. In the non-return slope, vehicles usually can not stop or return to lane, but directly ran to the bottom of the slope, so the slope cannot exist dangerous goods. In the dangerous, the vehicle roll over accident possibility is bigger.

Roadside drainage facilities include curb, ditch, culvert and other drainage structures. The design of ditch should not only meet the requirements of drainage, but also as far as possible not lead to off-road vehicle plunged into ditch or collision with the ditch.

Off-road vehicle will collide with roadside obstacles. In order to reduce such accidents, we should try to remove roadside obstacles.

When the roadside dangerous goods can not be removed shift and other means of disposal, it can brush reflective paint on the goods or set warning sign next to the dangerous.

4.4 Arterial highway roadside collision protection measures

Arterial highway roadside collision protection measures mainly are roadside fence, energy dissipating installation and buffer energy dissipation facilities.

Collision avoidance mechanism of roadside barrier is absorbing the energy of collision through barrier and vehicle elastic-plastic deformation, friction and displacement body, in order to protect the driver and passenger safety. Barrier itself is an obstacle, and it should properly handle roadside safety area' obstacle with design of tolerance idea. Its cost is high, but it must use in mountainous road.

In order to ensure the highway roadside safety, it should try to eliminate the potentially dangerous goods in the roadside area. But some facilities are essential, such as traffic sign, road lighting facilities and traffic signal emergency telephone. such facilities' rod has formed the fixed obstacles. When ensure such facilities that can resist wind load and ice load, it can realize yield and disintegration to erased collision through the sliding surface, plastic hinge and frangible element, in order to reduce the severity of accidents.

Buffer energy dissipation facilities usually set at highway horizontal curve, interchange, entrance of service area, bridge parapet ends and bridge piers, playing a warning and buffer role. Its cost is low and the use is widespread.

5 Conclusions

This paper analyzes the law of arterial highway accidents and the influence factors of arterial roadside accident, comparing the results of the roadside safety problem. Then it analyzes the various design elements and understands the design content. Finally it concludes roadside accident active preventive measures, roadside roll over and collision protective measures and roadside collision protection measures. This paper has great theoretical and practical significance.

References

YAO Xianghua. (2010). The Application of Roadside Safety Design Concepts in the WesternS334 in RuDong. Construction & Design for Project, (36):115-117

GAO Hailong, LI Changcheng. (2008). Roadside safety design guide. Beijing: China Communications Press, 18-23

LI Yang. (2008). Study on Side Highway Safety Technology and Application. Chang'an University Master's degree thesis, 51

PENG Wuxiong. (2007). Research on the reasonable spacing for driver's line of sight delineation facilities. Wuhan University of Technology Maeter's degree thesis, 7-10

Safety Effectiveness and Safeguards of Electronic Traffic Enforcement

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Abstract: Traffic electronic enforcement facilities were carried out widely in china, but its application effectiveness was lack to system evaluation. The time distribution, types, cause and severity degree of traffic accidents were comparatively studied on the basis of datum which were collected before and after the implementation of traffic electronic enforcement facilities, and the existing problems of traffic safety were concluded at signalized intersection after implementing traffic electronic enforcement. The analysis showed that traffic electronic enforcement could obviously improve the condition of traffic safety at signalized intersection, especially restrain the traffic accidents significantly which were caused by illegal driving that traffic electronic enforcement facilities could detect, but the severity degree of traffic accidents tended to worse. In order to improving the condition of traffic safety in the environment of traffic electronic enforcement, the safeguards should be set up from the aspects of education, engineering and management. The conclusion was helpful to guiding the scientific application of traffic electronic enforcement in china.
Keywords: Electronic enforcement; Safety effectiveness; Safeguards; Traffic accident.

1 Introduction

A number of researching works have been carried out abroad in the aspects of safety effect evaluation and safeguards of traffic electronic enforcement because of their longer application of traffic electronic enforcement facilities, the evaluation methods have been formed. For example, Flannery and Maccubbin used Meta analysis techniques to assess the safety effect of red light running cameras (A Flannery, 2002). Ruby and Hobeika evaluated the effectiveness of red light running cameras from the aspects of traffic violation, traffic accidents and socio-economic, pointed out that warning signs should be established at the upstream position of traffic electronic enforcement facilities (D E Ruby, 2003). Zwahlen and Suravaram analyzed the contribution of driver education, strict issuance of driving licenses and traffic electronic enforcement, pointed out that traffic electronic enforcement was the most efficient way to reduce traffic accidents (H T Zwahlen, 2007). Decina and Thomas systematically evaluated the situation of traffic safety at the sites of traffic electronic enforcement facility (L E Decina,2007). Stokes, Russell and Rys analyzed the feasibility, effectiveness, legitimacy and public acceptability of automated traffic signal enforcement in Kansas(R W Stokes,2003). Tarek and Paul proposed the evaluation method of intersection safety camera program in Canada (S Tarek, 2007) .

Because of significant difference of traffic environment between China and developed countries, moreover the traffic electronic enforcement facilities were carried out widely in China, so it was necessary to assess the situation of traffic safety improvement after its implementation in order to play the advantages, meet the shortfall and promote scientific applications of traffic electronic enforcement.

2 The characteristics of traffic accident

The accident data in this paper was provided by the traffic police department, relying on the national "863" project. The scope of investigation was traffic accidents at forty signalized intersections during three years before and after the implementation of traffic electronic enforcement in Harbin, China. Harbin implementation of traffic electronic enforcement began to be widely used in 2006, so the accident data for consecutive three years was 2002 to 2004 and 2006 to 2008. Statistical analysis of the data used comparison method, and through quantitative and qualitative analysis, the safety effectiveness of traffic electronic enforcement was mainly reflected.

(1) Key indicators comparison of traffic accidents

Table 1 lists the key indicators comparison of traffic accidents at forty signalized intersections before (from 2002 to 2004) and after (from 2006 to 2008) the implementation of traffic electronic enforcement in Harbin, China.

The datum in table 1 showed that the number and total economic loss of traffic accidents reduced obviously after the implementation of traffic electronic enforcement, the condition of traffic safety at signalized intersections had been improved, but death rate, injury rate and economic loss per traffic accident were rising, which death rate per traffic accident increased 0.087, the injury rate per traffic accident increased 1.039. The rising characteristics of traffic accidents were related with the situation that drivers accelerated to pass signalized intersection at the moment of rear yellow time in order to avoiding the punishment by traffic electronic enforcement. If the growth of traffic volume was considered before and after the implementation of traffic electronic enforcement, the accident rate per vehicle would decrease more and more after the application.

Table 1. Accident comparison at signalized intersection before and after the implementation of traffic electronic enforcement

Items	Accident number	Deaths	Injured	Economic loss(RMB)	Death rate per accident	Injury rate per accident	Economic loss per accident (RMB)
Before implementation	168	19	98	698300	0.113	0.583	4157
After implementation	45	9	73	195200	0.200	1.622	4338

(2) Comparison of traffic accident types

Except the number of traffic accidents reduced significantly, there were great differences in traffic accident types before and after the implementation of traffic electronic enforcement. Table 2 lists the types comparison of traffic accidents at forty signalized intersections in Harbin, China.

The datum in Table 2 showed that the number of traffic accidents in head-on collision, side collision, rear-end collision, on to scratch, same to scratch and roll-over reduced greatly at signalized intersection after the implementation of traffic electronic enforcement, which side collision accidents decreased 54, accounting for 32.1 percent of the total number of traffic accidents before the implementation, those were related with the reduction of illegal driving such as red light running. But the number of pedestrian-related traffic accidents increased 5, accounting for 11.1 percent of the total number of traffic accidents after the implementation, those were related with the situation that drivers didn't notice pedestrians enough when they accelerated to pass signalized intersection at the moment of rear yellow time in order to avoiding the punishment by traffic electronic enforcement.

Table 2. Accident types comparison at signalized intersection before and after the implementation of traffic electronic enforcement

Accident types	Accident number			Percentage (%)		
	Before implementation	After implementation	change	Before implementation	After implementation	change
Head-on collision	46	16	-30	27.38	35.56	+8.17
Side collision	70	16	-54	41.67	35.56	-6.11
Rear-end collision	15	2	-13	8.93	4.44	-4.48
On to scratch	11	0	-11	6.55	0.00	-6.55
Same to scratch	16	0	-16	9.52	0.00	-9.52
Scratching pedestrian	1	6	5	0.60	13.33	+12.73
Collision fixture	3	3	0	1.79	6.67	+4.88
Roll-over	1	0	-1	0.60	0.00	-0.60
Others	5	2	-3	2.98	4.44	+1.47
All	168	45	-123	—	—	—

(3) Time distribution comparison of traffic accidents

Figure 1 describes the time distribution difference of traffic accidents before and after the implementation of traffic electronic enforcement at forty signalized intersections in Harbin, China.

From the perspective of occurring time, traffic accidents mainly happened from 7:00 to 23:00 before the implementation of traffic electronic enforcement, which the number of traffic accidents in the periods of 8:00-10:00,11:00-12:00 and 15:00-18:00 was more than the ones in other time. The traffic easily fallen into congestion in the three time which coincided with the peak hours of traffic volume. At those times, drivers were prone to impatience, which would increase the possibility of illegal driving in the period of rear yellow time and the first part of red time.

Traffic accidents occurred more dispersed after the implementation of traffic electronic enforcement, which was related with the condition that traffic electronic enforcement restrained illegal driving.

(4) The cause comparison of traffic accidents

Figure 2 compares the cause difference of traffic accidents before and after the implementation of traffic electronic enforcement at forty signalized intersections in Harbin, China.

From the perspective of cause of traffic accidents, the number of traffic accidents which were caused by illegal driving that traffic electronic enforcement facilities could detect, such as illegal occupying lane, red light running, illegal U-turn, etc. decreased significantly from 42 to 9, accounting respectively for 25 percent and 20 percent of the total number of traffic accidents before and after the implementation of traffic electronic enforcement. But the number of traffic accidents which were caused by illegal driving that traffic electronic enforcement facilities could not detect was almost same before and after the application of traffic electronic enforcement, only decreased from 29 to 26, accounting respectively for 17.3 percent and 57.8 percent of the total number of traffic accidents before and after. The result showed that traffic electronic enforcement could restrain the traffic accident significantly which was caused by illegal driving that traffic electronic enforcement facilities could detect. The cause of the other traffic accidents mainly was focused on the driver negligence, improper operation, etc.

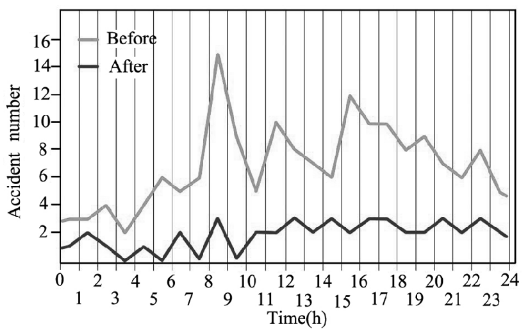

Figure 1. Time distribution of traffic accidents before and after the implementation of traffic electronic enforcement

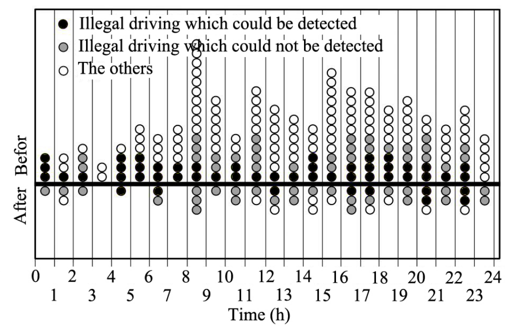

Figure 2. The cause of traffic accidents before and after the implementation of traffic electronic enforcement

(5) Severity degree comparison of traffic accidents

Figure 3 draws the severity degree difference of deaths-related traffic accidents before and after the implementation of traffic electronic enforcement at forty signalized intersections in Harbin, China.

From the perspective of severity degree of traffic accidents, the number of deaths-related traffic accidents decreased from 15 to 8, accounting respectively for 8.9 percent and 17.8 percent of the total number of traffic accidents before and after the implementation of traffic electronic enforcement. But the deaths-related traffic accidents mostly concentrated from 18:00 to 3:00 after the implementation instead of the dispersed deaths-related traffic accidents before the implementation of traffic electronic enforcement, and the rate of deaths-related traffic accidents of the total traffic accidents increased obviously, those were related with the high speed at signalized intersections in order to scrambling the rear yellow time and the low punishment possibility by traffic electronic enforcement at night.

Figure 4 shows the severity degree difference of injured-related traffic accidents before and after the implementation of traffic electronic enforcement at forty signalized intersections in Harbin, China.

The number of injured-related traffic accidents decreased from 76 to 34, accounting respectively for 45.2 percent and 75.6 percent of the total number of traffic accidents before and after the implementation of traffic electronic enforcement. The injured-related traffic accidents occurred relatively dispersed from 6:00 to 21:00

after the implementation instead of centralized injured-related traffic accidents in peak hours before the implementation of traffic electronic enforcement. But the rate of injured-related traffic accidents of the total traffic accidents increased greatly, the reason was same as the one of deaths-related traffic accidents.

The above analysis showed that the severity degree of traffic accidents tended to worse after the implementation of traffic electronic enforcement, so it was needed to strengthen the safeguards of traffic safety at signalized intersections in the period of yellow time in the environment of traffic electronic enforcement.

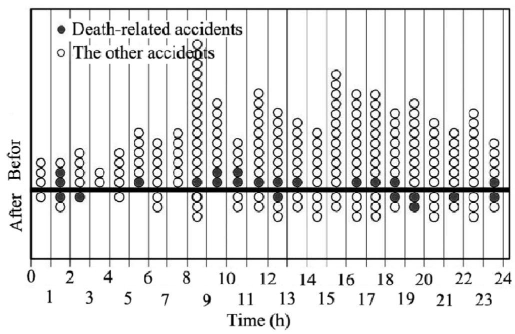

Figure 3. Comparisons of deaths-related traffic accidents before and after the implementation of traffic electronic enforcement

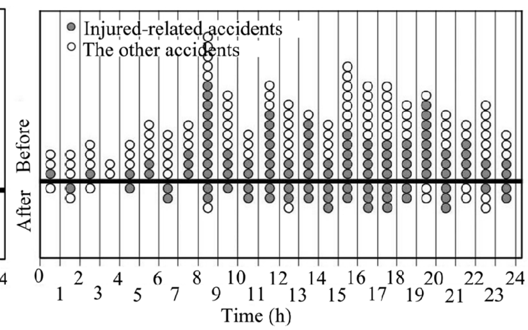

Figure 4. Comparisons of injured-related traffic accidents before and after the implementation of traffic electronic enforcement

3 Safety effectiveness of traffic electronic enforcement

The safety effectiveness which was taken by traffic electronic enforcement was mainly reflected in table 3.

Overall, traffic electronic enforcement was helpful to reduce traffic accidents and deaths or injured, improve the condition of traffic safety at signalized intersections. But some new problems such as pedestrian-related traffic accidents adding, severity degree of traffic accidents tending to worse, etc. must be paid more attention and solved effectively.

4 Safety safeguards in the environment of traffic electronic enforcement

In order to improve the condition of traffic safety at signalized intersections in the environment of traffic electronic enforcement, combining with foreign management experience and actual application situation in China, the following three aspects of safeguards were advised.

(1) Education

① strengthening the propagation of traffic electronic enforcement

The positions and types of traffic electronic enforcement, the serious consequences which were caused by illegal driving should be placard and propagated by broadcast, TV, text, internet and promotional panels, avoiding to occur serious traffic accidents at the location of traffic electronic enforcement because drivers understand deviation.

② improving awareness of traffic safety of traffic participants

Driver was the first factor which affected traffic safety, he should be improved safety awareness by education to fundamentally curb the occurrence of traffic violations and decrease the driving risk. At same time, pedestrians also should be strengthened to educate and propagate to protect them from being collided with vehicles. The educational contents included crossing the street civilization, crossing the street at the prescribed places and crossing the street under the traffic signal and traffic signs.

Table 3. Safety effectiveness conclusion of traffic electronic enforcement

Items	Effects and existing problems	Reasons
Overall effectiveness	Traffic accidents reduced obviously The total loss of traffic accidents reduced significantly	The times of traffic violation reduced The traffic order improved The continuous traffic violations suppressed
Time distribution of accident	Traffic accidents occurred more dispersed The high incidence periods of traffic accidents eliminated	Traffic violations reduced significantly in peak hours
The cause of accident	Traffic accidents which were caused by illegal driving that traffic electronic enforcement facilities could detect reduced obviously Traffic accidents which were caused by illegal driving that traffic electronic enforcement facilities could not detect almost kept same	Illegal driving that traffic electronic enforcement facilities could detect reduced significantly Traffic electronic enforcement facilities could not restrain the illegal driving which could not detect
Severity degree of accident	Death-related traffic accidents reduced, cumulative number of deaths reduced Death-related traffic accidents occurred at night or in the evening	Illegal driving reduced significantly such as red time running Detection accuracy of traffic electronic enforcement decreased at night, the deterrent effect reduced
	Injured-related traffic accidents reduced, cumulative number of injured reduced Average severity degree of injured-related traffic accidents increased	Illegal driving reduced obviously such as red light running High speed at signalized intersection in order to scrambling the rear yellow time
Accident types	Traffic accidents in collision and scratch reduced obviously Pedestrian-related traffic accidents increased	Illegal driving reduced obviously such as red light running High speed at signalized intersection in order to scrambling the rear yellow time

(2) Engineering

① perfecting signs and markings of traffic electronic enforcement

The study showed that traffic electronic enforcement could effectively restrain illegal driving only when there had complete traffic marking (H Ke ,2012). So the marking must be complete in the environment of traffic electronic enforcement to ensure the high level of deterrent effect.

In addition, it was very necessary to add warning signs at the location of traffic electronic enforcement in China. Not only the signs could strengthen the deterrent effect of traffic electronic enforcement, but also its could avoid the improper operation to lead to traffic accident, which was caused by driver tension when he suddenly saw traffic electronic enforcement facilities but there was not warning information in advance to meet psychological reaction time. In abroad, if the place was set up traffic electronic enforcement facilities, not only the location but also the position in front of 50-100 meters all were built warning signs, and the enforcement types such as red light running, over speed, etc. were marked, seeing figure 5.

② adding the stop marking in the period of yellow time

Driver often accelerated to pass signalized intersection to scramble the yellow time in order to escape the punishment by traffic electronic enforcement facilities. At this time, he rarely paid attention to the crossing pedestrians to lead to serious traffic accidents. One traffic marking was proposed to remind driver slowing down to avoid the driving behavior of scrambling yellow time when he didn't pass the marking at the moment of yellow light opening (J Xiancai,2011). The marking was set up in front of the stopping line; the detail position was described by formula (1).

$$L=YV-l \tag{1}$$

where, L was the maximum distance(m) that vehicle completely pass the stopping line under uniform speed when the yellow light lighted, Y was the yellow time(s), V was the maximum limited speed(m/s), l was the length of vehicle(m).

③ setting up protective measures for crossing pedestrians

If there existed significant confliction between vehicles and pedestrians at intersection, it was very necessary to set up protective measures for crossing pedestrians in addition to reminding driver to drive carefully, such as guardrail, safety island, etc. On the one hand those measures protected crossing pedestrians from collision with vehicles; on the other hand they could guide the behaviour of crossing pedestrian. If the turning sight distance was bad at intersections, some traffic safety facilities should be built such as convex mirror, speed lump.

Figure 5 the signs of traffic electronic enforcement

(3) Management

① ensuring scientific placement of traffic electronic enforcement

The placing principle of traffic electronic enforcement was to improve the condition of traffic safety and reduce the traffic violations. The total number and the rate of traffic violation, the traffic accidents should be considered more when the locations of traffic electronic enforcement were selected. The locations and types of traffic electronic enforcement should be published and propagated to improve transparent before application instead of concealed enforcement in order to fine.

In addition, uniformity should be considered to enhance the deterrent effect when traffic electronic enforcement facilities were placed. The situation should be avoided that traffic electronic enforcement facilities were placed intensively in part region but its were lack in other region. The inhomogeneity easily leads to decline the deterrent effect of traffic electronic enforcement, and increase driver's trusting to luck.

② taking mobile traffic electronic enforcement to enhance deterrence effect

It was needed to spend huge to realize the complete coverage of traffic electronic enforcement facilities in city, and it was not scientific solution plan. Mobile electronic enforcement facility could not only restrain illegal driving as fixed traffic electronic enforcement facilities did but also enlarge enforcement coverage in space. One hand it could save cost, on the other hand it also solved the blind spot that fixed traffic electronic enforcement facilities left, was helpful to restrain driver's trusting to luck.

③ improving the management efficiency of traffic violations to strengthen the deterrence degree

The efficient system of traffic electronic enforcement should be built quickly in order to detect rapidly, process fast, and publish immediately illegal driving. In management, traffic violators must be executed punishment to eliminate privileges and relationships; illegal driving must be checked by continuously improving the detection accuracy and range of traffic electronic enforcement facilities, timely maintaining the failure facilities of traffic electronic enforcement; the information of traffic violation must be informed promptly to driver by text, letter, etc. Those measures could enhance the deterrent effect of traffic electronic enforcement, completely dispel the driver's trusting to luck, and avoid the occurrence of continuous and multiple illegal driving in the process of driving.

5 Conclusions

Here we may draw the following conclusions.

(1) Traffic electronic enforcement could restrain the traffic accidents significantly which are caused by illegal driving that traffic electronic enforcement facilities could detect, but it was very limited to restrain the traffic accidents which are caused by illegal driving that traffic electronic enforcement facilities could not detect.

(2) The time distribution, types, cause and severity degree of traffic accidents had been changed greatly before and after the implementation of traffic electronic enforcement. Traffic electronic enforcement was helpful to reduce traffic accidents and deaths or injured, improve the condition of traffic safety at signalized intersections; but the severity degree of traffic accidents tended to worse after the implementation. So it was needed to strengthen the safeguards of traffic safety at signalized intersections in the period of yellow time in the environment of traffic electronic enforcement.

(3) In order to ensure traffic safety at signalized intersections in the environment of traffic electronic enforcement, the safeguards should be set up from the aspects of education, engineering and management. The purpose was to improve the deterrent

effect of traffic electronic enforcement to restrain more illegal driving, realize traffic accidents controllable.

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References

Decina, L. E., Thomas, L., Srinivasan, R., and Staplin, L. (2007). "Automated enforceement: a compendium of worldwide evaluations and results." *National Highway Traffic Safety Administration, Washington, DC. Office of Research and Development*, Report: DOT HS 810 763, 136.

Flannery, A., and Maccubbin, R. (2002). "Using meta analysis techniques to assess the safety effect of red light running cameras." CD-ROM .

Huang K. (2012). "The halo effect of automated enforcement and the traffic safety performance." *Dissertation for the master degree in engineering of Harbin Institute of Technology*, 17-28.

Jiang, X. C., Zhao Z. Q., and Huang K. (2011). "Analysis on the characteristics of driving behavior and traffic accident in automated enforcement." *Journal of Transportation Systems Engineering and Information Technology*, 11(2), 187-192.

Ruby, D. E., and Hobeika, A. G. (2003). "Assessment of red light running cameras in Fairfax county, Virginia." *Transportation Quarterly*, 57(3), 33-48.

Stokes, R. W., Russell, E. R., and Rys, M. J. (2003). "Feasibility of automated traffic signal enforcement in Kansas." *Kansas Dept. of Transportation*, Topeka, Report: KSU-01-4, 68.

Sayed, T., and De Leur, P. (2007). "Evaluation of intersection safety camera program in edmonton, Canada." *Transportation Research Record*, 2009(1) , 37-45.

Zwahlen, H. T., and Suravaram, K. (2007). "Crash reduction factors for education and enforcement." *Federal Highway Administration, Columbus, OH. Ohio Div.;Ohio Dept. of Transportation,* Columbus, 96.

Analysis of the Risk of Air Traffic Controllers' Fatigue Based on the SHEL Model

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Abstract: Much of the researches show that 75% of the accidents are caused by human factors, among them about 21% are connected with fatigue. The mission of civil aviation air traffic controllers is to prevent the aircraft from colliding and to guarantee the smooth flowing of air traffic. With the development of civil aviation of China, the flight number has increased dramatically; unsafe incidents caused by controllers' fatigue are also increasing. Considering the complicated and ambiguous characteristics related to fatigue, this paper, based on the SHEL model, investigates the air traffic controllers' fatigue from a new perspective with dividing it into 'L' subsystem, 'L-L' subsystem, 'L-H' subsystem, 'L-E' subsystem and 'L-S' subsystem. Some suggestions on reducing the fatigue risk of air traffic controller have been given.

Keywords: Aviation safety; Human factors; Air traffic controller fatigue; SHEL model.

1 Introduction

The purpose of air traffic control is to prevent collisions between civil aircraft and aircraft, civil aircraft and obstacles, and to maintain and expedite an orderly flow of air traffic. In order to prevent collisions, to organize and to expedite the flow of traffic, and to increase aviation safety, controllers need to provide information and other support to pilots. Based on these requirements, the air traffic control must be available 24 hours per day in many airports. Controllers have to work in shifts. Shift work or long hours patterns that disrupt the body's circadian rhythms often result in workers' fatigue. Controllers' fatigue is a threat to aviation safety because it can affect all tasks, whether it is because of impaired judgment, concentration difficulty, or other performance deficiencies.

The role of human error in aviation accidents is well established with previous studies reporting that between 70% -80% of aviation accidents result from some type of human error, 21% of reported aviation incidents are fatigue related (Shappell & Wiegmann, 2004;Jackson & Earl,2006). In recent years, the theory and method about the SHEL model analysis has been widely applied in areas such as medical (Molloy & O'Boyle, 2005; Antunes, Bandeira & Carriço, 2010), petrochemical industry (Mao Jian et al, 2010; Jiang Hongye et al, 2011), shipping (Wang & Zhao, 2012; Zeng & Gao, 2010), highway transportation (Cheng, 2007) and in civil aviation that is particularly prominent. Civil aviation communication error events are analyzed based on SHEL model (Sun & Shi, 2011); the SHEL model was applied to fuzzy comprehensive evaluation for aviation safety (Zhang & Wang, 2006); human factors in the maintenance efficiency is analyzed and the research based on the SHEL model (Li & Feng, 2009); aviation enterprises safety was evaluated and research based on neural network and the SHEL model (Wang, 2010).

On the basis of the traditional SHEL model using, with the analysis and summarization of the existing application and analysis model, controllers' fatigue risk is analyzed and research has been done from the L, L-L, L-H, L-E and L-S five aspects, and policy recommendations have been put forward, solution has been given for air traffic controllers' fatigue risk control.

2 The SHEL Model

SHEL model is firstly put forward by Edwards in 1972, then in 1987 Frank Hawkins had made modification, and now this model is widely used in research framework of artificial factor (Itoh, Mitomo, Matsuoka, & Murohara,2004).SHEL model is a conceptual model of human factors as an acronym of its constituent elements (Software, Hardware, Environment, and Liveware) (figure 1). The liveware is the center of the model and the most important factor of the system. Liveware, software, hardware, environment and the relationship among them, have made the four interfaces of the model: L-S, L-H, L-E and L-L interface. The relationship between each interface is uneven, which means the four interfaces are not made of completely perfect matches. The elements of the system should be considered with much caution, otherwise will lead to system crashes and accidents.

Figure 1. The SHEL model

3 Controllers' Fatigue Risk Analysis Based on the SHEL Model

The air traffic control work is an open, dynamic and multi-variable system in which man-made factors have a crucial role to play. Civil aviation is in a rapid development phase. The air traffic flow is increasing. The airspace is becoming more and more crowded. The workload of ATC is usually too big. The number of accidents caused by controllers' fatigue is growing. Controllers' fatigue, as a kind of human factors, is also combined with the liveware and its software, hardware, environment of interactive interface. Therefore, the SHEL model can scientifically analyze the factors affecting all aspects of controllers fatigue, easily find fatigue cause and take preventive measures from the comprehensive perspective, so as to minimize accidents risk caused by controllers' fatigue.

In the controllers fatigue risk assessment system:

L subsystem: that refers to the personal factors related to controllers' fatigue. Control work's particularity and shifting system can affect controllers' health, and poor health condition results in poor self-adaptive variation and poor adjustment ability. The cumulative fatigue is not easy to deal with. The work efficiency, the workload of the controllers, the controllers' business knowledge, skills and control experience would affect the fatigue. Personal physiological factors, psychological factors and living styles have an effect on fatigue as well as emergency and communication ability, safety awareness and sense of responsibility. Eating habits cannot be ignored.

L-L subsystem: in air traffic control system, that mainly refers to controllers and pilots, adjacent sectors, adjacent control room, the traffic control department coordination communication and control unit. Control team cooperation and interpersonal relationship, not only directly affect the working status and workload of the controllers, but also affect the controllers' psychological status, which make the mental load increased further. Controllers' communication with the related personnel and the degree of language standardization will affect the workload.

L-H subsystem: including radar system, communication system, telegram processing system and other facilities, or controllers and system entities, mainly refer to the relationship between the controller and hardware device. With the progress of modern science and technology in civil aviation, modernization of ATC equipment is widely used. But no perfect coordination can be found to match the controllers' operation habit. For example, the equipment design and fabrication are not consistent with people's physiological and psychological characteristics that will affect the controllers' fatigue the same. Work stability and accuracy of the hardware are also potential impact factors of controllers' fatigue.

L-E subsystem: including the internal environment and external environment. Bad weather will increase control calls and ATC workload. Controllers need to concentrate for a long time, with bad weather; controllers are more likely to get tired.

Family relationship is harmonious or not will affect controllers' psychological condition, that may be a cause of fatigue the same. The working environment such as temperature, humidity and lighting are connected with work efficiency. Unqualified working environment can not only reduce control efficiency, but also cause controllers' long-time accumulated fatigue. Sleep environment is comfortable or not directly affects the controllers' sleep quality and length. In recent years, with the increased number of the military training missions, especially after the implementation of RVSM, controllers' workload is greatly increased with the military coordination, .

L-S subsystem: mainly refers to the management factor, also includes the control program, the computer program, the progress strips use, information display and the other non-physical information. The particularity of the controls work requires controllers work on shift, and shift work disrupts controllers' normal circadian rhythm and affects sleep. That is why the shift system is reasonable or not is still a question. Rules and regulations of the design are reasonable or not, working procedure is standard or not, will increase the workload of the controllers to reduce the working efficiency.

4 Controllers Fatigue Risk Control Decisions and Recommendations

4.1 Controller implementation process of risk control methods

Controllers fatigue control scheme is future-oriented. It is based on the fatigue risk identification and assessment, to take measures to reduce the risk of controllers' fatigue. According to these measures, the concrete fatigue risk control scheme is made. In practice, it can be combined with the real-time control and feedback control.

According to the characteristics of the controllers' fatigue risk, the following fatigue risk control process is designed (as shown in figure 2):

Firstly, the controllers fatigue regulators issues a fatigue risk monitoring instruction; then the whole fatigue risk monitoring system starts. According to the controllers' fatigue risk analysis based on the SHEL model, from L, L - L, L - H - E, L - S, these five aspects, specific analysis has been made on fatigue risk evaluation factors to judge whether the evaluation indexes are in the normal range or not. With this comprehensive evaluation, if the risk of fatigue is in the allowed range, it can come back to monitor by state feedback system; if evaluation result of fatigue risk is beyond the allowed range, analysis needs to be made from the perspective of the overall system to select effective control method to implement risk control. To verify whether the control objectives are achieved or not, the control result needs to be sent to monitor as feedback for validation.

It has to be noticed that the fatigue is not easy to be found. The monitored objects that seem normal from the outside, but some factors have already seriously affected the fatigue state. Therefore, the task of monitoring and control system is very important. It is necessary to carefully monitor, identify and diagnose the indexes' state and always stay vigilant. Security is a relative concept, the index factors may change with the environment then seriously influence the fatigue state to cause accident symptom even accident. The controllers' fatigue risk control methods need continuous circulation monitoring and implementation to detect potential threat factors and control the fatigue within the scope of the permission.

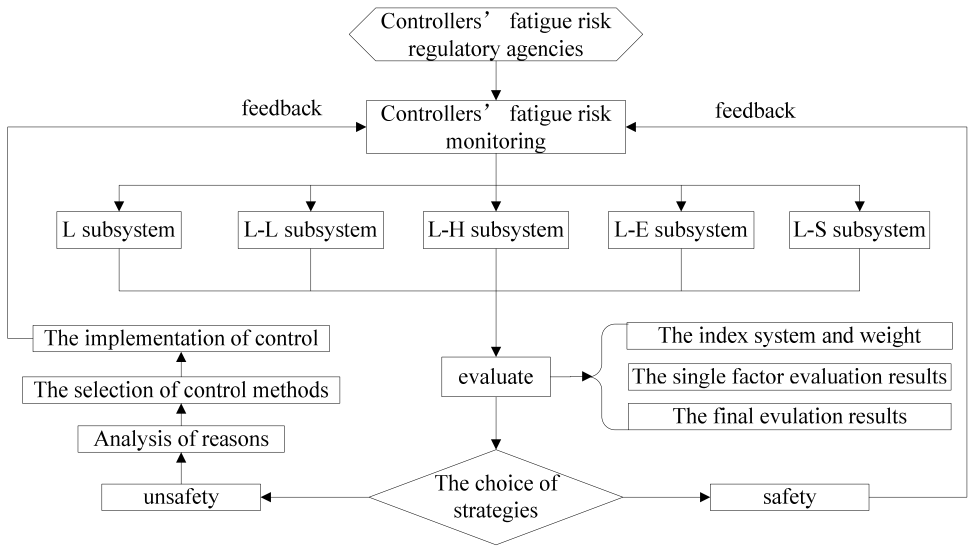

Figure 2. Implementation process controllers' fatigue risk control method

4.2 The controllers fatigue risk control decision-making suggestions

4.2.1 To strengthen education and training

A good education about the risk of fatigue, the cause of sleepiness and the importance of sleep habit is important to solve controllers' fatigue in the control environment. Some life style factors have been proved that would affect people to deal with fatigue well enough. For example, the controller with good health habits, such as physical exercising, eating a balanced diet, good sleep habits and good time management strategy can deal with fatigue more effectively. Managers, scheduling staff and crew all airline personnel should also get education about the effects of fatigue, the influence factors of fatigue and scientifically proved fatigue countermeasures. Finally, controllers, scheduling and management personnel must be aware of sleep and circadian rhythm is important, and to guarantee quality daily sleep as a good way to prevent the fatigue at work.

4.2.2 To strengthen management, maintain good coordination and cooperation among people

To build character complementary control team is important. If in the same team, all controllers are isolated, introverted and quiet, then the high strength workload can cause controllers' fatigue more easily, thus result in false, neglected or wrong control judgments that would end in control accident. On the contrary, if in the same team, all controllers are cheerful, outgoing, willing to chat, they will lead to safety accident due to chat distraction. It is also necessary to establish team intervention mechanism: the leaders should carefully observe the psychological change of the shift members, to find out the problems timely and to apply psychological intervention if necessary. More communication is needed to better understand the difficulty met by the crew. Leaders should help to solve the problems to avoid long time accumulation of mental fatigue that would impact control work. The flow rate and the number of flight conflict need to allocate should be in the control so that it would not surpass the controllers' workload.

4.2.3 To create a good environment for the controllers

Control environment mainly includes the working environment and living environment. Control room should be equipped with comfortable seats that are humanized in design and color. Control room's lighting, noise, humidity should be controlled in a reasonable range. Control room's light distribution should be set to avoid shadow; otherwise it may cause visual fatigue due to the impact of controllers' radar screen observation. That will affect control safety. To set some human-based rest area and exercise facilities in the workplace can make the controller to get relaxed after work. The controllers' family life and daily life stress should also be paid attention to. Family harmony degree will affect controllers' psychological condition. Controllers with psychological pressure will be influenced by the accumulation of mental fatigue, thus may impact control safety. To create a healthy and comfortable control environment can reduce the controllers' bad mood. To keep good mood is advantageous for the controllers to improve work efficiency, to eliminate the unsafe behavior, thereby to reduce or eliminate the happening of the accident.

4.2.4 To improve the organization and management function, to strengthen the construction of software

Shift system directly affects the health of the controllers and the work efficiency because it affects the working hours, rest intervals with the complexity of the work and effort. Therefore, the shift system needs to be optimized, to make it more adaptive with the abilities of human physiological regulation and fatigue recovery. Through the controllers' effect assessment of fatigue, to set controllers' on-duty time and rest time limit and management conditions as soon as possible. Rules, constraints and mutual supervision among the posts can be used to strengthen the supervision mechanism.

5 Conclusions

This paper has analyzed the influencing factors of air traffic controllers' fatigue with using the SHEL model and has built the control strategy of controllers' fatigue. Some suggestions have been given to reduce the air traffic controllers' fatigue.

6 Recommendations for Future Research

On the basis of this study, the future research can be focused on the comprehensive evaluation of air traffic controllers' fatigue in order to provide an effective basis for fatigue risk management. The combination of the comprehensive evaluation of air traffic controllers' fatigue and the control strategy can be used as a management tool of fatigue risk.

Acknowledgement

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References

Antunes P, Bandeira R, Carriço L. (2010). Assessing Risk in Healthcare Collaborative Settings. Human Resources in Healthcare, Health Informatics and Healthcare Systems, 154-166.

Cheng J.S. (2007). Research on Human Factors in Highway Construction Management Based on the SHEL Model. China Science Technology Information, (16), 41-42.

Itoh H., Mitomo N., Matsuoka T., & Murohara Y. (2004). An Extension of m-SHEL Model for Analysis of Human Factors at Ship Operation. In proc. of 3rd International Conference and Groundings of Ships (ICCGS), 118-122.

Jiang H.Y, Yao A.L., Mao Jian, et al. (2011). Research on Human Factors to Accidents of Gas Compressing Stations in Transmission Line. Oil Field Equipment, 40(3), 17-19.

Jackson C A, Earl Laurie. (2006). Prevalence of fatigue among commercial pilots. Occupational Medicine, 56(4), 263-268.

Li C.L. & Feng Z.Y. (2009). Research on Human Factors for Aircraft Maintenance Based on SHEL Model. The 2009 International Conference on Aviation Human Factors, 123-127.

Molloy G.J. and O'Boyle C.A. (2005). The SHEL model: a useful tool for analyzing and teaching the contribution of Human Factors to medical error. Academic Medicine, 80(2), 152-155.

Mao J., Jiang H.Y., Li Y.I., et al. (2010). Study on the Human Factors of Third Party Damage to the Oil and Gas Pipeline. Technology Supervision in Petroleum Industry, 26(1), 12-15.

Sun R.S. & Shi R.F. (2011). Analysis of Civil Aviation Communications Error Events Based on SHEL Model. International Conference on Transportation Information and Safety, 2115-2121.

Shappell S.A. and Wiegmann D.A. (2004). HFACS Analysis of Military and Civilian Aviation Accidents: A North American Comparison. International Society of

Air Safety Investigators, 2-8.

Wang H.Z. & Zhao Y. (2012). Analysis on Mechanism of Human Factors and Complexity in Ship Transportation Management. Journal of Theoretical and Applied Information Technology, 45(2), 609-614.

Wang Q.Q. (2010). Neural Network Safety Assessment Method for Aviation Enterprises Based on SHEL Model. China Safety Science Journal, 20(2), 46-53.

Zeng X.M. & Gao Y.L. (2010). Notice of Retraction: The Application of SHEL Model on Ship Safety Management. Management and Service Science (MASS), 1-4.

Zhang M.P. & Wang Y.G. (2006). Aviation Safety Multi-level Fuzzy Comprehensive Evaluation Based on the SHEL Model. *The 14th of the Taiwan Straits, Hong Kong and Macao Regions Attended the Academic Seminar on Occupational Safety and Health and Occupational and Health Association of China in 2006 Academic essays*, 361-364.

Risk Assessment of Rail Transit Financing Mode Using Land Reserve Based on Fuzzy Comprehensive Evaluation Method

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Abstract: The financing of land plays an important role in the process of the construction of rail transit. Risk assessment of financing is a systematic project, which needs scientific and rational design. This article divides 5 risk sources of financing by land in metro construction and operation, every risk source is divided into several risk factors. Afterwards, the article assesses the financing risk by using bi-level fuzzy comprehensive evaluation model. Finally, this paper analyses the merits and demerits of this method in actual application.
Keywords: Risk assessment; Rail transit financing; Fuzzy comprehensive evaluation.

1 Introduction

With the rapid development of national economy and the rising of people's living standards, the increasing traffic demand and the shortage of road resources has become the main factors restricting the development of the city. Against this background, rail transit become the first choice of the government to solve this problem because it has advantages such as high capacity, high speed, environmentally friendly etc. Yet it is always worth remembering that the investment of construction of rail transit is huge and it is not enough if only depend on the government financial subsidies(CAO Hongfei,2010).For example, the civil engineering cost of Beijing metro line 4 is 194.63 million yuan per kilometer(LI Wenxing, YIN Shuai, 2012). The combined effect of the land near the metro stations is strong and the appreciation space is large, so financing by developing the land near the stations plays an important role in the financing strategy such in Hong Kong, Tokyo(YE Xiafei, HU Zhihui, GU Baonan, 2002).However, the investment project of the metro has long construction period, high running costs, long investment recovery period, and public welfare(SHI Zhiwei,2013),on the other side, whether the financing can meet expected requirement of financing has a big impact on the construction and operation of rail transit network in the future. In conclusion, risk assessment of rail transit financing mode using land reserve is highly relevant.

2 Financing risk analysis

As is well known, various factors influence the risk of rail transit financing. This article divides the risk into 5 risk sources, 16 risk factors.

2.1 National risk source (3 risk factors)

It refers to the risk caused by war, coup or economic collapse. National risk source may cause the rail transit project shut down or destroyed. The risk factors of national risk source are: war risk, political risk and the risk of social instability.

2.2 Engineering risk source(3 risk factors)

Engineering risk means the loss caused by the decision-making mistakes of rail traffic engineering construction. For example, the mistake of route-selection may lead to the increasing cost of construction. The risk factors of engineering risk source are accident risk, engineering technology risk and extension risk.

2.3 Land risk source(3 risk factors)

Land risk is always caused by the difference of land location during land reserve, land developing and land transfer. In some place, the land risk is also closely associated with land properties, the suitability and limitations of land. There are 3 risk factors in land risk source: the risk of land reserve, the risk of land development and the risk of land transfer.

2.4 Industrial market risk source(3 risk factors)

The change of industrial market may lead to the loss of ticket revenue or the income of land transfer under some circumstances. This risk source is also associated with the price fluctuation of the construction materials and facility instruments such as rebar, metro vehicle, signaling system. The risk factors of industrial market risks are ticket price risk, the risk of related industries, the risk of market supply and demand.

2.5 Fiscal and financial risk source(4 risk factors)

During financing period, the distribution of revenue and the operation of land bonds or land funds are very important. We must take revenue distribution risk and operation risk of land bonus or land funds into consideration. Besides, financing by land reserve and development is affected by international financial scene. Above all, the risk factors of fiscal and financial risk source are revenue distribution risk, operation risk of land bonus, operation risk of land funds and international financial scene risk.

3 Model construction

3.1 Hierarchy division

The model required for our purposes is focused on a proper evaluation of the expected frequency of accidents.

Based on the theory of fuzzy mathematics, we divide the risk assessment of rail transit financing mode into 3 layers: objective layer, risk source layer and risk factor layer.

Objective layer: objective layer is recorded as "P" ,it is the evaluation criterion of the risk in this mathematical model. The objective layer can be expressed as:

$$P=\{9,7,5,3,1\}$$

The assignment from 1 to 9 means the financing risk increase gradually.

Risk source layer: there are 5 risk sources in this layer: national risk, engineering risk, land risk, industrial market risk, fiscal and financial risk. These risk sources are recorded as "B_1, B_2, B_3, B_4, B_5" .The weighting factors of these risk sources can be defined as a set named W, each risk factor is recorded as

$$W_i\,(\sum_{i=1}^{n} W_i = 1 \quad (n=5)).$$

Risk factor layer: this layer is the secondary partition of risk source layer, each risk factor is named as B_{ij} , B_{ij} means it belongs to the *i*th risk source (B_i)and the *j*th risk factor of B_i.We are assuming that the *i*th risk source has J_i risk factors. The weighting factor is defined as

$$W_{ij}\,(\sum_{j=1}^{J_i} W_{ij} = 1).$$

3.2 The construction of weight vectors

The risk sources in the second layer have different effect on rail transit financing mode using land reserve, so we have to assign different weights to these risk sources and risk factors in each layer. These weights constitutes weight vectors. Though the weight distribution can't avoid the effect of subjective factors, choosing the suitable method can minimize the impact. In this article, we use *AHP* method to solve this problem because it has consistency check during the calculation. Consistency check can reduce the effect of subjective and the errors due to considering each source or factor separately in certain extent. Each weight factor is named as t_i .The weight vector is called A and $A=\{t_1,\ t_2 \ldots\ldots t_n\}$

3.3 Building a fuzzy evaluation matrix

Fuzzy evaluation matrix can be expressed a set of risk probability based on the judgments of experts. In this model, the risk level is divided into 5 levels: very low, low, medium, high, very high. If the experts' number is Z, the number of expert who think the probability of risk factor B_{ij} is Z_{i1}、Z_{i2}、Z_{i3}、Z_{i4} and Z_{i5} ,so the row vector of fuzzy evaluation matrix is defined as

$$R_{mi} = \{\frac{Z_{i1}}{Z}, \frac{Z_{i2}}{Z}, \frac{Z_{i3}}{Z}, \frac{Z_{i4}}{Z}, \frac{Z_{i5}}{Z}\}$$

Assuming that the *m*th risk sources have *n* kinds of risk factors ,the fuzzy evaluation matrix can be expressed as:

$$R_m = \begin{pmatrix} R_{m1} \\ . \\ R_{mi} \\ . \\ R_{mn} \end{pmatrix} = \begin{bmatrix} \frac{Z_{11}}{Z} & . & . & \frac{Z_{15}}{Z} \\ . & . & & . \\ . & & . & . \\ \frac{Z_{n1}}{Z} & . & . & \frac{Z_{n5}}{Z} \end{bmatrix} = \begin{bmatrix} r_{11} & . & . & r_{15} \\ . & . & & . \\ . & & . & . \\ r_{n1} & . & . & r_{n5} \end{bmatrix}$$

3.4 The choice of fuzzy arithmetic operator

After the construction of fuzzy evaluation matrix, we should make the fuzzy evaluation and get a row vector named C_m, the process of calculation can be expressed as:

$$C_m = A_m \bullet R_m$$

Where:

A_m is the weight vector of risk factors belongs to the *m*th risk sources.

"$\bullet$" is the fuzzy arithmetic operator.

There are 2 kinds of fuzzy arithmetic operator are widely applied in the risk assessment(XIE Lijuan,CHEN Qiao,2012):

(1) （∨—∗）

The operation principle of this arithmetic operator is :

$$C_j = \bigvee_{i=1}^{n} (t_i * r_{ij}) = \max((t_1 * r_{1j}),(t_2 * r_{2j}),(t_3 * r_{3j})\ldots\ldots(t_n * r_{nj}))$$

We can notice that this arithmetic operator taking the impact between t_i and r_{ij} into consideration, but the outermost layer of this arithmetic operator uses *Max-min* algorithm. Generally speaking, *Max-min* algorithm may lose some important information of risk factors especially in the condition of many risk sources or risk factors.

(2)(+—∗)

It is a weighted average arithmetic operator. The operation principle as described below:

$$C_j = \sum_{i=1}^{n} t_i * r_{ij}$$

In this arithmetic operator, the weight factor and membership are taken into consideration. C_j is determined by all risk sources and factors, not only by some specific combinations of weight factor and membership.

Therefor by comparing the characteristics of ∨—∗ and +—∗,we use the second arithmetic operator.

3.5 Fuzzy comprehensive evaluation(first level)

The first level of fuzzy evaluation includes 2 layers: risk source layer and risk factor layer. For any risk source, we figure out it's weight factor by using *AHP* method. As shown in 3.2,risk factor layer's weight vectors is recorded as A_i.The fuzzy evaluation matrix of first level can be expressed as:

$$C_i = A_i \bullet R_i$$

Where

i means *i*th risk source.

3.6 Fuzzy comprehensive evaluation(second level)

After the first level of fuzzy evaluation, we get a set of fuzzy comprehensive evaluation row vectors $C_1 \sim C_5$.The final fuzzy evaluation matrix is recorded as C

$$C = \begin{pmatrix} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \end{pmatrix}$$

In this step, we use *AHP* method again to get weight vector of risk sources. This weight vector is named as A .This article use arithmetic operator "+ — *" to get risk evaluation matrix R ,

$$R = A \bullet C$$

In the end, we get matrix $\overline{R}$ by normalization matrix R .The risk evaluation result $K = P * \overline{R}^{\mathrm{T}}$

4 The example

In this part, we take a rail transit network for example to calculate this model.

In this network, we assume that the weight vectors from A_1 to A_5 are as follows:

$$A_1 = \begin{pmatrix} 0.1932 & 0.0833 & 0.7235 \end{pmatrix}$$
$$A_2 = \begin{pmatrix} 0.1497 & 0.0991 & 0.7512 \end{pmatrix}$$
$$A_3 = \begin{pmatrix} 0.0915 & 0.2014 & 0.7071 \end{pmatrix}$$
$$A_4 = \begin{pmatrix} 0.2737 & 0.0869 & 0.6394 \end{pmatrix}$$
$$A_5 = \begin{pmatrix} 0.0475 & 0.2830 & 0.1082 & 0.5613 \end{pmatrix}$$

The weight vector of risk sources is defined as A

$$A = \begin{pmatrix} 0.1292 & 0.2210 & 0.5470 & 0.0355 & 0.0673 \end{pmatrix}$$

According to the judgments of experts, we get fuzzy evaluation matrix from R_1 to R_5:

$$R_1 = \begin{bmatrix} 0 & 0 & 0.1 & 0.8 & 0.1 \\ 0 & 0 & 0 & 0.3 & 0.7 \\ 0.3 & 0.5 & 0.2 & 0 & 0 \end{bmatrix}$$

$$R_2 = \begin{bmatrix} 0 & 0.2 & 0 & 0.5 & 0.3 \\ 0.1 & 0 & 0.5 & 0.3 & 0.1 \\ 0 & 0.3 & 0.3 & 0.2 & 0.2 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} 0 & 0 & 0.4 & 0.3 & 0.3 \\ 0.1 & 0.3 & 0.5 & 0 & 0.1 \\ 0.2 & 0.4 & 0.3 & 0.1 & 0 \end{bmatrix}$$

$$R_4 = \begin{bmatrix} 0 & 0.1 & 0.2 & 0.2 & 0.5 \\ 0 & 0 & 0.2 & 0.4 & 0.4 \\ 0 & 0 & 0.3 & 0.4 & 0.3 \end{bmatrix}$$

$$R_5 = \begin{bmatrix} 0 & 0 & 0.1 & 0.5 & 0.4 \\ 0.2 & 0.3 & 0.4 & 0.1 & 0 \\ 0.2 & 0.4 & 0.2 & 0.2 & 0 \\ 0.3 & 0.3 & 0 & 0.2 & 0.2 \end{bmatrix}$$

Fuzzy comprehensive evaluation(first level):

$$C_i = A_i \bullet R_i$$

$$C_1 = (0.2170 \quad 0.3618 \quad 0.1640 \quad 0.1796 \quad 0.0776)$$

$$C_2 = (0.0099 \quad 0.2553 \quad 0.2749 \quad 0.2548 \quad 0.2051)$$

$$C_3 = (0.1616 \quad 0.3433 \quad 0.3494 \quad 0.0982 \quad 0.0475)$$

$$C_4 = (0 \quad 0.0274 \quad 0.2639 \quad 0.3453 \quad 0.3634)$$

$$C_5 = (0.2466 \quad 0.2966 \quad 0.1396 \quad 0.1860 \quad 0.1312)$$

$$C = \begin{pmatrix} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \end{pmatrix} = \begin{bmatrix} 0.2170 & 0.3618 & 0.1640 & 0.1796 & 0.0776 \\ 0.0099 & 0.2553 & 0.2749 & 0.2548 & 0.2051 \\ 0.1616 & 0.3433 & 0.3494 & 0.0982 & 0.0475 \\ 0 & 0.0274 & 0.2639 & 0.3453 & 0.3634 \\ 0.2466 & 0.2966 & 0.1396 & 0.1860 & 0.1312 \end{bmatrix}$$

Fuzzy comprehensive evaluation(second level):

$$R = (0.1292 \quad 0.2210 \quad 0.5470 \quad 0.0355 \quad 0.0673) \bullet \begin{bmatrix} 0.2170 & 0.3618 & 0.1640 & 0.1796 & 0.0776 \\ 0.0099 & 0.2553 & 0.2749 & 0.2548 & 0.2051 \\ 0.1616 & 0.3433 & 0.3494 & 0.0982 & 0.0475 \\ 0 & 0.0274 & 0.2639 & 0.3453 & 0.3634 \\ 0.2466 & 0.2966 & 0.1396 & 0.1860 & 0.1312 \end{bmatrix}$$

$$= (0.1352 \quad 0.3119 \quad 0.2918 \quad 0.1580 \quad 0.1031)。$$

$$\overline{R} = (0.1352 \quad 0.3119 \quad 0.2918 \quad 0.1580 \quad 0.1031)$$

$$K = P * \overline{R}^{T} = 5.43$$

5 Conclusions

As we all known, risk assessment is hard to quantify, but this article overcomes this problem by using fuzzy comprehensive evaluation method. Furthermore, the model in this article also takes the effect between risk sources and risk factors into consideration. The result of evaluation is relatively objective and the model has quite strong systematically. We can also get the risk assessment result by using computer programming. The algorithm is easy to realize in C# programming language.

However ,the risk assessment method has some disadvantages and the main point is that the assessment result will be influenced by the expert's scoring. When metro-transportation corporation about to make the risk assessment, they should choose the experts with high level of professional standards to guarantee the objectivity of the assessment result.

References

CAO Hongfei.(2010). The Risk Analysis on the Urban Rail Transit Financing. Dongbei University of Finance and Economics.

LI Wenxing, YIN Shuai.(2012). Analysis on Cost of Urban Rail Transit. *Journal of Transportation Systems Engineering and Information Technology*, 12(2):9-14.

SHI Zhiwei. (2013).Risk Analysis of Government Financing Patterns in Urban Rail Transit Project. *Value Engineering*, 32(13):104-105.

XIE Lijuan, CHEN Qiao.(2012). The Choice of Composite Operators in Fuzzy Comprehensive Evaluation. *Science & Technology Association Forum*, (9):103-104.

YE Xiafei, HU Zhihui, GU Baonan.(2002). Analysis of Financing Model and Successful Experience of Japanese Urban Mass Transit Construction. *China Railway Science*, 23(4):126-131

Study on the Influencing Factors of Recycling Household Electronic Waste Based on Consumer Participation under the EPR System

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Abstract: Based on combining with the domestic and foreign theoretical research about consumer participation in recycling waste household electronic, this paper considered behavioral attitude, subjective norms, environmental knowledge, behavior disorders and behavior motivation, and designed questionnaire and investigated the public, and analyzed the survey results. At last, this paper found the main factors influencing consumers to participate in recycling waste household electronic under extended producer responsibility system.
Keywords: Extended producer responsibility system; Waste household electronic; Take-back models.

1. Introduction

With the implementation of "circular economy promotion law of the People's Republic of China", the modern producers' responsibility already extended to the recycling, utilization and disposal stage of disposed products from the pure production stage. It means that consumers and enterprises all have a responsibility to recycle waste household appliances.

Therefore, under extended producer responsibility system, it is an important aspect what factors will influence on the participation behavior of consumers about the research on recycling waste household electronic.

Based on combining with the domestic and foreign theoretical research about consumer participation in recycling waste household electronic, this paper refined the influencing factors of recycling waste household electronic, including behavioral attitude, subjective norms, environmental knowledge, behavior disorders and behavior motivation. This paper designed questionnaire and investigated the public, and analyzed the survey results. At last, this paper found the main factors influencing consumers to participate in recycling waste household electronic under extended producer responsibility system, and analyzed on the difference in perception of these influence factors between different consumers.

2. Sample extraction conditions

The empirical research used the questionnaire form, the 300 questionnaires were sent out, and collect 280 copies, of which there are 259 valid questionnaires, and effective recovery rate is 86.3%. Questionnaire distribution is shown in table 1.

Table 1. The questionnaire distribution table

Demographic variables		Percent	Demographic variables		Percent
Sex	male	53.7	Age	15-22	38.6
	female	46.3		23-40	38.2
profession	Scientific education and environmental sanitation field	9.7		41-54	14.3
	engineer	13.5		Above 55	8.5
	Management	8.5	Education	The junior high school and above	5.0
	Worker	8.5		High school	12.4
	Service personnel	8.5		College and University	70.3
	housewife	13.9		postgraduate	12.4
	Retire	8.5	Monthly income	Less than 1000 RMB	18.6
	Student	15.8		1001-3000 RMB	45.1
	others	13.1		3001-5000 RMB	24.4
				More than 5001 RMB	11.9

3. Factor analysis

Through factor analysis on the 20 initial variables of the influencing factors, the value of KMO was 0.788 (>0.5), it shows that this group of data is suitable for factor analysis. According to that the characteristics root extraction factor is larger than 1 and the varimax rotation method, six new factors can be extracted as main factor of the 20 initial variables, and the cumulative contribution rate of the 6 major factors was 77.136%, which can reflect that the amount of information about the original 20 variables was 77.136%.The loading matrix of 6 factors is shown in table 2.

Table 2. Orthogonal rotated factor loading matrix of the influencing factors

	Component					
	1	2	3	4	5	6
Waste household electronic Contains a large number of heavy metals, the environment will be polluted if discarding them	.845	.240	-.132	.121	-.048	-.076
Waste household electronic is the main source of heavy metals in municipal solid waste	.850	.094	.250	.194	-.025	-.127
Burning the incineration of waste household electronic will polluting the environment	.779	.119	-.033	.036	.090	-.019
Dumping the treated waste liquid will pollute the groundwater	.799	.120	.040	.045	.052	.285
Regeneration of waste household electronic can reduce the pollution of the environment	.760	.279	.073	.045	-.075	.236
Regeneration of waste household electronic can save resource	.695	.318	.072	.072	-.002	.250
The government recycling is a good thing.	.284	.797	.023	.276	.054	.742
I support the government ordered collection	.249	.147	.823	.184	-.007	.432
I have no time to sent them to the recycling point	.230	.094	-.021	.760	-.130	.278
I have no ability to sent them to the recycling point	.138	.066	.062	.878	-.006	.028
Participating in recycling can earn a little income	-.070	.065	.222	-.016	.817	.306
Participating in recycling is to obtain income	-.058	.038	-.023	-.088	.855	.006
Whether paid recovery is important to me.	.121	.098	.223	.009	.048	-.184
I am satisfied to door-to-door recovery service	.091	.124	.746	.288	.167	-.221
I feel very convenient with door-to-door recovery service	.056	.423	.764	.198	.288	-.062
I am satisfied to door-to-door recovery free service	.015	.163	.725	-.174	.046	.366
It is very important to door-to-door recovery service for me	-.076	.362	.686	-.215	-.017	.220
My family thinks I should participate in the government recovery	.027	.824	.115	.086	.079	.077
My friends and neighbors think I should participate in the government recovery	.132	.881	.179	.126	.085	-.012
Neighbors are very active to participate in the government recovery	.135	.830	.192	.054	.048	.126
characteristics root	4.145	2.467	2.394	2.080	1.867	1.532
the contribution rate	21.098	13.355	12.420	11.549	10.394	8.322

the cumulative contribution rate	21.098	34.452	46.872	58.421	68.814	77.136
Cronbach's alpha	0.9000	0.8554	0.7834	0.8108	0.7680	0.7880

According to the original information and statistical analysis result, six main factors can be redefined as: Y1 is environmental knowledge, Y2 is subjective norm, Y3 is service motivation, Y4 is behavior disorders, Y5 is economic motivation, Y6 is behavior attitude.

4. Regression Analysis

This paper used SPSS20 software as a statistical tool, analyzed survey data, and obtained the following results:

(1) In the regression model, F=16.050, P <0.001, which showed that the regression model has statistically significant and better fitting degree.

(2) All variables were forced into the equation in enter mode, the analysis results are shown in table 3.

Table 3. Regression analysis results

	Not standardized coefficient		standardized coefficient	t	Sig.	R2	Adjusted R2
	B	Std. Error	Beta				
（constant）	4.355	.026		169.210	.000	.239	0.224
environmental knowledge	-.004	.029	-.009	-.154	.878		
subjective norm	.083	.026	.160	3.163	.002		
service motivation	.171	.026	.331	6.649	.000		
behavior disorders	-.068	.027	-.131	-2.510	.013		
economic motivation	.093	.026	.179	3.604	.000		
behavior attitude	.122	.027	.235	4.470	.000		

The results of regression analysis showed that: firstly, about environmental knowledge, P=0.878 (>0.05), which shows that it does not have statistically significance, namely environment knowledge is not significantly influence for consumers to participate in the behavioral intention. Secondly, about service motivation, economic motivation and behavior attitude, $P<0.001$, which has statistically significance, and about subjective norm, $P<0.01$, which has statistically significance, and about behavior disorders, $P<0.05$, which has statistically significance. Thirdly, through the size of the corresponding β value, the influencing degree to consumers' intention of waste household electronic recycling can be judged: service motive>behavior attitude> economic motivation>subjective norms. Fourthly, behavioral disorders have a significant negative impact on recycling behavior intention.

5. The difference analysis

After found five factors that have significant influence on consumers' behavior of participating in recycling waste household appliances, variance analysis is carried out according to the different gender, age, occupation, education and income levels of the consumers. The results of the analysis are shown in table 4.

Table 4. The variance analysis

	sex	Age	occupation	education	income levels
subjective norm	.054	.542	.123	.512	.002
service motivation	.001	.363	.258	.223	.000
behavior disorders	.032	.020	.000	.000	.030
economic motivation	.255	.121	.015	.000	.001
behavior attitude	.388	.787	.566	.116	.123

According to the results of the analysis, it can obtain the following conclusions:

(1)The perception of different sex on subjective norms, economic motivation, behavior attitudes has no significant difference (the corresponding P values are greater than 0.05), however, the perception of different sex on service motivation and behavior disorders has significant difference (the corresponding P values are less than 0.05), It can be concluded through the sample that service motivation and behavior disorders influenced women more than others.

(2) Different age does not exist significant differences on subjective norm, service motivation, economic motivation and behavior attitude (the corresponding P values are greater than 0.05), however, it exists significant differences on behavior disorders ($P<0.05$); further through afterwards Scheffe test, it is found that the perception of consumers of 24 ~ 40 years old on behavior disorder is obvious weaker than the other age groups of consumers.

(3) The perception of different occupation on subjective norm, service motivation and behavior attitude has no significant difference (the corresponding P values are greater than 0.05), however, the perception of different occupation on economic motivation and behavior disorders has significant difference (the

corresponding P values are less than 0.05). Further through afterwards Scheffe test, it is found that the perception of workers and housewives on behavior disorder is obvious weaker than the other groups of consumers. At the same time, the perception of housewives on economic motivation is obvious stronger than the other groups of consumers.

(4) The perception of different degrees on subjective norm, service motivation and behavior attitude has no significant difference (the corresponding P values are greater than 0.05), however, the perception of different degrees on economic motivation and behavior disorders has significant difference (the corresponding P values are less than 0.05). Further through afterwards Scheffe test, it is found that the perception of consumers of the junior high school on behavior disorder is obvious weaker than the other groups of consumers, the perception of the higher education consumers on economic motivation is less obvious.

(5) The perception of different monthly income on behavior attitude has no significant difference (the corresponding P values are greater than 0.05), however, the perception of different monthly income on subjective norm, service motivation, economic motivation and behavior disorders has significant difference (the corresponding P values are less than 0.05). Further through afterwards Scheffe test, it is found that the perception of higher income consumers on subjective norm, service motivation is more obvious, the perception of consumers of income less than 3000 on behavior disorder and economic motivation is obvious stronger than the consumers of income more than 3000.

6. Conclusions

This paper designed questionnaire and investigated the public, and analyzed the survey results. Through the factor analysis, regression analysis and the difference analysis, this paper found the main factors influencing consumers to participate in recycling waste household electronic under extended producer responsibility system, including subjective norm, service motivation, behavior disorders, economic motivation and behavior attitude. At last, this paper analyzed on the difference in perception of these influence factors between different consumers.

References:

Bai Yuwei (2009). Building recycling system of waste household appliances in China. *Logistics Technology,* (10).

Han Gang (2007). Study on market operation model of reverse logistics about waste household appliances. Dalian maritime university.

Jia Yanglei (2007). The key factors of selecting reverse logistics models. Logistics Technology, (7).

Xu Minli (2011). Study on reverse logistics models of waste household appliances. *Green economic*, (8).
Zhao Yan (2011). The efficiency of dealers trade-in. *Procurement of China*, (9), 68-69.

Frontal Structure Safety Analysis of Minibuses Based on Chinese In-Depth Accident Studies

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Abstract: This paper analyzes accident characteristics from several factors like accident type, reason, environment and crash part by reporting in-depth accident that involved minibus passenger injured of China in-depth accident study program (CIDAS). The paper uses PC-CRASH simulation software, sets the minibus simulation model and gets the equivalent collision speed by simulation. Then the relationship between equivalent collision speed, maximum deformation, collision overlap, passenger injury and frontal structure safety of minibus are analyzed. By analyzing opposite collision vehicle type, deformation characteristic of minibus and structural failure of minibus passenger cabin deformation of frontal collision, the characteristics of structural failure of minibus are studied. Finally, the paper compares the minibus accident cases and China passenger vehicle frontal impact occupant protection regulation of equivalent collision speed and collision overlap, analyzes the different between test factors of regulation and statistics of real accident, and give the improving opinion for passenger vehicle frontal impact occupant protection regulation.
Keywords: Minibus; CIDAS; Frontal structure; Safety.

1 Introduction

There is a unique appearance vehicle that is usually called ‘bread style vehicle’ in China, and it is divided in classification of minibus. The first generation of minibus in China came from Japan, in japan it is called minibus too. After introducing to China, due to low cost, wide application and relatively simple producing progress the minibus was widely used. Minibus is increasingly important in passenger vehicle market of China as the policy of ‘bringing autos to the countryside’ published.

On the one hand, minibus sales are growing rapidly, on the other hand, the road traffic safety of it is not going well. As we all known, the frontal structure of minibus is relatively shorter than other kinds of vehicle. So the passenger compartment of front is easily deformed when head on collision happen. This paper classify the minibus based on character of frontal structure. Then the paper analyze the accident type of frontal collision of minibus based on database of China in-depth accident study (CIDAS), and acquire equivalent energy speed by using PC-CRASH software for accident reconstruction. Finally the correlation of equivalent energy speed and risks of injury are analyzed.

2 Characteristic and Classification of Frontal Structure

The characteristics of minibus can be divided into three types according to the frontal structure, as table 1 showed. Type A of minibus is nearly with no existent frontal deformation zones; Type B of minibus have the frontal deformation zones, but the engine is not installed in the front of deformation zones; Type C is similar to ordinary vehicles, and there is a relatively longer frontal deformation with engine installed in there.

The type a minibus is early introduced from Japan, so there is almost no frontal deformation zones. As the collision regulations and occupant protection laws and regulations are implemented, in order to pass legislation test to sales vehicle in the market, all the OEMs of minibus involved in the research of frontal safety. Most of type a minibus changed into type b minibus through several ways like increase the frontal deformation zones, optimize the structure of front parts stiffness and longitudinal beam size position, etc.

Table 1. Classification of minibus

Type	External characteristic	Structural characteristic
Type A		Without frontal deformation zones
Type B		With frontal deformation zones Without engine installed
Type C		With relatively longer frontal deformation zones With engine installed

3 Data and Accident Type

China in-depth accident study (CIDAS) was started in 2011, and it collects traffic accidents in five cities, Changchun, Beijing, Weihai, Ningbo and Foshan. The investigation engineers worked 24 hours on duty, when the accident occurred, the engineers and police arrived at the scene of the accident at the same time, so they collected the first hand data of the accident. Then the engineers inquired the parties involved in the accident and collected medical injury information, completed the CAD sketch drawing combined with photographs and field measurements. Finally the accident information was input the CIDAS database for in-depth study.

There is a total of 13 frontal collision occurred of minibus from the database of CIDAS, and all accidents resulted in passengers injured or death, table 2 shows the basic information of frontal impact of minibus.

Table 2. Information of frontal collision of minibus

Accident number	Vehicle type	Casualty	Passenger involved
13	Type A：1 Type B：11 Type C：2	42	68

The road distribution of minibus frontal impact is showed in figure 1. Straight road number up to account for 47.8% of the total, followed by the expressway accident accounted for 21.7%, the T-junction and the crossing accident account for 17.4% and 8.7%, the bridge only account for 1 accident, 4.3% of the overall.

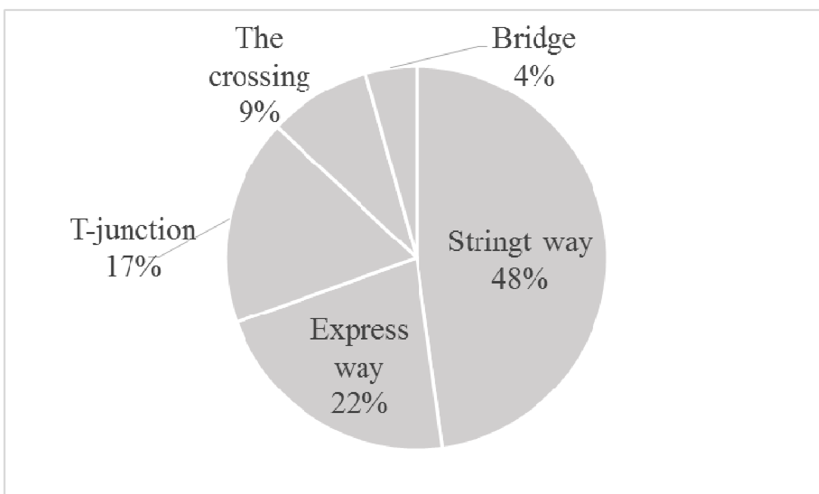

Figure 1. Distribution of accident location

Frontal impact accident occur mostly in straight road, accounts for nearly half of total. The T-junction and the crossing road account for 26% of total, the least is the express way that account for 22% of total.

4 Frontal Structure Analysis

By using the pc-crash software, the equivalent energy speed (EES) is acquired. Figure 2 is the distribution of equivalent energy speed (EES), rate of front collision overlap and the maximum deformation depth. The horizontal axis represents rate of front collision overlap, the vertical axis represents equivalent energy speed and the area of circle represent the size of deformation depth (area is bigger, the deformation depth is longer).

In all cases, there exists passenger compartment deformation when EES exceed 20km/h. to be fair, 20km/h is not a high speed for frontal collision. In this part, small overlap impact factors should be considered, such as the EES of 28.7km/h has caused the minibus passenger compartment deformation for the case of 18.1% overlap. Of course, it should be seen that minibus performance is not good enough for a relatively large overlap rate, such as 73.0% overlap with 30.4km/h EES.

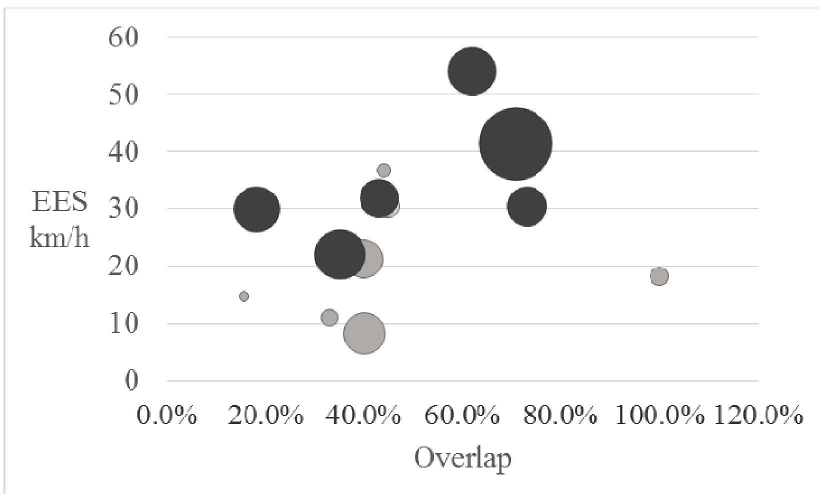

Figure 2. Distribution of EES, overlap and maximum deformation depth

New injury severity score (NISS) was first proposed in 1997, its basic idea is that not to consider the division of parts of the injured body, but with the most three serious AIS score (sum of squares) of multiple injuries as the injury severity score.

Figure 3 represents the correlation of NISS of frontal passenger and maximum deformation depth. The correlation coefficient R^2 value is 0.502. This points out that with the increase of depth of deformation, the wounded NISS values show a rising trend, the correlation is obvious, there is a moderate intensity correlation of deformation depth and passenger injuries.

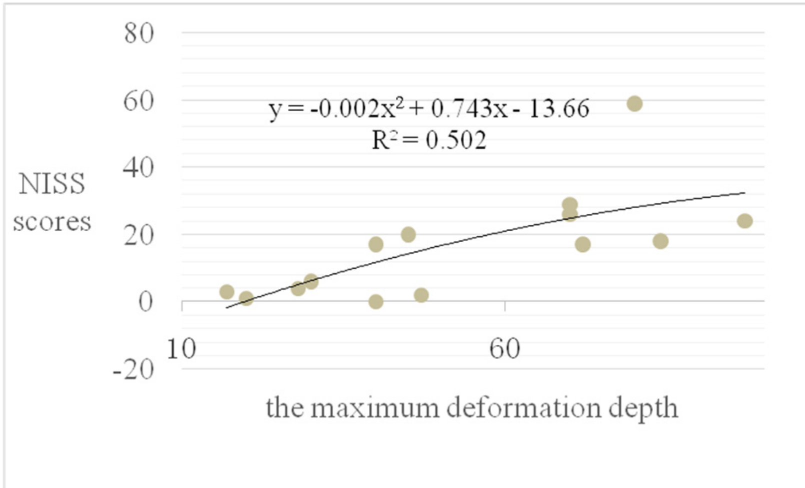

Figure 3. Correlation of NISS and maximum deformation depth

As figure 2 showed that there is a concentration on the overlap of 40%. There are two standards of frontal impact of passenger vehicle. One is GB11551-2003 the protection of the occupant in the event of a frontal collision for passenger car, the other is GB20913-2007 the protection of the occupants in the event of an off-set frontal collision for passenger car, the details information is showed in Table 3.

Table 3. Occupant protection standards of front crash in China

Number	Overlap Rate	Crash Speed	Barrier Type	Standard Type
GB11551-2003	100%	50km/h	Rigid	Compulsory
GB20913-2007	40%	56km/h	Deformable	Recommended

The number of accident of the overlap around 40% is the most (57.1% of total). From the view of quantity, the test for frontal collision of 40% overlap is necessary, from the structure safety view, it's necessary to set the test protocol of 40% overlap frontal collision test from recommended to compulsory test in order to avoid deformation of passenger compartment at relatively lower collision speed by optimizing the frontal structure of minibus.

5 Conclusions

When frontal collision happened, even at a lower EES, the minibus can have a large deformation, and this caused the passenger compartment reduced. Relatively lower (40%) overlap and relatively higher (80%) overlap collision at lower equivalent energy speed (lower than the speed of frontal collision protection standards) are all working not well enough to deal with the deformation. There is a positive (R^2=0.502) correlation between maximum deformation of frontal and New injury severity score, this represents it has a high risk of the front row passenger of minibus to get injured or death when frontal collision happened at a low speed.

References

Graham J L Lawarence (2003) “Study of improved safety for minibuses by better seat and occupant retention. ’

Hiroyuku Mitsuish, Yoshihiro Sukegawa (2006). “Research on Bus Passenger Safety in Frontal Impact.”

Nelson Luiz Batista de Oliveira, Regina Marcia Cardoso de Sousa (2005) “Accident analysis and prevention.” 37,327-333

Walter Niewohner, F Alexander Berg. (2011). “Accident with vans and box-type trucks).” Transporters: results from official statistics and real-life crash analysis.

Traffic Relief Based on the Construction Characteristics of Urban Roads

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Abstract

In order to meet the process of urbanization and solve supply and demand contradiction of urban traffic, departments and government put a lot of manpower, material and financial for municipal facilities. In cities, there are many new roads under construction, reconstruction and maintenance. It will bring a huge change to city when those municipal roads completed. However, construction of road will occupy limited resources and make urban traffic more crowded. Construction of subway station and line is also belonging to urban road construction. At present, large-scale subway construction is ongoing in Nanchang. According to this situation, this paper describes basic conditions for traffic relief during subway construction. And proposed urban traffic relief should be combined with different construction schemes to make a reasonable arrangement. Method of construction should also meet requirements of traffic relief plan proposed by traffic management department, taking into account feasibility of construction program and construction risk.

Keywords: Construction of city road; New ideas for traffic relief; Basic conditions for traffic relief; Construction methods; Traffic relief.

1 Overview of urban road construction

Urban road construction projects include various types, it have a great impact on normal operation of urban roads and the construction area in city road network. Generally speaking, it include urban expressways, trunk roads, interchanges, large bridges, rail lines and stations, large square, large pipe networks and so on. According to the influence characteristics to transport system, we put these large projects into point, line and area engineering works (Mao, 2001).

Point project includes: Interchange, large bridges, rail stations, transportation hubs, large square, etc.

Line project includes: Urban freeway, main roads, urban rail transit lines, etc.

Area project includes: Large pipeline construction, etc.

Since Nanchang is constructing rail transit lines and stations, construction of these subway lines and stations pose a serious impact to Nanchang's traffic. Therefore, this paper will focus on city's traffic relief during the construction of subway project belonging to the point and linear project such as rail transit lines and stations.

2 New ideas and methods about traffic relief during subways construction

2.1 Construction optimization program based on traffic relief

Different construction methods have different effects on urban transport, in these methods, the greatest is open-cut method. Construction methods proposed by subway design and construction units are often made from the view of subway project investment, construction period, safety and quality, but lack of traffic. It is necessary to change construction program by comprehensive comparison and meet traffic relief needs when construction program has a great impact on traffic or price of traffic relief is too high to afford. In the optimization program, with co-ordination arrangements technical advantages of owner, designer, constructer and supervisor should be fully utilized to modify construction process and plan, reducing construction fence time, narrowing construction fence area, thereby reduce traffic impaction (Huang, 2009).

2.2 New ideas and methods

Facing of growing traffic pressure, traffic management departments are often more focused on demand of urban traffic and less to consider subway construction when approval the scheme about construction fence relating to subway, such as subway construction period, project investment, security management, etc. So we should change ideas when formulate traffic relief scheme. In order to make subway project plan or construction method rational, operability, traffic workers should make early intervention in subway preliminary design stage. To carry out the plan of traffic relief during subway's construction, we should investigate construction site fully and communicate with design units about program or construction method.

3 Basic conditions for traffic relief reasonably during subways construction

To provide a scientific, operability plan during construction, construction features must be clearly along subway lines, interval and associated road, this is the basis to determine reasonable plan of traffic relief (Liu, 2012).

(1) The alignments of subway line and each range segment
(2) Design of station along with subway and interval
(3) There are three forms of the subway station: underground station, ground station and elevated station; Design Line range also includes underground line, ground line, overhead lines and the transition section line.
(4) The settings situation of entrance along subway station
(5) Construction methods of subway stations. According to the geographical and environmental conditions where the station is located, there are three construction methods: open-cut method, cover excavation method and tunneling method.
(6) Traffic situation on the ground and pipeline layout facilities (Shi, 2010).

From the conditions above we can see: In order to facilitate the analysis of subway construction impact on the surrounding city traffic situation and to give full consideration to the influencing, constraints and other coordination factors around construction site when formulate traffic relief plan .The plan should be based on range of stations along involved, analyze and master the subway construction methods, environmental conditions surrounding the construction site. Technically, the impact of subway construction on traffic mainly refers to the influence of the occupation of road construction, transport facilities demolition within scope of construction, construction methods, management of construction (Zhang, 2008).

4 The construction method of the subway station

Forms of construction fence are closely related to construction methods and the surroundings, so it must consider in conjunction. Generally, Different methods lead to different construction fence forms. Determining construction method and form of construction fence have a significant impact for safety, quality, time and cost. So we should make a reasonable choice based on planning condition along line, engineering geological and hydrogeology conditions. At the same time, role of ground buildings existing and planning should be taken into consideration. After completion of station structure, station structure safety should not be affected by near building structures or other engineering activities. Meanwhile we should consider environmental factors, putting adverse effects on surrounding environment to minimize during and after the construction. There are three methods commonly used in subway construction: Direct excavation-shoring construction, Cover-excavation method, Tunneling method.

4.1 Open cut method

Open cut method is the most economical compared with other methods and it also a method that is safety and reliable. If the conditions allowed, it should have priority.

Direct excavation-shoring construction is often applied to the situation that the ground has condition of open excavation and enough of construction site. It can be combined with ground demolition and widening roads. Using this method, the station can be located in road within or outside. In order to make ground traffic flow to be evacuated, temporarily interrupted of some roads is allowed during construction and using temporary diversion when conditions permitted (Tan, 2005).

4.2 Cover-excavation Method

Cover-excavation method can be divided into the following process: first, excavating from ground down to a certain depth; then, closed the top, constructing the rest of lower part project under closed roof. If the interruption is not allowed due to road traffic and the roof above the pit can't be once formed then a down side cover-excavation method can be a choice. Cover-excavation method generally applies to traffic must not be interrupted, and the roads are narrow areas or the underground station structure have special protection requirements for the surrounding structures.

4.3 Tunneling method

Under the following conditions tunneling method can be used: ground has no condition to carry out unconditionally open cut; engineering geological conditions are good and water table is low, no groundwater and no confined water. When the tunneling method used in subway station construction, it have no effect on ground traffic and has less ground demolition (Chen, 2009).

By analyzing advantages and disadvantages of different construction methods, pointing out their application, we can know that if the ground has enough sites, roads can be occupied in long time and underground pipelines can remove, then direct excavation-shoring construction should be considered firstly. Besides, According to geological conditions of Nanchang, because of poor strata self-stability and in order to control the excessive subsidence on the surface of the earth, ensure proper use of underground pipelines and ground built structures often requiring additional auxiliary construction technology, carrying tunneling construction of large cross-section and large span structures in the quaternary soft soil layer often need additional auxiliary technology. It is clear tunneling method has high cost and risky. Therefore, according to the surrounding environment, the station of subway Line 1 in Nanchang recommend open cut method and cover-excavation method.

5 Examples of verification

These methods will affect traffic in different degrees, but the holding time and degree of road is different. Regardless of which method used in constructing, traffic basically has partial be closed. Theoretically cover-excavation can guarantee ground vehicle traffic during construction, but for the following reasons construction method of station is generally not considered the method of cover-excavation. The reasons are: Firstly, due to construction of temporary roads, pipeline relocation, the construction of retaining wall in the early times, roads also need to be partially closed temporary. Secondly, for various technical reasons in late construction, traffic needs a second partial close again. Thirdly, the temporary road system is expensive.

This paper describes bayi hall subway station in Nanchang which has greater difficulty in construction. Analysis the construction method of open cut method and ground traffic relief during the construction of subway station. Station of bayi hall is located in the intersection of zhongshan road and xiangshan road where is in the commercial center of Nanchang. There are large building density along this station and has little red building retreat. By considering location, engineering geological and hydrogeology conditions, the construction of station mainly use open cut method in stages, partly use the method of cover-excavation– reverse. Details are as follows:

In the first stage, construct the west side of roof blanket of 3rd line and ground subsidiary structure by using open cut method. As can be seen from traffic relief plan that a large defective is it has large area of road closure and serious impact to traffic. So when making traffic relief plan we should take full advantage of surrounding roads, rational organization of transport to realize the rationality of traffic relief. The scheme of traffic relief can be shown specific in figure 1:

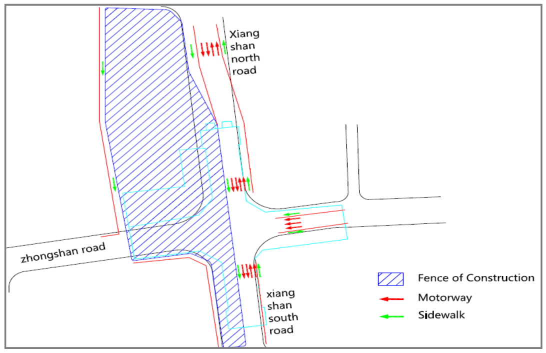

Figure 1. First stage of bayi hall subway station

Corresponding traffic relief plan: Disconnect the traffic of Zhongshan road at xiangshan road, move the traffic of xiangshan north and south road to eastward, Keep the original four lanes and sidewalks that total width is 17.4m.

In second stage, construct the east side of the roof blanket and ground subsidiary structure by using open cut method. Traffic relief scheme can be shown in figure 2.

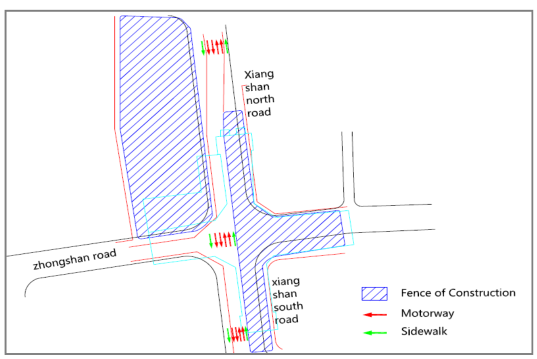

Figure 2. Second stage of bayi hall subway station

Corresponding traffic relief plan: Disconnect the traffic of Zhongshan road at xiangshan road, move the traffic of xiangshan north and south road to eastward, keep the original four lanes and sidewalks that total width is 15.5m. The width of the sidewalk in the zhongshan road is 5.5m.

In the third stage, construct pit in east and west of 1rd line and west side of the northern section of subsidiary pit, using cover-excavation–reverse method to construct the station of 3rd. Bayi hall station is the only one in all 24 stations of Nanchang subway 1rd using cover-excavation– reverse to construct. This method can shorten the time of construction fence as far as possible. It can make road traffic recover as soon as possible. The scheme of traffic relief can be shown specific in figure 3.

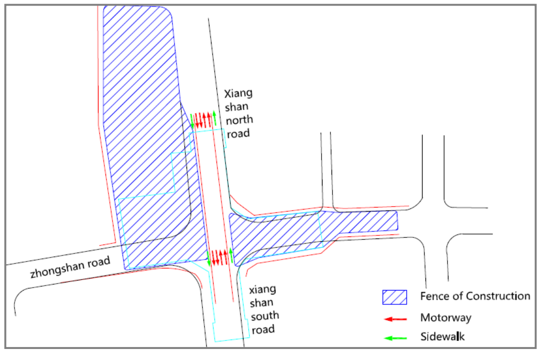

Figure 3. Third stage of bayi hall subway station

Corresponding traffic relief plan: Disconnect the traffic of Zhongshan road at xiangshan road, recover original road traffic of xiangshan north and south road, keep original four lanes and sidewalks that total width is 20m. The width of the sidewalk in zhongshan road is 5.5m.

In the four stages, construct the main structure, subsidiary structure in the east and west end and the main structure of subsidiaries of 3rd station in the west of the northern section by using open cut method. The scheme of traffic relief can be shown specific in figure 4.

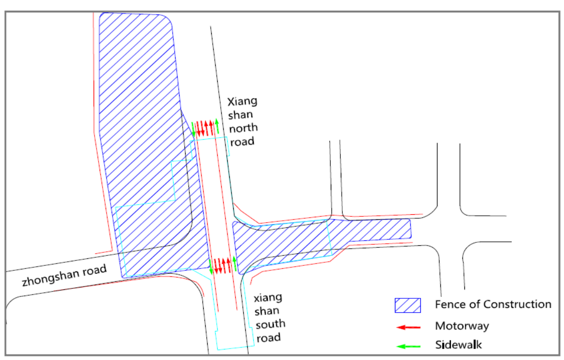

Figure 4. Four stage of bayi hall subway station

Corresponding plan: Disconnect the traffic of Zhongshan road at xiangshan road, recover the original road traffic of xiangshan north and south road, keep the original four lanes and sidewalks that total width is 20m. Set sidewalk in zhongshan road.

6 Conclusions

Traffic relief is a complicated systematic project related to many units such as planning, building, traffic management and construction sector, etc. It requires constant coordination between different departments. In many times it needs to conduct the process "construction conditions - project design- feedback" repeatedly. Due to the unforeseen factors, construction prerequisite, repeated changes of sort plan, so traffic relief plan should have elasticity during construction. So that can we cope with various adverse factors generated during construction.

Reference

Chen, S. K. (2009). "Traffic organization methods and evaluation in the area of urban road construction." *Southeast University*, 21-24.

Huang, J. J. (2009). "Traffic organization during the construction of large municipal projects." *Southwest Jiaotong University*, 12-15.

Liu, Y. C., and Zhou, S. (2012). "The innovation of work idea and method in traffic relief during Cheng-du subway construction." *Traffic Engineering*, 17: 16-19.

Mao, H., and Xie, Z. M. (2001). "Explore ways of road traffic organization in big cities during subway construction." *Journal of Chongqing Jiaotong Institute*, 20: 54-57.

Shi, B. F. (2010). "Research of Traffic Organization Methods during Urban Rail Transit Construction." *Journal of Ningbo University of Technology*, 22:49-53.

Tan, X. L., and Yang, G. B. (2005). "Analysis and Countermeasure Study on Road Construction Influence on Urban Traffic." *Journal of Urban Roads Bridges & Flood Control*, (3): 110-113.

Zhang, C. (2008). "Ground traffic organization during construction of subway station." *Urban Mass Transit*, 2:62-64.

Analysis of the Safety of the Linchuan Section on Donglin Highway

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Abstract: In order to improve the B road's traffic safety level, take Linchuan section on Donglin highway as an example. According to the traffic accident data from January 2009 to December 2013, analyzed the main law of Linchuan section on Donglin highway traffic accident. Then using the based on the primary element of the grey association degree analysis method to analysis the main reason of Linchuan section on Donglin highway traffic accidents, analyzed the reasons for the formation of accidents from the design and planning of the accident black point, especially analyzed the causes of the two main dangerous intersection. Finally, put forward the traffic accident prevention and control countermeasures from four aspects of people, vehicles, road, environment, to the traffic management departments are proposed.
Keywords: Broad; Traffic accidents; Primary element; Grey association degree.

1 Introduction

There's a lot of researches on road traffic accident in our country, the largest is highway research, however, specifically for distributing function of provincial highway traffic accident cause analysis and countermeasures of prevention and control of research is less. Provincial highway have differences in features of other highway, it always connects cities and counties, the traffic distribution function is obviously, most of the road through the villages and towns, makes sections mixed models, the density of the access is big, feeder roads planning and design is unreasonable, and thus influence the operational efficiency of the thread; especially the Linchuan section on Donglin highway in Fuzhou city, it is located in the urban-rural fringe, throughout three villages and towns, as two or three rounds of motorcycle over the years, the number of two or three rounds of electric vehicles has greatly increased, the driver of the vehicle traffic safety consciousness is low, traffic violations to highlight, coupled with the increase of traffic volume, the provincial highway traffic accidents, serious impact on the provincial highway connecting the full realization of the superiority of the urban and rural areas, threatening the safety of people's life and property.

2 Field Data

In this paper, using grey correlation analysis method based on the primary elements to analysis the road traffic accident of Linchuan section on Donglin highway. At the same time, this paper analyzes the reasons of accident black point design and accident reason and cause dangerous intersection point planning, points out the hidden trouble in security of Linchuan section on Donglin highway and the hidden trouble causing traffic accidents, in carried on the systematic analysis and summary.

Linchuan section on Donglin highway only 13 km，but the access almost 71. Highway design for level 1, level 1 design speed of 90 km/h, mixed traffic. Between January 2009 and December 2013, 700 road traffic accidents happened, 34 people were killed and 279 injured, and caused the economic loss of 10460860 yuan. Investigate its objective reasons, can be divided into the following:

(1) The road traffic, big truck overloading, the car speeding
(2) Of motor vehicles and non-motor vehicles mixed driving
(3) The road damage and destruction
(4) Facilities lack integrity Settings, maintenance is not in place
(5) Flat crossing too much
(6) Models is complex, the speed of the car a span

3 Data Analysis

The grey correlation analysis method based on the main elements macro analysis of the causes of road traffic accidents, can not only consider the influence between the elements of a road traffic system, but can also find out the influence factors of road traffic accidents and the related degree between the size of the effect. Grey correlation analysis process is as follows:

(1) The main element set and the determination of main influence factors

Based on the characteristics of road traffic accident analysis and previous accident statistics of Linchuan section on Donglin highway, combined with the mechanism of traffic accident, determine the main factors that influence the main element and the corresponding subsystems, see table 1.

Table 1. Traffic accident factors and the main influence factors of them

Road subsystem	The main elements	Main factors influencing
Motor vehicle	Motor vehicle status	Normal and abnormal
Motor vehicle drivers	State of the drivers	Normal, overspeed, illegal overtaking each other, not to Change lanes and other regulations to give way, illegal
Motor drivers and	State of non-motor	Normal, illegal

pedestrians	vehicles and pedestrians	
The road	Intersection situation	Flat crossing road, the crossing road
The traffic environment	The weather conditions	Sunny, rain, overcast

(2) Determine the sequence analysis

Road traffic accident has three indicators as the basic statistics, statistics of the corresponding main factors influencing the number of traffic accidents, the number of deaths, injury. Set the reference sequence (also called mother sequence) for $X_0^{'}$; Compare sequence (also known as a sequence) $X_i^{'}$, $i=1,2,\Lambda,n$ .To pose with the sequence of $X_0^{'}$ and $X_i^{'}$ the original data sequence, constructs a matrix with the original data sequence, see type (3.1).

$$\left(X_0^{'}, X_1^{'}, L, X_n^{'}\right)=\begin{bmatrix} x_0^{'}(1) & x_1^{'}(1) & K & x_n^{'}(1) \\ x_0^{'}(2) & x_1^{'}(2) & K & x_n^{'}(2) \\ M & M & O & M \\ x_0^{'}(N) & x_1^{'}(N) & K & x_n^{'}(N) \end{bmatrix}_{N\times(n+1)} \quad (3.1)$$

Among them, $X_i^{'}$ is the main influence factor of the accident, matrix represents a main element.

(3) To the dimensionless variables

Due to various factors in the system data in a column may be due to the different dimensions, comparison, or in more difficult to get the correct conclusion. So the grey correlation analysis, generally must carry on the dimensionless processing of data. Eliminated by dimensionless calculation can achieve different dimensional data value differences between the impact, at the same time also can reflect the main influencing factors on the influence degree of the overall road traffic accident. Using (3.2) to the original data sequence is dimensionless.

$$x_{ij} = \frac{x_{ij}^{'}}{\sum_i x_{ij}^{'}} \quad (3.2)$$

x_{ij} refers to the main impact factor i of the j accident indexes of dimensionless results; $x_{ij}^{'}$ refers to the main impact factor i of the j original accident index; $\sum_i x_{ij}^{'}$ refers to the corresponding to j of the three index of the accident of the original value is the sum of the accident. See the data resulting from the dimensionless sequence type (3.3)

$$(X_0, X_1, L, X_n) = \begin{bmatrix} x_0(1) & x_1(1) & K & x_n(1) \\ x_0(2) & x_1(2) & K & x_n(2) \\ M & M & O & M \\ x_0(N) & x_1(N) & K & x_n(N) \end{bmatrix}_{N\times(n+1)} \quad (3.3)$$

For each of the main elements to select the optimal reference sequence, choose the method of major elements of the optimal sequence of reference type (3.4).

$$X_0 = (x_0(1), x_0(2), K, x_0(2))' \quad (3.4)$$

Among them: $x_0(j) = \max_{1 \le i \le n} \{x_i(j)\}, j = 1, 2, K, N$.

(4) Calculating correlation coefficient

$\xi_{0i}(k)$ is the correlation coefficient of $x_0(k)$ and $x_i(k)$, see type（3.5）

$$\xi_{0i}(k) = \frac{\min_i \min_k |x_0(k) - x_j(k)| + \rho \max_i \max_k |x_0(k) - x_j(k)|}{|x_0(k) - x_i(k)| + \rho \max_i \max_k |x_0(k) - x_j(k)|} \quad (3.5)$$

Remember: $\triangle_{0i}(k) = |x_0(k) - x_i(k)|$,

$$\triangle_{\min} = \min_i \min_k |x_0(k) - x_j(k)| ,$$

$$\triangle_{\max} = \max_i \max_k |x_0(k) - x_j(k)| \quad (i = 1, 2...n; k = 1, 2, ...N)$$

$\triangle_{\min}$ is the smallest range, $\triangle_{\max}$ is the biggest range. $\rho \in (0, \infty)$ is distinguish coefficient, the general values is $0.1 \sim 1$, the smaller ρ can improve can improve the correlation coefficient between the difference, the greater the resolution, specific values can take as the case maybe. When $\rho \le 0.5463$, the resolution is the best, so usually take $\rho = 0.5$.

(5) Computing correlation:

Because of the correlation coefficient is a sequence and reference in each moment the connection degree of (that is, each point in the curve) value, so its number to more than one, and information too scattered is not convenient to compare integrity. So it is necessary to every time (that is, each point in the curve) of the correlation coefficient of concentration of a value, its average, namely as a comparative sequence and the number of correlation degree between the reference sequence, the correlation formula of r_{0i} is as follows:

$$r_{0i} = \frac{1}{n} \sum_{k=1}^{n} \xi_{0i}(k), k = 1, 2, \Lambda, n \quad (3.6)$$

Correlation is adopted generally calculate the average correlation coefficient is computed, but three indicators of traffic accidents in the accident influence degree is different, so can't will severity index of different simple accumulation, this will cause misjudgment. Such analysis that it is necessary to adopt the weighted average method to evaluate correlation, we can use type (3.7) correlation calculation.

$$r_{0i} = \sum_{k=1}^{n} \omega_k \xi_{0i}(k), k = 1, 2, \Lambda, n \tag{3.7}$$

ω_k is the weight of the three indicators for traffic accident (the number of accidents, deaths, and the number of injured),we can using expert scoring method to determine. Expert scoring method to determine the weights of three indexes: the weight is 0.1, the number of accident death toll index weight is 0.6, the number of injured weight of 0.3.

4 Discussion of Results

Take the traffic accident of Linchuan section on Donglin highway during January 2009 to December 2013 into consideration, 700 traffic accidents occurred, 34 people were killed and 279 injured. According to the actual situation of Linchuan section on Donglin highway from the main influence factors, such as: stadia, road slope and road camber, roadside disturbance factor, because most of Linchuan section on Donglin highway the road is straight, no sharp, road slope, it should not, so there is no statistical these factors.

4.1 K231 + 200 accident causes dangerous intersection analysis

K231 + 200 accident is a dangerous crossroads intersections, the east is 7% up to the sun town central primary school and the town of old street branch of the west is 9% of the uphill to the Luohu town and new village branch. The intersection between January 2009 and December 2009, to a maximum of 86 traffic accidents occurred, killed seven people and injured 43 people, accounting for 18% of the total number of flat crossing traffic accident.

(1)Traffic signs obscured, branches and leaves of trees incredibly hides the intersection of the "cross" mark.

(2)Access sights of bad, because of the trees in the shade of buildings, caused by intersection of east and west two line stadia is only 80 meters and 70 meters respectively, is far less than 110 meters of stadia.

(3)After the entrance to the slope is too large, slope is found on both sides of the branch of the main road, the east branch of the uphill slope of 7%, on the west side of the hill slope has reached 9%, lack of mandatory reduction measures in a bar.

(4)Big four intersection traffic, the flat crossing traffic and traffic are larger, at the same time these people's traffic safety consciousness is low, branch vehicles don't come near the main vehicle.

4.2 K236 + 300 accident causes dangerous intersection analysis

K236 + 300 accident is a dangerous crossroads intersections, the east is 6% of the uphill to the Luohu town and the village of east branch, the west is the gateway to a new house in the village of branch. The intersection between January 2009 and December 2009, to a maximum of 63 traffic accidents occurred, killed 3 people and wounded 34 others, accounting for 13.4% of the total number of flat crossing traffic accident.

(1)The lack of traffic signs, the road does not have a road sign.

(2)Poor access sights, as a result of the doers of the word, buildings and slope block, caused by intersection of east and west two line stadia is only 50 meters and 75 meters respectively, stadia is far less than 110 meters.

(3)After the entrance to the slope is too large, the main branch is on the west side of the slope, on the west side of the hill slope of 8%, lack of mandatory reduction measures in a bar.

(4)Four intersection was badly damaged, the crossing overload truck traffic, perennial water caused by the road surface is damaged, the driver in order to choose travel route and reduces the main idea of the vehicle.

5 Conclusions

Respectively from the people, vehicles, road and environment four aspects analyzes the influence of the main causes of traffic accidents, put forward to reduce and prevent the happening of the road traffic accident, to ensure the safety of corresponding measures. Here we may draw the following conclusions.

(1)Strengthen the traffic safety education, to reduce road traffic offence;

(2)Strengthen the vehicle maintenance, improve vehicle safety performance;

(3)To improve road safety facilities, and constantly improve road conditions;

(4)In order to strengthen the management of road traffic, optimize the environment of road traffic safety.

6 Recommendations for Future Research

(1)The system, from the viewpoint of the mechanism of traffic accident qualitative research, to analyze the general process of the traffic accident, but how to quantitatively analysis the law of action between various factors within the system, still need further study.

(2)The secondary roads such low grade road, the traffic safety is often after accidents caused enough attention, thus caused many unnecessary casualties and property losses. So, how to carry out the low level of road traffic safety evaluation, in a timely manner to eliminate potential hidden trouble of road traffic safety is an urgent need to study.

References

DENG J L (1990). *Grey system theory tutorial*. Huazhong University of science and Technology Press, Wuhan.

Evans, L (2004). *Traffic Safety*. Bloomfield Hills, Michigan: Science Serving Society.

GUO Z Y，FANG S S. (2003) *Road safety engineering* .People traffic press, Beijing .

Kenichiyoshimoto (2000). *Progress of Traffic Safety in JaPan*.4thASIA 一 PACIFIC ITS SEMINAR, Beijing, China.

ZHE X (2008). *The road traffic accident cause analysis method study*. Tongji University, master's thesis

Road Traffic Accident Forecasts Based on Cointegration Analysis

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Abstract: Road traffic fatalities account for the maximum portion of total production accident fatalities in China, although they exhibit steady annual reductions in recent years. Road traffic accident forecast is a core component of a target setting which proves to be an effective measure to improve road safety by the best-performing countries. In this paper, a traffic accident prediction model aimed to set road safety targets is proposed. Based on cointegration analysis of Chinese crash and economic data, the model avoids spurious regression and shows a satisfactory precision. The prediction results can be a good reference to policymakers on their target setting.

Keywords: Traffic accident; Death rate forecasting; Cointegration analysis; Error correct model.

1 Introduction

The annual number of road traffic casualties is above 200,000 in China (RIHMT, 2013). With such a high price for motorized road mobility, road traffic safety problems attract great attention of Chinese governments. To combat traffic accidents, the 12th Five-Year Plan of Road Traffic Safety (12th FYPRTS) was published at the end of 2011 (CSCOSPC, 2011). This is the first nation-level special plan for road safety, which offers a nationwide comprehensive framework for reducing road traffic accidents and fatalities. According to the FYPRTS, each local government above the county level is supposed to develop their own road safety plans.

For a road safety plan, the safety target setting is essential. Some models have been developed by domestic researchers to forecast the Chinese road safety tendency such as a multi-level recursive death toll prediction model (Li Xiangyong, 2006), a death toll prediction model based on neural network (Qin Liyan, 2010) and a multiple linear regression model of traffic accidents (Fang Yuerong, 2012). However, the short-term relationship between road safety and economic factors isn't taken into account in these models, which is important for target setting.

This paper aims to build a relatively simple model of traffic accident death rate prediction, revealing how road safety reacts to economic factors. The rest of the paper is organized as follows. Firstly, the methodology used in modeling is explained and the data sources are given. Secondly, the prediction model is built with the help of statistic software Eviews7.2. Thirdly, several main conclusions are summarized.

2 Methodology and Data

2.1 Methodology

Most macro road safety analysis and forecasts are conducted within the framework of linear regression (Yong-Jun Kweon, 2010; George Yannis, 2014). But some attention should be paid to spurious regression phenomenon (Granger, 1974). In a spurious regression, the standard t-statistic indicates that a sound relationship exists between the variables when, in reality, there is no such relationship. This is because the variance of the errors is not consistently estimated. To deal with the problem, the conduct of cointegration analysis is needed. Engle–Granger two-step method (Engle, 1987) can test the cointegration relationship. The first step is to find out integrated order of each time series by Augmented Dickey–Fuller (ADF) test method. If the time series has the same integrated order, the cointegrated regression model can be established as follows.

$$y_t = \hat{b}_0 + \hat{b}_1 x_{1t} + \cdots + \hat{b}_N x_{Nt} + e_t$$

where $\hat{b}_0, \hat{b}_1, \cdots, \hat{b}_N$ is estimated by ordinary least square (OLS) method, and e_t is residual error.

The second step is to test the stationary of $\{e_t\}$. If it is stationary, the series are regarded as cointegrated. Otherwise, they are not cointegrated.

An error correction model (ECM) can be built when the series are cointegrated. ECM is proposed by Davidson et al. (Davidson et al., 1978). It is a useful tool to estimate both long period and short period relationship between cointegrated time series.

For two variables, the structure of the first-order ECM is presented as below.

$$\Delta y_t = a_1 \Delta x_t - \lambda \cdot ECM_{t-1} + u_t$$

$$ECM_{t-1} = y_{t-1} - b_0 - b_1 x_{t-1}$$

where a_1 is short-term coefficient, λ is an adjustment coefficient and u_t is equilibrium error.

2.2 Data sources

The mortality rate per ten thousand vehicles data (Table 1) used in this paper are collected from The People's Republic of China on road traffic accident statistics report 2013 (MPSTMB, 2013). Economic data (Table 2) are obtained from the web of National Bureau of Statistics of the People's Republic of China.

Table 1. The mortality rate per ten thousand vehicles (1978-2013)

Year	Mortality rate	Year	Mortality rate	Year	Mortality rate	Year	Mortality rate
1978	120.20	1988	46.05	1997	17.50	2006	6.16
1980	119.62	1989	38.26	1998	17.30	2007	5.10
1981	104.47	1990	33.38	1999	15.45	2008	4.33
1982	95.85	1991	23.15	2000	15.60	2009	3.63
1983	85.32	1992	20.19	2001	15.46	2010	3.15
1984	84.35	1993	27.24	2002	13.71	2011	2.78
1985	42.99	1994	24.26	2003	10.81	2012	2.50
1986	62.39	1995	22.48	2004	9.93	2013	2.34
1987	61.12	1996	20.41	2005	7.57		

Table 2. Real Gross Domestic Product Per Capita (1978-2013)

Year	GDP Per Capita (yuan)	Year	GDP Per Capita (yuan)	Year	Mortality rate	Year	GDP Per Capita (yuan)
1978	381	1988	862.203	1997	1788.414	2006	3789.807
1980	404.241	1989	883.539	1998	1910.334	2007	4303.776
1981	430.53	1990	904.113	1999	2037.969	2008	4694.301
1982	447.675	1991	973.836	2000	2192.655	2009	5101.59
1983	480.822	1992	1098.804	2001	2357.247	2010	5607.177
1984	525.399	1993	1237.869	2002	2554.224	2011	6099.429
1985	597.408	1994	1384.173	2003	2793.111	2012	6534.531
1986	668.655	1995	1518.666	2004	3056.382	2013	7000.875
1987	717.042	1996	1653.159	2005	3382.137		

3 Model development

3.1 Variable selection

The most common indicator used in Chinese quantitative road safety targets is deaths per 10,000 motor vehicles (DPMV). Therefore, DPMV is selected as explained variable in this paper. Gross domestic product per capita (GDPPC) is chosen as explanatory variable, characterizing economic conditions. To avoid the influence of inflation, real GDP per capita data are adopted.

3.2 Model development

The data between 1978 and 2011 are used to determine the parameters of ECM. The data in 2012, 2013 are used for forecast comparison.

The results of ADF test of two variables and their difference series are summarized in Table 3.

Table 3. The ADF test result for the series

Variables	t-Statistic of ADF test	Critical value (1% level)	Critical value (5% level)	Critical value (10% level)
LnGDPPC	-2.635628	-4.296729	-3.568379	-3.218382
LnDPMV	0.364961	-3.632900	-2.948404	-2.612874
ΔLnGDPPC	-3.732707	-4.309824	-3.574244	-3.221728
ΔLnDPMV	-8.443748	-3.639407	-2.951125	-2.614300

Table 3 shows LnGDPPC and LnDPMV are nonstationary with 1-order integration. Therefore, the cointegrated regression model is estimated as below.

$$LnDPMV_t = \underset{(27.65058)}{12.55957} - \underset{(-21.29609)}{1.301374} \cdot LnGDPPC_t + e_t$$

The equation shows a high fitting degree with R^2=0.985350. The constant term and coefficient term passed through t-test. The ADF result of residual error is shown in Table 4.

Table 4. The ADF test result for residual error

	t-Statistic of ADF test	**Prob**
ADF test statistic	-3.032789	0.0035
Test Critical value (1% level)	-2.636901	
Test Critical value (5% level)	-1.951332	
Test Critical value (10% level)	-1.610747	

According to Table 4, the residual error is stationary. The two variables are proved to be 1-order integrated and cointegrated. The ECM model equation can be built as:

$$\Delta LnDPMV_t = -\underset{(-5.042306)}{1.310458}\Delta LnGDPPC_t - \underset{(-2.983101)}{0.158041}ECM_{t-1}$$

R^2=0.646012, DW=2.159929. The statistical fit of the ECM to the data is satisfactory. The forecasting results of the model are illustrated in Table 5.

Table 5. Forecast result comparison

Year	Predicted value	Real value	Error (%)
2012	2.619222	2.50	4.7689
2013	2.412894	2.30	1.9084

According to Table 5, the model has high precision.

4 Conclusions

Road safety tendency is essential to set proper road safety targets. It is necessary to develop a prediction model especially for this purpose. To avoid spurious regression, cointegration theory is introduced to forecast the fatality rate. The error correction model is built using deaths per 10,000 motor vehicles as explained variable and GDP per capita as explanatory variable. The prediction results show a satisfactory precision and can be a good reference to policymakers.

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References

China State Council Office of Safety Production Committee. (2011). *Twelfth Five-Year Plan of Road Traffic S*afety. < http://www.chinasafety.gov.cn/newpage/ Contents/ Channel_5347/2012/0121/166492/content_166492.html> (December 20, 2014)

Davidson, J. E. H.; Hendry, D. F.; Srba, F.; Yeo, J. S. (1978). "Econometric modelling of the aggregate time-series relationship between consumers' expenditure and income in the United Kingdom." *Economic Journal*, 88:352, 661–692.

Engle, R.F., Granger, C. (1987). "Co-integration and error correction: representation, estimation and testing." *Econometrica*, 55:2, 251-276.

Fang Yuerong, Shen Feiming. (2012). "Development trend analysis and prediction of traffic accident." *Journal of Safety Science and Technology*. 8:3, 141-146.

George Yannis, Eleonora Papadimitriou, Katerina Folla. (2014). " Effect of GDP changes on road traffic fatalities." *Safety Science*. 63:42-49.

Granger, C. W. J., Newbold, P. (1974). "Spurious regressions in econometrics. " *Journal of Econometrics*. 2(2): 111-120.

Li Xiangyong, Tian Peng, Zhang Nan, Long juren. (2006). “Multi-level recursive forecasting method for road accidents.” *Journal of Southwest Jiaotong University*, 41:1, 107-110.

Ministry of Public Security Traffic Management Bureau. (2013). *The People's Republic of China on Road Traffic Accident Statistics Report 2013*. Beijing, China.

Qin Liyan, Shao Chunfu, Zhao Liang. (2010). “Macro Prediction Model of Road Traffic Accident Based on Neural Network.” *Journal of Wuhan Uniersity of Technology (Transportation Science & Engineering)*, 34:1, 154-157

Research Institute of Highway Ministry of Transport. (2013). *The blue book of road safety in China 2013*, China Communications Press, Beijing.

Young-Jun Kweon. (2010). “Data-driven reduction targets for a highway safety plan.” *Transport Policy*. 17:4, 230-239.

Hazardous Location Identification of Multi-Lane Expressways

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Abstract: Based on the achievements of key research project of Liaoning Province Transportation Department "Research on Road Safety and Traffic Operation of Expressway", hazardous location of eight-lane expressway are identified adopting quality control method in this article, and comparing with the hazardous location of four-lane and six-lane expressway. The effect of expressway entrance & exit on hazardous location is further analyzed. The preliminary conclusion is achieved that entrance & exit of eight-lane expressway and above is the primary cause of traffic accident. The research results of this article can provide theoretical basis for the design and lane layout of eight-lane expressway and above
Keywords: Multi-lane expressway; Traffic safety; Hazardous location.

1 Introduction

Multi-lane expressway means eight-lane expressway and above. In order to meet the needs of social development and traffic operation, several expressways have been or about to be reconstructed and extended in China recently. Multi-lane expressway is the development trend of expressway in future. The regulations on multi-lane expressway are almost blank, especially on eight-lane expressway and above, the hazardous location identification of eight-lane expressway and above have been seldom researched.

This article adopts a hazardous location identification method combining with the level of safety of service (LOSS), quality control method and probability distribution of accidents. The hazardous location includes sections, expressway tool stations, entrances & exits. Represented by Shenyang-Dalian expressway (eight-lane expressway), the hazardous locations of multi-lane expressway are identified applying this method. By comparing with four-lane and six-lane expressway in Liaoning Province, the cause and characteristic of hazardous locations are analyzed.

2 Hazardous Location Identification

2.1 Hazardous section identification based on LOSS

At the level-four safety service, the expressway traffic safety situation is badly, and the various accident indicators are clearly above than average. Thus, the sections of level-four safety service can be regarded as the traditional hazardous sections. Based on the level of safety of service, 16 hazardous sections of Shenyang-Dalian expressway are identified as follows.

Table 1. Hazardous sections of Shenyang-Dalian expressway based on LOSS

No.	Hazardous Location	No.	Hazardous Location
1	K9-K10	9	K159-K160
2	K19-K20	10	K165-K166
3	K22-K24	11	K264-K265
4	K34-K35	12	K280-K281
5	K41-K42	13	K290-K291
6	K44-K45	14	K297-K298
7	K123-K124	15	K301-K302
8	K144-K145	16	K334-K335

2.2 Hazardous location identification based on quality control method

(1) Hazardous location identification method

The quality control method is based on the probability theory. The critical rate $Rc^{\pm}$ could be obtained after comparing the accident rate of specific location with the average accident rate of similar characteristic location. The quality control method takes into account both the number of accidents and traffic flow, and becomes a classical method of hazardous location identification. The critical rate $Rc^{\pm}$ is computed according to Eq. (1)

$$R_c^{\pm} = A \pm K\sqrt{\frac{A}{M}} \pm \frac{1}{2M} \quad (1)$$

With Rc^{+} is the upper limit value of critical accident rate, Rc^{-} is the lower limit value of critical accident rate, A is the average accident rate of similar characteristic location, K is the statistical parameter, equal to 1.96(95% confidence), M is the traffic volume of specific location during the survey period(100 million vehicle).

The identification criterion of quality control method is as follows:

□ If the actual accident rate is less than the lower limit value of critical accident rate Rc^{-}, the traffic safety situation of this section is quite good;

② If the actual accident rate falls between the lower limit value of critical accident rate Rc^{-} and average accident rate A, the traffic safety situation of this section is good;

③ If the actual accident rate falls between the average accident rate A and the upper limit value of critical accident rate Rc^{+}, the traffic safety situation of this section is bad;

④ If the actual accident rate is more than the upper limit value of critical accident rate Rc^{+}, the traffic safety situation of this section is quiet bad, and could be identified as hazardous location

(2) Results of hazardous section identification

Based on the quality control method, 31 hazardous sections of Shenyang-Dalian expressway are identified as follows.

Table 2. Hazardous sections of Shenyang-Dalian expressway based on quality control method

No.	Hazardous Location	No.	Hazardous Location	No.	Hazardous Location
1	K307-K309	12	K111-K112	23	K264-K265
2	K332-K334	13	K116-K117	24	K280-K281
3	K371-K372	14	K123-K124	25	K290-K291
4	K394-K395	15	K144-K145	26	K301-K302
5	K59-K60	16	K159-K160	27	K307-K308
6	K65-K66	17	K164-K166	28	K311-K312
7	K75-K76	18	K172-K173	29	K322-K323
8	K79-K81	19	K229-K230	30	K327-K329
9	K89-K90	20	K240-K241	31	K334-K335
10	K92-K93	21	K255-K256		
11	K96-K97	22	K260-K261		

2.3 Hazardous toll station identification based on probability distribution of accidents

Based on probability distribution of accidents, if the accident rate of one toll station is more than the sum of average and 1.5 times standard deviation of accident rate, this toll station could be regarded as hazardous toll station. The results of hazardous toll stations identification are shown in table 3.

Table 3. Hazardous toll stations of Shenyang-Dalian expressway

No.	Tool Station Name	Accident Rate(per year per lane)
1	Liaoyang County Station	8.90
2	Jinzhou Station	11.81

2.3 Results of hazardous location identification

Synthesizes LOSS, quality control method and probability distribution of accidents, and combining the suggestion of expressway management, the total number of hazardous location of Shenyang-Dalian expressway is 20, including 5 hazardous sections, 2 hazardous toll stations, 10 hazardous interchange areas. In order to further analyze the cause of multi-lane expressway hazardous locations, the hazardous locations of six-lane expressway(Shenyang-Shanhaiguan expressway), four-lane expressway(Shenyang-Dandong expressway, Changchun-Shenzhen expressway, Shenyang-Kangping expressway, Siping-Kangping expressway) are compared. The specific results are shown in table 4.

Table 4. Summary table of hazardous location identification

No.	Hazardous Location	Type	Expressway Name	No.	Hazardous Location	Type	Expressway Name
1	K306-K307	Toll Station	Shenyang-Shanhaiguan Expressway	25	K76-K77	Interchange Area	Shenyang-Dalian Expressway
2	K661-K662			26	K117-K118		
3	K345-K346	Service Area		27	K270-K271		
4	K395-K396			28	K291-K292		
5	K534-K535			29	K320-K323		
6	K307-K314	Basic Section		30	K338-K339		
7	K368-K373			31	Benxi Toll Station	Toll Station	Shenyang-Dandong Expressway
8	K417-K420			32	K23-K24	Basic Section	
9	K527-K529			33	K40-K43		
10	K565-K568			34	K47-K49		
11	K65-K66	Toll Station	Shenyang-Dalian Expressway	35	K52-K60		
12	K338-K339			36	K62-K63		
13	K0-K1	Basic Section		37	K71-K72		
14	K18-K19			38	K80-K86		
15	K122-K124			39	K99-K101		
16	K224-K225			40	K138-K140		
17	K295-K297			41	K147-K152		
18	K300-K303			42	K1-K2	Interchange Area	
19	K327-K329			43	K254-K257	Basic Section	Changchun-Shenzhen
20	K334-K336			44	K290-K293		

21	K7-K10	Interchange Area		45	K375-K378		expressway
22	K47-K48			46	K23-K28	Basic Section	Siping-Kangping expressway
23	K52-K53			47	K55-K59		
24	K65-K66			48	K42-K49	Basic Section	Shenyang-Kangping expressway

From the distribution of hazardous locations showed in table 4, we can conclude that hazardous locations of four-lane and six-lane expressway are mainly located at basic sections, a total of 18 hazardous locations are identified on four-lane expressway, including two toll stations and two interchange areas, accounting for 11%. A total of 10 hazardous locations are identified on six-lane expressway, including two toll stations and three interchange areas, accounting for 50%.

To further analyze the location characteristic of eight basic sections, we can find six sections are located front or behind the interchange area, which are shown in table 5.

Table 5. Hazardous section of Shenyang-Dalian expressway front and behind the interchange area

No.	Section Beginning	Section Ending	Accident Rate (100 million-vehicle per kilometer per year)	Direction	Comment
1	K0+000	K1+000	51.64	Dual-way	Expressway entrance， weaving areas
2	K18+800	K19+800	48.35	Dalian	Front Shilihe Interchange
3	K122+300	K124+000	68.63	Shenyang	Front and behind Haipan Interchange
4	K224+000	K225+000	48.74	Shenyang	Front Liguan Interchange
5	K295+000	K297+000	64.74	Dalian	Front Jindao Interchange
6	K300+900	K302+900	61.91	Dalian	Front Haiwan North Interchange

Thus, a total of 20 hazardous locations are identified on eight-lane expressway, and 90% of hazardous locations are located at toll stations, interchange area and front or behind interchange area.

3 Main Safety Problems of Multi-lane Expressway

(1) The conflict of lane changing is primary reason of traffic accident. From the

statistical data of traffic accident, we can conclude that the 90% of accidents are caused by lane changing on eight-lane expressway, while 11% and 50% of accidents are caused by lane changing on six-lane and four-lane expressway respectively.

(2) A fair amount of traffic accidents occurred near the interchange area. From the statistical data of traffic accident, we can conclude that accidents occurred near the interchange area on eight-lane expressway significantly more than six-lane and four-lane expressway. For multi-lane expressway, when the vehicles change lane from interior lane to external lane, it will need more time to drive off expressway. If the drivers are clumsy, they will not complete the operation. The accidents occur easily if the vehicles force to exit. Besides, some vehicles always park at the triangle channelization area to judge path, this situation lead to accidents easily.

(3) The roadside signs are often blocked. According to the traffic regulations and driving habits, most large trucks drive on the external lane. When the traffic volume is large, the large trucks that driving on the external lane will easily block the small vehicles driving on the interior lane, thus the small vehicle drivers are influenced to obtain information from roadside signs, the signs information will be invalidated.

4 Macroscopical Safety Countermeasures of Shenyang-Dalian Expressway

(1) Before the toll station, the sign of “SLOW DOWN” is suggested to be set.

(2) The deceleration marking is suggested to be set on exit ramp to warn driver.

(3) The toll station columns should be coated on reflective material to improve the night vision.

(4) The signs of lane distribution and speed limitation of different types of vehicles are suggested to be set at interchange area.

(5) Before the expressway exit, warning marks should be set to warn drivers weaving section ahead.

(6) Speed-limit signs, warning signs of slow down and speed camera signs are suggested to be set for controlling speed on the downhill pat, small radius curves sections, etc.

(7) The vision induced signs are suggested to be set on small radius curves sections, and the signs of forbid overtaking should be set on poor visibility sections.

References

Andrew P.Tarko, Mayank Kanodia.(2004) “*Effective and Fair Identification of Hazardous Locations*[C]”.Transportation Research Board.

National Transportation Safety Board.(2002). Transportation Safety Databases. Safety Study NTSB/SR-02/02. Washington, DC: 65~72.

Robert R V,Veeraragavan A.(2004). “*Hazard Rating Scores for Prioritization of Accident Prone Sections on Highways*. [C]”.Transportation Research Board.

Research of Chengdu's Sustainable Development Based on a DEA Model

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Abstract: Sustainable Development takes interest in long-run economical development, emphasizing to satisfy the needs of contemporary people, but not to damage the profit of future generations. As the lifeline of economic development, sustainable development of transportation System makes decision concern. The development of Chengdu Transportation at high Speed is sustainable or not is a vital problem. So we use the DEA (data envelopment analysis) model to conduct a comprehensive analysis about the input and output of the field of traffic Chengdu city nearly ten years, combining sustainable development indicators. We estimate the sustainable development state and get important influence factors to obtain the sustainable development of Chengdu City traffic.
Keywords: Chengdu; Transportation; Sustainable; DEA.

1 Introduction

Along with the continuous development of modern society, especially the further expansion of economies, the scale of city traffic will significantly increase. The contradiction with the limited city resources ecological environment and nervous energy also will be more and more serious. In the current situation, the development of traffic system is no longer adapted to only improve the road network performance, ease the traffic pressure. Then we should focus on promoting the sustained and harmonious development, paying attention to the rationality of road planning, the sanity of traffic management and control. so as to facilitate traffic, for facilitating the traffic environment social and economic development greatly together.

The key of city traffic sustainable development is to make economic development, ecological environment and quality of life have the relative balance. Through the research and implement of the planning program, the city traffic sustainable development planning promote the balanced development between city economy, social environment and city traffic, achieving the traffic economic sustainability, social sustainability and environmental sustainability. There are not too many methods or models Specifically for the sustainable development of city traffic system. The main research methods at home and abroad so far are following: The weighted average method, AHP analysis method, principal component analysis, fuzzy evaluation and data envelopment analysis (DEA) method. The first four methods are not good at Dynamic evaluation, timing evaluation, binding test, and their subjective is strong. Moreover what they only make evaluation but analyzing or adjusting is not conducive to decision makers to make improvement in following work. But DEA Method can not only evaluate The relative effectiveness of the same type of every decision, but also further analysis the reasons of non valid DEA unit and the direction of future improvement of each decision, Providing important information for decision makers. Next in importance, it needn't any weight hypothesis, but getting optimal weights by actual data of input and output, Excluding many subjective factors, which has the very strong objectivity. In addition, as the DEA Method doesn't integrate data directly, we need not non-dimensional data before using the DEA Method to establish mathematical model. So I use the DEA to research sustainable development of Chengdu traffic system.

2 The basic idea and model of the DEA method

2.1 Sketch

DEA Method is short for Data Envelopment Analysis. using DEA can Investigate Scale validity and technological efficiency of city development along the production frontier. In the determination of the relative effectiveness of unit, we optimize every unit, making relative efficiency biggest and weight best. And for the non effective unit, we point out the direction of adjustment index, as well as give the amount of adjustment.

2.2 DEA model

C^2R model among DEA in this thesis:

$$\begin{cases} \min\left[\theta - \varepsilon\left(\sum_{r=1}^{t} S_r^+ + \sum_{i=1}^{m} S_i^-\right)\right], \\ \sum_{j=1}^{n} \lambda_j x_{ij} + S_i^- - \theta x_{ij_0} = 0, \\ \sum_{j=1}^{n} \lambda_j y_{rj} - S_r^+ = y_{rj_0}, \\ \lambda_j \geq 0, \quad j = 1,2,\ldots, \quad n \\ S_i^- \geq 0, \quad S_r^+ \geq 0. \end{cases} \tag{1}$$

In the formula, n is decision making units (DMU), here NMU j means a particular year, x_{ij} represent input of type i from DMU j, y_{rj} represent output of type r from DMU j. ε is Non Archimedes infinitesimal that is generally equal to 10^{-6}; λj is weight variable; S^-_i is a slack variable, S^+_r is the remnant variable. λ_j. S_i^-,S_r^+ and θ are estimating parameters.

1) Usually, when $\theta^*=1$ and $Si^{-*}=Sr^{+*}=0$, DEA of DMU is called effective, the effective frontier formed from it is constant returns to scale, and DMU is scale and technical efficiency..

2) If $\theta^*<1$ or $Si^{-*}\neq0$, $Sr^{+*}\neq0$, DMU is considered DEA invalid, or technique inefficiency, or scale inefficiency, if $Sr^+=Si^-=0$, DMU is considered technique efficiency; Make $K=\frac{1}{\theta}\bullet\sum_{j=1}^{n}\lambda_j^*$, when K=1, DMU is called scale efficiency, and when K>1, it is the increasing return to scale, otherwise it decreases progressively.

3) If DMU is inefficiency, we may improve non-DEA efficiency decision-making unit on relative efficiency plane through DMU, in the context without decreasing the input, the primary input to some extent decreases or in the context without increasing the input, the output to some extent increases ($y0\geq0$),

$$\text{i.e.}\quad \begin{cases} x_0=(1-\theta^*)x_0+S^{-*}\geq0 \\ y_0=S^{+*}\geq0 \end{cases}.$$

4) In DEA dynamic evaluation in consideration of time, make i>0, if $\theta^0(t-i)<\theta^0(t)$, the system remains sustainable development track, at this time, the efficiency of input-output is somewhat improved over time; If $\theta^0(t-i)=\theta^0(t)$, the development track of system is inferior to sustainable development track.

In practical application, each input and output value have definite dimension, it can be proved that the optimal efficiency index of decision-making unit is independent of the selection of dimension of input and output value. The selected DMU should have several features: Same task object, same environment and same input as well as output. Note that the input indicator is not "the smaller, the better", and the output indicator is not "the larger, the better".

3 Data Analysis

3.1 indicators select

We classify the urban traffic large scale system as three sub-systems: the transportation self-development sub-system, energy environment development sub-system, and social and economic development sub-system. In which in the first two sub-systems key indicators are selected as the input, while in the social and economic development sub-system those are selected as the output.

The input indicator in transportation self-development sub-system is: Commercial car ownership, the length of road in urban areas; the input indicator in energy environment development sub-system is: funds for transportation maintenance construction; and the input indicator in social and economic development sub-system is: the number of employees in year-end transportation, the gross value of production of the tertiary industry. Specific input-output data is shown in Table 1.

Data of table 1 comes from "Sichuan Provincial Bureau of Statistics", "Sichuan Province Statistical Yearbook" and "Chengdu City Statistical Yearbook" in 2008~2013.

Table 1.Output and input of Chengdu traffic system in 2008~2013

index \ year	2008	2009	2010	2011	2012	2013
The number of Business vehicles（vehicle）	114010	120605	134989	142121	134464	140819
The urban road length（kilometer）	2418	2645	2610	2704	2797	2706.6
The construction and maintenance funds of urban transportation（ten million yuan）	21.373	16.690	59.195	42.053	35.317	40.764
Number of employed in transportation（million）	1.66	1.93	2.10	2.28	2.44	2.54
The third industry GDP（hundred million yuan）	1814.2	2233.0	2868.4	3383.4	4000.3	4574.2

3.2 Model Solute and analysis

Bring the data of table 1 in C^2R model, I can get the following results in table 2 and table 3 by Matlab 7.0.

Table 2. The results of the model solution

DMU	θ	λ_1	λ_2	λ_3	λ_4	λ_5
2008	0.8702	0.1455	0.1061	0	0	0.5344
2009	1	0	0	0	0	1
2010	0.8621	0.7666	0.0627	0	0	1.0269
2011	0.8985	0.8976	0	0	0	0.3265
2012	1	0	1	0	0	0
2013	1	1	0	0	0	0
DMU	λ_6	S_1	S_2	S_3	S_4	S_5
2008	0	0	0	0	0	469.3442
2009	0	0	0	0	0	0
2010	0	0	0	17.5705	0	888.7313
2011	0	889.1045	0	1.1934	0	722.5748

2012	0	0	0	0	0	0
2013	0	0	0	0	0	0

Table 3.Evaluation results of Chengdu traffic sustainable development ability

year	$\sum \lambda_j$	$K = \frac{1}{\theta} \bullet \sum_{j=1}^{n} \lambda_j^*$	θ	The relative effectiveness
2008	0.786	<1	0.8702	×
2009	1	=1	1	√
2010	1.8562	>1	0.8621	×
2011	1.2241	>1	0.8985	×
2012	1	=1	1	√
2013	1	=1	1	√
year	The Scale validity	The technical efficiency	The sustainable development track	
2008	Decrease	×		
2009	Appropriate	√	On the track	
2010	Increase	×	Inferior to the track	
2011	Increase	×	Inferior to the track	
2012	Appropriate	√	On the track	
2013	Appropriate	√	Weakly Inferior to the track	

From table 3, we can analysis Chengdu traffic development in recent 6 years: the evaluation results of year 2009、2012、2013 are DEA effective, meaning that input and output reached the optimal state. Both scale and technology are effective. Meanwhile reflects Chengdu traffic development have been fully aware of the coordinated development of the whole traffic system, try to improve the efficiency of input and output.

In table 3, non DEA efficient units are all technical inefficiency, illustrate that combination of resources between the various transportation subsystem is not the best, input or output surplus deficit, scales in year 2010~2011 this two are increasing, which is not reasonable. Comprehensive technical invalid I can get that the increasing scale depends on large investment in resource, but the dependence of technology and the efficiency of input and output is not high.

Then we improve and adjust the non DEA efficient units, figure out savings amount of input in table 4, for reference.

Table 4. non DEA efficient units improve and adjust

year	θ	The number of Business vehicles （vehicle）	The urban road length （kilometer）	The construction and maintenance funds （ten million yuan）
2008	0.8702	14798.50	313.86	2.77
2010	0.8621	18614.98	359.92	25.73
2011	0.8985	15314.39	274.46	5.46

Through the improvement and adjustment of non DEA efficient units, we may safely draw the conclusion that increasing scale maybe rely on substantial investment of resources, especially the traffic construction and maintenance funding in 2010.

3.3 Countermeasures and suggestions for the sustainable development of Chengdu traffic system

In the transport sector, the target of sustainable development construction is the basic condition to establish and promote the sustainable development of human settlements. The methods mainly are: the land use in combination with transportation planning; establish traffic less demand mode; the development of public transport; improving the traffic management; to encourage non motorized modes of transport etc..

By establishing and solving the DEA model, I conduct a comprehensive evaluation of the analysis of the sustainable development of Chengdu City traffic system nearly 6 years, face the future sustainable development of Chengdu City traffic system goal, put forward the following suggestions:

1) Development is the premise and basis of the system collaborative development, so the Chengdu economic development is the key and dependence of the city transportation development. At present and in the future several years, vigorously develop the Chengdu City Economic and reasonable industrial layout is very important to promote and adjust the Chengdu City transportation
2) Development mode of city traffic system in order to change the high input, high consumption, high yield. Improve the technology innovation ability of industry and enterprise in city traffic system, increase their added value; further integrate the transport resources, human resources, capital investment, energy and environmental resources, optimize the control, reasonably adjust investment and development mode, vigorously improve the scale effect and technical efficiency.
3) Give full play to talent resource advantage and research strengths of Chengdu City traffic , develop and utilize clean energy in Chengdu traffic system, reasonably control speed and scale of city traffic development, coordinate traffic environment, and gradually improve the effectiveness of collaborative development of traffic system.

References

Qin Shoukang. (2003). “Theory and Application of Synthetic Evaluation.” *Publishing House of Electronics Industry in Beijing*, 77.

Wang wei, Chen Xuewu, Lu Jian. (1996). “City traffic system of sustainable development theory system research .” *Science Press in Beijing.*

Zheng Zhaoning. (2001). “System Analysis of Sustainable Development in County Area.” *Master's Paper of Beijing University of Technology*, 77-78.

Building and Simulation of a Modified Cell Transmission Model for an Urban Expressway

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Abstract: For supporting analyses of traffic evolutions and traffic situation assessment, a Modified Cell Transmission Model (MCTM) for urban expressways is presented. The calibrated Van Aerde single regime model is used to replace the supposed triangle or trapezoid structural fundamental diagram, which makes the MCTM more adapting to describing expressway traffic flow characteristics. For different link connection types on expressways, rectilinear, merging, diverging and weaving transmissions of traffic flow are formulated using the proposed MCTM model. Using the designed experimental expressway section, three scenarios are simulated using CTM, MCTM, and INTEGRATION respectively, including normal traffic simulation without any incident, traffic simulation with accident, and traffic simulation with accident and managements. Results show that MCTM model can directly show the traffic flow condition and evolution process on expressways.
Keywords: Urban traffic; Modified cell transmission model; Urban expressway; Van Aerde single regime model.

1 Introduction

At present, traffic congestion is inevitable. Recurrent congestions have statistically significant features, and the congestion duration and breadth can be estimated and predicted. Relatively, because the occurrence time and space of traffic incident is random, the influence of non-recurrent congestions cannot be replicated. Therefore, once the traffic event happen, how to estimate the change of traffic status and how to predict the probable duration and breadth is the important basis of implementing traffic management and traffic information service.

Cell Transmission Model (CTM) is one typical method of describing the mechanical properties of a continuous traffic flow, which reveals the macroscopic traffic characteristics of segments, roads, and network under non-congested and congested conditions, including shock waves, queuing, interplay between traffic flows on different links, etc. (Daganzo, 1994; Daganzo, 1995) Due to considering temporal and spatial transfer characteristics of traffic flow, CTM is often used in estimations of urban traffic flow parameters (Hu, 2010), analyses of traffic flow transmission and state evolution rules (Gao, 2011), impact analyses of traffic events

(Jiyang, 2008; Chen, 2009), project designs of traffic control and information service (Shang, 2008; Zeng, 2006), and other aspects. In addition, specialized studies on parameter calibrations and adaptations of traffic models were carried out (Daganzo, 1997; Chen, 2010; Wang, 2010).

On the basis of the existing research methods and results, this paper constructs a modified cells transmission model (MTCM) for urban expressway to estimate state and assess traffic situation, through analyzing physical structures, traffic flow characteristics, and traffic data collections on domestic urban expressways.

2 Methodology

2.1 Fundamental of cell transmission model

The continuous traffic flow on section without on- and off-ramps meets the following conservation relations (Lighthill, 1955; Richards, 1956):

$$\frac{\partial q}{\partial x}+\frac{\partial \rho}{\partial t}=0 \tag{1}$$

where q represents traffic volume; ρ represents traffic density; x and t are respectively spatial and time variables. CTM processes the space and time in the discrete way, and supposes the link be a set of cells with a certain length. So the moving process of traffic flow on links is shown as the following Figure 1.

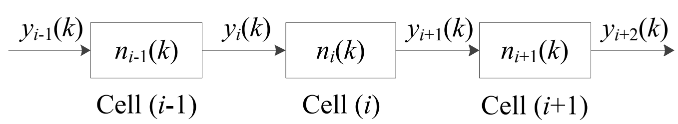


Figure 1. Transmission of traffic flow between cells in CTM

Based on the conservation equations of fluid mechanics, the moving process of vehicles satisfies:

$$n_i\left(k+1\right)=n_i\left(k\right)+y_i\left(k\right)-y_{i+1}\left(k\right) \tag{2}$$

where $n_i\left(k\right)$ is the vehicle number on the ith cell at the kth time interval; $y_i\left(k\right)$ is the vehicle number from the $\left(i-1\right)th$ cell to the ith cell at the kth time interval.

The cell length in CTM is equal to the distance of vehicles running with the free flow speed during one time interval. Therefore, the transmission volume between cells depends on both the existing vehicle number on the upstream cell and the vehicle number that can be accommodated in the remaining space of the downstream cell. Considering the back-transfer characteristics of the crowded traffic wave, $y_i(k)$ can be expressed:

$$y_i(k) = \min\left\{n_{i-1}(k), Q_i, \delta \cdot \left(N_i - n_i(k)\right)\right\} \tag{3}$$

where Q_i is the maximum number of vehicles that can run into the ith cell at one unit interval, and it can be expressed as $Q_i = q_{max,i} \times \varepsilon$; N_i is the maximum capacity of the ith cell, and it can be expressed as $N_i = \rho_{j,i} \times l_i$.

The maximum number of vehicles running out from the upstream cell is defined as the sending capacity, i.e. $S_i(k)$; and the maximum number of vehicles that can be accepted by the downstream cell is defined as the receiving capacity, i.e. $R_i(k)$.

$$\begin{cases} S_i(k) = \min\left\{n_i(k), Q_i\right\} \\ R_i(k) = \min\left\{Q_i, \delta\left(N_i - n_i(k)\right)\right\} \end{cases} \tag{4}$$

Thus, the Equation (3) can be transformed into Equation (5) as follows.

$$y_i(k) = \min\left\{S_{i-1}(k), R_i(k)\right\} \tag{5}$$

2.2 Modified cell transmission model for urban expressway

The traditional CTM assumes the flow-density relationship meet the simple trapezoidal structure, which do not match the actual traffic characteristics on expressways. Based on the detected data of traffic flow on Beijing expressways, the curve fitting result shows that the Van Aerde single-regime model can express the relationships of traffic flow-density (Zhao, 2009). Therefore, the Van Aerde model is introduced in this study to modify the traditional cell transmission model, so as to improve the accuracy of the model for describing traffic flow states on expressways.

According to Equation (4), for any unimodal flow-density relationship (as shown in Figure 2), the sending rate (s_i) and receiving rate (r_i) at each unit interval can be expressed as Equations (6) and (7). ρ_c is the traffic density corresponding to the capacity.

$$\begin{cases} s_i = q_i \\ r_i = q_{\max} \end{cases}, \text{ if } 0 \le \rho_i \le \rho_c \tag{6}$$

$$\begin{cases} s_i = q_{max} \\ r_i = q_i \end{cases}, \text{ if } \rho_c < \rho_i \le \rho_j \tag{7}$$

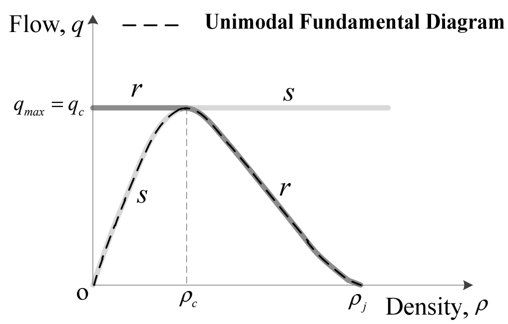


Figure 2. Receiving and sending rates based on unimodal fundamental diagram

Then the follow equation can be derived:

$$\begin{cases} s_i = q_{max} \\ r_i = q_i \end{cases}, \text{ if } \rho_c < \rho_i \le \rho_j \tag{8}$$

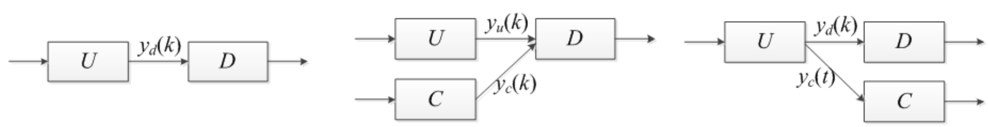
In the Van Aerde single-regime model, the relationship of density-speed is as Equation (9) (Rakha, 2009).

$$\rho = \frac{1}{c_1 + \frac{c_2}{v_f - v} + c_3 v} \tag{9}$$

where ρ and v are traffic density and speed respectively; c_1, c_2, c_3 are three intermediate variables, which can be derived by calibrating four characteristic parameters, i.e. free flow speed v_f, capacity q_c, jam density ρ_j, and speed-at-capacity v_c. Based on the speed-density-flow relationship of $q = \rho v$, the flow-density relationship can be gotten to be used in MCTM .

2.3 Transmission principles of traffic flow on different sections of expressway

According to whether connecting the ramp, expressways can be divided into three type segments, including basic segment, merging segment, and demerging segment, as shown in Figure 3. *U* and *D* respectively represents the upstream and downstream cell on the main road, *C* is the cell on the on-ramp or off-ramp. $y_u(k)$ is the vehicle volume running out from *U*, $y_d(k)$ is the vehicle volume running into *D*, $y_c(k)$ is the traffic volume running out from on-ramp or off-ramp.



(a) Basic segment (b) Merging segment (c) Demerging segment

Figure 3. Three types of segments on expressways

On the basic segment, there is the equation of $y_d(k) = y_u(k)$. The transmission traffic volume depends on the sending capacity of the upstream cell and the receiving capacity of the downstream cell, which can be expressed as follows:

$$y_d(k) = \begin{cases} S_u(k), & if\ S_u(k) \le R_d(k) \\ R_d(k), & if\ S_u(k) < R_d(k) \end{cases} \quad (10)$$

On the merging segment, $y_u(k)$, $y_d(k)$, and $y_c(k)$ satisfied Equation (11).

$$\begin{cases} y_u(k) \le S_u(k) \\ y_c(k) \le S_c(k) \\ y_d(k) = y_u(k) + y_c(k) \le R_d(k) \end{cases} \tag{11}$$

If $R_d(k) \ge S_u(k) + S_c(k)$, then,

$$\begin{cases} y_u(k) = S_u(k) \\ y_c(k) = S_c(k) \\ y_d(k) = y_u(k) + y_c(k) \end{cases} \tag{12}$$

And if $R_d(k) \ge S_u(k) + S_c(k)$, then,

$$\begin{cases} y_u(k) = \text{mid}\{S_u(k), R_d(k) - S_c(k), R_d(k) \cdot p_u(k)\} \\ y_c(k) = \text{mid}\{S_c(k), R_d(k) - S_u(k), R_d(k) \cdot p_c(k)\} \\ y_d(k) = y_u(k) + y_c(k) = R_d(k) \end{cases} \tag{13}$$

where $p_u(k)$ is the flow rate of running straight on main road, and $p_c(k)$ is the flow rate of running through the on-ramp.

On the demerging segment, the flow rate of running straight is $\beta_d(k)$, the flow rate of running through the off-ramps is $\beta_c(k)$, and $\beta_d(k) + \beta_c(k) = 1$. Thus,

$$\begin{cases} y_d(k) = y_u(k) \cdot \beta_d(k) \\ y_c(k) = y_u(k) \cdot \beta_c(k) \end{cases} \tag{14}$$

Due to the relations of $y_u(k) \le S_u(k)$, $y_d(k) \le R_d(k)$, and $y_c(k) \le R_c(k)$, the $y_u(k)$ can be expressed as Equation (15).

$$y_u(k) = \min\{S_u(k), R_d(k)/\beta_d(k), R_c(k)/\beta_c(k)\} \tag{15}$$

3 Case Study

An experimental section is chosen to carry out traffic simulations on the expressway. The length of the section is 3.6 km, which contains twelve main links, one on-ramp, and one off-ramp, as shown in Figure 4. Each link is one cell. Thus the characteristic parameters of the fourteen cells are calibrated, as shown in Table 1.

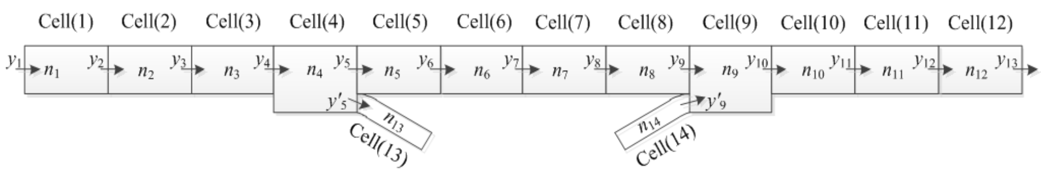


Figure 4. Cell structure design for the experimental expressway

Table 1. Values of traffic flow characteristic parameters for each cell

Cell ID	Num. of Lanes	Length (m)	v_f / (km • h^{-1})	q_c / (veh • h^{-1} • lane^{-1})	v_c / (km • h^{-1})	ρ_j / (veh • km^{-1} • lane^{-1})	N_i / (veh)	Q_i / (veh)
1	3	300	65	1887	45	151	136	16
2	3	300	65	1786	44	151	136	15
3	3	300	65	1778	44	151	136	15
4	4	300	67	1569	42	138	166	15
5	3	300	65	1887	45	151	136	16
6	3	300	65	1887	45	151	136	16
7	3	300	65	1887	45	151	136	16
8	3	300	65	1887	45	151	136	16
9	4	300	67	1569	42	138	166	16
10	3	300	65	1778	44	151	136	15
11	3	300	65	1786	44	151	136	15
12	3	300	65	1887	45	151	136	15
13	1	150	50	900	30	120	18	3
14	1	150	50	900	30	120	18	3

Three scenarios are simulated respectively using the models of CTM, MCTM, and INTEGRATION. INTEGRATION model was developed on the basis of the Van Aerde single-regime model, and it also fuses the microcosmic driving behavior model and the macroscopic traffic stream model to describe the vehicle running status better. On this context, INTEGRATION model is as the platform to derive the data under different traffic states, which are used as the comparative basis.

The three scenarios are expressed as follows: (1) No accident happens on the expressway section. The entrance volume on the main road is 4000 veh/h, and both the volume through the on-ramp and the off-ramp is 500 veh/h. (2) An accident happens on the outside lane of the 10th cell, which continues 15 min. The capacity of this link is 1725 veh/h/lane, the free flow speed is 64 km/h, the speed-at-capacity is 55 km/h, and the jam density is 150 veh/km/lane. (3) The upstream on-ramp (i.e. the 14th cell) is closed in 2 min after the accident. The information notice is also carried out to guide more vehicles leaving the main road. The volume through the off-ramp increases by 70%, i.e. 850 veh/h.

Density contours are drawn using the output data from CTM, MCTM, and INTEGRATION, as shown in Figure 5. Based on the simulation results of INTEGRATION, Mean Absolute Deviation (MAD) and Mean Absolute Relative Error (MARE) are calculated to compare the results of CMT and MCTM. The results of MADs and MAREs are shown in Figure 6.

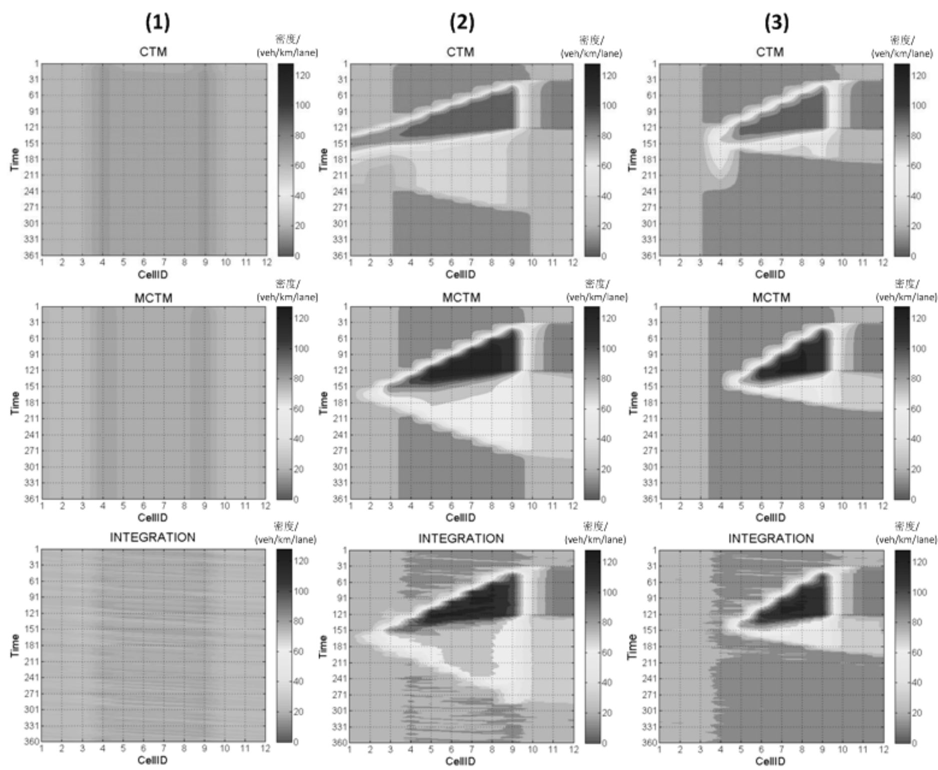


Figure 5. Comparisons of simulated density results

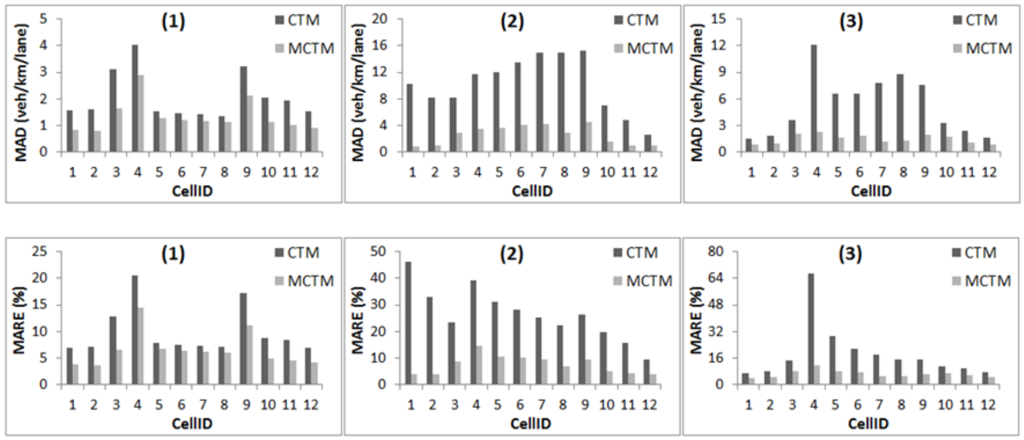


Figure 6. MADs and MAREs of traffic density estimations (CTM vs. MCTM)

For three scenarios, the density results estimated by MCTM are closer to the results of INTEGRATION. The MADs are less than 5 veh/km/lane, and the MARE values are within 10% except that of the 4th cell.

4 Conclusions and Recommendations

Carrying out studies on traffic flow states and evolution rules are fundamental basis of traffic situation assessment, traffic organization and management. This paper grasped the advantages of CTM in describing the shock wave, queuing, and influence of traffic flow, and then built the MCTM which focusing on calibrating the traffic parameters of urban expressways using the Van Aerde single-regime model. Comparing with CTM, MCTM can better describe the complex traffic moving and transmission process on expressways. And comparing with the traditional traffic simulation model, MCTM does not need to build the complex network platform. The structure of MCTM is simple and it can be solving fast.

In addition, considering the deviation and insufficiency of MCTM in estimating traffic flow parameters, it is recommended that further studies be conducted on calibrations of parameters on different cells. It is also recommended that the Noise variables be introduced into MCTM to improve the accuracy of the model.

References

Chen, Q. and Li, W. (2009). "Influence rang of emergency under special events based on CTM." *Journal of Southeast University (English Edition)*, 25(2), 257-261.

Chen, X., Shi, Q., and Li, L. (2010). "Location specific cell transmission model for freeway traffic." *Tsinghua Science and Technology*, 15(4), 475-480.

Daganzo, C. F. (1994). “The cell transmission model: A dynamic representation of highway traffic consistent with the hydrodynamic theory.” *Transportation Research Part B,* 28(4), 269-287.

Daganzo, C. F. (1995). “The cell transmission model, part Ⅱ: Network traffic.” *Transportation Research Part B*, 29(2), 79-93.

Daganzo, C. F. (1997). “The lagged cell-transmission model.” *The 14th International Symposium on Transportation and Traffic Theory*, Jerusalem, Israel, 81-104.

Gao. Z. Y., Long, J. C., and Li, X. G. (2011). “Congestion propagation law and dissipation control strategies for urban traffic.” J*. University of Shanghai for Science and Technology*, 33(6), 701-708.

Hu, X. J., Wang, W., and Sheng, H. (2010). “Urban traffic flow prediction with variable cell transmission model.” *Journal of Transportation Systems Engineering and In-formation Technology*, 10(4), 73-78.

Lighthill, M. J. and Whitham, J. B. (1955). “On Kinematic Waves, I: Flow Movement in Long Rivers. II.: A Theory of Traffic Flow on Long Crowded Road.” *Proceedings of the Royal Society*, London, Series A, (229), 281-345.

Jiyang, B. B. (2008). “Research on prediction method of traffic incident duration.” *A dissertation submitted to Tongji University*, Shanghai.

Rakha, H. (2009). “Validation of Van Aerde’s Simplified Steady-state Car-following and Traffic Stream Model.” *Transportation Letters: The International Journal of Transportation Research*, 1(3): 227-244.

Richards, P. I. (1956). “Shockwaves on the Highway.” *Operations Research*, (4), 42-51.

Shang, H. Y., Huang, H. J., and Gao, Z. Y. (2008). “Design real-time traffic information by cell transmission model.” *Journal of Beijing University of Aeronautics and Astronautics*, 34(2), 234-238.

Wang, P. (2010). “Conditional cell transmission model for two-way arterials in oversaturated conditions.” *Tuscaloosa: Department of Civil, Environmental, and Construction Engineering*, The University of Alabama.

Zeng, J. Q., Wang, J. J., Tang, L., et al. (2006). “CTM-RH based line control for urban traffic lights.” *Journal of University of Science and Technology of China*, 36(11), 1232-1236.

Zhao, N. L., Yu, L., Zhao, H., et al. (2009). “Analysis of Traffic Flow Characteristics on Ring-Road Expressways in Beijing Using FCD and RTMS Data.” *Transportation Research Record: Journal of the Transportation Research Board, No. 2124*, 178-185.

Relationship between Traffic Accidents and the Road Traffic Operation Index—A Case Study of Beijing

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Abstract: Road Traffic Operation Index can comprehensively reflect the traffic state of the urban road network. In order to research the temporal distribution and the incidence relation, various traffic accident and traffic index is selected as the research object. This paper select the traffic accident data (occurrence location, occurrence time, accident category attribute) and traffic index data within the Beijing Fifth Ring Road from January to June 2014, as the basis to identify the monthly distribution and the daily distribution of total traffic accident, and the monthly distribution of various traffic accident. The occurrence location and the occurrence time of traffic accident is used for determining the traffic index value when the accident occurred. Regression analysis and SPSS is used and the results of each method is evaluated by R^2 values and F values. The results show that there is a positive correlation between total traffic accident, vehicle collision, other accident and traffic index. Vehicle breakdown and traffic index does not exist a positive correlation.
Keywords: Traffic accident; Road traffic operation index.

1 Introduction

In recent years, the contradiction between demand and supply of urban transport is increasingly prominent (the motor vehicle population of Beijing at the end of 2013 is 5.437 million). The congested urban traffic operating state, the seriously mixed traffic flow and the chaotic traffic order made the probability of occurrence of road traffic accident increased. On the other hand, traffic accident would destroy the fragile traffic operating state, increase the degree and the duration of congestion. There are some differences in the effect of various traffic accident on the traffic operating status.

Based on the traffic accident data of Xi'an and Jiangsu Province, Professor Chen Kuanmin, Bai Shuan studied the spatial and temporal distribution of traffic accident. Beijing Transportation Research Center studied and established the urban road traffic operating evaluation techniques and application systems. And road traffic operation index (traffic index) is applied to the Beijing road network operational monitoring. Traffic index can make the road operating state indexing and digital. It can comprehensively reflect the traffic situation of road network, and provide the data basis for the relationship study between traffic accident and traffic index.

This paper select the traffic accident data and traffic index data within the Beijing Fifth Ring Road from January to June 2014, as the basis to study the temporal distribution of total traffic accident and various traffic accident. Using the occurrence location and the occurrence time of traffic accident to determine the traffic index value when the accident occurred. And the regression analysis is used to study the relationship between total traffic accident, and various traffic accident and traffic index.

2 Study Object

2.1Traffic accident

Traffic accident is defined as the personal injury or property loss due to the fault or accident on the road in *People's Republic of China Road Traffic Safety Law*. According to the classification rule of traffic accident in *Data Format for Radio Data System-Traffic Message Channel Part 1: Event and Information Codes*, traffic accident is divided into vehicle breakdown, vehicle collision and other accident.

This paper select 2536 traffic accident information from January to June 2014 as the accident data basis. It include 362 vehicle breakdowns, 947vehicle collisions and 1227 other accident.

2.2 Traffic Index

This paper select the traffic index monitoring data of Beijing Transportation Research Center as the data basis. The update frequency of monitoring data is 15 minutes and the number of traffic index is 17376 from January to June 2014.

Traffic index can comprehensively and simply described space, time, intensity and other characteristics of traffic congestion. Using traffic index, travelers can understand the road network traffic congestion in real time. The range of traffic index is shown in Figure 1. It is 0 to 10, and is divided into 5 grades. 0～2, 2～4, 4～6, 6～8, 8～10 is respectively corresponded to smooth, mainly smooth, mild congestion, medium congestion, severe congestion. The higher values indicate more serious traffic congestion.

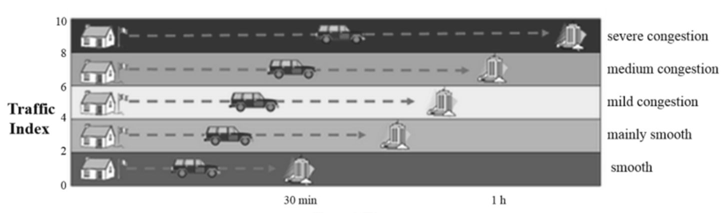


Figure 1. Relationship between traffic index and travel time

3 Temporal Distribution of Traffic Accident

According to the occurrence month and the occurrence hour of traffic accident, the frequency distribution of traffic accident is analyzed. Based on it, the temporal distribution of traffic accident is studied.

3.1 Monthly Distribution

The monthly distribution of total traffic accident and traffic index from January to June 2014 is shown in Figure 2.

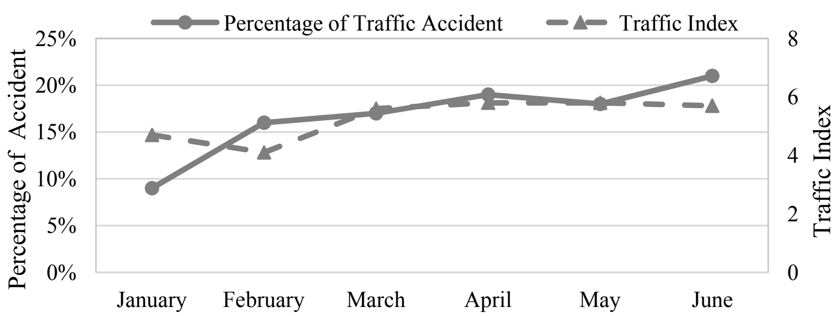


Figure 2. Monthly distribution of total traffic accident and traffic index

Figure 2 shows that the number of accident trend to increase with the increasing of traffic index. Traffic index of January is lower than the average level because of student holidays and a large number of passenger leaving Beijing. In terms of the number of accident, January also is lower than other months. Compared to January and February, traffic index of March, April, May and June have a substantial increase. And the number of accident also show a same increasing trend. But we need to concern about February. Traffic index of February is 4.1 that is the lowest point because of Chinese New Year. However, the number of accident of February is higher than January. It show an opposite trend with other months.

The total number and the monthly number of vehicle breakdown, vehicle collision and other accident is counted. The monthly distribution of various traffic accident is shown in Figure 3.

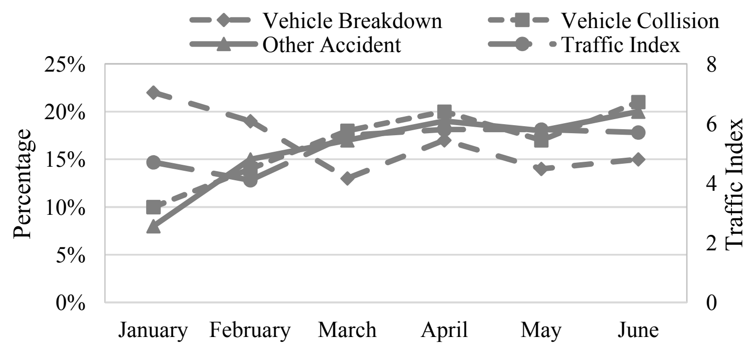


Figure 3. Monthly distribution of total traffic accident and traffic index

The trend of vehicle collision and other accident is same as the trend of total traffic accident. It has a large difference with vehicle breakdown. The number of vehicle breakdown in January and February is higher than other months, because that the low temperature of winter is easy to cause vehicle breakdown. In the monthly distribution of vehicle collision and other accident, the number of accident trend to increase with the increasing of traffic index, and the number of accident in Chinese New Year is relatively high.

3.2 Daily Distribution

We select 30 minutes as the interval to account the number of total traffic accident. Based on it, the percentage of each interval is determined. And the interval of accounting traffic index also is 30 minutes. Traffic index of this period is the mean of two update frequency. The daily distribution of total traffic accident and traffic index is shown in Figure 4.

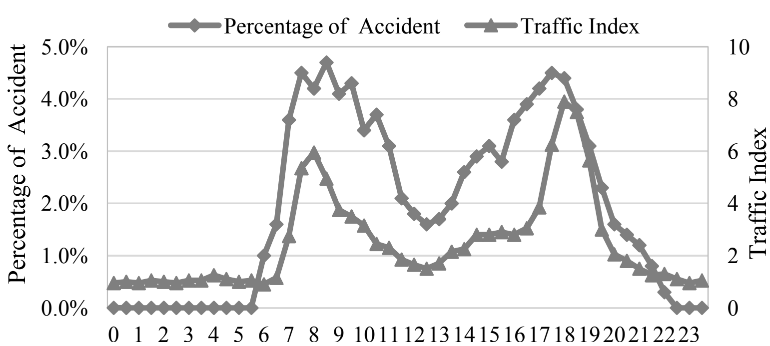


Figure 4. Daily distribution of total traffic accident and traffic index

Like the daily distribution of traffic index, the daily distribution of accident also has morning peak and evening peak. But the morning peak periods of accident is 8：00 to 10：00, and the evening peak periods is 16：00 to 18：30. It has some difference with the daily distribution of accident. In this periods, traffic operating state is congested and traffic system is relatively unstable. Traffic accident is easy to happen.

4 Correlation Analysis of Traffic Accident and Traffic Index

Traffic accident is the result of multiple factors, such as people, vehicle and environment. Simultaneously, the results of monthly distribution and daily distribution indicate that traffic accident and traffic index has a close relationship.

Cluster analysis and regression analysis is used for analyzing traffic index data and accident data, and establishing the relational model of accident and traffic index.

The occurrence location and the occurrence time of traffic accident is used for determining the traffic index value when the accident occurred. The input value is the daily number of accident and the average of index value when the accident occurred.

4.1 Analysis Result

This paper select 173 groups of data as basis. Linear, logarithmic, quadratic and cubic function is used for regression analysis, and the “level of significance” value is 0.95. The fitting curve of regression analysis is shown in Figure 5 to 8. The result of regression analysis is shown in Table 1 to 2. The analysis results is evaluated by R^2 values, and R^2 values can explain the proportion or percentage of the total variation in Y via the regression model. And the analysis result of various traffic accident only use the result of the best method.

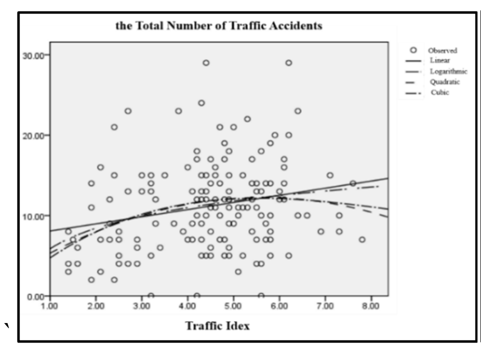


Figure 5. Total accident fitting curve

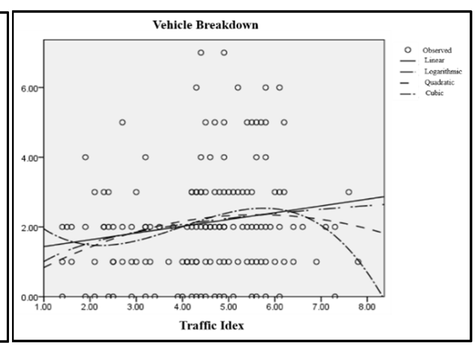
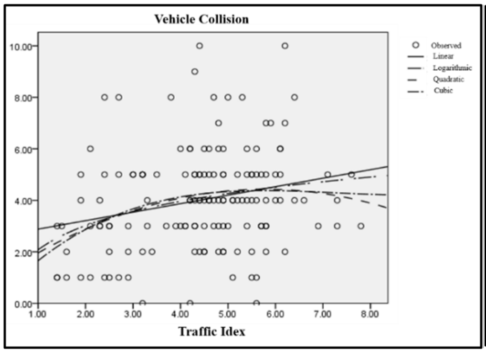


Figure 6. Vehicle breakdown fitting curve



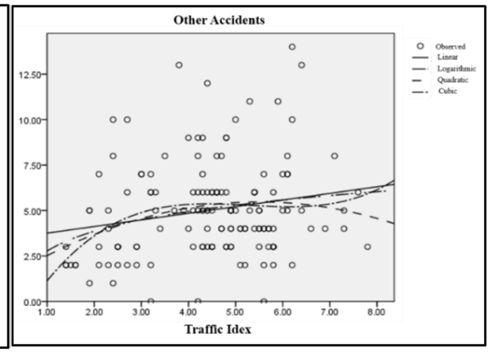


Figure 7. Vehicle collision fitting curve **Figure 8. Other accident fitting curve**

Table 1. Analysis result of total traffic accident

Function	R Square	F	F'	df2	df1	Sig.
Linear	0.103	18.635	3.9	171	1	.002
Logarithmic	0.114	21.983	3.9	171	1	.001
Quadratic	0.122	11.801	3	170	2	.003
Cubic	0.121	7.745	2.6	169	3	.001

Table 2. Analysis result of various traffic accident

Property	Function	R Square	F	F'	df1	df2	Sig.
Vehicle Breakdown	Quadratic	0.029	2.539	3	2	170	.052
Vehicle Collision	Logarithmic	0.139	27.607	3.9	1	171	.001
Other Accident	Cubic	0.118	7.537	2.6	3	169	.003

Table 1 indicates that there is a positive correlation between total traffic accident and traffic index. But the value of R Square only is 0.122, so the correlation is poor and unobvious. F' is the theoretical value of F-test. And all F values are greater than F', so assuming causality of regression analysis is significant. Traffic congestion only is one of factors leading to total traffic accident, and it is not the primary cause.

In table 2, the R Square value of vehicle breakdown only is 0.029 and F value is less than F'. It means that assuming causality of regression analysis isn't significant, so vehicle breakdown and traffic index does not exist a positive correlation. On the contrary, vehicle collision, other accident and traffic index exist a positive correlation. But like total traffic accident, the correlation also is poor and unobvious. The value of R Square only is 0.139 and 0.118.

5 Conclusions

Based on the analysis result of above paper, the distribution of total traffic accident has a temporal feature. Total traffic accident and traffic index exist a positive correlation. The probability of accident is greater when traffic index is higher.

There are some differences between the correlation of various traffic accident, total traffic accident and traffic index. Vehicle breakdown and traffic index does not exist a positive correlation. The number of vehicle breakdown in January and February is higher than other months. Vehicle collision, other accident and traffic index exist a positive correlation. During peak period, traffic congestion is severe and the state of traffic flow is unstable with increasing traffic index. And the probability of accident is increasing. So this paper suggest increasing traffic enforcement and safety management efforts.

Acknowledgement

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References

Bai Shuan, Chen Xuewu (2009). "Research on Time-space Distribution and Preventive Measures of Traffic Accident." *Modern Transportation Technology*, 6(4), 78-81.

Chen Kuanmin, Wang Yuping (2003). "Distribution characteristics and countermeasures of urban traffic accidents." *Journal of Traffic and Transportation Engineering*, 1(3), 84-87.

Guo Jifu, Wen Huimin. (2005). "Data Format for Radio Data System-Traffic Message Channel Part 1: Event and Information Codes." Beijing.

Standing Committee of the National People's Congress. (2008). "People's Republic of China Road Traffic Safety Law." *China Communications Press*, Beijing.

Wen Huimin, Sun Jianping (2011). "Urban road traffic performance index." Beijing.

Zhang Xi, Wen Huimin (2012). "The Practical Application of Traffic Congestion Prediction in Beijing." *Excellent Proceedings of the Seventh China Intelligent Transport Annual Meeting*, Beijing.

How to Evaluate the Road Consistency and Driving Comfort of a Newly-Built Freeway—A Case Study of the Wu-Liu Freeway in Guangxi

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Abstract: The freeway from Wuzhou to Liuzhou is a newly built branch in freeway network planning of Guangxi Zhuang Autonomous Region in China, providing more convenient access from Guangxi to the Pearl River Delta area. This study aims at improving safety performance and risk tolerance of this newly built freeway, in which a 40km segment with complex geometric design was investigated. Driving simulation experiments were carried out based on a 3D model constructed with data of regional terrain and geometric design. 20 experienced drivers participated in the simulating experiments. Road consistency was evaluated through driver's speed choice. Data on speed indicators were collected and analyzed, including average speed, standard speed deviation, speed variation coefficient, and speed difference between driving speed and design speed. Evaluation of driving comfort was obtained from driver's heart rate, lateral acceleration and corresponding track deviation. The results show that the overall design of Wu-Liu freeway is of good quality and potential problems lie in S curve, curves with small radius, continuous curves with divergent radiuses and entrances to tunnels.

Keywords: Road consistency; Driving comfort; Speed; Safety; Driving behavior.

1 Introduction

Safety evaluation is necessary and important for improving geometric design of road network, but currently most safety evaluation is based on vehicle's speed and crash rate. Therefore, it is difficult to predict the safety level in advance of the operation of road. Driving simulator has become an ideal surrogate measure on account of its advantages in safety, efficiency, resourceful data, and excellent experimental control (Bella, 2008). Its validity for analysis on driver's behavior was confirmed in some previous studies (Godley et al, 2002, Manser, 2007).

The Wu-Liu freeway connects Wuzhou and Liuzhou, providing a shortcut from Liuzhou, which has expanded to be an industrial base, to Guangzhou, the capital city of Pearl River Delta. Its operation makes the most energetic area in southern China becomes more accessible for residents and enterprises in Guangxi Zhuang Autonomous Region, which encourages the economic development in this area. The 40km target road segment of this two-way four-lane freeway runs from pile K85 to

K125, including two long tunnels and two overpasses. In this project with design speed of 100km/h and the maximum gradient of 4%, the minimum radius is 700m for horizontal curve and 10000m for vertical curve.

2 Method

2.1 Questionnaire

The 40km target segment was divided into 20 sections, with average 2km for each section, while guaranteeing the completeness of bridges and tunnels. The questionnaire was conducted in two aspects: road consistency and driving comfort. Drivers were asked to score road consistency and driving comfort for each section and answer some subjective questions on their speed choice and expected speed limit of the freeway segment. Suggestions on the questionnaire were also made.

2.2 Road consistency evaluation

Road consistency in this paper refers to the consistency of road alignment design. Its change leads to adjustment of driving behavior. If the change of road alignment exceeds driver's expectation, operation error may occur when the driving task is performed. Usually the vehicle runs in the trajectory which the driver believes to be safe (Misaghi and Hassan, 2005). The risk would be very limited if the expected track is consistent with road geometric design. In the case that the driver drives on a track inconsistent with road alignment, the vehicle would deviate from the center of lane and risk would increase. The following indicators were chosen to evaluate road consistency. The criteria of evaluation levels were displayed in Table 1.

(1) Lateral deviation

For the target freeway segment, the lane width is 3.75m, the width of simulation vehicle is 2m and the width of marking is 0.2m. It was calculated that lateral deviation ought to not exceed 0.775m to keep good road consistency. The smoothness of driving track and intercross frequency were also considered.

(2) Lateral acceleration

The lateral acceleration also changes with road alignment. In general, the more fluctuant is lateral acceleration variance, the worse is road safety performance.

(3) Speed consistency

Driving speed is the highest speed the driver would choose according to real-time road condition and traffic environment. The speed consistency was reflected by the difference between driving speed and design speed.

(4) Speed variation coefficient Cv

Cv=Speed standard deviation/Average speed

The variation coefficient overcomes the influence of sample fluctuation in speed analysis and contributes to further study on correlation between speed fluctuation and crash rate.

(5) Section speed difference ΔV

ΔV is the absolute value of speed difference between adjacent road sections. It is an important indicator in road design evaluation.

$\Delta V=|V_{85i}-V_{85i-1}|$

Where V_{85i} is the 85% speed of the target section, V_{85i-1} is the 85% speed of road section ahead of the target section.

Table 1. Evaluation levels of road consistency indicators

Evaluation level	lateral deviation	|driving speed –design speed|	Speed variation coefficient Cv	Section speed difference ΔV
Good	$\leq$0.775m	$\leq$10km/h	$\leq$0.031	Between -10 and 11
Fair	Between 0.875m and 0.775m	Between 20km/h and 10km/h	Between 0.031 and 0.046	Between -15 and -10 or Between 11 and 16
Poor	$\geq$0.875m	$\geq$20km/h	$\geq$0.046	$\leq$-15 or $\geq$ 16

2.3 Driving comfort evaluation

(1) Heart rate change

The driving experience is pleasant only when driver's emotional and physical burden are reasonably controlled. When driver's heart rate increases over 20 beats per minute, senses of oppression, tension and panic would appear and driving safety would be negatively affected or even threatened.

(2) The transverse acceleration

When driving through a curve, the driver experiences the transverse acceleration generated from centrifugal force. Driver and passengers in the vehicle would be uncomfortable if the acceleration is too high or changes too fast.

3 Experimental Setup

3.1 Experiment equipment

The driving simulation experiment was based on a simulator system with eight degrees of freedom. SCANeR, the software applied to simulation, was developed by French Company OKTAL. The simulation vehicle was a Renauh Megane III with engine removed, data collection system installed and rear-view mirror replaced by a LCD screen. It was fixed in the center of a concealed sphere-shaped driving cabin. The projection system of five projectors was built on the roof, providing a 250º view of simulated driving environment. Data was recorded in the experimental driving process, including driving time, trip meter, speed, wheel change, lane deviation, brake force, acceleration, gear shift, etc.

Smart-Eye was used to measure driver's head pose and gaze direction. It comprised four cameras to capture gaze and head movement and another three to record driving environment.

Cardio tachometer 400sd, which was produced by Finish Company POLAR, was used to record driver's heart rate during the experiment.

3.2 Experiment design

20 experienced drivers (24-50 years old) were selected through telephone and internet interviews. Firstly, the working mechanism of the simulator system and how to prepare for the experiment were explained to them, then they were informed of specific instructions on their driving task and invited to complete basic information questionnaire, including personal information and driving experience. Before formal experiment, participants drove for 3-5min in simulator for adaption to the simulating driving environment. Their normal heart rates were recorded in the process.

4 Results

4.1 Questionnaire

The target freeway was divided into 20 sections. The score for each section scaled from 1 to 4 and 3.50 was determined as the minimum threshold value. Sections with score lower than that were investigated. It turns out that section 15 16 and 17 are located at the bottom of continuous downward slopes and in each of them at least one small-radius horizontal curve is included; section 18 consists of curves with divergent radiuses; section 19 and 20 lead to the tunnel entrance.

4.2 Road consistency and driving comfort

After analysis of data obtained from simulator system, sections with potential risk were identified. The relations between curvature and speed (and standard deviation), lateral deviation (and standard deviation), lateral acceleration (and standard deviation), driver's heart rate, the difference between driving speed and design speed were explored respectively and displayed in the figures below.

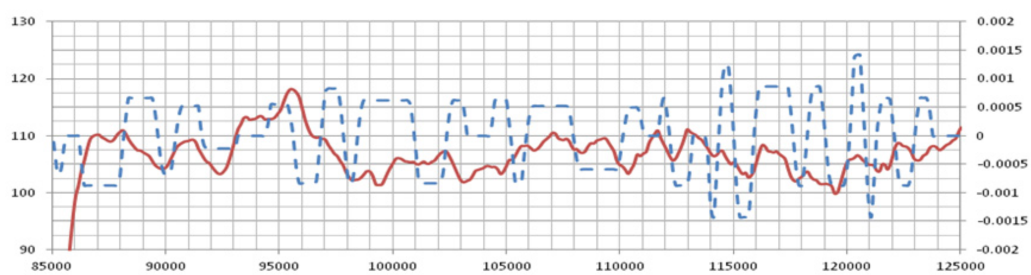

Figure 1. Speed and curvature

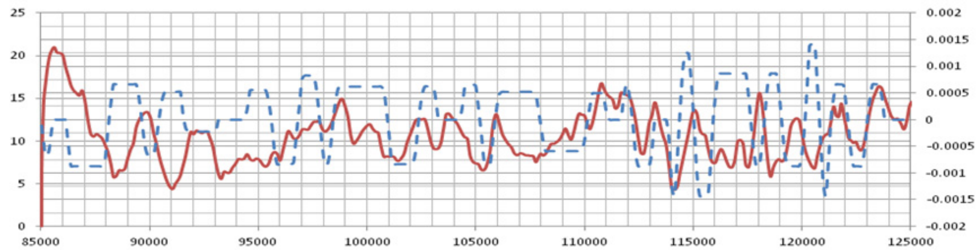

Figure 2. Speed standard deviation and curvature

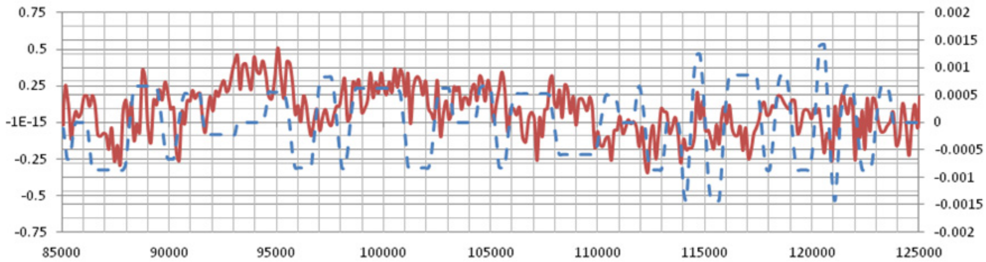

Figure 3. Lateral deviation and curvature

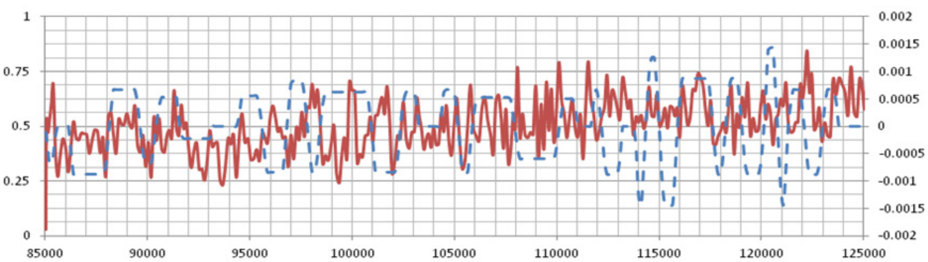

Figure 4. Lateral deviation standard deviation and curvature

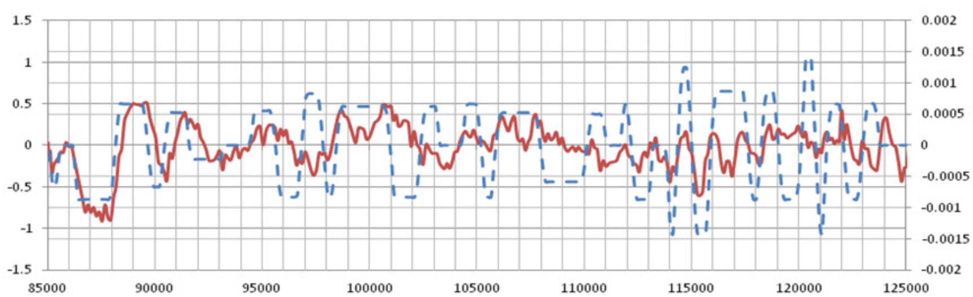

Figure 5. Lateral acceleration and curvature

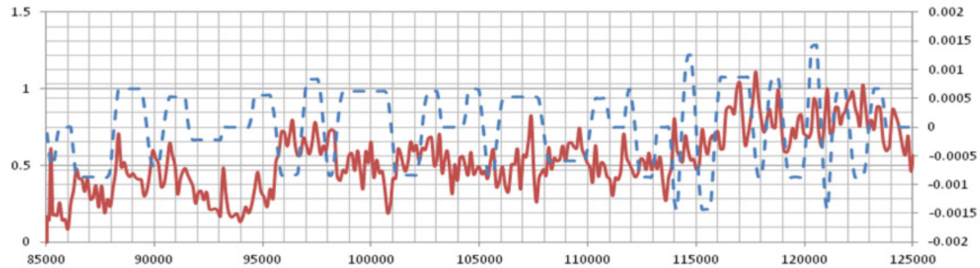

Figure 6. Lateral acceleration standard deviation and curvature

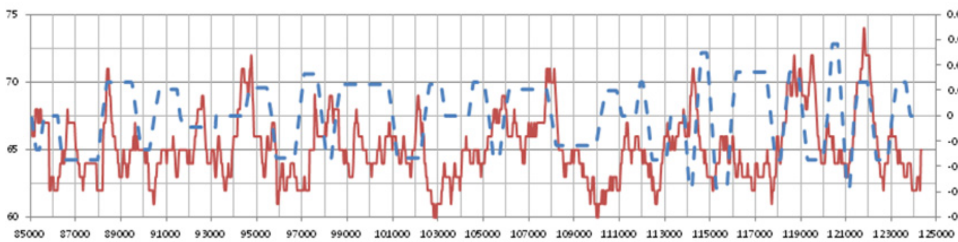

Figure 7. Heart rate and curvature

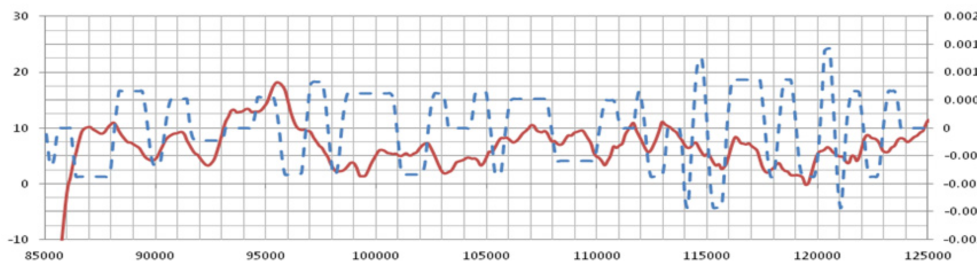

Figure 8. The difference between driving speed and design speed and curvature

It could be learned from these figures that curvature and lateral acceleration are positively correlated. High or highly fluctuant lateral acceleration implies difficulties and risks in performing driving task. In the experiment, drivers choose various speeds in the same section, but they always keep the vehicle running in the lane since lateral offset is kept below 0.775m. Significant relation between heart rate and curvature is shown in Figure 7. As illustrated in Figure 8, driving speed is greater than design speed during most time. This indicates that the overall road alignment is of good quality that the driver could drive safely at a relatively high speed, and drivers are rarely affected by other vehicles in free traffic flow.

5 Conclusions

For the target road segment of Wu-Liu freeway, the overall design is of good quality. Potential problems lie in curves with small radius, continuous curves with divergent radiuses or in opposite directions (S curve), and entrances to tunnels.

Safety evaluation is necessary and important for improving geometric design of road network, but it is inconvenient to conduct for a newly built freeway. This study provides a method of completing the task with driving simulation experiments, in which driving environment of the newly built freeway is constructed in a 3D model and projected in a board front view. Analysis helps road engineers to locate black spots on the road and make improvement designs or compensation measures in corresponding road sections.

References

Bella, F. (2008). "Driving simulator for speed research on two-lane rural road." Accident Analysis Prevention, 40(3), 1078-1087.

Godley, S.T., Triggs, T.J., Fildes, B. (2002). "Driving simulator validation for speed research."*Accident Analysis Prevention*, 34, 589-600.

Manser, M.P., Hancock, P.A. (2007). "The influence of perceptual speed regulation on speed perception, choice and control: tunnel wall characteristics and influences."*Accident Analysis and Prevention*, 39, 69-78.

Misaghi, P., Hassan, Y (2005). "Modeling operating speed and speed differential on two-lane rural roads."*Journal of Transportation Engineering*, 131 (6), 408-417.

Car-Following Model Based on Ahead Acceleration and Velocity Differences

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Abstract: The traditional car-following theory suppose that drivers' reaction absolutely depend on leading-vehicle behavior. Actually, drivers make decisions based on the information of leading-vehicle and the second leading-vehicle, even more. Recent researches only consider the speeds and locations of multiple leading-vehicles, but the acceleration of leading-vehicle also plays a vital role in the car-following characteristics. Based on the FVD (Full Velocity Difference) model and the OV (Optimal Velocity model) model, the MAAVD (Multiple Ahead Acceleration and Velocity Differences) model which take accelerations and velocities of multiple leading-vehicles into account is established. Linear stabilization and sensitivity of susceptibility of different models are simulated and compared. The result shows that the new model could improve the stability of traffic flow by considering the information of leading-vehicle and second leading-vehicle and could improve the stability better by considering the acceleration of leading-vehicle.
Keywords: Car-following model; Multiple leading vehicles; Stability.

1 Introduction

Driving behaviors of experienced drivers are effected by not only the leading vehicle but also the second leading vehicle. But in the study of traditional following behaviors, in order to simplify the calculation, the effect of leading vehicle was only considered (Wang D H, 2012). As the car-following theory is gradually getting mature, more and more scholars begin to study the car-following behavior which consider the effects of multiple leading vehicles and take more concentrate on finding the reasonable models to simulate the actual following behavior more realistically. At present, the studies of multiple vehicles car-following mainly focus on optimal velocity (OV) (Bando, 1995) model and full velocity difference (FVD)(Jiang R, 2006).

On the basis of OV model, multi-cooperation driving model was established with the consideration of effect of multiple headways on car-following(Ge H X, 2005).On the basis of FVD model, multiple velocity differences (MVD) model was established by introducing multiple velocity differences(Wang T, 2006). The multiple ahead and velocity difference (MAVD) model was presented with consideration of the position and velocity information of multiple vehicles (Sun D H, 2010). Some researchers find that the stability of car-following model which considers the reaction time of driver is improved and the traffic capacity also could be improved in the car-following model (Hu Y, 2014). There are also some researches show that the consideration of the position and velocity information of multiple vehicles also could reduce the adverse impact of the reaction time of driver (Chen J, 2014). Moreover, the number of vehicle which should be considered in car-following also isn't different. It is proved that three leading vehicles should be included in the congestion. However, two leading vehicles is enough in the free (Zhang X, 2014). The models which consider the information of multiple vehicles ignore the effect of acceleration. But the full velocity difference and acceleration (FVDA) model show that the overall consideration of headway, speed difference and acceleration of leading vehicle provides the car-following higher stability than FVD model and provide the vehicle faster acceleration (Yu S, 2013). In conclusion, the acceleration of leading vehicle should be considered in the multiple car-following model.

In this paper, the new model is presented by introducing the headways and speed differences of leading vehicle and second leading vehicle on the basis of MVD model. The new model has considered the effect of acceleration of leading vehicle. The linear stability of the new model is analyzed through the linear stability theory, and mathematical simulations are done to the comparative analysis of different car-following models.

2 Multiple Ahead Acceleration and Velocity Differences Model

MVD model is presented on the basis of FVD model and introduces the velocity difference of multiple leading vehicles (Wang T, 2006). The MVD model is shown as:

$$a_n(t) = \alpha\left[V(\Delta x_n(t)) - x_n(t)\right] + \sum_{l=1}^{m} \lambda_l \Delta v_{n+l-1}(t) \quad (l = 1, 2, \ldots, m; m \ll N) \tag{1}$$

Where α is the sensitive coefficient of drivers for headway. *N* is the total number of vehicles in the road. *m* is the number of multiple leading vehicles. λ_l is the weight coefficient of velocity difference and is less than λ_{l+1}. $V(\Delta x_n(t))$ is the function of optimal velocity. $\Delta v_{n+l-1}(t)$ is velocity difference between leading vehicle and following vehicle.

When $m=0$, MVD model is equivalent to OV model. When $m=1$, MVD model is equivalent to FVD model.

MVD model just considers the influence of multiple velocity differences and ignores the headways of multiple leading vehicles and the acceleration of leading vehicle. But these parameters are important for simulating car-following and could decide the accuracy of simulation. Consequently, based on MVD model, this paper establishes a new model (MAAVD) with the consideration of ahead acceleration and multiple velocity difference. The MAAVD model is shown as

$$\begin{aligned} a_n(t) = \alpha\left\{(1-p)V\left[\Delta x_n(t)\right] + pV\left[\Delta x_{n+1}(t)\right] - v_n(t)\right\} \\ + \lambda\left[(1-q)\Delta v_n(t) + q\Delta v_{n+1}(t)\right] + ka_{n+1}(t) \end{aligned} \quad (2)$$

Where α, λ are the sensitive coefficient of driver for headway and for relative velocity; k is the influence coefficient for acceleration of leading vehicle; *p* and *q* are weights of second leading vehicle for headway and relative velocity; $\Delta x_n(t)$ and $\Delta v_n(t)$ are the headway and the speed difference between the *n*th and the (*n+1*)th vehicle; $a_n(t)$ is the acceleration of the *n*th vehicle.

3 Stability analysis of the MAAVD model

In order to analyze the characteristic of the MAAVD model, especially the stable domain, the linear stability analysis is carried. To assume that the initial state of the fleet is stable, the fleet moves with the headway which is h. The position of *n*th vehicle could be expressed by

$$x_n^0(t) = V(h)t + hn \quad (3)$$

$y_n(t)$ is defined as the tiny disturbance which is applied in *n*th vehicle. Its expression is shown as:

$$y_n(t)=exp(i\theta n+zt) \quad (4)$$

Therefore, the actual position of *n*th vehicle could be presented as:

$$x_n(t) = V(h)t + y_n(t) + hn \tag{5}$$

The new function of optimal velocity which is built through substituting formula (5) into formula (4) is expanded by Taylor method. Subtracting the high order terms, the expression could be got as:

$$V[\Delta x_n(t)] = V(h) + \dot{V}(h)\Delta y_n(t) \tag{6}$$

Substituting Fouries series expansion of the disturbing function and formula (6) into MAAVD model, the following expression could be got.

$$\begin{aligned} z^2 = \alpha\left[(1\text{-}p)\dot{V}(h)\left(e^{i\theta}\text{-}1\right) + p\dot{V}(h)e^{i\theta}\left(e^{i\theta}\text{-}1\right)\text{-}z\right] \\ +\lambda z\left[(1\text{-}\beta)\left(e^{i\theta}\text{-}1\right) + \beta e^{i\theta}\left(e^{i\theta}\text{-}1\right)\right] + kz^2 e^{i\theta} \end{aligned} \tag{7}$$

To assume that $z=\omega i+\gamma$, γ is usually zero. Combining Euler formula $e^{i\theta}=cos\theta+i\bullet sin\theta$ the real part and the imaginary part of formula (7) are taken as zero, we can get the stability equation, which can be solved by elimination and L Hospital rule. The solution can be expressed as

$$\dot{V}(h) = \frac{\frac{\alpha}{2}(1+2p)+\lambda}{1\text{-}k} \tag{8}$$

In order to contrast the three models expediently, λ is chosen as the recommended value $\lambda = 0.2$, k , p are the introduced parameters, $k=0.1$, $p=0.2$ .The critical curves between headway and sensitivity coefficient in different models are shown in Figure 1.

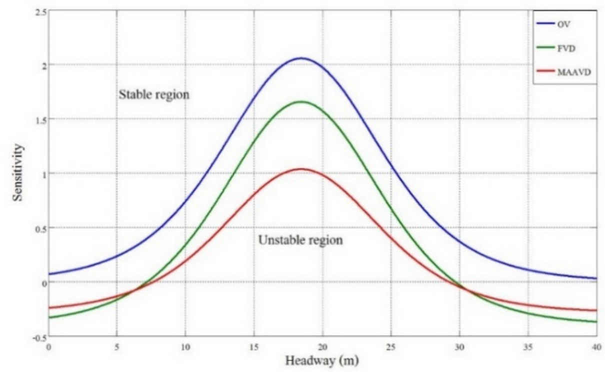

Figure 1.The critical curves between headway and sensitivity coefficient in different models

The critical stability curves of OV Model, FVD Model and MAAVD Model are shown in the Figure 1. Vehicles can be driven smoothly in a certain range (no congestion), which is above the critical curve. As is shown in the figure1, compared to OV Model and FVD Model, the MAAVD model has a larger stable region and a smaller unstable region, which avoids the indefinite time headway in OV Model. We can draw a conclusion that considering the acceleration of the leading vehicle and the second leading vehicle will facilitate the achievement of the stability of traffic flow could be drawn.

4 Mathematical Simulation

Mathematical simulation was taken to OV model, FVD model and MAAVD model in order to figure out the contribution of the MAAVD model. To make the simulation more practical, this paper cites the function of optimal velocity which was tested by Helbing and Tilch through experimental data (Helbing, 1998). Its expression is shown as

$$V\left[\Delta x\right]=V_1+V_2\tanh\left[C_1\left(\Delta x-l_c\right)-C_2\right] \tag{9}$$

Where, $V_1=6.75\,m/s$, $V_2=7.91\,m/s$, $C_1=0.13$, $C_2=1.57$, l_c is the length of vehicle which is 5 meters. Defining vehicle number as 20, initial speed as 11m/s, headway as 10m, $a_1(t)=0.5$ when $100\le t<122$, $a_1(t)=-0.3$ when $222\le t<262$.

Same values was taken for the same parameters in each model, where α=*1.4* , λ=*0.2* , *k=0.1* , *p=0.2* , *q=0.2* . The result of the mathematical simulation are shown from figure 2 to figure 5.

Figure 2 to 4 show that at the beginning of the simulation, the desire speed is less than the initial speed in each model when the headway is 15m, so all vehicles in three models choose to decelerate. The OV model has the biggest amplitude of the deceleration, and the MAAVD model has the smallest amplitude. For the following stage which all vehicles speed up to keep the desire headway and speed, there are overshoot in the OV and FVD model, while vehicles in the MAAVD model accelerate to the desire speed with no overshoot. The result reflects that the MAAVD, considering multiple leading-vehicles, has the ability to predict the behavior of the leading vehicles in detail, which helps make perfect choice.

The headway and speed of vehicles in three model are basically the same when the model goes to the first stable stage, while the next stages when the cars slow down to still and then speed up, the speed curves of three model are quite different. For the MAAVD model, the speed curves of each vehicles are similar to each other, and are smoother as the number increase; while for the OV model and FVD model, the oscillation appears when the number of vehicles go up to 15 for OV model and 10 for FVD model.

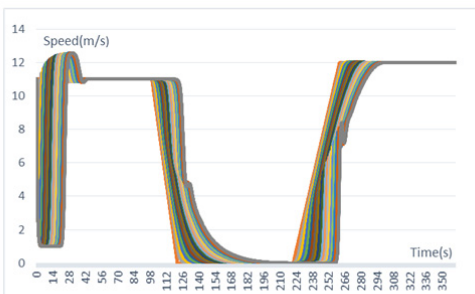

Figure 2.The speed curves of vehicles under OV model

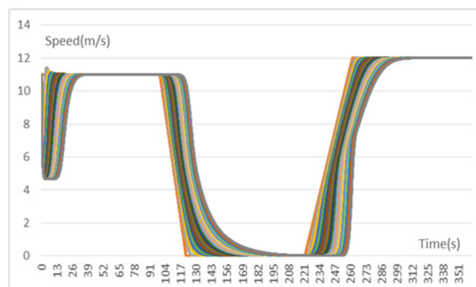

Figure 4.The speed curves of vehicles under MAAVD model

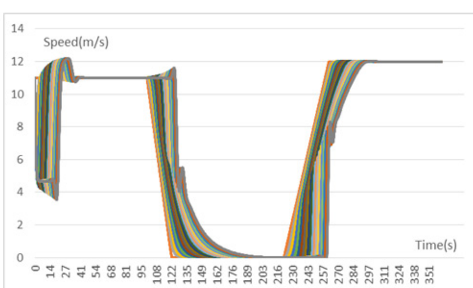

Figure 3.The speed curves of vehicles under FVD model

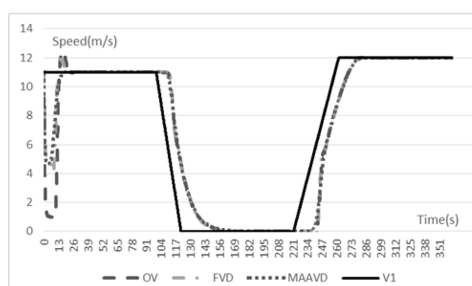

Figure 5.The speed curves of the tenth vehicle under different car-following models

Then we take a look at the speed of the tenth vehicle of each model, as it shown in Figure 5, the three models are mathematically stable when the vehicles are less than10. Figure 5 shows that the variation trend of speed of the tenth vehicle in OV model and FVD model are similar, and both of them have an overshoot which are 25% of the stable speed. It takes 14s for the MAAVD model from the beginning to stable state (|a|<0.5m/s), 21s for the FVD model and 22s for the OV model.

5 Conclusions

In this paper, a MAAVD model is constructed by considering the behaviors of leading-vehicle and the second leading-vehicle. Based on the linear stabilization, the critical stable condition of MAAVD model is obtained. By analyzing simulation results, conclusions are reached as follows.

(1) Comparing with OV model and FVD model by linear stability analysis, MAAVD model has a smaller critical value of sensitivity coefficient, which means a greater stable region of traffic flow.

(2) With the same initial conditions and disturbances, MAAVD model responses to the disturbance faster, contributing to more smooth speed.

References

Chen J, Shi Z, Yu L, et al. Nonlinear Analysis of a New Extended Lattice Model With Consideration of Multi-Anticipation and Driver Reaction Delays. Journal of Computational and Nonlinear Dynamics. 2014, 9(3): 31005.

Ge H X, Zhu H B, Dai S Q. (2005). "Cellular automaton traffic flow model considering intelligent transportation system", *Acta Physica Sinica,* 2005, 54(10):4621-4626.

Hu Y, Ma T, Chen J. (2014) "An extended multi-anticipative delay model of traffic flow." *Communications in Nonlinear Science and Numerical Simulation*. 2014, 19(9): 3128-3135.

Helbing D, Tilch B. Generalized force model of traffic dynamics. Physical Review E. 1998, 58(1): 133-138.

Jiang R, Wu Q S. (2006). "Study on the Complex Dynamic Properties of Traffic Flow from the Micro and Macro Modelling." *Journal of the Graduate School of the Chinese Academy of Sciences*. 2006, 23(6): 848-854.

M. Bando, K. Hasebe, A. Nakayama, A. Shibata, and Y. Sugiyama. (1995). "Dynamical Model of Traffic Congestion and Numerical Simulation", *Phys. Rev. E* 51, 1035-1042.

Sun D H, Li Y F, Tian C. (2010). "Car-following model based on the information of multiple ahead & velocity difference." *Systems Engineering-Theory & Practice.* 2010(7): 1326-1332.

Wang D H, Jin S. (2012). "Review and Outlook of Modeling of Car Following Behavior." *China Journal of Highway and Transport.* 2012(01): 115-127.

Wang T, GAO Z Y, ZHAO X M (2006). "Multiple velocity difference model and its stability analysis." *Acta Physica Sinica.* 2006(02): 634-640.

Yu S, Liu Q, Li X. (2013) "Full velocity difference and acceleration model for a car-following theory." *Communications in Nonlinear Science and Numerical Simulation*. 2013, 18(5): 1229-1234.

Zhang X. Empirical Analysis of a Generalized Linear Multi-anticipative Car-Following Model in Congested Traffic Conditions. Journal of Transportation Engineering 2014.

Effect of Break Time on an Evaluation Index of Driving Characteristics

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Abstract: Long continuous driving will generate traffic safety hazard due to the driver's own characteristics. In order to study driver perception, judgment and operating characteristics, the study tested and analyzed evaluation indicators and their changing rules under different rest time. Established the relation model between rest time and each evaluation index. According to the relation model, draw the operation driver's driving characteristics change over time and given the appropriate break time for driver.
Keywords: Break time; Driving characteristic; Continuous driving; Traffic safety.

1 Introduction

A long time continuous driving can easily lead to driving fatigue, resulting the decline of the driver's perception, judgment and operating characteristics, which could lead to accidents. In order to ensure driving safety, (D. Wylie, 1996) found that the continuous driving time is the main factor affecting driving fatigue. (Connor J., 2002) found that the driver in the normal resting state, the main driving fatigue are the time and times of continuous driving. Through the sort of importance, (Li, 2003) established the driving fatigue hierarchical structure model, given the impact of sorting which provides a new way of thinking about driving fatigue. (Ma, 2009) select evaluation indicators of driving characteristics, and shows the relationship between the indexes and driving time, gives recommendations require the driver needs to stop resting after 3.5h. On the basis of fatigue cumulative time of long-distance bus driver, (Zhai, 2012) make a break halfway experiment studied.

After driving, the degree of fatigue significantly increased, while the driver’s operating characteristics significantly lowered (Niu, 2014). From the perspective of driving characteristics, we analysis the relationship of break time and evaluation of index, and gives the suggestion about the length of break time after continuous driving.

2 Driving Characteristics and Evaluation Index

Driving characteristics of the driver in the information processing is demonstrated in its own characteristics, based on the expanding of the human behavior classic model S-O-R, the information processing can be classified into three stages, perception, judgment and operating (Ma, 2009).

2.1 Evaluation index of driving characteristics and testing instrument

When study the driving characteristics of perception, judgment and operating after a continuous driving, we should choose the evaluation index which can accurately represent the driving characteristics and the testing equipment easy to measure. After comparative analysis, the final selection of evaluation index and test equipment are shown in Table 1.

Table 1. Evaluation indicators and test equipment

Classifications	Evaluation index	Testing instrument
perception	Depth perception differences, speed perception differences	Depth perception analyzer, Perceptual speed meter
judgment	Choice reaction time, note assign values	Visual response analyzer, Note assignment instrument
operation	Correct operation times, error operation times	Note assignment instrument Action judge Miriam

2.2 Test samples selected

Based on (Ma, 2009) experimentally research in a row after driving 3.5h, test driver perception, judgment and operating indicators variation of the break time. The test index and equipment are shown in Table 1. Stratified random sampling method to select 40 drivers who are in health and have not had an accident before, including 32 males, 8 females; with the average age of 37; 1 to 28 years of driving experience, with an average 18 years of driving experience. Each driver test at least twice, a total of 120 cases to obtain test samples. Choose drivers who are under the same continuous driving time as the research object, at the end of the driving, measured once every five minutes.

3 Relativity between the Length of Break Time and the Evaluation Index

First, the raw data sample screening test to determine the available samples of 108 cases. Analyze the correlation between the rest time and each evaluation index, the correlation test results in Table 2. Rules can be seen as follow:

1) There was a significant negative correlation between the length of time to rest with depth perception differences, differences in the speed of perception, choice reaction time, error operation times and subjective fatigue.

2) There was a significant positive correlation between the length of break time the note assign value and correct operation times.

Table 2. Breaks between each evaluation index

Evaluation index	Correlation coefficient R	P
Choice reaction time	0.821	<0.01
attention assign value	0.869	<0.01
Correct operation times	0.757	<0.01
Speed perception	-0.855	<0.01
Depth perception	-0.892	<0.01
Error operation times	0.902	<0.01
Subjective fatigue	0.859	<0.01

4 Analysis the Effect of Break Time on the Evaluation Index

4.1 Depth perception

Analyze on the difference of depth perception y_1 of the driver with different break time t. The results shown in Figure 1. Between break times with depth perception difference cubic curve equation can be established, the relationship model is as follows:

$$y_1 = 2\times10^{-4}t^3 - 0.0031t^2 - 0.2769t + 8.1205 \quad (1)$$

Seen from Figure 1, the test data were in the confidence interval range, and coefficient of determination was 0.9211, indicating that the establishment of a more reasonable curve equation, with the growth of the break time, the driver's depth perception ability to gradually rise.

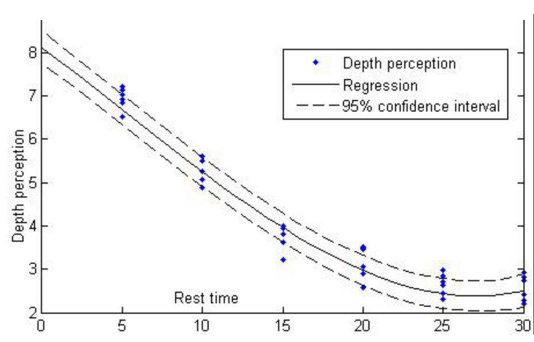

Figure 1. Depth perception

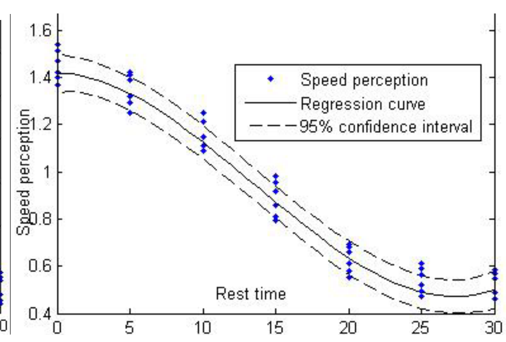

Figure 2. Speed perception

4.2 Speed perception

The relationship between break time and differences of speed perception y_2 is shown in Figure 2.The relationship model is as follow:

$$y_3 = 1\times10^{-4}t^3 - 0.0037t^2 - 0.0015t + 1.4193 \quad (2)$$

Seen from Figure 2, the test data were in the confidence interval range, and coefficient of determination was 0.8929, indicating that the establishment of a reasonable curve equation, and with the growth of the break time, the driver's speed perception differences are on the rise.

4.3 Reaction ability

The relationship between break time and the choice reaction time y_3 is shown in Figure 3. The relationship model is as follow:

$$y_2 = 3.4\times10^{-5}t^3 - 0.0026t^2 - 0.0695t + 1.2565 \quad (3)$$

Seen from Figure 3, the test data were in the confidence interval range, and coefficient of determination was 0.9117, indicating that the establishment of a reasonable curve equation, and the increasing of break time, the driver's choice reaction time decreased and the reaction ability improved.

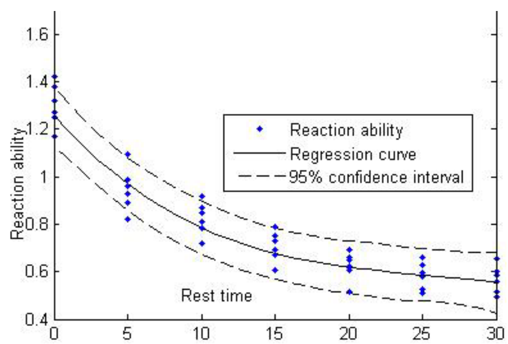

Figure 3. Reaction ability

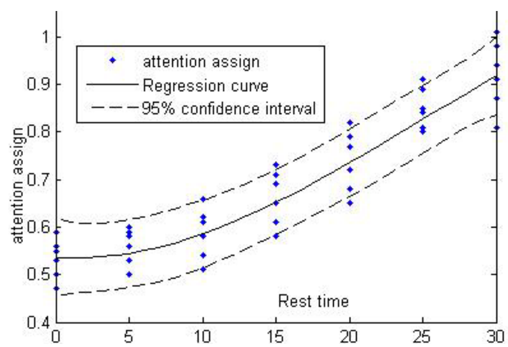

Figure 4. Attention assign

4.4 Attention assign

The relationship between break time and the attention assign value y_4 is shown in Figure 4. Which follows the relational model:

$$y_4 = -1.1\times10^{-4}t^3 - 0.0083t^2 - 0.0023t + 0.5364 \quad (4)$$

Seen from Figure 4, the test data entirely within the confidence interval range, and the coefficient of determination was 0.7835, indicating that the establishment of a more reasonable curve equation, the longer break time, the higher attention assign value, the better attention.

4.5 Correct operation times

The relationship between continuous driving time and the correct operation times y_5 is shown in figure 5. Which follows the relational model:

$$y_5 = -2\times10^{-3}t^3 + 0.0695t^2 + 1.0071t + 95.7619 \quad (5)$$

Seen from Figure 5, the test data entirely within the confidence interval range, and the coefficient of determination was 0.8166, indicating that the establishment of a reasonable curve equation, and the increasing of break time, the operating characteristics also rising, and the correct operation times increased.

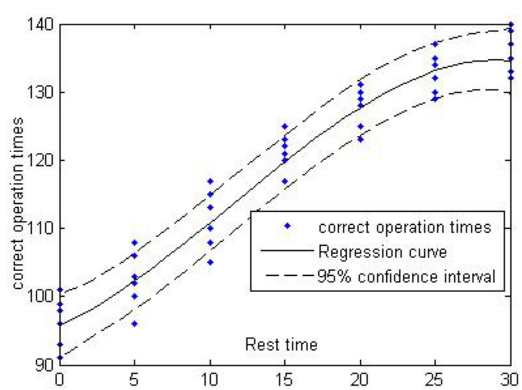

Figure 5. Correct operation times

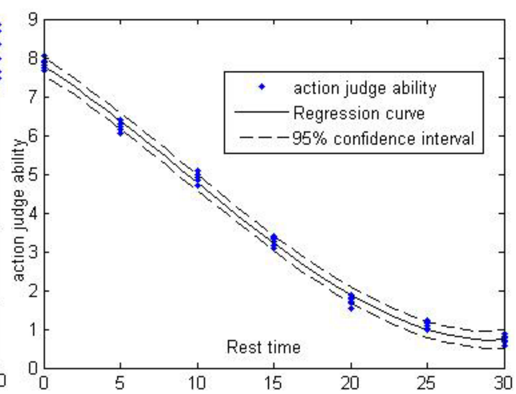

Figure 6. Action judge ability

4.6 Action judge ability

The relationship between rest time and the action judge ability y_6 is shown in Figure 6. Which the relational model as follows:

$$y_6 = 3\times10^{-3}t^3 - 0.0076t^2 - 0.2514t + 7.7762 \quad (6)$$

Figure 6 shows the test data within the confidence interval range, and coefficient of determination was 0.7370, indicating that the establishment of a more reasonable curve equation, and the increasing of break time, the operating characteristics also rising, and the error operation times decreased.

5 Suggestions about the length of break time based on driving characteristics

According to the Ma (2007) and Li (2001), the use of experimental psychology test methods to determine the driving characteristics of the individual evaluation index threshold level, and to determine the driving characteristics of comprehensive evaluation based on fuzzy clustering (Niu, 2014). The results are shown in Table 3.

Table 3. Synthesis Evaluation Classifications of Driving Characteristics

grade	A	B	C	D	E
value	0.91-1.00	0.75-0.90	0.58-0.74	0.45-0.57	0.30-0.44

Different individuals have very different individual indicators, individual indicators in the detection of the driver, with high specificity, it should adopt multi-index portfolio, through a comprehensive evaluation to improve the accuracy of the determination (Ma, 2009). Based on the length of break time on the driving characteristics evaluation index analysis, using the formula (1) to (6) estimated the value of the driver's driving characteristic evaluation index after a period of rest time. Based on the evaluation index threshold of driving characteristics to determine driver's individual evaluation index grade under the appropriate length of break time, while using fuzzy clustering method, to make a comprehensive evaluation of the driver's driving characteristics under the corresponding break time. Calculation results of the analysis are shown in Table 4.

Table 4. Test Results of Driver's Characteristics after a Period of Rest Time

Time	depth perception	speed perception	Choice reaction	Distribution attention	Correct operation times	Error operation times	Grade
0	8.01	1.42	1.27	0.53	96	7.82	E
5	6.93	1.32	0.93	0.56	102	6.21	E
10	5.27	1.15	0.81	0.58	110	4.93	D
15	3.62	0.86	0.69	0.65	121	3.25	D
20	3.05	0.61	0.61	0.72	128	1.72	C
25	2.64	0.52	0.58	0.85	132	1.09	C
30	2.41	0.49	0.56	0.91	135	0.71	B

From Table 4, under the same length of break time, there are obvious differences between the different grades of individual evaluation indexes and comprehensive evaluation grade. Therefore, an integrated evaluation level has a certain rationality. Based on the analysis results in Table 4, the driver at the time of 20min or more break time, driving characteristics of the driver more comprehensive evaluation rating in good state. With the increase of the length of break time, the driving characteristics of the driver of a comprehensive evaluation level gradually rises, when it reaches 30min, driving characteristics at a high state, In this case, the driver's attention ability is good, can accurately determine the speed of perception and the choice reaction time. Therefore, we recommend that when the driver have a continuous driving time for 3. 5 h, needed to have a rest stop at least 20min.

6 Conclusions

Based on ergonomics theory, the driving characteristics can be classified into perception, judgment and operating characteristics, based on the experimental psychology to determine the evaluation indicators of driver's perception, judgment and operating characteristics.

Study on the impact of the length of break time on the driver’s perception, judgment and operating characteristics evaluation index, the results show that with the break time increasing the driving characteristics gradually rising. With the growth of the break time, depth perception difference with speed difference between the estimated value of the driver are decreased, the driver's choice reaction time decreases, attention assign value increased, the number of the correct operation of the driver gradually increases, while the number of error operation of the driver gradually reduced. Based on the relational model of break time with the established evaluation index and driving characteristics between the comprehensive evaluation results, we recommend that when the driver have a continuous driving time for 3. 5 h, needed to have a rest stop at least 20min.

References

Connor J et al. (2002). “Driver sleepiness and risk of serious injury to car occupants: population-based control study.” *British Medical Journal.*

D. Wylie, etc. (1996). Commercial Motor Vehicle Driver Fatigue Alertness Study. NTIS.

Li, X. Y., and Jiang, G. F. (2003). “Analytic Hierarchy Process (AHP) in the cause of driver fatigue analysis of the application.” *Ergonomics*, 9(2), 58-60.

Li, B. C., Sun, J. H. and Xiao, L. J. (2001). “Formulating Standards for Detect ion of Suitability of Chinese Professional Automobile Drivers.” *Journal of Safety and Environment*, 1(3), 7- 10.

Ma, Y. L. (2007).Study on Characteristics of Driving and its Countermeasures to Road Safety. Harbin Institute of Technology, Harbin, China.

Ma, Y. L., and Pei, Y. L. (2009). “Influences of Continuous Driving Time on Test Indicators of Driving Characteristics.” China Journal of Highway and Transport, 22(1), 84-88.

Niu, Z. L., and Li, H. B. (2014). "Study on risky Behavior of Commercial Drivers Based on Clustering Analysis". *Journal of ShanDong JiaoTong university,* 22(1), 19-23.

Zhai, B. T. (2012). "Research on operating Long-distance bus driver accumulated fatigue experiment." Harbin Institute of Technology, Harbin, China.

Risk Assessment on the Effect of Weather Factors on Civil Engineering Facilities in a Metro System

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Abstract: In recent years, the global climate change has triggered higher occurrence rate of natural disaster, the failure of civil infrastructure function has caused enormous social and economic loss, which reminds people to recognize the importance of risk assessment on civil engineering facilities. This paper takes safety risk assessment of influence of weather factors on urban metro transit facilities by using the methods of FTA, AHP and fuzzy evaluation theory, provides risk assessment index system, calculates the relationship between weights of three weather factors, and establishes a Risk evaluation model based on AHP-Fuzzy Synthetic Evaluation with an example of the section between Beiyuan station and Wangjingxi station in line 13 in Beijing. The results are useful to identify security risks in urban metro transit facilities system, and to improve it.
Keywords: Metro; Risk assessment; The fault tree; Weather effect.

1 Introduction

With the rapid development of urban rail transit, human beings attached increasingly importance to the safety of urban metro transit operation. As urban metro transit facilities system is a vast and complex system engineering, there are many security risks in its operation throughout the process. Weather's effect on metro facilities has a lot to do with metro emergencies. For example, part of subway lines inundated and significant delay was resulted in New York, USA in August, 2007; line 1 exit collapse caused by sustained downpour caused 11 deaths in Hangzhou, China in November, 2008.

There have been some researches on risk assessment of railway, but few of them do with weather factors' affect on urban metro transit facilities. According to a literature review by (Osberghaus, 2010), transport, together with the health sector, is characterized by large uncertainties in conjunction with potentially high adaptation costs in the future. (Nathanail, 2014) proposed a Framework for Monitoring and Assessing Performance Quality of Railway Network Infrastructure. As a result, risk assessment on the effect of weather factors on civil engineering facilities in metro has is of great practical significance towards improving the urban metro transit operation safety level.

This paper takes safety risk assessment of influence of weather factors on urban metro transit facilities by using the methods of FTA, AHP and fuzzy evaluation theory, provides risk assessment index system, calculates the relationship between weights of three weather factors, and establishes a Risk evaluation model based on AHP-Fuzzy Synthetic Evaluation with an example of the section between Beiyuan station and Wangjingxi station in line 13 in Beijing. The results are useful to identify security risks in urban metro transit facilities system, and to improve it.

2 Importance Analysis of Weather Factors

Weather disasters include disasters caused by typhoon, rainstorm(snowstorm), cold wave, strong wind (sandstorm and/ or duststorm), low temperature, high temperature, drought, thunderstorm and lightning, hail, frost and fog. To understand where the risks are and what weather factors have the most significant effect, this article sets up a fault tree. Considering the damage of rail transportation due to the weather cause, the top event indicated that the existing metro facilities cannot operate safely. The total fault tree will be set up relatively based on the four middle events: the subgrade damage, poor construction or maintenance, tree invasion and track damage. Further research will be studied to analyses all kinds of factors aroused risks and therefore the logical relationships will be shown among those factors. The fault tree is shown in figure 1.

We can obtain minimal cut sets based on the structure of the fault tree, then we can calculate the importance degree of each basic event:

$$I_{\phi}(i) = 1 - \prod_{x_i \in k_j}\left(1 - \frac{1}{2^{N_j - 1}}\right) \quad (1)$$

Where Nj is the number of basic events and Kj is the jth minimal cut set. The results are as follows:

X1=X7=0.999≈1，X3=0.937，X8=0.911，X4= X9= X10=0.859，X5= X6= X11= X13=0.75， X2= X12= X14= X15=0.5,

So X1=X7 >X3>X8>X4= X9= X10>X5= X6= X11= X13>X2= X12= X14= X15

Then it can be seen that damaged whether caused by windstorm, especially extreme severe whether like typhoon, has the most serious damage to the rail transportation civil facilities. In addition, accumulated snow and heavy rain damaged rail transportation to a large extent as well.

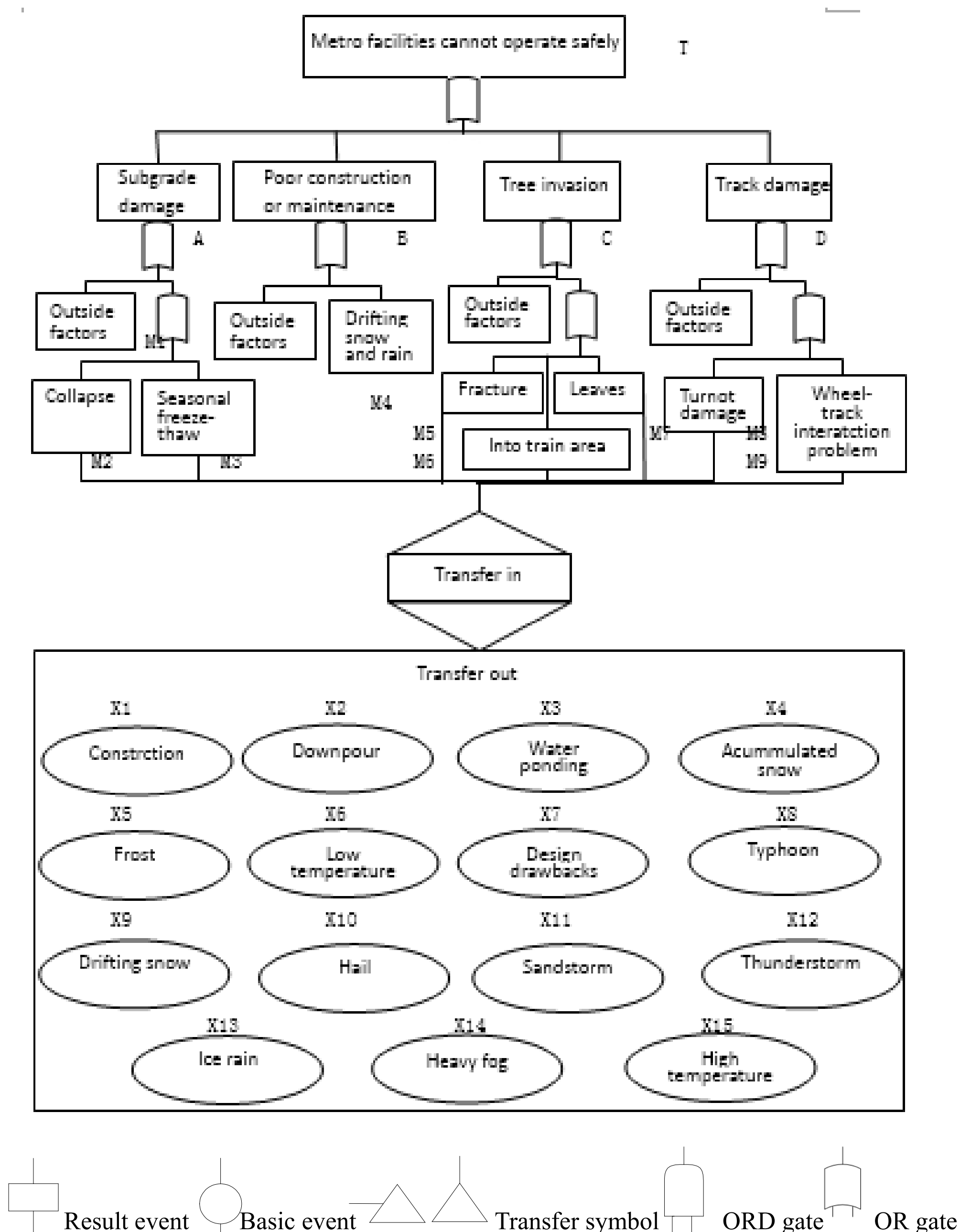

Figure 1. Fault tree

3 Weather Effect Risk Evaluation Index System

According to statistical analysis of data from Beijing subway operating company in recent years and lots of spots investigation, we have the weather effect risk evaluation index system, based on which we can design questionnaire for weather factor on metro facilities as bellow. The membership degree matrix can be obtained by scores form experts. For example, the shadow part of the Table1 is the shadow part.

Table 1. Questionnaire for weather factor on metro facilities

Index \ Grade(score)			Ext. high (8)	Very high (7)	Fairly high (6)	High (5)	Medium (4)	Low (3)	Fairly low (2)	Ext. low (1)
Wind A	A1	Station protection area trees								
	A2	Temporary buildings surrounding the station								
	A3	High-rise buildings outside the protection area	**Judgment matrix of factor wind**							
	A4	Height coefficient of wind pressure								
	A5	Shape factor of wind load								
	A6	Wind barrier								
Rain B	B1	Ground elevation of station entrance / exit								
	B2	Catchment area of station entrance/exit								
	B3	Step number of station entrance /exit	**Judgment matrix of factor rain**							
	B4	Station roof shape								
	B5	Drainage facility capacity								
	B6	Facility service life								
Snow C	C1	Station roof shape								
	C2	Monitoring system	**Judgment matrix of factor snow**							
	C3	Rain and snow tent								
	C4	Turnout snowmelt equipment								
	C5	Snow sweeper								

4 AHP-Fuzzy Synthetic Risk Evaluation

This paper takes the section between Beiyuan Station and Wangjin West Station as case study, which is located in Chaoyang District, Beijing. Beiyuan Station is a station on the 13th line and Wangjing West Station is a transfer station between 13th line and 15th line. Beiyuan Station is located at the west side of the Guangying East

Road, with one exit. Wangjing West Station is located at the west side of Dawangjing village. The platform of the Wangjing West Station is of double island, and there are total 4 tracks, the outside two of which are reserved for the 13th lateral line, including the A and B exit of 13th line and the C exit of 15th line. The total length between Beiyuan Station and Wangjing West Station is 6.8 km, situated between the 4th ring and 6th ring. Both elevated and ground line are used for line laying, and sound barrier are installed at both sides of the track.

4.1 Decide Evaluation Factors

The evaluation factors are the same as in the AHP analysis, including six factors: U_A={Station protection area trees, temporary buildings surrounding the station, high-rise buildings outside the protection area, height coefficient of wind pressure, shape factor of wind load, wind barrier}

4.2 Decide The Evaluation Set

The choice set is described as following: V={Extremely high, very high, fairly high, high, medium, low, fairly low, extremely low}.

4.3 Decide Weight Vectors

The relatively weight vector of each risk factors of wind condition subsystem calculated through the AHP method is shown below:

w_A=(0.339，0.278，0.070，0.137，0.137，0.039)

4.4 Decide Membership Matrix

The membership degree matrix can be obtained based on the judgment matrix (shadow part in table 1) which is calculated by scores form 20 experts.

$$R_A=\begin{bmatrix} 0 & 0.563 & 0.313 & 0.124 & 0 & 0 & 0 & 0 \\ 0 & 0.438 & 0.188 & 0.188 & 0.188 & 0 & 0 & 0 \\ 0 & 0.250 & 0.375 & 0.125 & 0.250 & 0 & 0 & 0 \\ 0 & 0 & 0.313 & 0.313 & 0.375 & 0 & 0 & 0 \\ 0 & 0 & 0.250 & 0.375 & 0.375 & 0 & 0 & 0 \\ 0 & 0.563 & 0.370 & 0.063 & 0 & 0 & 0 & 0 \end{bmatrix}$$

4.5 Calculate The Fuzzy Synthetic Evaluation Set

The Fuzzy Synthetic evaluation set can be achieved by multiplying the weight vector of wind effect factors by the membership degree matrix as shown followed.

$B_A=W_A\times R_A$==（0，0.352，0.276，0.225，0.147，0，0，0）

In the same way, we can get B_B=（0，0.088，0.350，0.318，0.221，0.023，0，0; B_C=0，0，0.068，0.287，0.232，0.234，0.088，0）

4.6 Comprehensive Risk Evaluation

After respective risk evaluation of each weather factor, we can conduct comprehensive risk evaluation . There are three risk factors evaluated according to the weather condition: U={heavy wind, rain, snow }. w=(0.230，0.667，0.103) .

B=W×R= (0.230，0.667，0.103)×
=（0，0.072，0.057，0.334，0.537，0，0，0）

4.7 Results Analysis

$$V = \frac{\sum_{j=1}^{m} b_j v_j}{\sum_{j=1}^{m} b_j} = 4.664$$

So the result of the risk level evaluation is between high and medium, which is allowed to appear and be accepted by controls.

According to the standard in table 2, the section between Beiyuan Station and Wangjing West Station is at level 1 under the effect of wind, at level 2 at level 1 under the effect of rain, at level 2 under the effect of snow, and the comprehensive risk evaluation result under three factors is at level 2.

Table 2. Standard for metro facilities in response to weather disaster in Beijing

Risk level of metro line section	Risk grade
Level 1	Extremely high, very high
Level 2	High, medium,
Level 3	Low, fairly low, extremely low

5 Conclusions

Here we may draw the following conclusions：

(1) Through the analysis on the rail transit construction facilities under the effects of weather factor, it can be concluded that the first three serious weather factors are heavy wind, rain and snow. All of these factors are evaluated by the fault tree analysis from the cases that the facilities are out of order by the weather factors.

(2) Based on the fuzzy synthetic evaluation on section between beiyuan station and wangjing west station in beijing rail transit 13^{th} line, it's evaluated that it is the first class under the effect of heavy wind; it's the second class under both effects of rain and snow condition. Therefore, it can be comprehensively evaluated as the second class.

References

Jiaqi Ma, Yan Bai, Jianfeng Shen et.a1. (2014). "Examining the Impact of Adverse Weather on Urban Rail Transit Facilities on the Basis of Fault Tree Analysis and Fuzzy Synthetic Evaluation". Journal of Transportation Engineering, 140(3),

Nathanail, E. (2014). "Framework for Monitoring and Assessing Performance Quality of Railway Network Infrastructure: Hellenic Railways Case Study." J. Infrastruct. Syst., 20(4), 04014019.

Osberghaus D, Reif C (2010). "Total costs and budgetary effects of adaptation to climate change: an assessment for the European Union". Discussion Paper No. 10-046, ZEW (Zentrum für Europäische Wirtschaftsforschung).

Cabinets of Comprehensive Inspection Train Random Vibration Analysis

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Abstract: In this paper an accurate of railway vehicles random vibration analysis method and engineering application systems is employed to do random vibration analysis, geometric models of electrical control cabinets of comprehensive inspection train is build. The model is excited by German low interference spectrum and 5 different results are calculated. As the speed increases vertical and lateral acceleration standard deviation are also increase and the lateral acceleration standard deviation of 220-250km/h more sensitive than the vertical. Cabinet installation support lateral acceleration standard deviation relatively large.
Keywords: Comprehensive inspection train; PEM; Random vibration; Cabinets.

1 Introduction

Integrated high-speed detection employ EMU as the carrier, with track inspection, pantograph line supply, wheel/rail dynamics detection, communication, signal detection and other precision measuring equipment, the integration of modern measurement, time and space positioning synchronous, data exchange, real-time image recognition and data processing, and other advanced, in the high-speed operation of track and catenary, isokinetic testing infrastructure such as communication, signal condition, in order to improve the detection efficiency and guide the railway infrastructure on-site maintenance and repair, it is an important technical equipment which ensure the safety of train.

Figure1. High speed inspection testing train

The first 250 km/h high-speed integrated testing train of our country is designed and manufactured by CNR Changchun railway vehicle co., LTD. as shown in Figure 1. The highest detection speed is 250 km/h; the maximum traction power is 5500 kW. Rail detection, catenary inspection, wheel/rail dynamics, communication and signal detection system are carried by the car. At the same time, train special network, positioning synchronous, environment video information collection multimedia display and data processing system also are set up and the integration of the information, share, and comprehensive is analysis by itself (Moretti M, 2004).

High speed inspection testing train which is needed to make sure that the storage of equipment work is in order. Due to the complexity of running environment variable and the structure of the vehicle, car body are motivated by the random vibration in the operation process, the vibrations can pass to the seat of the cabinet which affect the operation of the equipment which may be damaged due to excessive vibration. Therefore understand the rack installation random response of structure design parameter is particularly critical. Traditional vehicle dynamics employ multi-body dynamics to simplify the model. The inside elastic damping and mass distribution relationship of carbody frame and other structures are ignored. For the rough model, the vehicle dynamics proper function is weakened which make modern vehicles design has some deficiencies. The local details information of vibration components cannot be obtained by calculation especially for opposite high frequency, so that the effect on the dynamics indicators of the local structure change is not sensitive. The data can only create the actual kind of car, as measured by field tests. Using traditional methods to analyze, as mentioned in the above, when there is local structure change, it is difficult to solve this problem, this paper uses the research and development of efficient algorithms program of random vibration of railway vehicles using the Mode Decomposition and the pseudo-excitation method (Lin Jiahao，Zhang Yahui, 2004) as the foundation to solve the structure vibration(Zhang Youwei,2013). With different speed cabinet installation support on the random vibration is analyzed then compared the results in order to find out the reasonable design parameters.

2 The structure random vibration analysis of simulation system

Railway vehicles efficient algorithm program involves the theory formulas of random vibration will be introduced in the literature (TONG Wei,2014). Take cabinet installation support calculation data as an example, this paper briefly introduces the analysis process. Figure 2 for vibration analysis flow chart.

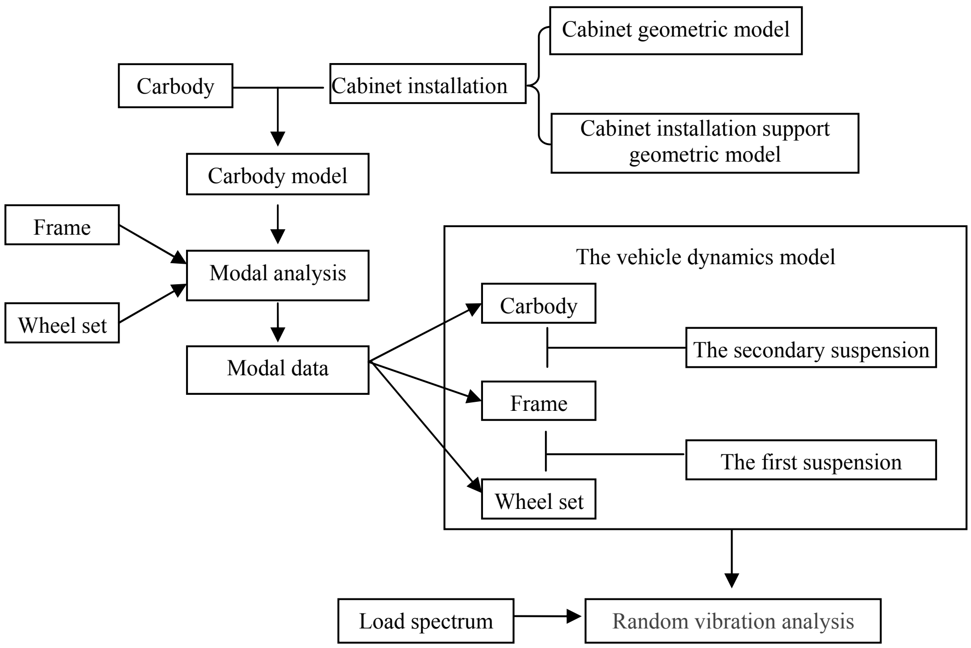


Figure 2. Flow diagram of vibration analysis

3 Calculation model

3.1 Dynamic model of vehicle structure

The quality of high-speed integrated test train cabinet is 300 kg, there are four cabinets are installed on the lower floor is equipped with elastic support, upper with roof chute are connected by bolts. Material parameters are listed in table 1.

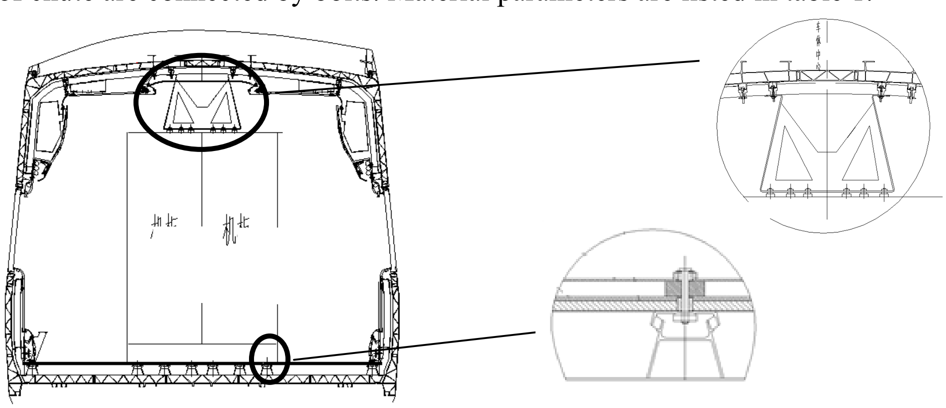


Figure 3.Cabinets installation and partial enlarged detail

Table1. Material parameters

	Density	Modulus of Elasticity	Poisson's ratio
Cabinets (steel)	$7.85g/cm^3$	210Gpa	0.3
Carbody 5-5A02(aluminum)	$2.7g/cm^3$	70Gpa	0.33

The detail of the cabinets' installation is shown in figure3. The structure is rubber, the static displacement is controlled by it and the initial stiffness (Zhang Xiangning,2012) listed in table 2.

Table 2. Initial stiffness of rubber

	Initial stiffness（unit：MN/m）
Longitudinal direction	180
Lateral direction	400
Vertical direction	171.5

Model established in this paper is divided into two parts, the first part is structural model, including installation cabinet, frame, the wheels of the model, as shown in figure 4, the second part is the second spring suspension devices including spring and damping element. The calculation model are 209598 nodes, dynamic degree of freedom are about 1 million. The first 100 order modal include all parts, cutoff frequency is respectively: 40 Hz for carbody, 292 Hz for frame and about 2382 Hz for wheel.

Figure 4. The finite element model

3.2 Load model

Track irregularity power spectrum state of track irregularities is to describe all of the most effective form; it reflects the amplitude-frequency characteristics of track irregularity. Track irregularity power spectrum is important basis of locomotive vehicle and bridge line tunnel design, calculation and evaluation. The size and shape spectra and the level of spectral density are connected with structure and state of the circuit. A large number of measurement and analysis are the fundamental of spectral density. At present, track irregularity power spectrum include PSD of U. S. railways and German high-speed track spectrum is used for analysis, considering the specific load spectrum, the German high-speed track spectrum which divided into high interference and low interference track spectrum, two kinds of spectral function expression of the orbital spectrum. This paper uses German low interference spectrum.

3.3 The computational conditions

The simulation is divided into 5 conditions which is listed in table 3.

Table 3. Introduced of condition

Speed	Introduced of condition
160km/h	The design of the low speed
180km/h	Test low average running speed, compared with the calculation results
200km/h	The average running state, in order to provide more reference
220km/h	The average speed of the test
250km/h	The highest speed of actual operation state

4 The calculation result analysis of random vibration

4.1 The acceleration standard deviation of vehicle structure

The railway vehicle random vibration efficient algorithm program is employed which could get the acceleration standard deviation of cabinets. Standard deviation of each point on the structure of the relative acceleration root mean square value which reflects the structure of each point on the relative acceleration vibration amplitude of the statistical data (The level of curve left the equilibrium position). The maximum lateral and vertical acceleration under different speed standard deviation of carbody is shown in Figure5, with the speed is increasing; the vertical and lateral direction acceleration standard deviations of carbody are also increasing. Vertical acceleration standard deviations were much more than the lateral, but the increase of lateral amplitude from 220 km/h - 250 km/h is larger than vertical. It can be seen that speed range the sensitive of lateral acceleration standard deviation is more sensitive than the vertical.

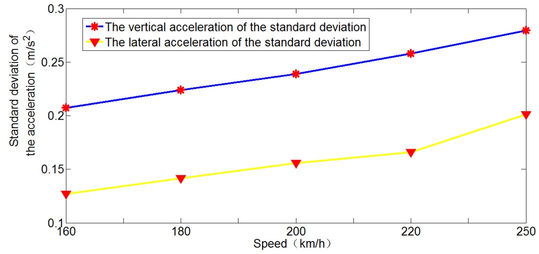
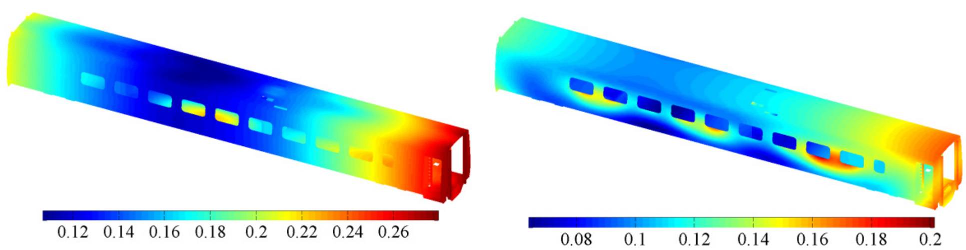


Figure 5. Carbody acceleration standard deviation of different speed

As shown in Figure 6, the car body vertical and lateral acceleration standard deviation of running 250 km/h. The maximum of vertical acceleration standard deviation is $0.28\mathrm{m}/s^2$, which appear at carbody side of the door and central of vehicle chassis. The maximum lateral acceleration standard deviation is $0.2\mathrm{m}/s^2$, in the corner of the window near the side of door. The results are shown that carbody structure is 1/2 symmetric structure. The side of door stiffness is weak. With the speed is increasing, the vibration acceleration of the standard deviation is also increasing.



a) Vertical b) Lateral

Figure 6.Vertical and lateral acceleration power spectrum of 250km/h

4.2 Random vibration analysis of the cabinet installation

According to the different speeds, random vibration analysis was carried out for the cabinet installation; Figure7 shows the maximum vertical and lateral acceleration standard deviation of cabinet installation. As the speed is increasing the vertical and lateral acceleration standard deviation is also increasing, but with the difference of the carbody is given, lateral is always greater than the vertical. This is because the installation on rubber bearing, in the process of traditional analysis for in-car equipment or car lifting equipment is often based on the analysis of the vibration of the car body to unify judgment. However, for in-car equipment which is installed on the elastic support, the results capture traditional analysis is not exact. The study of the vibration detail characteristic is necessary which traditional analysis is very difficult to do. Railway vehicle random vibration efficient algorithm program can analysis the specific location for the further.

When the speed of vehicle is 250km/h, the maximums vertical acceleration standard deviation of the cabinet installation is $0.122\ \mathrm{m}/s^2$ and the lateral is $0.165\ \mathrm{m}/s^2$. In the vertical direction, the cabinet installation of the maximum acceleration standard deviation of the carbody decrease by 56%, this is for the reasonable design and installation location selected is more reasonable and the maximum lateral direction acceleration the carbody decreases by 17.5%. The parameters of the lateral installation design compared to vertical to be weak. It's also due to the installation structure of nature, for in the lateral direction there is only one bolt connect to the carbody, so according to the results, there still have some improvement to do for the structure.

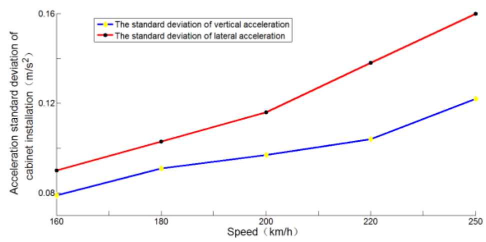
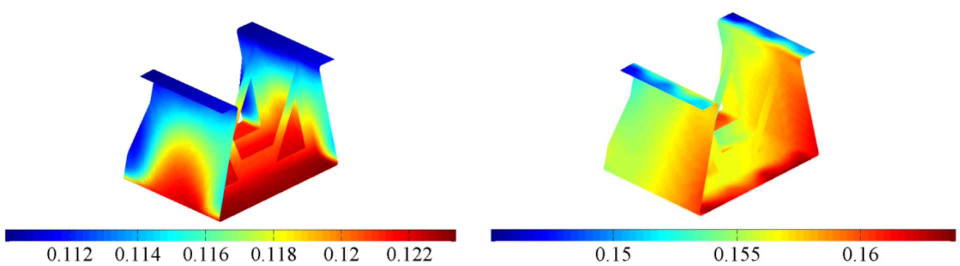


Figure7. Cabinet installation acceleration standard deviation



a) Vertical b) Lateral

Figure8.Vertical and lateral acceleration power spectrum of 250km/h

5 Conclusions

In this paper, we established cabinets of comprehensive inspection train structure model and an efficient vehicle random vibration process algorithm is employed to carry out random vibration analysis then we get the following conclusion:

(1) As the speed increases vertical and lateral acceleration standard deviation also increases and between 220-250km/h lateral acceleration standard deviation more sensitive.

(2) When the vehicle speed is 250 km/h, the vertical acceleration standard deviation of the cabinet installation is 0.122 m/s^2 and the lateral is 0.165 m/s^2. Cabinet installation in the vertical direction of the maximum acceleration standard deviation of the carbody vertical decreased by 56%, the maximum lateral direction acceleration of the carbody is decreased by 17.5%.

References

Lin Jiahao，Zhang Yahui(2004). Random vibration of Pseudo-excitation method. Bei Jing，Science Press，42-58

Moretti M，Triglia M，Maffei G(2004)．ARCHIMEDE-the first European diagnostic train for global monitoring of railway infrastructure//2004 IEEE Intelligent Vehicles Symposium. Parma，522-526

TONG Wei, WANG Di, GUO Hanfei, ZHANG Youwei(2013). Random Vibration Well-Meshed Structure Analysis of 25T Soft Berth Coaches. Journal of Dalian Jiaotong University, 58-62

Zhang Xiangning, Li Minggao(2012). Study on Rubber Isolator of Hoisting Device for Hanging EMU Equipment. Journal of Dalian Jiaotong University, 19-22

Zhang Youwei(2013). Efficient Random Vibration Analysis and Optimization for Coupled Vehicle-Track Systems.Da Lian, Dalian university of technology

Risk-Sharing Rationalization of an Intercity Railway PPP Project

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Abstract: The critical factor to achieve a PPP project is risk management. we need to analyze the connotation of the intercity railway PPP project first, then summarize the major risk factors of the project in every stage by collecting and studying the investigation. At last, we should build the mathematic model of the risk-sharing for the purpose of maximum satisfaction of the whole project to use game theory to acquire the result of the risk-sharing to sum up general principles in any risk taken by the participants of the biggest residual coefficients.
Keywords: Intercity railway; PPP project; Risk allocation; Game theory.

These years, PPP project has been widely used in the intercity railway construction. Owning to its large number of the participants, extensive covers, complex organization structure and huge difference in all parties' interest demand, the risks of every stage as well as the risk-sharing become highly critical in studying the intercity railway PPP project.

1 The Connotation of the PPP Project Taken by Intercity Railway Construction

Intercity railway is a transportation system with great passenger transporting capacity and connects every city in the urban agglomeration, which mainly helps transport passengers between big cities and the middle cities as well as those in middle and small cities to improve urbanization and the development of regional economic integration. The typical existed intercity railways are Beijing-Tianjin, Shanghai-Ningbo Pearl River Delta and so on.

PPP is the abbreviation of Public-Private-Partnership. Win-win or multi-win is the heart of PPP's cooperation idea. When participating in a project, responsibility won't be shifted to private enterprise, but is taken by both sides. The sectors or representatives of government call for bids to decide partner (private enterprise), set up a project company with the bidding company, and sign the franchising contract. During the franchising time, the project company is responsible for financing, and the government compensates for the private investment in the way of capital, land comprehensive development and so on. In short, the PPP project stresses on complementing each other's advantages, risk sharing and pooling-or-interest.

The PPP project is used essentially to construct the intercity railway by the government and private enterprises and finally come to the long-term cooperation relationship during the business time. Government grants the private enterprises franchise in a certain period and reasonable reward for investment to attract the third party, accelerate the railway construction, improve the service quality and release the traffic pressure. Government changes from the roles of the infrastructure investor or facilitator into the roles of administrator or cooperative to release the investment pressure and increase the public commodity supply. The private enterprise is allowed to join in railway construction, which widens the ways to invest the railway construction and activates the capital market.

2 The Stage Division and Major Risk Factors of the PPP Project

The intercity railway PPP project's operation process can be divided into 4 stages: preparatory phase, determination of the PPP project company, project implementation and project handover. Departments involved and main process are shown in graph 1.

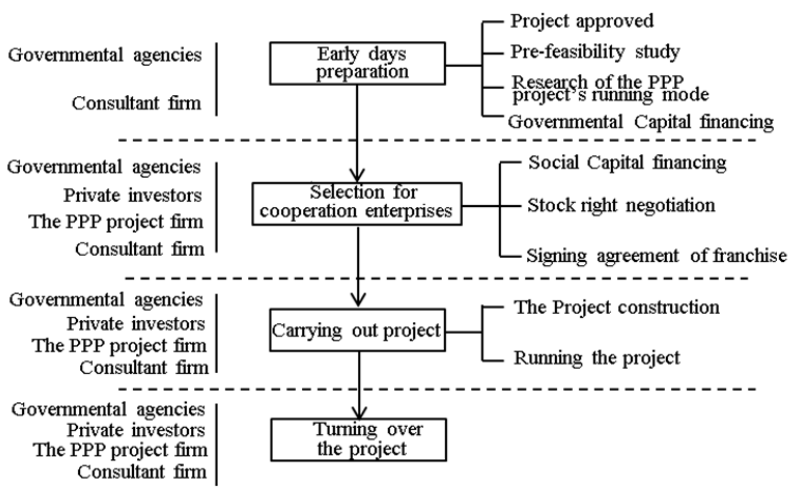

Figure 1. The PPP project's process of conduct

There are six main risks in the project, including: politics, finance, credit, and so on. Risks in every stage are shown in the table 1.

Table 1. The PPP project's risk

Risk sorts		Early days preparation	Selection for cooperation enterprises	Carrying out project	Turning over the project
Politics	Official corruption	✓	✓	✓	✓
	Official credit	✓	✓	✓	✓
	Examining and approving delay			✓	✓
	Newly released law	✓	✓	✓	✓

	tax			✓	✓
Finance	Inflation	✓	✓	✓	✓
	Exchange rate		✓	✓	✓
	Foreign exchange	✓	✓	✓	✓
	Failure of financial regulation		✓	✓	✓
Credit	Government default	✓	✓	✓	✓
	Private enterprises default	✓	✓	✓	✓
	Entrepreneur default			✓	✓
Closing	Resident removing and compensation			✓	
	Design change			✓	
	Budget overspending			✓	
	Delay			✓	
	Quality problems			✓	
Production And operation	Industrial disputes			✓	✓
	Bankruptcy			✓	✓
	Lack of management experience				✓
	Political opposition	✓	✓	✓	✓
	Bankruptcy of project firm			✓	✓
Market	Passenger flow	✓	✓	✓	✓
	Official price and profit limitation				✓
	Lack of side line business profit			✓	✓
	Mating infrastructure		✓	✓	✓

3 Risk-sharing's Model Building

3.1 Model Building

In the balanced market, profit is in positive correlation with risk, which means the greater the risk is, the higher the profit will be. Before the risk-sharing, the participants of the project have taken varieties of measure against all kinds of risks. Risks to be solved are inevitable, which means that how much profit or how many risks taken by participants is only related with the risks of their own. Assuming risk sharing each participating body is rational, targeting the overall satisfaction with the program risk-sharing schedule, the risk-benefit, cost of risk, the risk of resistance is known, the PPP project model is built.

Given that the project is divided into l stages, , $l \in (1,2,3,\cdots K)$, and i participants who are faced with j kinds of risks, $i \in (1,2,3,\cdots N)$, $j \in (1,2,3,\cdots M)$, we can use x_l^{ij} to represent that participant i undertake risk in stage j, $x_l^{ij} = \begin{cases} 0 & non-risk-sharing \\ 1 & risk-sharing \end{cases}$.

Any party in risk-sharing not only gets the profit but also pays for certain risk cost. Given that participant i's profit is Y_l^i and risk cost is C_l^i in stage l, then the follows are obtained：

$$Y_l^i = F(x_k^{nm}) \tag{1}$$

$$C_l^i = G(x_k^{nm}) \tag{2}$$

It's given that $\lambda = Y_k^i - C_k^i$, which is called risk residual coefficients. Only when $Y_k^i - C_k^i > 0$, activity will be created to cover the risks. The risk residual coefficients is linked with participants' activity and ability to control the risk when the risks occur. Under certain risk, the PPP project is aimed at getting maximum overall satisfaction, which means to get max risk residual coefficients. That is:

$$f(x_l^{ij}) = \max \sum_{l=1}^{K} \sum_{i=1}^{N} \sum_{j=1}^{M} \left[F(x_l^{ij}) - G(x_l^{ij}) \right] \cdot x_l^{ij} \tag{3}$$

Given that $H(x)$ is the function of the ability to undertake the risk, with the different resource taken by every participant and the different ability against risk, D_l^i is used to express that participant i in l stage can take how many risk. Then we get:

$$\sum_{j=1}^{M} H(x_l^{ij}) \le D_l^i \tag{4}$$

Generally speaking, a participant only takes one sort of risk. However, because a few risks are special such as act of god, two or more participants have to go through these risks. Given that the number of these participants are certain, W_l^j is used to express that participant j takes most kinds of risks in stage l, we can get:

$$\sum_{i=1}^{N} x_l^{ij} \le W_l^j \qquad (5)$$

With (3)、(4)、(5), we can get optimized model as follows:

$$f(x_l^{ij}) = \max \sum_{l=1}^{K}\sum_{i=1}^{N}\sum_{j=1}^{M}\left[F(x_l^{ij}) - G(x_l^{ij})\right]\cdot x_l^{ij}$$

$$S.t \quad \sum_{j=1}^{M} H(x_l^{ij}) \le D_l^i \quad i \in (1,2,3,\cdots N),\quad l \in (1,2,3,\cdots K)$$

$$\sum_{i=1}^{N} x_l^{ij} \le W_l^j \qquad j \in (1,2,3,\cdots M), l \in (1,2,3,\cdots K)$$

$$x_l^{ij} = 0,1 \qquad i \in (1,2,3,\cdots N), j \in (1,2,3,\cdots M), l \in (1,2,3,\cdots K),\quad W \in (1,2,3\cdots,N)$$

3.2 Analysis of risk-sharing result

In a PPP project, risk profit cost and ability against risk can be worked out in some ways, and then the reliable result will be obtained by the model. From the model, the existence of the best risk-sharing projects is reasoned in theory. Given that risk residual coefficients function is linear, there is enough power against the risk and a participant at most take one risk, we will find that a risk is taken by a participant with the highest risk residual coefficients and that the overall satisfaction is max. That is, in a certain risk, the lager the risk residence is, the more suitable it is to take this risk.

Considering only officials and private enterprises conducting a project who aim at max overall satisfaction of risk-sharing, government need to keep balance between the economical profit and the social profit by using the game theory to negotiate with the private to come to that state.

(1) When λ of government and the private enterprises is less than 0, in this game, both sides will meet Nash-Equilibrium. However, considering the purpose (to acquire max overall satisfaction), the one whose λ is biggest take this kind of risk.

(2) When government's λ is more than 0 while the private is not, only one can meet the Nash-Equilibrium. Because of the private's weakness in the risk, the government should bear it.

(3) When the private's λ is more than 0 while the government's is not, it is similar to（2）, the private enterprises should bear the risk.

(4) When λ of both of them is less than 0, none of them can meet the Nash-Equilibrium and is unwilling to assume this kind of risk. Once the risk is taken by any side, the party must pay cost. In this situation, they have to negotiate with each other to come to the appointment that they will bear the risk together and decide how much each party should bear.

4 Conclusions

Here we may draw the following conclusions:

(1) The government departments should undertake the risk of legal change, service facilities and other aspects because it has stronger resistance than the private sector. Financing and market risks should be taken by the private sector because they are more powerful in control these problems that are directly related with their profit. In most situations, the private take steps to move their troubles to contractors, suppliers, carriers, banks or insurance firms. Due to lacking of control against act of god, the government department and the private sector must sign the contracts to undertake these risks jointly after negotiation in order to design the risk aversion mechanisms (such as price adjustments, extending the concession period, the buffer fund, etc.) to avoid them.

(2) Varieties of the risks are shared by all participators. Academically, risks should be given to those who are reliable and full of power to bear them, which means that the risk in a stage should be assumed by those whose risk residual coefficients are biggest, so that during the project period the overall satisfaction will reach the maximum. However, in the process of project, risk-sharing is a course of dynamic game among the all parties, which finally leads to Nash-Equilibrium to benefit maximization of all participants and realize Pareto Optimality.

It is firmly convinced that the more deeply the PPP project is studied, the more standardized and reasonable the recognition and allocation of the mechanism for railway PPP project risk are. Therefore, there is no doubt PPP financing mode will play an increasingly critical role in Chinese intercity railway construction.

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References

A . Ng , M artin Loosemore Risk-sharing in the private provision of public infrastructure *International Journal of Project Management* 25(2007)66-76.

LIU Jiang-hua. A Research on the Issue of the Risk During the Project Financing. *Wuhan: Department of Economic and Management in Wuhan University*, 2005.

Forecasting Method for Urban Rail Transit Ridership at the Station-Level Using a Weighted Population Variable and Genetic Algorithm Back Propagation Neural Network

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Abstract: Distance-decay affect of contribution rate of population in different distance to ridership has not been considered in current model. As a result, prediction of ridership at station-level is not accurate. Population in near distance to the station contributes more to ridership than that in far distance. So population used to predict should be weighted by corresponding contribution rate. Multivariate correlation analysis is used to analyze relationship between weighted population and ridership, and also to analyze relationship between other predictors and ridership, which can pick out significant predictors affecting ridership. To solve the irrationality of linear prediction model, model of Back Propagation Neural Networks (BP) which can express strong relation between independent and dependent elements and needs no formula in detail has been built. To avoid local solution, Genetic Algorithm (GA) is used to improve the model. Ridership result predicted by GA-BP with weighted population is compared with that predicted by linear model with weighted population, that predicted by GA-BP with total population and that predicted by linear model with total population. The comparation shows model in this essay exceeds others, taking minimum and maximum relative error, average relative error, and root of mean square error into consideration. So, GA-BP model with weighted population is perfect when forecasting ridership of urban railway transit at station-level.
Keywords: Ridership of urban railway transit at station-level; Weighted population; Back propagation neural networks; Genetic algorithm.

Urban Rail Transit (URT) ridership at the station-level is an important component of URT ridership, which is critical for determining the scale of stations and access facilities. There is a strong interrelation between land use within station service area and ridership at station-level whereas change of land use can cause sudden change of ridership. General "four-step" (McNally, 2000; Li, 2009; Wang, 2009; Shi, 2011) and "trip chain" (Dong, 2012; Lan, 2009) methods are not suitable for this timely ridership prediction. Because this two methods rely on complex basic reference of OD and focus on regional all transport modes, which cost a large amount of time and money. They belong to static prediction and can not supply timely ridership varied by land use change within service area of station.

Multivariable regression is able to predict timely ridership according to land use change within service area of station, which takes predictors as independent variable and ridership result as dependant variable. References (Zhao,2003; Kuby,2004; Chu, 2004;Javier,2011) analyze specific main elements affecting ridership, among which inhabitant population and employment are recognized as the important elements. References (Kuby,2004;Chu,2004) take inhabitant population and employment and other element affecting ridership as independent variable and use linear regression to predict daily ridership. There exists two problems in previous research. The first is that total population used in the prediction model which do not comply with distance-decay rule. Taking Aoto Station in Tokyo, Japan as an example, within service area of the station, 0-1km, 1-2km, 2-3km, 3-4km bands population contributes to the ridership at the rate 0.48，0.094，0.013, 0.005(unit: person/person). So population needs to be weighted by corresponding rate according to the distance to the station,

Another problem is irrational using of linear regression. There are so many issues which are not considered clearly in the model, for example, effect of the balance of inhabitant population and employment on ridership is non-linear. However, there are so many expressions for non-linear relationship, which make the specific expression for this prediction difficult to decide. It is necessary to find out one specific model which can express relationship between predictors and the ridership in our essay.

1 Key Predictors Affecting Ridership

Referring to (Zhao,2003;Kuby,2004;Chu,2004;Javier,2011), select preliminary predictor such as weighted population, road density, number of shuttle lines, land use mix within the service area of station, number of unidirectional trains, number of interchange lines, number of park&ride facilities of the station, whether the station is terminal or not, distance from station to city center.

Weighted population means the accumulation of population multiplied by weight corresponding to the distance within the service area of the station. Total population means the accumulation of population within the service area of the station, in another words, weight is 1 for all population in different distance in this situation. The figure illustrating the weight is as follows.

Total population Weighted population

Figure 1. Weight of distance-decay and total population

Weighted population is calculated as follows:

$$P_i = \sum_{k=1}^{m} (p_k w_{ik}) = \sum_{k=1}^{m} (p_k g(d_{ik})) \tag{1}$$

P_i: Weighted population within service area of Station I;

p_k: Population of Traffic Zone k; d_{ik}: Distance from Traffic Zone k to Station i;

w_{ik}: Weight at distance d_{ik} from Station i; $g(d_{ik})$: Expression of weight, which is the function of d_{ik}; Reference (Blainey,2009) puts forward 5 types of expression (power function, normality negative exponential form, common negative exponential form, quadratic function, logistic function)

m: Number of traffic zones within Station i

Road density measures accessibility to the station. Higher road density can cause more ridership. Number of shuttle bus measures convenience to the station by bus; Land use mix is expressed by the following formula:

Higher land use mix (Lin,2008;Qian,2003) can bring high balance between inhabitant population and employment within the service area of station, which means less ridership.

$$P_{mix} = \left| D_{popu} \times \log_{10}(D_{popu}) \right| + \sum_{k=1}^{n} \left| (D_{em})_k \times \log_{10}(D_{em})_k \right| \tag{2}$$

Where:

P_{mix} is land-use mix ratio of service area;

D_{popu} is population density of service area (unit: per/hectare);

D_{em} is density of the k th type employment (unit: per/hectare) of service area;

n is total number of employment types in service area.

Number of unidirectional trains is accumulation of unidirectional trains departing from the station in peaking hour. If there exists a few lines in the station, that is total number of unidirectional trains of all the lines in peak hours. This element measures the attraction of station which affects the ridership.

Number of park&ride facilities measures interchange convenience from shuttle modes to the URT. More park&ride facilities mean more ridership.

Whether the station is terminal or not also measures the attraction of station. It is expressed by bi-variable, If it is, its value is 1, and if it is not, its value is 0.

Identifying key factors is critical. If all the above variables are used to formulate forecasting model, the performance of model will be unsatisfying because of the correlation between these variables.

Partial correlation analysis is used to find key factors to avoid other confounding factors when analyzing relationship between two variables. The formulas are listed as follows:

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}} \quad (3)$$

$$r_{xy,z_1} = \frac{r_{xy} - r_{xz_1} r_{yz_1}}{\sqrt{(1 - r_{xz_1}{}^2)(1 - r_{yz_1}{}^2)}} \quad (4)$$

$$r_{xy,z_1z_2} = \frac{r_{xy,z_1} - r_{xz_2,z_1} r_{yz_2,z_1}}{\sqrt{(1 - r_{xz_2,z_1}^2)(1 - r_{yz_2,z_1}^2)}} \quad (5)$$

$$r_{xy,z_1\ldots z_n} = \frac{r_{xy,z_1\ldots z_{n-1}} - r_{xz_n,z_1\ldots z_{n-1}} r_{yz_n,z_1\ldots z_{n-1}}}{\sqrt{(1 - r_{xz_n,z_1\ldots z_{n-1}}^2)(1 - r_{yz_n,z_1\ldots z_{n-1}}^2)}} \quad (6)$$

Where,

r_{xy} : Simple correlation coefficient of variable x and y ;

r_{xy,z_1} : Correlation coefficient of variable x and y when controlling z_1 ;

r_{xy,z_1z_2} : Correlation coefficient of variable x and y when controlling z_1 and z_2 ;

$r_{xy,z_1\ldots z_n}$: Correlation coefficient of variable x and y when controlling $z_1 \ldots z_n$;

x_i , $\bar{x}$: The i th value of variable x and the mean value of x ; The meaning of y_i , $\bar{y}$ is same as x_i , $\bar{x}$.

The partial correlation coefficient needs to be tested for significance further. The null hypothesis is that the partial correlation coefficient to be tested is not significantly different from zero. The corresponding T-statistic for the test is shown in Eq. 6.

$$t = \frac{r\sqrt{n-1}}{1-r^2} \tag{7}$$

Where,
t: Statistic value of test;
r : Partial correlation coefficient to be tested;
n :Sample size.

When degree of freedom is $n-1$, the probability value p corresponding to t is obtained to be compared with 0.01 and 0.05. If $p < 0.01$, association between the two variables is strongly significant. If $0.01 < p < 0.05$, association between the two variables is generally significant. If $p > 0.05$, association between the two variables is not significant.

2 Prediction Model of UMT

Liner model for prediction can not actually express the relationship between the key predictors and ridership. For example, in liner model, ridership is proportional to inhabitant population or employment population, which means, more population cause more ridership. However, if inhabitant population balances employment population within the service area of the station, which means inhabitant population do not seek job outside and do not take UMT and the ridership decrease, which is a nonlinear relationship.

Back Propagation Neural Network(BPNN) (Shi,2009) model is a typical type of artificial neural network, which can learn and save large amount of input-output reflection relationship, and needs no specific formula, having extraordinary large-scale processing and information distribution ability, which is generally used in function approaching, mode cognition, category and data compacting is selected as the forecasting model for URT ridership at station-level. Structure of BPNN includes input layer, hidden layer and output layer. The learning algorithm is comprised of upward spread of information and back propagation of errors. For the upward spread of information, nodes in input layer collect outside information and spread it to the nodes in hidden layer. According to information change ability, hidden layer can be designed of single or more layers. Finally, information spread from nodes in hidden layer to output layer can be output after the final processing. If actual output is not coincided with the expected output, back propagation of errors starts. Errors spread from output layer to hidden layer and then the input layer. In this process, weight and bias of layer are adjusted according to gradient descent. Periodical upward spread of information and back propagation of error are the process for weight and bias adjusting, which is also the learning process of BPNN, and the process will not stop until the output can be accepted.

BPNN is adopted to predict the UMT ridership at station-level.

2.1 BPNN Model

The theory shows that three layers BPNN can realize any reflection from input to output. So

Three layers BPNN model is adopted. According to experience, hypothesize that the number of key factors affecting ridership is n, which is also the number of nodes in input layer. In output layer, there is only 1 node: ridership. The number of nodes in hidden layer is $\left|\sqrt{n}\right|$, which is square root of product of number of nodes in input layer and number of nodes in output layer. Formula of BPNN model for forecasting ridership at station-level is constructed as follows:

min

$$E\left(w,b,v,c\right)=\frac{1}{2q}\sum_{p=1}^{q}\sum_{k=1}^{l}\left(O_k(p)-\widehat{O}_k(p)\right)^2 \tag{8}$$

Subject to

For output layer:

$$o_k=f\left(\sum_{j=1}^{m}v_{jk}y_j+c_k\right) \qquad k=1,2,\cdots l;\ j=1,2,...m \tag{9}$$

For hidden layer:

$$y_j=f\left(\sum_{j=1}^{m}w_{ij}x_i+b_j\right) \qquad j=1,2,\cdots m;\ i=1,2,...n \tag{10}$$

In which，transform function $f\left(x\right)=\frac{1}{1+e^{-x}}$

Where,

$E\left(w,b,v,c\right)$: The objective function, minimizing the MSE of the actual and predicted ridership;

w,v are matrix of weights variable;

b,c are bias vector variable ;

$O_k(p)$, $\widehat{O}_k(p)$: The actual and predicted ridership of the k th neurons in output layer of the p th station sample. In our model, there is only one node in output layer and thus $l=1$.

v_{jk}: The weight of the j th node in hidden layer related to the k th node in output layer;

w_{ij}: The weight of the i th node in input layer related to the j th node in hidden layer;

y_j: The output of the j th node in hidden layer;

x_i: The input of the i th node in output layer, that is the value of key variables;

c_k: The k th bias node in output layer;

b_j : The j th bias node in hidden layer;

m : Number of node in hidden layer, which is rounded off of $\sqrt{n}$.

n : Number of node in input layer.

q : Total number of station samples.

2.2 Solution of BPNN

Steepest gradient descent method is adopted to update the weight and bias at the each iteration *(28)*. The detailed solution steps are described as follows:

Step1: Initialization. Values of every weight and bias are randomly given within (-1, 1). Then, it is needed to set prediction accuracy and the maximum number of learning iterations.

Step2: Select input (predictors) /output (actual ridership) of any station randomly. Use BPNN with initial weights and bias to forecast and obtain the predicted ridership. Then, MSE can be obtained by comparing the predicted ridership with actual ridership of the station. Calculate partial derivative $\delta_o = (\hat{o} - o)o(1-o)$ which is from MSE to node in output layer.

Step3: Calculate partial derivative $\delta_h(j) = \delta_o v_j y_j (1-y_j)$ which is from MSE to nodes in hidden layer using v_{jk} , δ_o and y_j .

Step4: Adjust each weight v_{jk} using δ_o and y_j , that is $\Delta v_j = \eta \delta_o y_j$. Adjust each weight w_{ij} using $\delta_h(j)$ and x_i , that is $\Delta w_{ij} = \eta \delta_h(j) x_i$. η is the learning rate of BPNN.

Step5: Use BPNN and weights and bias obtained from Step 4 to forecast ridership of all stations using input (predictors) of these stations. Then, the objective function E , can be obtained by comparing the predicted ridership with actual ridership of all stations and summing the difference up. If E satisfies the prediction accuracy requirement or the maximum number of learning is satisfied, then the optimal value is obtained and the calculation procedures are terminated. Otherwise, select input (predictors) /output (actual ridership) of next station, back to Step2 and go to the next iteration:

2.3 Genetic Algorithm Optimize Initial Parameter of BPNN

Solution of BPNN relies greatly on initial weight and bias whose irrational selection will converge to local solution. However, GA is devoted to obtain the global solution because it only uses evaluated function, not gradient or other complementary information. Even for polymorphic and non-continuous function, it can also converge to nearly global approximation. As a result, GA is used to optimize the initial weight and bias of BPNN, and the optimized weight and bias are taken into BPNN for further solution. The steps are as follows: (1) Initialize iteration, group number, crossover proportion, mutation proportion; (2) Code the group with real value, taking the average error between the actual output and expected output as evaluation function.(in this essay, the evaluation function of GA is the goal function of BPNN); (3)Periodically process selection, crossover and mutation and compute the evaluation until iteration are reached. The chart flow that GA optimizes initial parameter of BPNN is as follows:

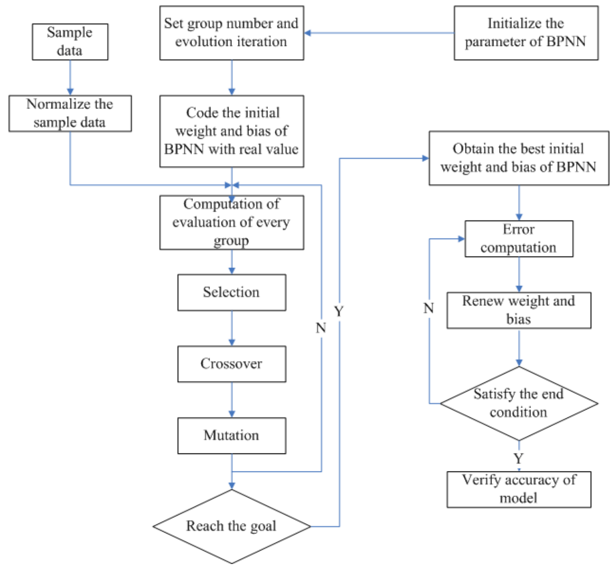

Figure 2. GA optimize BPNN

3 Case Study

3.1 Data source

Case study is the prediction of ridership entering the station in the morning peak hour in Tokyo, Japan, and the number of station selected is 33. The stations selected exist on JR, private railway, subway. Ridership data is referred to as "Total Rail Season Tickets Classified by Departure Stations and Inhabitant Zones of Tokyo" (MLIT of Japan,2010a) at 2010 which gives specific amount of ridership and which inhabitant zone they come from. Population data is referred to as "Day and Night Population Classified by Chomes" (MLIT of Japan,2010b) of Tokyo statistical information. Distance from the inhabitant zone to the station is gauged on google map along the road network. Taking Aoso station in Tokyo, Japan as an example, the code of inhabitant zone which produce the ridership, the specific amount of ridership, chomes in this inhabitant zone, distance from every inhabitant zone to the station and total population in the inhabitant zone are in Table 1.

Table 1. Ridership and population of Aoso Station in morning peaking hour

Code	Chomes	Ridership entering staion In morning peak hour(person)	Population (person)	Distance to station(km)	area(km^2)
12205	Shinjuku 5 - 6 chomes	21	3908	3.4	0.59
12213	Aoto 7 - 8 chomes、Kameari 1 - 2 chomes、Swan 4 chome	2305	10970	1.62	0.77
12218	Ohanajaya 1 - 3 chomes、Swan 1 - 3 chomes、Higashihorikiri 1 - 2 chomes	23	20276	1.91	1.12

12219	Aoto 1 - 6 chomes	8654	17873	0.34	1.17
12220	Okudo 7 - 8 chomes、Takasago 1 chome、Hosoda 2 chomes	1252	5789	1.5	0.81
12223	Menhir 1 chome、Menhir 3 - 4 chomes、Menhir 6 - 8 chomes	2780	16690	1.025	1.06
12224	Takaracho 1 - 2 chomes、Menhir 2 chome、Menhir 5 chome、Yotsugi 5 chome	75	15019	1.76	0.93
12230	Okudo 1 - 6 chomes	207	15933	2.4	1.41
Total		15317	106458		7.86

Road density is total road length divides total area within the service area of station(unit: km/km^2); Taking Aoso Station as an example, its road density is 18 km/km^2.

Data for land use mix within service area of the station refers to "The Number of Enterprises and Employment Classified by Chomes and Industries" (MLIT of Japan,2010c) of Tokyo statistical information, where the 16 types of employment are agriculture-forestry-fisheries, mining, construction, manufacturing, electrical, gas heating and water supply Industry, information and communications, transport, wholesale and retail trade, finance and insurance, real estate, restaurant accommodation, medical welfare, education and learning supported industry, composite services, services not classified, unclassified public services. Accumulate area of all chomes within service area of station, and accumulate population, all types of employment. Land use mix can be calculated according to Formula 2. Taking Aoso Station as an example, the population is 106458 persons and the above types of employment are 0, 0, 2005, 8421，74，192，3260，9061，692，1197，2959，4480，1993，94，4623，768 persons separately. The area is 7.86 km^2. And then the land use mix within service area of Aoso Station is 0.849.

Number of unidirectional trains, number of interchange lines, number of park&ride facilities of the station, whether the station is terminal or not, distance from station to city center all refers to official website of operation companies in Japan.(JR operation company, Keio Electric Railway, Keisei Electric Railway, Odakyu Electric Railway, Tokyo Metropolitan Bureau of Transportation, All Subway)

3.2 Selection of key predictors

3.2.1 Weight population

Weight curve of every station varies. Weight curves of urban stations are different from that of suburban stations. The two are also different from that of out-suburban stations. Because in out-suburban area, distance people would like to accept form their home to the station increases. Population locating at same distance to station contributes more in out-suburban area than that in urban area. As a result, stations are categorized to three types, that is urban area(0-15km), suburban area(15-30km) and out-suburban area(more than 30km). For every type station, draw the curve that contribution rate of population to ridership in different distance, which is weight curve for population.

Select another 48 stations of Odawara Line in Japan for statistic. Range from Shinjuku Station to Tamagawa Station belongs to urban stations, the number of which is 17. Range from Noborito Station to Machida Station belongs to suburban stations, the number of which is 10. Range from Sagamiono Station to Odawara Station belongs to out-suburban station, the number of which is 21. Accumulate total ridership and population at different distance within service area of every station of every type separately. Then fit them with 5 functions mentioned in Reference [11] on MATLAB. Taking residual sum of squares of the data as index, weight curve of three types of station are all normality negative exponential function curve. The specific formula of weight for population at different distance is in Figure 3.

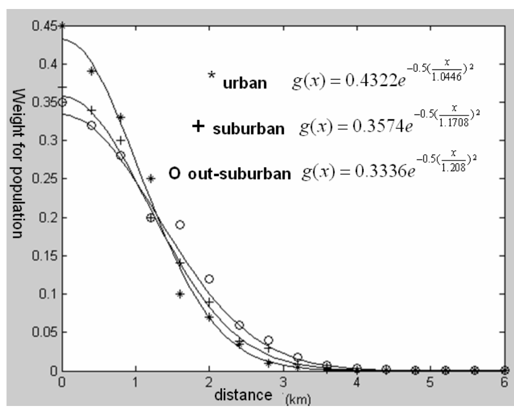

Figure 3. Weight curve of population in different area

Even though there exists unique feature for weight curve of every type of station. However, the above curve concluded can reflect whole trends of weight for population in this area and it is considered reasonable. Taking Aoso Station as an example, it is 9.6km away from the city center, belonging to urban stations, and so weight curve of urban station is chosen. Combining relative data in Table 1, compute the weight population within its service area according to Formula (1) as follows:

$$P = 3908 \times g(3.4) + 10970 \times g(1.62) + 20276 \times g(1.91) + 17873 \times g(0.34) + 5789 \times g(1.5) + 16690 \times g(1.025) + 15019 \times g(1.76) + 15933 \times g(1.41)$$

Which is 17858 persons.

3.2.2 Key predictors

Weighted population of 33 stations can be obtained according to Section 3.2.1. Combining with data statistic in Section 3.1, the value of road density, number of shuttle bus, land use mix, number of unidirectional trains in peak hours, interchange lines of station, number of PR facilities at station, distance to city center can be obtained. Correlation analysis can proceed according to Formula (3)—(7) in Section 1. The result is in Table 2.

Table 2. Correlation analysis between independent variables and ridership

	population		Road density	Number of shuttle bus	Land use mix	Number of unidirectional trains	Number of interchange lines	Number of P&R facilities	Whether it is terminal	Distance to the city center
	total	weighted								
ridership	-0.039	0.455**	0.07*	0.18*	0.164*	0.043*	0.101	0.251	0.028*	0.04

*** express significant**

**** express high significant**

The Figure 2 illustrates that the relative coefficient for total population and ridership is negative and they have no relation. Obviously, it is unreasonable to use total population as predictor. The relative coefficient for total population and ridership is 0.455, whose relation is high significant. The relative coefficient for number of unidirectional trains and number of interchange lines is 0.924 according to Formula (3)—(7), also whose relation is high significant, which means one predictor can be expressed by another one. As a result, combing with Table 2, the number of interchange lines is deleted. The relative coefficient for road density and distance to city center is 0.542, also whose relation is high significant. As a result, distance to city center is deleted. Finally, 6 variables that weighted population, road density, number of shuttle bus, land use mix, number of unidirectional trains and whether the station is terminal or not are selected as key predictors.

3.3 GA-BP model predicting ridership

3.3.1 Prediction model

6 key predictors are selected in Section 3.2, which means number of nodes in input layer is 6. As a result, number of nodes in hidden layer is $\sqrt{6}$, nearly 3. The 6-3-1 BPNN model is constructed, where the total number of weight that 6 nodes in input layer corresponds to 3 nodes in hidden layer is 18, and total number of bias of hidden layer is 3. the total number of weight that 6 nodes in hidden layer corresponds to 3 nodes in output layer is 3, and total number of bias is 1. Total number of value to be solved is 25. 28 stations' data are used to train and the other 5 stations' data are used to test.

3.3.2 GA optimize the parameter and solve the model

GA is used to optimize the initial weight and bias. ①Initialize the iteration of GA 100, group scale 30, mutation proportion 0.3, crossover proportion 0.1; ②Code weight and bias to be solved with real value, which is random value between [-1，1]. One group of code is a chromosome. Built 30 chromosomes randomly; ③Decode 30 chromosomes and put them in BPNN model and compute the goal Function (8) according to (9)—(11), which is also evaluation function of GA. ④Chromosome with minimum evaluation is selected among 30 chromosomes and inherit directly. Other chromosomes crossovers with each other at 0.3 proportion, mutates with each other at 0.1 proportion. As a result, a new generation chromosome come up. Repeat ③until 100 generation.

It shows that minimum evaluation in every generation in the process of optimization in Figure 3. It can be seen that rapid convergence comes up from beginning to 50 generations and then it slows to stability from 80 to 100 generations and the initial weight and bias are obtained.

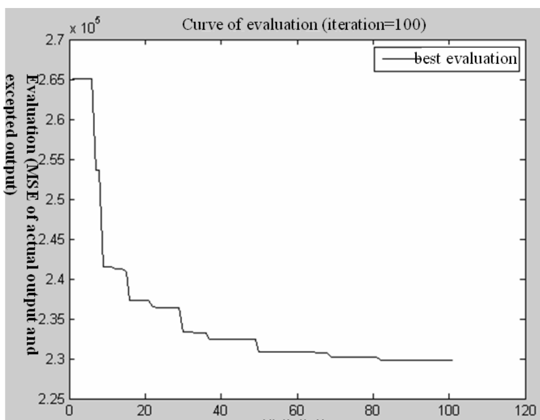

Figure 4. Iteration of initial parameter of BPNN optimized by GA

Put initial weight and bias after optimization into BPNN model, solve the model according to Section 2.2. Set calculation accuracy 0.001, the max number of iteration 30000. When the iteration reaches 25893, the accuracy of goal function is 0.001 and the algorithm stops. The final weight and bias is in Figure 5, where w in turn are weights that 6 variables (road density, number of shuttle bus, land use mix, number of unidirectional trains, whether the station is terminal or not and weighted population) corresponds to nodes in hidden layer. v in turn are weight that nodes in hidden layer corresponds to nodes in output layer. b are bias of nodes in hidden layer and c is bia of node in output layer.

Compare performance of BPNN with parameter which is not optimized with that with parameter which is optimized with GA. It can be obviously seen that BPNN with parameter which is not optimized can easily converge to local solution whose goal function is 0.1 and can not reach the global solution whose goal function is

0.001. That GA-BPNN can converge to the global solution shows its excellence.

$$w=\begin{bmatrix}0.8624 & 0.3358 & -0.4343\\ -0.3238 & 0.2069 & 0.1619\\ -0.331 & -0.0064 & 0.1036\\ -0.7171 & 0.5506 & -0.207\\ 0.041 & 0.4145 & -0.8768\\ -0.9031 & 0.3747 & 0.5604\end{bmatrix},v=\begin{bmatrix}-0.7904\\ -0.7442\\ 0.0991\end{bmatrix},b=\begin{bmatrix}-0.3248\\ 0.2157\\ 0.4825\end{bmatrix},c=-0.214$$

Figure 5.The final weight and bias of GA-BP neural network

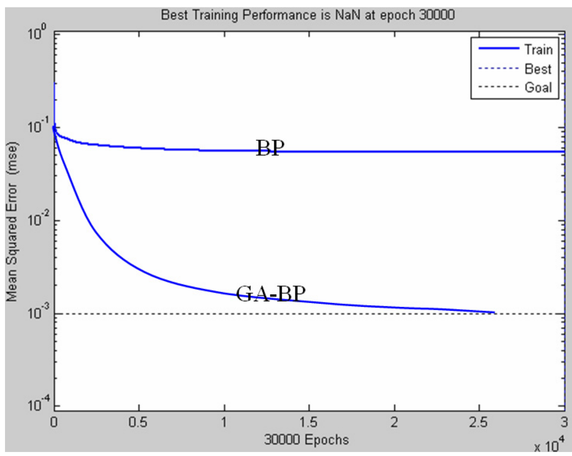

Figure 6. Compare of training performance between GA-BP and BP

3.3.3 Analysis of model result

To verify the excellence of GA-BPNN model with weighted population for prediction, we compare the result of it with the result of GA-BPNN model with total population, the result of linear model with weighted population, the result of linear model with total population. The other 3 models also take the same 28 station data for training and another 5 station data for test. The linear model is based on SPSS software for regression. The compare is in Table 3. Average absolute error and average relative error of GA-BPNN model with weighted population are minimum, which means it can reflect the interrelation between predictors and ridership actually. After this interrelation is decided, ridership can be predicted timely if one predictor changes.

Table 3. Indexes of four kinds of model

station	GA-BPwith weighted population	GA-BP with total population	Linear with weighted population	Linear with Total population	Actual ridership
Hikifune	2278	3049	2899	1049	2406
Horikiri	350	483	259	560	372
Kita-Senju	12302	10566	11265	6783	12503
Gatannno	10854	8259	13225	9096	10736
Nishiarai	17028	13220	18543	27557	16956
Average absolute Error(%)	108	1781	1184	3901	
Average relative error(%)	1.26	20.7	13.8	45.4	

4 Conclusion

(1) The factors affecting the UMT ridership at station-level is analyzed. Weighted population is put forward for the distance-decay rule. To avoid deviation, key predictors should be selected by multivariate correlation analysis.

(2)BPNN model is constructed for prediction. Because solution of BPNN relies on initial weight and bias greatly, GA is used to optimized the parameter.

(3)Relative data of 33 stations in Tokyo, Janpan are used to train and test the model, where the weight curve for population is fit according to the data of Odwara Line in Japan. Relative analysis is used to seek the relationship between factors affecting ridership and ridership. As a result, 6 variables are selected as key predictors, based on which, construct BPNN model with 6 nodes in input layer, 3 nodes in hidden layer and 1node in output layer. Compare of the result of GA-BPNN with weighted population with BPNN with weighted population shows that GA-BPNN can get global solution. Compare of the result of GA-BPNN with weighted population with the other three models(GA-BPNN with total population, linear model with weighted population, linear model with total population) shows the excellence of GA-BPNN model with weighted population.

(4)Case study in this essay is prediction of ridership in morning peak hour. The model put forward by this essay can also be used to predict ridership in dawn peak hours and daily ridership at station-level.

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References

Blainey, S.P. (2009). "Forecasting the Use of New Local Railway Stations and Services Using GIS". *Thesis for the degree of Doctor of Philosophy*, University of Southampton.

Chu, X. (2004). "Ridership Models at the Stop Level". National Center of Transit Research, University of South Florida.

Dong, Z.G. (2012). "Trip-chain model research of Shanghai railway transit".Research on Urban Rail Transit, 15(7):15-21.

Javier, G., Cardozob, O.D., García-Palomares, J.C. (2011). "Transit ridership forecasting at station level: an approach based on distance-decay weighted regression". Journal of Transport Geography. 19, 1081–1092.

Kuby, M., Barranda, A. (2004), Upchurch, C. "Factors influencing light-rail station boardingsin theUnited States". Transportation Research Part A 38,223–247.

Li, M., Wang, H. (2009). "Ridership prediction model research of transit railway station". Rail Engineering Journal, (3):67-71.

Lan, P., (2009). "Ridership prediction model research based on trip-chain". Beijing: Beijing Jiaotong University.

Lin, H., Li, J. (2008). "Research of relationship between trip space distribution and mix of land use". Program Research,9(32):53-57.

McNally, M.G., (2000). "The Four Step Model". Institute for Transportation Studies,University of California, Irvine.

MLIT of Japan. (2010a). http://www.mlit.go.jp/sogoseisaku/transport/sosei_transport_tk_000035.html>(Mar. 20, 2012)

MLIT of Japan. (2010b). http://www.toukei.metro.tokyo.jp/tyukanj/2010/tj-10index.htm>(Aug.14,2013)

MLIT of Japan. (2010c). http://www.toukei.metro.tokyo.jp/jigyou/2006/jg06v20100.htm(Mar.1,2013)

Qian, L. (2003). "Trip space distribution of people and mix of land use". City Research. (3):7-11.

Shi, C., Yang, C. (2011). "Ridership analysis of urban rail transit based on trip-chain". Research on Urban Rail Transit, 14(4):29-32.

Shi, Y., Han, L., Lian, X. (2009). "Design and case analysis of neural network". Press of Beijing University of Posts and Telecommunications.23-70.

Wang, W. (2009). "Ridership prediction research on transit railway of Fuzhou". Wuhan: Wuhan Technology University.

Zhao, H.(2003). "Forecasting Transit Walk Accessibility: A Regression Model Alternative to the BufferMethod". Transportation Research Record: Journal of the Transportation Research Board, (1835) 34-41.

Bus System Evaluation Based on a Structure Entropy Weight-Matter Element Analysis Method

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Abstract: It is important to evaluate bus system development level for public transportation system operations management. In his paper, 22 indicators are selected to establish the evaluation target system of the bus system development level. A new combined evaluation method based on structure entropy weight- matter element analysis is proposed. In this method, structure entropy method can make the weight calculation more objective, matter element analysis can ensure the integrity of the qualitative and quantitative information and easier to operate. Finally, case study of Dalian, after analyzing the particularity of bus system in Dalian, it specifically evaluates the development level of the bus system in Dalian used structure entropy weight - matter element analysis method, and gets the level is “medium”, among all of the indicators, the rating of peak hour load factor is “pass”, then it proposes some reference countermeasures to improve the development level of bus system in Dalian for the evaluation results.
Keywords: Urban transportation; Public transit; Evaluation; Structure entropy weight; Matter element analysis.

1 Introduction

The rapid growth of car brings a lot of problems to limited road space, this determines the cities must give priority to the development of public transport system. Now the development level of the public transport system is lagging behind in large and medium-sized cities, especially the regular bus system. Therefore, a whole, objective and impartial evaluation and analysis is particularly important for public transport system, by assessing and analyzing the operate situation of public transport systems, propose a more reasonable, high feasibility of improving program has become more urgent.

In recent years, various combinations of evaluation model are widely used in public transport evaluation system, especially the method which combined AHP and other methods is favored by the majority of scholars (Yang et al. 2014, Guo et al. 2014, Meng et al. 2012). It is worth mentioning that, in addition to the common method AHP, a current method named Structure Entropy method is increasingly used to determine the weight. At the same time, the evaluation model which combined Structure Entropy weights method and other evaluation method is continuous exploring (Xie et al. 2014).

This paper establishes the evaluation system of regular bus system from the facility level, benefit levels, service level. In terms of evaluation method selection, I choose the Structure Entropy weights method which combined qualitative analysis and quantitative analysis to determine the weights. A more concise and easier to operate evaluation methods which named Matter Element Analysis method is combined with Structure Entropy weights method, forming a new combination evaluation model applied in this paper.

2 Evaluation System

The valuation of urban public transport system contents lots and involves broad, Therefore, evaluation of selected factors also should be considered more. This article selected 22 specific indicators from the facility level, efficiency level, service level to build the of regular transit system evaluation system (Ren et al. 2014, Huang et al. 2011) (as shown in Figure 1).

3 Structure Entropy - Matter Element Analysis Introduction

Structure Entropy weight method is a new method to determine the weights which combined qualitative analysis and quantitative analysis. Its basic principle is to combine Delphi expert method and fuzzy analysis method. First of all, it forms a typical sort. Then it uses entropy decisions formula to calculate entropy and analysis blind degree. At the same time, it also statistics and processes the potentially bias data.

Matter-element theory as a modern uncertainty theory of mathematic determines the relevance of the target element by considering the distance and position between every index value and its classical field and segment field, then determine the level according the classical field that the correlation value belongs to. This method can analysis both qualitative and quantitative factors. And its result is in the real number field, to some certain extents, this overcomes the loss and changed of the information. In this paper, a comprehensive evaluation method that combine Structural Entropy weight method and Matter Element Analysis named Structural Entropy - Matter Element Analysis is applied. Its specific steps are shown below(as shown in Figure 2).

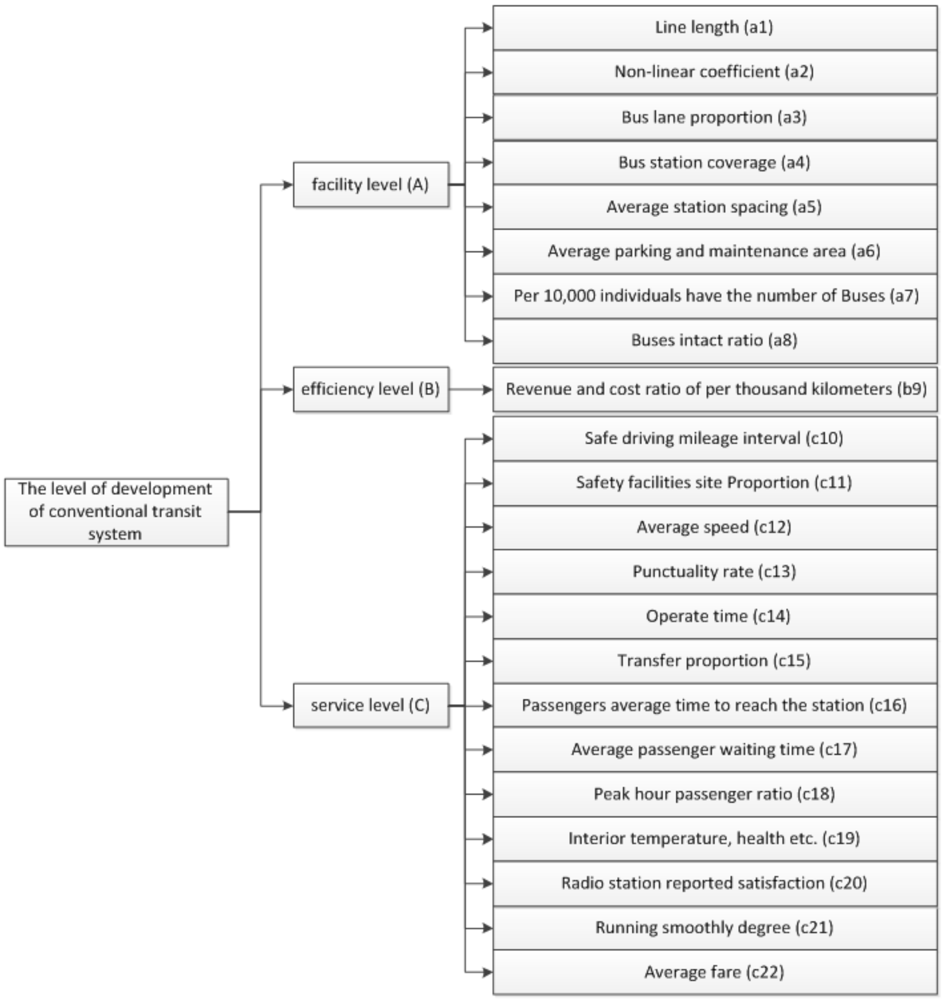

Fig.1 Evaluation index system of bus system

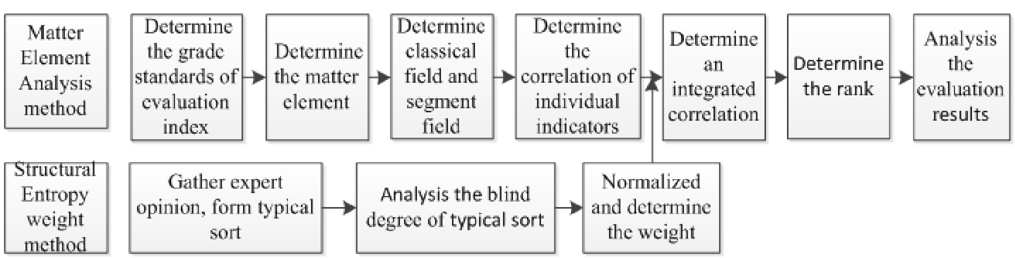

Fig.2 The steps of structure entropy weight - element analysis evaluation model

3.1 Evaluation Grade Standard

After reviewing the relevant literature, this article gives the index evaluation criteria of regular bus system, making the evaluation more fair and objective. The specific evaluation criterion is shown below.

Table 1 Evaluation indicators grade standard recommended value(Wang 2003)

	Index Name	Grade standard				
		A (Excellent)	B (Good)	C (Medium)	D (Passing)	E (Poor)
a1	Line length (km)	[10,15]	[5,10],(15,20]	(20,25]	(25,30]	(30,50]
a2	Non-linear coefficient	[1,1.4]	(1.4,1.9]	(1.9,2.4]	(2.4,2.9]	(2.9,3.5]
a3	Bus lane proportion (%)	(30,100]	(20,30]	(10,20]	(5,10]	[0,5]
a4	Bus station coverage (%)	(95,100]	(85,95]	(75,85]	(65,75]	(0,65]
a5	Average station spacing (m)	(0,300]	(300,500]	(500,700]	(700,900]	(900,2000]
a6	Average parking and maintenance area (km^2)	(200,300]	(180,200]	(160,180]	(140,160]	(0,140]
a7	Per 10,000 individuals have the number of Buses	(30,50]	(25,30]	(20,25]	(15,20]	(0,15]
a8	Buses intact ratio (%)	(95,100]	(90,95]	(85,90]	(80,85]	(50,80]
b9	Revenue and cost ratio of per thousand kilometers	(1.6,10]	(1.4,1.6]	(1.2,1.4]	(1,1.2]	(0,1]
c10	Safe driving mileage interval (million km)	(1.50,5]	(1.3,1.5]	(1.1,1.3]	(0.9,1.1]	(0,0.9]
c11	Safety facilities site Proportion (%)	(90,100]	(80,90]	(70,80]	(60,70]	[0,60]
c12	Average speed (km/h)	(25,50]	(20,25]	(15,20]	(10,15]	(0,10]
c13	Punctuality rate (%)	(90,100]	(80,90]	(70,80]	(60,70]	(0,60]
c14	Operate time (h)	(18,24]	(16,18]	(14,16]	(12,14]	[3,12]
c15	Transfer proportion (%)	(0,22]	(22,30]	(30,40]	(40,50]	(50,100]
c16	Passengers average time to reach the station (min)	(0,5]	(5,10]	(10,15]	(15,20]	(20,40]
c17	Average passenger waiting time (min)	(0,5]	(5,10]	(10,15]	(15,20]	(20,40]

c18	Peak hour passenger ratio (%)	(0,70]	(70,80]	(80,90]	(90,100]	(100,150]
c19	Interior temperature, health etc. (%)	(90,100]	(80,90]	(70,80]	(60,70]	(0,60]
c20	Radio station reported satisfaction (%)	(90,100]	(80,90]	(70,80]	(60,70]	(0,60]
c21	Running smoothly degree (%)	(90,100]	(80,90]	(70,80]	(60,70]	(0,60]
c22	Average fare (yuan)	(0,1]	(1,2]	(2,3]	(3,4]	(4,10]

3.2 Determine Matter Element，Classical Field and Segment Field

The evaluation object denoted thing U, each index as feature $C=(c_1,c_2,\ldots,\ c_n)^T$. the value of Features denoted $X=(x_1,x_2,\ldots,\ x_n)^T$. The three elements with sequence $R=(U,C,X)$ composed the matter-element (Cai 1994) denoted:

$$R=\begin{bmatrix} M & c_1 & x_1 \\ & c_2 & x_2 \\ & \cdots & \cdots \\ & c_n & x_n \end{bmatrix} \tag{1}$$

Among them: x_i is the value of c_i , (i=1, 2,…,n).

The value of c_i is $x_{oji}=[a_{oji},b_{oji}]$ (i=1, 2,…, n)，named classical field (Cai 1994) ，and $X_{oji}=[x_{oj1},x_{oj2},\ldots,\ x_{ojn}]^T$, so the matter element of classical field is shown as below.

$$R_{oj}=\begin{bmatrix} M_{oj} & c_1 & x_{oj1} \\ & c_2 & x_{oj2} \\ & \cdots & \cdots \\ & c_n & x_{ojn} \end{bmatrix}=\begin{bmatrix} M_{oj} & c_1 & [a_{oj1},b_{oj1}] \\ & c_2 & [a_{oj2},b_{0j2}] \\ & \cdots & \cdots \\ & c_n & [a_{ojn},b_{ojn}] \end{bmatrix} \tag{2}$$

Segment Field is denoted by Rp .

$$R_p=\begin{bmatrix} M_p & c_1 & x_{p1} \\ & c_2 & x_{p2} \\ & \cdots & \cdots \\ & c_n & x_{pn} \end{bmatrix}=\begin{bmatrix} M_p & c_1 & [a_{p1},b_{p1}] \\ & c_2 & [a_{p2},b_{p2}] \\ & \cdots & \cdots \\ & c_n & [a_{pn},b_{pn}] \end{bmatrix} \tag{3}$$

3.3 Structure Entropy Method to Determine Weight

(1) Gather experts opinion, form typical sort

If there are 22 indicators, the qualitative ordering number from 1 to 22, 1 represents the most important and 22 represent the most important, the rest is similar. This is typical sort.

(2) Analysis the blind degree of typical sort

To reduce the uncertainty of typical sort, it is necessary to statistical analysis and process the qualitative judgment conclusion as follows.

There are k experts consult in the investigation, we will get k pieces of consult papers, each one corresponding to an index set, denoted $U=\{u_1,u_2,\ldots, u_n\}$, the Corresponding typical sort denoted $(a_{q1},a_{q2},\ldots,a_{qn})$. So k pieces of consult papers give an indicators sort matrix $A(A=(a_{qi})_{k\times n}, q=1,2,\ldots,k, i=1,2,\ldots,n)$. The a_{qi} represents the evaluation from *q-th* expert to *i-th* indicator, and the value of $a_{q1},a_{q2},\ldots,a_{qn}$ choose from $\{1,2,\ldots,n\}$ (Cheng 2010).

After transforming the qualitative order, we define it is membership function.

$$\zeta(I)=\frac{\ln(m-I)}{\ln(m-1)} \tag{4}$$

I is the number of qualitative order, $\zeta(I)$ is membership function value, I=1,2,⋯,n, n is the number of indicators, m is the conversion parameter, m=n+2. If we put $I=a_{pi}$ to formula (4), we can get $b_{pi}(\zeta(a_{pi})=b_{pi})$, b_{pi} is the membership value, $B=(b_{pi})_{k\times n}$ is the membership matrix.

We think the k experts give same contribution to the same indicator ζ_i, then we denote the k experts' average contribution to ζ_i by b_i.

$$b_i=(b_{1i}+b_{2i}+\ldots+b_{ki})/k \tag{5}$$

We define the *q-th* expert uncertainty cognitive to ζ_i as the blind degree, denoted by Qi.

$$Qi=\left|\left\{\left|\max(b_{1i},b_{2i},\ldots,b_{ki})-b_i\right|+\left|\min(b_{1i},b_{2i},\ldots,b_{ki})-b_i\right|\right\}/2\right| \tag{6}$$

The overall understanding of the k experts to ζ_i is denoted by x_i.

$$x_i = b_i(1-Q_i), x_i > 0 \tag{7}$$

So the evaluation matrix of the k experts give to the all indicators as $X = (x_1, x_2, \ldots, x_n)$.

（3）Normalization

If we make $w_i = x_i / \sum_{i=1}^{m} x_i$ ， then $W = (w_1, w_2, \ldots, w_n)$ is the weight matrix of $U = \{u_1, u_2, \ldots，u_n\}$.

3.4 Determine the Correlation Coefficient

Correlation function is correlation of evaluated level, it means that the similarity between the two grades. Extension Set correlation function can be expressed algebra, making things incompatible quantified (Cai 1994).

Suppose the distance from one point x_i to an interval $x_{oji} = [a_{oji}, b_{oji}]$ is following.

$$\rho(x_i, x_{oji}) = \left| x_i - \frac{a_{oji} + b_{oji}}{2} \right| - \frac{b_{oji} - a_{oji}}{2} \tag{8}$$

Similarly, we can also get the distance from x_i to $x_{pi} = [a_{pi}, b_{pi}]$.

So the correlation function is following.

$$k(x_i) = \begin{cases} \dfrac{-\rho(x_i, x_{oji})}{|x_{oji}|}, & x_i \in x_{oji} \\ \dfrac{\rho(x_i, x_{oji})}{\rho(x_i, x_{pi}) - \rho(x_i, x_{oji})}, & x_i \notin x_{oji} \end{cases} \tag{9}$$

3.5 Determine the Grade Level of Evaluation

If we have the correlation and weight of all indicators, we can get the summing correlation.

$$L(x_i) = \sum_{i=1}^{n} w_i k(x_i) \tag{10}$$

Correlation value indicates the degree of compliance with the grades. The larger the value, the thing is more in line with the grade. This evaluation level is determined based on the principle of maximum degree of membership.

4. Case of Dalian Evaluation

Dalian unique geographical conditions make conventional transit system has a greater degree of influence for the residents. By investing the development level of Dalian bus system, we get the value of each index in the table below.

Table 2 Evaluation indicators values of bus system in Dalian

indicator	value	indicator	value	indicator	value	indicator	value
a1	15.9	a7	22.5	c13	75	c19	80.7
a2	1.72	a8	98.9	c14	15	c20	75.45
a3	15.3	b9	1.25	c15	35	c21	74.95
a4	92	c10	1.48	c16	10.4	c22	1.67
a5	607.2	c11	99.7	c17	4		
a6	168	c12	17.5	c18	94.5		

Combined with the above data, the weight and evaluation result by using the structure entropy method and matter-element analysis method is in the table below.

Table 3 Correlation calculations Fact Sheet

indicator	weight	result	indicator	weight	result	indicator	weight	result
a1	0.044	good	b9	0.053	medium	c17	0.050	excellent
a2	0.051	good	c10	0.047	good	c18	0.056	passing
a3	0.041	medium	c11	0.035	excellent	c19	0.022	good
a4	0.055	good	c12	0.058	medium	c20	0.023	medium
a5	0.052	medium	c13	0.057	medium	c21	0.033	medium
a6	0.036	medium	c14	0.043	medium	c22	0.050	medium
a7	0.057	medium	c15	0.052	medium	summing	1	medium
a8	0.042	good	c16	0.043	medium			

Look at the table 3, we can know that most indicators are in the medium level, few indicators rank excellent, good, passing .We haven't obtained the poor level. The summing results of comprehensive correlation is $k_3 = \max_{j=1,2,3,4,5} L(x_i) = 0.1218$, The results show that the public transport system in Dalian ranks the medium level. Among them, in the evaluation of the results of a single index, the evaluation rating of "passing" is only one---The load factor of peak hours. Therefore, relevant departments should take serious measures towards this index in order to promote the development of public transport system in Dalian. Following recommendations are presented below: Increase the number of buses which are loaded with a higher rate.

Ensure that a bus can be taken during peak hours and reduce the grid spacing, thereby reducing load factor of peak-hour.

5 Conclusions

Now the development level of bus system in a lot of cities has the problem that the bus system cannot meet the need of people travel. Therefore, the operation situation of bus system needs a whole, objective and impartial evaluation and analysis, so that we can propose some targeted and high feasibility improving program. This paper presents an evaluation method that based on structure entropy - Matter Element Analysis. This combination evaluation method can work with the characteristics of qualitative and quantitative factors well. Using Entropy method to determine weight improve the objectivity of the weight calculation. Matter element analysis method can reduce the distortion of information of evaluation. it is also an easy method to operated. In this paper, we use the conventional method to carry out the actual calculation and evaluation of the public transport system in Dalian city. We get a comprehensive evaluation grade of conventional public transport system in Dalian, it ranks intermediate level. These indicate that the conventional public development in Dalian is in general level. This paper takes Dalian as an example to ensure the effectiveness of this combination evaluation method, and I hope this method can provide some reference to the public transport system evaluation of other cities.

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References

CAI W. (1994). "Matter element model and its application". *Beijing: Science Press*.

CHENG Q Y. (2010). "Evaluation index weights determined by the structure of entropy method". Systems Engineering-Theory & Practice,30(7)：1225-128.

GUO X Z, WENG X X. (2014). "Bus service fuzzy comprehensive evaluation based on AHP". Journal of transport information and safety, 32(03):42-46.

HUANG S, MENG J Y, WANG X Y. (2011). "Index system of evaluation of small urban public transport". Journal of transport information and safety, 29(01): 32-36.

MENG J, ZHAO L X. (2012) "Evaluation system study of urban public transport services". Journal of Wuhan University of Technology (Transportation Science & Engineering), 32(03):620-623.

REN Q L, XIAO Q R, YANG Y et al. (2014). "Public transportation convenience evaluation studies based on vague matter element". Journal of transport information and safety, 32(02): 50-56.

WANG W. (2003). “Urban traffic management evaluation system”. Beijing: China Communications Press.

XIE X L, ZHANG W H, DING H. et al. (2014). “Evaluation method for the development level of the urban public transportation based on the improved TOPSIS method”. Journal of Transport Science and Engineering, 30 (02):79-83+88.

YANG X D, MENG X H. (2014). “Fuzzy comprehensive evaluation of small urban transit systems”. Journal of transport information and safety, 32(03):36-41.

Operation and Management of Urban Rail Transit Education Reform Based on CDIO

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Abstract: Through detailed analysis of Conceive, Design, Implement, and Operate (CDIO) engineering education mode, the operation and management of urban rail transit education is innovated in combining basis theory, personal capability and collaboration of team and environment of society. In view of Capability Maturity Model (CMM), a model of operation and management of urban rail transit education reform Based on CDIO is developed, and the program optimizing method called Prepare, Assess, Summary, and Adjust (PASA) based on CDIO is put forward, furthermore, the basic tasks and demands of the method are also discussed in detail. When the CDIO engineering education model with the project as its carrier is build, the Flexible, Module, and Season (FMS) organization mode of teaching is actively promoted, and the requirements of the project implementation arrangements are met. From the method had been implemented since 2010, the system has got the approval of the teachers and students, which stimulates students' interest, and has a better effect in practice.
Keywords: CDIO; Urban rail transit; Education reform; CMM; PASA; FMS.

1 Introduction

Knowledge and ability are two basic concepts in the field of education. The organic combination of the learning of knowledge and nourishment of knowledge based ability is an important and difficult problem. So some problems on their relationship have been valued and explored by many scholars and cooperation-education and problem-based-learning are some fruit of their exploration. There are some defects in these explorations, for they catch one and lose another in solving the problem of the relationship between knowledge and ability. The emerging model of CDIO emphasizes the link between knowledge and ability and provides new ideas and models in combining the learning of knowledge and nourishment of knowledge based ability.

CDIO denotes conceive, design, implement and operate (Gu,2009), it is the newest research result of international engineering education reform in recent years.

The theory of “learning-by-doing” and “project based education and learning” is focus on summary and abstract expression. Innovative talents who have the ability to innovate doesn’t inherent, almost of them are cultivated by acquiring learning and practice. Carrying out the creative education is the most directed and valid way to cultivate innovation ability. How to cultivate innovative engineering and technical talent is hot spot of domestic and abroad higher engineering education reform in recent years.

2 CDIO-Based Engineering Education Modes

CDIO takes the engineering projects (including products, production processes and systems) as the training objectives, R&D and product operation as its carrier and engineering professional practice environment as the engineering teaching environment. so that students can learn in the way of active and practical courses which link to learn engineering. CDIO not only inherits but also develops the idea of European and American engineering education reform more than twenty years. Even more important, it proposed systematic ability cultivation, comprehensive implementation guide, complete implement process and rigorous inspection including twelve standards and has strong operability. CDIO is one of the patterns under the strategy of “learning-by-dong”. It is a kind of education concept which combines abstract education and practical education, and its syllabus competence goals and innovative talents quality fit highly.

CDIO curriculum design is established on the basis of the talent training goal’s comprehensive analysis. It includes four aspects: technical knowledge and reasoning, career skills and quality, interpersonal communication and team coordination ability as well as the CDIO under the enterprise and society environment. That just meets the requirement of business world to innovative engineering talents. Due to the modern engineering system’s more and more dependence on multidisciplinary background knowledge, the students must grasp suitable technical knowledge and have rigorous reasoning ability. Personal and professional skill is the core competencies which is necessary to mature engineers. Students must grasp the interpersonal skills and have good communication ability for working under the environment based on team cooperation. At last, in order to actually accomplish the establishment and operation of products and system, students must have the ability to conceive, design, implement and operate products and system on enterprise and society level(Crawley,2009,Wang,2007).

3 CDIO Operation and management of urban rail transit education Mode Based on CMM

Although CDIO engineering education proposes specific requirements with one vision, four levels of capacity requirement, twelve criterion of teaching concept and five guiding ways, it hasn’t pointed out the further description of how to gradually train and systematically evaluate students' CDIO engineering ability, that is to say, the increasing process of students' CDIO engineering ability is undefined. Therefore, using the basic thought of software capability maturity model (CMM) (Carnegie,1994), this paper constructs CDIO operation and management of urban rail transit education mode based on CMM is established and shown by Fig. 1. Reflect students' CDIO engineering ability's practical and needed improving direction by ability mature grade characteristics, and then make students' DCIO engineering ability matures continuously through orderly growth (Hu,2010).

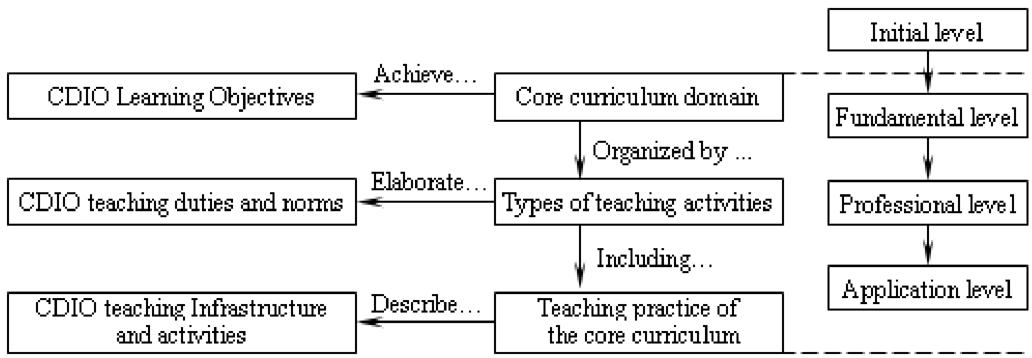

Figure 1.CDIO operation and management of urban rail transit education mode based on CMM

In Fig. 1, except for the initial level, each grade of the rest levels formulates some core curriculum domain. In the professional study process, the students basically start study taking the curriculum as a unit; therefore, teaching curriculum study is the most basic CDIO study process practical activity. Core curriculum domain includes a series of core curriculum teaching practical activities which are organized by teaching activity types and influence CDIO engineering capacity's formation by their execution. When a core curriculum domain's whole core curriculum teaching practice can be implemented according to the requirements, the CDIO learning objectives ought to be achieved by core curriculum domain guide can be realized, that is to say, cyclic iteration incremental training on students' CDIO engineering ability through the execution of core curriculum teaching practice and core curriculum domain.

Each core curriculum domain should contain four teaching activity types: formulate curriculum teaching standard, ascertain curriculum teaching condition, execute curriculum teaching and evaluate teaching results. Practical activity like teaching standard establishment generally describes the teaching standard and strategy of teaching curriculum, for example, formulate curriculum teaching outline standard according to CDIO engineering education idea and CDIO teaching target. Practical activity like ascertaining curriculum teaching condition mainly determines the precondition needed by curriculum teaching, including CDIO teaching infrastructure and pre-study curriculum determination and so on. Practical activity like executing curriculum teaching mainly describes the curriculum teaching's content, form, method and so on, including formulating teaching calendar according to teaching outline, executing teaching according to teaching calendar, recording students' study situation and so on. Practical activity like evaluating teaching results is mainly about ensuring that teaching activity can be conducted according to the established standard, checking the state and effectiveness of the execution process at any time, executing suitable measurement, analysis and comments, for example, visit a class, teaching archives inspection, students comments etc.. while describing the teaching curriculum practice, the CDIO teaching infrastructure and practical activity, which has great influence on the realization and standardized execution of curriculum domain target, generally emphasize what to do other that how to do.

4 CDIO personnel training plan Optimization with PASA method

Education plan's improvement needs the cooperation of educational circles, industrial circles and evaluation organization. Confirm the knowledge, skill and quality should be possessed by engineering undergraduate talents and propose the content and measurement of education plan's improvement to perfect the education plan of education target and requirement. Meantime, on the aspect of curriculum setting, it is necessary to highlight the relevance of curriculum setting to avoid the unnecessary repetitious content so that students can grasp the relationship of knowledge of each curriculum to solve the comprehensive problems. Moreover, we should pay attention to the formation and cultivation of students' CDIO engineering capacity. We should focus on industry internship and engineering training while avoiding the too small and too narrow curriculum setting. The talents education plan's optimization based on CDIO mainly aims at the defect of students' CDIO engineering capacity. It is composed of four sections: preparation, assessment, summary and adjustment, "PASA method" for short. This method's core is the establishment of integrated curriculum plans. The optimization process is shown in Fig.2.

It can be seen in Fig.2, the design process of integrated curriculum plan based on CDIO has two main closed loops: study effect closed loop and integrated curriculum plan closed loop based on CDIO outline. The former is used to improve CDIO, and the latter is for integrated curriculum plan design execution using CDIO. The existing condition is the sum of all the factors influencing the present curriculum plan, including school system, the existing curriculum plan's structure, profession target, educational system, the state's requirement to talents and so on.

4.1 Preparation

The design process of integrated curriculum plan based on CDIO has two main closed loops: study effect closed loop and integrated curriculum plan closed loop based on CDIO outline. The former is used to improve CDIO, and the latter is for integrated curriculum plan design execution using CDIO. The existing condition is the sum of all the factors influencing the present curriculum plan, including school system, the existing curriculum plan's structure, profession target, educational system, the state's requirement to talents and so on.

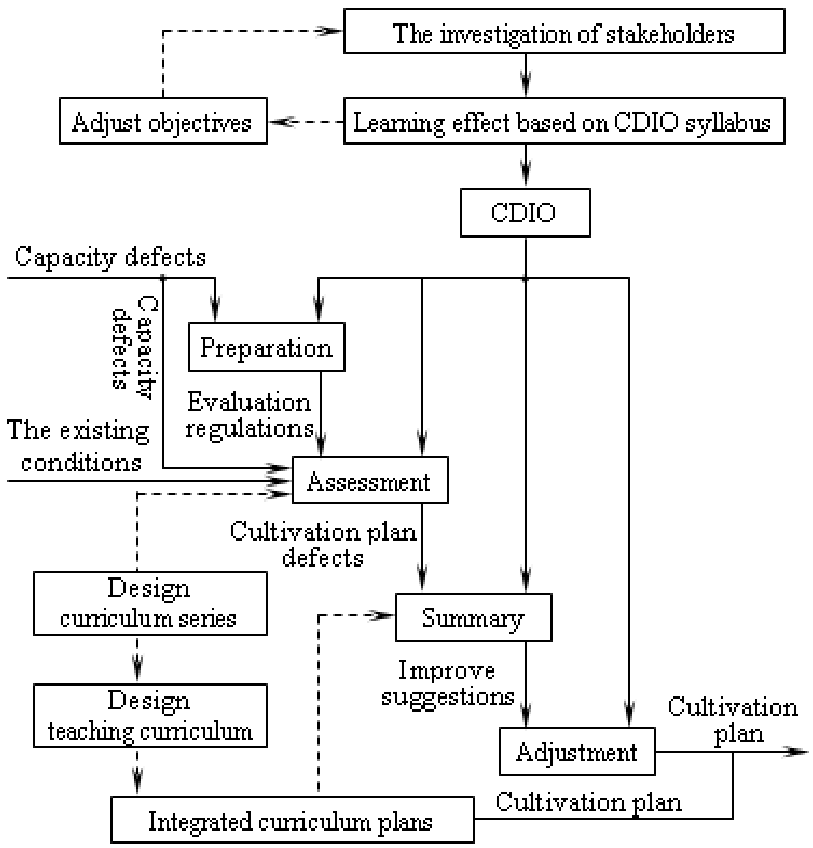

Figure 2.The cultivation plan optimization and the design process of integrated curriculum plans

4.2 Assessment

With contrast to CDIO stand and references on existing condition, find out the defects of the cultivation plan which causes students' CDIO engineering capacity defect according to the evaluation regulation fixed at the preparation phase. At first, cultivation plan execution organization reports the relevant content and implementation status of cultivation plan, expounds the principles and guiding ideology of cultivation plan establishment, explains how to gradually trains student's CDIO engineering capacity and solves the existing problems through implementation cultivation plan, what is the characteristic of the cultivation plan, etc.. Then, the evaluation group picks up the relevant files of cultivation to read, and picks up the relevant files of cultivation plan execution status when its necessary, and analyzes the existing problems of cultivation plan according to CDIO. Aiming at the existing problems of cultivation plan, make clear the relationship between cultivation plan and students' CDIO engineering capacity defect through ways such as students' interviews, teachers' discussion, field survey of cultivation plan execution and so on. Find out the cultivation plan defect which brings about capacity defect through comprehensive analysis.

4.3 Summary

Provide all the scores of cultivation plan indexes according to CDIO standard, and extensively exchange and communicate with students, teachers and teaching management section through evaluation situation announcement according to cultivation defect, moreover, should pay attention to listening the business world engineers' relevant opinions, and then propose the cultivation plan's improvement suggestion. In addition, evaluation organization also needs to compose a final report to fix the modes and methods used by this evaluation, the main content, the results, completion status and existing problems of this evaluation for reference while the cultivation plan implementation organization is executing the evaluation plan.

4.4 Adjustment

With the contrast to CDIO standard, improve the present cultivation plan according to the improve suggestion to eliminate the cultivation plan defect which brings about capacity defect. During the adjustment process of the cultivation plan, we should proceed with extensive lecture and organize discussion with students, teachers and teaching management staff based on the modified plan. Comprehend the cultivation target and requirement of the cultivation plan, familiarize with the various teaching practical activity standard of the curriculum setting plan and try our best to make sure the cultivation plan can be smoothly implemented according to the regulations.

5 CDIO Teaching Organization based on FMS

In order to ensure the implementation of CDIO engineering teaching mode, based on the project teaching' confession and CDIO cognition our school seriously use the successful experience of Department of Industrial Engineering of Tsinghua University and Singapore Nanyang Technological University's project teaching for reference. Aiming at the problems which is came across by the operation and management talents when they face enterprise choice, combining with CDIO relevant standard and China's actual situation, we construct CDIO engineering teaching mode taking the project teaching as the carrier, and positively impel FMS teaching organization mode, namely, flexible, module, season. We proceed with project teaching innovation taking the operation and management of urban rail transit as the practical object and find a set of feasible capacity training plan so that the students' comprehensive vocational ability and sustainable developing capacity can be improved.

5.1 Implement Flexible Teaching Management

In order to adapt to the marketing economy's demand variation to production, make sure the teaching content keep in step with enterprise's production flow, and promote learning with working mode's development so that the example can come from the first production line in time and the project selection can be in accordance with the enterprise's real requirement. Meantime, for the purpose of students' projects' timely inspection in practice, our school change the rigid management into flexible service, flexibly adjust study module according to producing training or the enterprise production's requirement to internship, and adjust school's teaching organization mode in time to make the teaching organization flexible. Especially, at in-post practice phase, we can elastically adjust CDIO four sections according to the students' internship arrangement in batches.

5.2 Design Module Curriculum Group

To implement engineering education, we should dynamically organize module curriculum group mode according to engineer professional role demand. after the curriculum development conducted by school and enterprise based on working process, in order to implement semester project, we should organize and establish curriculum group such as software design engineers taking semester object as the core, embedded system engineers, network engineers, information system integration engineers, e-commerce and so on. A curriculum module is a assembly of professional curriculum, professional quality curriculum and elective curriculum to a task field. And then sort the assembly according to the growth law of the professional ability in order to connect the knowledge among the curriculums.

The students can finally become different roles through studying different knowledge module and grasping tools and skills. The traditional curriculum pays great emphasis on theory completeness and analytical calculation and neglect engineering application. The innovated curriculum takes both classical content and modern technology into consideration, emphasizes on basic theory and pays attention to methods, especially engineering application.

5.3 Realize Season Teaching Organization

In order to make it easier to implement semester object, ensure flexible teaching management, our school firstly carries out season teaching in the operation and management major. In terms of teaching organization, we take 7~8 weeks as a season teaching unit to shorten the teaching cycles and adapt to flexible management. In terms of curriculum arrangement, the curriculum which needs strong continuity should be arranged in a season; the curriculum which trains mind skills normally should be divided into basic part and improving part which should be arranged separately in two seasons; the curriculum about professional quality should be arranged in each season according to the students' quality formation characteristics. In the terms of project execution, we proceed with midterm inspection, project conclusion and evaluation through project-week.

7 Conclusions

At present, the transformation from traditional education to engineering education is becoming the trend of education mode innovation. Many colleges and universities is exploring practical engineering education. Operation and management of urban rail transit education innovation according to CDIO education mode has got obvious effect in practice. Its teaching way has motivated the students' interests, strengthened the ability of solving problems, cultivated team spirit, and upgraded the profession quality. This just realizes the teaching target under CDIO concept and meets the business world's need to innovative engineering talent. However, the profession's teaching innovation is a long-term and comprehensive task. We need to do further research and exploration if we want to gain comprehensive teaching effect.

Acknowledgement

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References

Gu X. (2009). "Connecting abstract theories with concrete engineering skills in the CDIO learning cycle," Research in Higher Education of Engineering, No. 1, pp. 11-23.

Crawley E, Malmqvist J, Ostlund S, et al. (2007). "Rethinking Engineering Education," Springer, pp. 5-20.

Wang S., Hong C.(2009). "CDIO: the Classic Mode of Engineering Education in MIT--An Unscrambling on the CDIO Syllabus," Journal of Higher Education in Science & Technology, Vol. 28 No. 4, pp. 116-119.

Carnegie Mellon Univ. Software Engineering Inst.(1994). "The Capability Maturity Model Guidelines for Improving the Software Process," Addison-Wesley Professional.

Hu Z., REN S., CHEN Z., FEI H. (2010). "Program Optimization Based on CDIO-CMM for Undergraduate Education in Engineering," Research in Higher Education of Engineering, No. 6, pp. 20-28.

Urban Rail Transport Coordination Based on Travel Time Cost

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Abstract: The study focuses on the travel time costs of public traffic, calculates them under different conditions in order to analyze the coordination of them. It's finished by two stages. At the first stage, using generalized travel cost share rate forecasting model to forecast the share rates of different income groups using different travel modes. At the second stage, the share rate is used to determines the travel time cost function. Selecting distance and time as characteristic variables of the function, studying the change of it. Finally, taking Guangzhou as an example to analyze the coordination of the urban rail transit. The results indicate that it's necessary to control the length of the line coincides between the subway and bus within 4km. It improves the accuracy and practicality of the model with consideration of more factors affecting the resident travel mode choice.
Keywords: Transportation economy; Travel time cost; Passenger coordination.

1 Introduction

To make full use of urban rail transport's capacity, it's necessary to consider different travel modes' coordination which means the relationship between them. There are 2 kinds of coordination forms: competition and coexist. The research of urban rail transport's coordination is mainly about studying the relationship between urban rail transport and other travel modes, improving overall passenger capacity of the city by reducing competition or improving coexist of other travel modes. TTC (travel time cost) is the time consumption in one trip. It's a effective way to analyze the travel mode's coordination by calculating the travel mode's TTC.

In recent years, the researches of TTC in developed countries are mainly for city traffic model classification, the total cost of the quantification and basis of the travel cost charge policy. Logit model and its improved model are the most common methods so far. Kaoris establish a travel mode probability prediction model and apply it in the decision making process (M and A 2000). Henshers use disintegration model to establish a joint choice model of residential address and travel mode (D and W 2002). Kwigizies select the personal, social, economic attributes and other factors, apply cross stratified logit model to estimate the probability of residents travel mode (V et al. 2011). The study on the value of travel time in our country begins in the mid-1980s. Zhong Fangs establish a comprehensive model which can calculate the value of travel time by introducing the time factor, it make a improvement to the traditional method (Fang et al. 2009). Zhao Shuzhi puts forward a calculation method to residents' travel time value model in view of different travel modes (Shu-zi and Bei 2011). Xu Tings who regard the travel behavior as a research object use the correlation to analyze the factors closely related to the residents' travel modes (Ting et al. 2013). On account of the utility function determination in logit model depends on the individual travel behavior investigation, the parameter estimation is affected by many uncertain factors. This paper aims to use generalized travel cost to predict the traffic mode share rate, searches for the quantification method of various public travel mode's TTC based on the time value theory. Then enhancing the urban rail transport's coordination by comparing the TTC of urban rail transport with other public travel modes under different conditions.

2 The calculation model of travel time value and travel time cost

2.1 The calculation of different income level Residents' value of travel time

VOT (value of time) is the benefit increment amount produced as time elapsing and the monetary expression of efficiency loss caused by the non productive expenditure of time. Personal saving time value is generally considered equal to the cost of someone that is willing to pay his time saving. Before calculating the residents' VOT, the residents should be classified on the basis of their income level first, it's generally divided into 6 grades from low to high. The range of each grade is decided by the specific economic situation of the city.

This paper adopts the most common production method to calculate different income level residents' travel time value. The production method based on the passengers' travel time is for the production that can create national income or GDP. This method is generally used to calculate the VOT for work. This paper aims to modify the calculating formulas to calculate the VOT according to the residents from different income levels VOTj (Jianzhong 2009), the calculation formula is as follows:

$$VOT_j = \frac{M_j}{(365 - J) \times 8} \tag{1}$$

VOT_j: The value of time according to the residents of income level j;

M_j: Per capita annual income according to the residents of income level j;

J : Annual weekends, statutory holidays (115 d).

2.2 TTC model

TTC (travel time cost) mainly refers to the time consuming that travelers throughout the travel. It can be measured by money which is also called narrow travel expenses including the VOT and travel expenses. Seen from above that travelers from different income levels have different VOT. Although it won't be affected by the travel modes directly, but the type and ratio of travelers that each travel mode attracts are not the same. The VOT of different income levels with its proportion in all travel modes, it's able to get the VOT of this travel mode, and then get the TTC (wei et al. 2010).

$$VOT_i = \sum_j \theta_{ij} \times VOT_j \tag{2}$$

$$TTC_i = (t_{i0} + t_{i1} + t_{i2}) \times VOT_i + r_i \tag{3}$$

VOT_i: The value of time according to the i-th travel mode;
θ_{ij}: The proportion of passengers according to j income level in the i-th travel mode;
TTC_i: The travel time cost according to the i-th travel mode;
t_{i0},t_{i1},t_{i2}: The transfer time, waiting time, travel time according to the i-th travel mode;
γ_i: The expense according to the i-th travel mode.

3 Sharing rate prediction model based on the generalized travel cost

3.1 Generalized travel cost

Generalized travel cost represents the cost of passenger travel process required to pay. The generalized travel cost is the sum of the travel influential citys' average utility of different factors. It's also the point that differs it from TTC. It usually includes the following factors. Economy that refers to the freight paid in passenger trave. Rapid, the time passengers spend in the travel reflects the quality of various travel modes' service. Convenience which refers to the convenience of non-riding stage in the trip. Snug which is generally represented by 8% conversion fee, meaning ease produced fatigue properties in travel. According to the independence and addition principle of service quality characteristics in travel modes, it's able to construct the generalized travel cost function:

$$V_i = E_i + F_i + C_i + S_i = 1.08R_i + (T_i + Y_i) \times VOT \tag{4}$$

E_i, F_i, C_i, S_i: Economy, fast, convenience, snug of the i-th travel mode;
R_i: The average cost of the residents spend on the i-th travel mode;
T_i: The average operating time of the i-th travel mode;
X_i, Y_i: Distributed time, waiting time of the i-th travel mode.

3.2 Share rate forecasting model

In this paper, VOT model is used to predict the share rate of transport (Wei-chao 2013). This model assumes that urban residents choose to travel in a minimum of generalized travel cost way. Affected by economy, residents of different income levels choose a different probability of different travel modes. Based on previous research, it's generally believed that the VOT obeys lognormal function:

$$f_j(VOT)=\begin{cases}\dfrac{1}{2\sigma_j VOT\sqrt{\pi}}\exp\left[-\dfrac{(\ln VOTj-\mu_j)^2}{\sigma_j^{\ 2}}\right] & VOT>0\\ 0 & VOT<0\end{cases} \quad (5)$$

$$\mu_j=\ln VOT \quad (6)$$

$$\sigma_j=\left|\ln VOT-\mu\right| \quad (7)$$

$$\mu=\sum_j \ln VOT\times\alpha_j \quad (8)$$

αi: The proportion of urban residents of different income levels j;
μ: The value of city residents average unit time.

This paper studies the share rate of residents on different income levels on bus, subway and taxi. The generalized travel cost of these travel modes are respectively expressed as V1,V2,V3. For the passengers of different income levels, the difference of the generalized travel cost are modest. Ignoring the effect of income level on the passenger travel cost, the time value model diagram as shown in Figure 3-1:

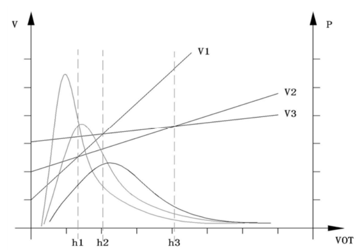

Figure 1.Time-value model that passengers choose three modes of transport

Using the formula function and linear function characteristics of V_1, V_2, V_3, it's possible to calculate the figure of h_1, h_2, h_3. According to the properties of probability distribution function. For the residents of j-th income level, the distribution function that the value of time in different ranges corresponds is the probability of selecting travel modes F_{ji} (Xiao 2012), then it's able to get θ_{ij}.

$$F_{ji}=\int_{si} f_j(x)\mathrm{d}x \quad (9)$$

$$\theta_{ij}=\frac{\alpha_j\times F_{ji}}{\sum_j \alpha_j\times F_{ji}} \quad (10)$$

$F_{j1,\ 2,\ 3}$: The probability passengers of j-th income level select the1, 2, 3-th travel mode;
s1, 2, 3: The integration intervals of 3 travel modes are respectively (0, h_1), (h_1, h_2), (h_2, ∞)

α_j: The proportion of residents in j-th income level;

4 The example analysis

4.1 The value of travel time calculation of residents in Guangzhou

This paper takes Guangzhou city as a example to analyze the coordination of subway line in 2005. Dividing residents into 6 grades by their income level. Grading standards and the proportion refer to the latest data from the recruitment enterprise of Guangzhou. There are also some assumptions in this paper. A. the lognormal standard deviation that the Guangzhou residents' unit time value obeys is as same as the residents' time value in China. B. the per capital GDP in 201l-2015 is increasing by 10% per year in Guangzhou. C. the division of residents' income level in Guangzhou is as same as the division in 'Chinese statistical yearbook 2010'. Calculating the value of residents average equivalent unit time in Guangzhou according to formula (4), it's shown in table 1.

Table 1. The prediction of value of travel time in Guangzhou City

Parameters	The lowest income	Low income	Lower-middle income	Middle income	Higher-middle income	High income	The highest income
Monthly income (yuan)	<2000	2000 ~3000	3000 ~4000	4000 ~5000	5000 ~6000	6000 ~8000	>8000
Proportion (%)	2.9	11.23	17.48	16.4	11.77	16.32	23.9
2015 Predictive value M_j (yuan)	7892.40	10859.81	14073.91	18214.43	24100.27	31024.67	46711.89
VOT_j	3.95	5.43	7.04	9.11	12.05	15.51	23.36
μ_j	1.37	1.69	1.95	2.21	2.49	2.74	3.15
σ_j	1.06	0.74	0.48	0.22	0.06	0.31	0.72

4.2 Residents travel share forecasting

According to the 'city road traffic planning and design specifications', the residents' travel survey data in 2005 Guangzhou and per capita income data in 2011 Guangzhou, annual traffic report data in 2011 Guangzhou, Guangzhou city traffic bureau of Guangzhou city price parking fees and standards, it's possible to get the data. Considering the capacity problem of taxi, assuming each taxi loads 3 passengers during the rush hour. Per expense is 7.6 yuan. Forecasting the generalized travel cost of these travel modes in 2015 by formula (1) , shown in table 2.

Table 2. The commuting parameters and values of Guangzhou city residents

travel modes	T_i(min)	X_i(min)	Y_i(min)	R_i(yuan)	V_i
bus	38	10	7.5	1.79	1.93+0.93VOT
subway	31	10	2	3.22	3.48+0.72VOT
taxi	31	0	0	22.8	8.21+0.52VOT

Using the properties of linear function to calculate the generalized travel cost. The intersections of V_1, V_2, V_3 are respectively 7.6, 15.32 and 23.65. Expressed by h_1, h_2, h_3. According to the properties of probability distribution function, using formula (5) to (7) to calculate the probability residents of different income levels select these travel modes. Then using formula (8) to calculate the proportion of the different income levels residents' in i-th travel mode, shown in table4-4. Combining the value of different income levels residents' time with formula (2) , then getting the VOT of these travel modes, shown as table 3.

Table 3. The VOT of residents in Guangzhou

θ_{ji}	1	2	3	4	5	6	7	VOT_i
1	0.0861	0.3087	0.4029	0.1373	0	0.0073	0.0577	7.56
2	0.0104	0.0546	0.1211	0.2114	0.1911	0.2387	0.1726	13.15
3	0.0094	0.0189	0.0073	0	0	0.1045	0.8599	21.90

4.3 Analysis of passenger coordination based on TTC

On the assumption that the Guangzhou city residents choice travel mode obeying the principle of minimum generalized travel cost, it's able to calculate the VOT of these travel modes. Assuming that a section of route in Guangzhou can be used by these travel modes and the trip distance of them is the same. According to the total transfer time and waiting time in Guangzhou, assuming that the total transfer time and waiting time of bus is respectively 15min and 5min, the total transfer time and the total waiting time of subway is respectively 5min and 3min, the waiting time of taxi is 3min. Finally the TTC function can be got by using formula (3).

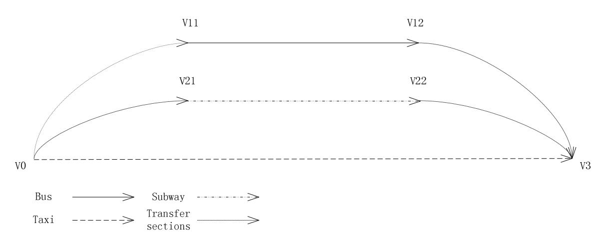

Figure 2. Paths of travel modes

L is travel distance, V_{i2} is the driving speed of i-th travel mode. From above, knowing that TTC is close related to L and V_{i2} which is affected by the road saturation. Under the condition that the road is in good state, it would be okay to assume that the driving speed of travel mode 1, 2, 3 are respectively 20 km/h, 35 km/h, 40 km/h. Considering the fare of tickets in Guangzhou, the TTC-L graph of the various travel modes is plotted as figure 3(Jun et al. 2014).

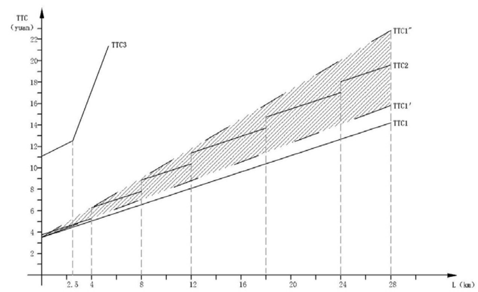

Figure 3. The relationship between L and TTC

This paper mainly focus on the relationship between TTC_1 and TTC_2. Knowing from figure3, when the bus speed is below a certain valueV'_{12}, TTC_1 is higher than TTC'_1. In this case, the presence of L makes TTC_1 higher than TTC_2. When the bus speed is above a certain value V''_{12}, TTC_1 is higher than TTC''_1. At this point, no matter what the value of L is, TTC_1 is rival to TTC_2. Using the nature of linear function, it's easy to calculate that V'_{12} and V''_{12} are respectively 17.28km/h and 11km/h. Assuming that the operating speed dropping to 3/4 of the original in traffic jams, which means the lowest operating speed of bus in Guangzhou is 15km/h. Only when $L \in (1.85,4), \cup (42.18, \infty)$, TTC_1 is higher than TTC_2. Under the assumption that bus and subway have the same travel distance and the waiting time of them are determined, TTC_1 is lower than TTC_2 in Guangzhou. In fact, due to the limit of ground conditions, bus lines are generally longer than the subway line when the staring points ending points are the same, the factors that will further narrow the gap between the two travel modes. As public transports, they undertake the similar purpose passenger flow. Under the above assumptions when the bus and subway travel routes overlaps more than 4km in Guangzhou, the coordination between subway and bus is low. At this time, the passenger competition will be formed between the two kinds of public transportation which will result in unnecessary waste of resources. The results indicate that it's necessary to control the length of the line coincides between the subway and bus within 4km.

5 Conclusions

As one of the city's most important modes of transportation, the coordination between urban rail transport and other travel modes will affect the city's passenger capacity directly. In this paper, we calculates the time value of different income levels by dividing income levels. By constructing predictive traffic share rate mode based on generalized travel cost. Forecasting the proportion of residents on different income levels in kinds of travel modes. Calculating the VOT and TTC of travel modes by weighting VOT. So far, the model is completed. By comparing the TTC of travel modes in different operating speed and travel distance. Finally, we study the coordination between urban rail transport and other travel modes, then determine the suitable travel distance and line layout program.

Acknowledgement

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References

D, H., and W, G. (2002). "Specification and estimation of the nested logit model: alternative normalizations." *Travel modeation Research Part B: Methodological,*, 6(1), 17.

Fang, Z., cai, J. Z.-i., yong, Z. H.-i., and JIAHong-fei (2009). "Calculation and Application of Value of Travel Time." *Journal of Transportation Systems Engineering and Information Technology* (03), 114-119.

Jianzhong, H. (2009). "The Constitution Theory and Quantitative Evaluation Method of TriP Cost about Private Carin Urban Area.", Beijing Jiaotong University.

Jun, L., Xinjun, L., and Lin, H. (2014). "Share Rate Analysis of Urban Transportation Mode Based On Individual Marginal Cost." *Journal of Whhan University of Technology (Transportation Science ＆ Enigineering)* (04), 725-729.

M, K., and A, T. (2000). "A logit model for modal choice with a fuzzy logic utility function." *Traffic and travel modeation Studies*, 4(5), 18.

Shu-zi, Z., and Bei, Z. (2011). "Value of travel time of urban resident under multifactor influence." *Journal of Jilin University (Engineering and Techology Edition)* (01), 46-50.

Ting, X., Zhen, L., Da-wei, H., Xiao-duan, S., and Wei-li, W. (2013). "Influence of trip cost on trip mode for resident." *Journal of Traffic and Transportation* (01), 91-97.

V, I., D, V., and T, S. (2011). " A cross-nested logit model for trip type-mode choice: an application." *Advances in travel modeation Studies*, 23(2), 12.

Wei-chao, L. (2013). "The Analysis of Public Transportation Competitiveness Based on Travel Cost Measurement Model.", ShangDong University.

wei, F.-i., JINWen-zhou, and LINFu-cheng (2010). "Calculation of Time Value for Urban Public Travel with MNL model." *Journal of Transportation Systems Engineering and Information Technology* (02), 148-152.

Xiao, W. (2012). "Passenger transport contribution rate of multiple modes of transport in transport corridor." *JOURNAL OF RAILWAY SCIENCE AND ENGlNEERlNG* (06), 119-125.

NEW CABLE INSULATION DETECTION APPROACH AND DESIGN FOR THE SUBWAY TRAIN

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Abstract: On-board cable in the subway is an essential competent in the whole power system for the electric transmission, power allocation and signal control. The cable insulation condition plays an important role in safe and reliable operation of the subway. Traditional insulation detection devices haven't taken into account the impact of the electromagnetic interference on insulation test detection. Severe electromagnetic interference would impact the unstable operation and the data volatility of the online monitoring system. Therefore, the paper proposes optimal double T filter based new approach to cable insulation detection in the subway, and analysis its transmission characteristic by using mathematic method. From the software simulation and actual measure, the paper concludes that the proposed approach can not only improve the detection accuracy of the cable insulation, but can also fit with 50Hz noise signal interference produced by on-broad machine in the subway. With the proposed approach, stability of equipment operation can be guaranteed.

Key words: *The subway equipment, cable insulation detection, optimalizing double T filter, Electromagnetic interference*

1 The necessity of electric cable insulation measurement in the subway

Today's subway is complete in almost every function, and be equipped with various electrical equipment. Therefore more cables are laid correspondingly. The train body is mainly made of stainless steel and aluminum alloy. Once cables are scratched or broken, electricity leakage will occur and take serious effects for the train operation and passengers' safety. Additionally, when the cable insulation is damaged, the ground fault will occur, lead to the faulty operation of signal circuits and control circuits, or even result in serious consequences such as fire hazard and equipment damage. More seriously, these effects will break the normal operation of the whole system, and even cause casualties.

In urban rail transit systems, many electronic power's frequency are 50Hz, and it's very easy for the power signal to produce noise interference by many ways. These devices include overhead traction wires, leakage coaxial cable, mobile communication modules, etc. Some testing equipment is more sensitive to electromagnetic interference. This device can't work normally or even lead to mis-operation, if affected by electromagnetic interference. It will bring serious consequences to the safe operation of rail transit system.

The traditional design of cable insulation detection concept fails to go through the field noise filter processing. However, because of the complexity of on-board power grid and operating environment in subway train, the noise interference is a necessary considered factor to improve the precision of the cable insulation detection. Based on traditional experiences, there are few researches about precise insulation detection in the complex noise interference the environment of the subway train. Therefore the high precise cable insulation detection approach is particularly important for complex noise interference environment in the subway train.

2 Double T filter based new cable insulation detection hardware design for the subway train

In the subway train operating environment ,there is serious electromagnetic interference produced by working machine which disturbing insulation detection system .In order to eliminate the measurement error produced by 50Hz noise jamming ,we combine double T filter circle with insulation detection system.

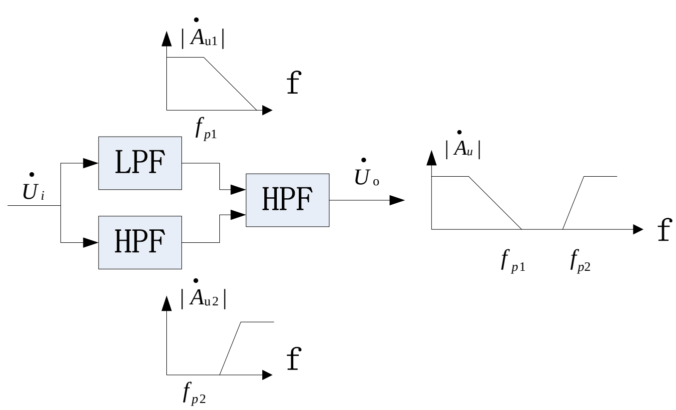

Figure 1. Block diagram of band-stop filter

In the signal processing circuits, it is often to use the band stop filter blocking interference signals fleeing. As shown in figure 1, band-stop filter usually use a low-pass filter (LPF) and a high-pass filter (HPF) in parallel. The cutoff frequency, fp1, of the low pass filter should be lower than the cutoff frequency, fp2, of high-pass filter. The value of the stop band is (fp2 - fp1).Band-stop filter can constitute a noise-squelch circuit which can have very good filtering effect on strong interference signals at certain frequency.

The double T filter makes use of the characteristics of capacitance that the impedance of capacitance changes with fluency. By appropriately selecting the value of capacitors and resistor, the double T filter can effectively select the desired frequency signal and filter out interference signals.

Assume that $\dot{U}_i$ is the input signal of the double T network filter and $\dot{U}_o$ is the output signal of the double T network filter. Using F stands for its frequency characteristic, it follows that.

$$F = \frac{\dot{U}_o}{\dot{U}_i} = \frac{s^2 + w_o^2}{s^2 + 4sRC + w_o^2} \quad (1)$$

Let $s = jw$, we can get:

$$F = \frac{1 - w^2C^2R^2}{(1 - w^2C^2R^2) + j4wRC} \quad (2)$$

Let $w = w_0 = \frac{1}{RC}$, we can get:

$$|F| = \frac{|1 - w^2C^2R^2|}{\sqrt{(1 - w^2C^2R^2)^2 + (4wCR)^2}} \quad (3)$$

From the above equation, it can follow that double T filter presents a good filtering ability for w_0 signal .In order to make use of the double T filter's characteristics filtering out interference signals from source which can have influence on the accuracy of sampling the voltage, double T filter is integrated into the Insulation test voltage sampling circuit.

Cable insulation detection band stop filter is shown in Figure 2 which is composed of RC low pass filter and RC high pass filter. A low pass filter is composed of resistor R15, R16 and capacitor C33.It constitutes a T-network filter; high-pass filter is composed of capacitors C33, C37 and resistor R12 .It constitutes a T-network filter. Two filters are symmetrical T-shaped structure, which is called a symmetrical double-T network band-stop filter.

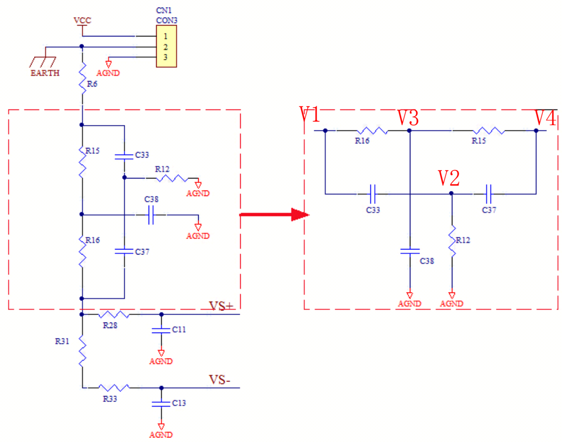

Figure 2. Double T filter

In figure 2 each components must reach following require relationship: C33=C37=C;R16=R15=R;C38=2C;R12=R/2;

Accroding to electronic circuit, we can get the equation：

$$(V_1\text{-}V_2)sC = \frac{2V_2}{R} + (V_2 - V_4)sC \tag{4}$$

$$\frac{V_1 - V_3}{R} = \frac{V_3 - V_4}{R} + 2V_3 sC \tag{5}$$

$$\frac{V_3 - V_4}{R} + (V_2 - V_4)sC = 0 \tag{6}$$

Finally, we can get the relationship as following:

$$w_0 = \frac{1}{CR}, 2\beta = \frac{4}{CR}, Q = \frac{w_0}{2\beta} = \frac{1}{4}$$

3 Positive Feedback Double T filter based new cable insulation detection hardware design for the subway train

The electronic circuit in figure 2 has a shortcoming that the value of Q only be 1/4.So, we can't adjust the Q. If we want to make Q be adjustable, and we want to try ourselves best to increase the filter effect, we must take advantage of positive feedback. The revised electronic circuit was shown in figure3.

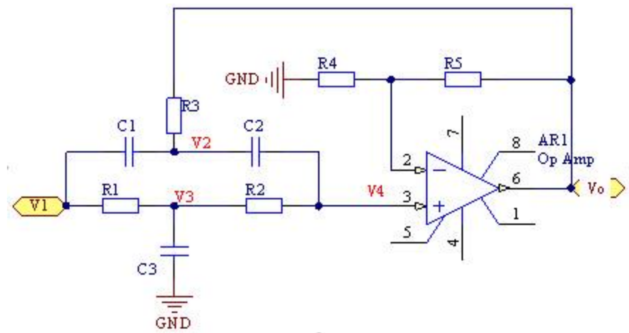

Figure 3. Optimal Double T Filter circuit

$$(V_1 - V_2)sC = \frac{2(V_2 - AV_4)}{R} + (V_2 - V_4)sC \tag{7}$$

$$\frac{V_1 - V_3}{R} = \frac{V_3 - V_4}{R} + 2V_3 sC \tag{8}$$

$$\frac{V_3 - V_4}{R} + (V_2 - V_4)sC = 0 \tag{9}$$

We can get:

$$\frac{V_4}{V_1} = \frac{C^2R^2S^2 + 1}{C^2R^2S^2 + (4-2A)CRs + 1} \tag{10}$$

By calculating, we can get:

$$Q = 1/(4-2A)$$

From the relationship between A and Q, we can know that the more A trends towards 2 the more the Q are. If A>2, the system will be unstability. We can see the difference from the below figure.

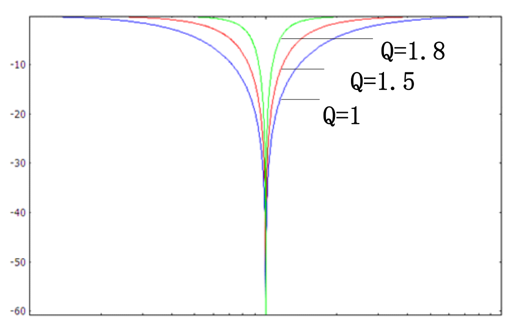

Figure 4. Amplitude-frequency when A=1, A=1.5andA=1.8

Among the figure 4, the blue line stands for the amplitude-frequency when A=1.The red line stands for the amplitude-frequency when A=1.5.The green line stands for the amplitude-frequency when A=1.8.

4 Insulation resistance sampling principle

Figure 5 shows the insulation resistance sampling, this electronic circuit don't use the double T filter with the positive feedback. However, the resistance sampling principle is the same thing , We can catch the principle of insulation resistance sample by the following figure.

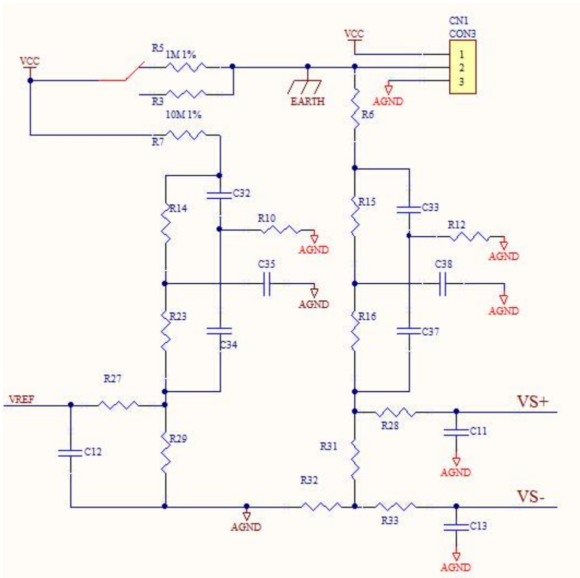

Figure 5. Insulation resistance of the sampling, correction module circuit diagram

VREF is benchmark power of ADC. V + and V - are the ADC input voltage signal (sampling voltage waited for conversion) the principle of insulation resistance measurement is stated as follows:

By controlling relay to connect 1M R5 to insulation resistance sampling circuit, the R5 is measured insulation resistance.

Where, n stands for the resolution of the AD converter,

X_{1M} is the conversion result when the value of insulation resistance is 1M. we can get:

$$\frac{\frac{R_{31}}{R_{29}}*(R_7+R_{14}+R_{23}+R_{29})}{R_5+(R_{15}+R_{24}+R_{31}+R_{32})}=\frac{X_{1M}}{2^n} \tag{11}$$

Let $(R_{15}+R_{24}+R_{31}+R_{32})$ =B and $\frac{R_{31}}{R_{29}}*(R_7+R_{14}+R_{23}+R_{29})$ =A, we can get:

$$\frac{2^n*A}{R_5+B}=X_{1M} \tag{12}$$

A and B are the parameter to be corrected.

In the same way, by controlling relay to connect 10M R6 to insulation resistance sampling circuit. At present the R6 is measured insulation resistance.

Eventually we can obtain equation (13):

$$\frac{2^n*A}{R_6+B}=X_{10M} \tag{13}$$

Where, X_{10M} is the conversion result when the value of insulation resistance is 10M.According to the equation (12) and (13) we can obtain the equations group.

$$\frac{2^n*A}{R_5+B}=X_{1M}\ ;\ \frac{2^n*A}{R_6+B}=X_{10M} \tag{14}$$

Though calculating we can obtain the value of A and B.

A= A_1 、B= B_1

Finally we can get equation (15)

$$\frac{2^n*A_1}{R_x+B_1}=X \tag{15}$$

Where, R_x is the insulation resistance of the cable under test, X is the conversion result produced by AD converter when R_x is the insulation resistance of the cable. Before operating electric cable insulation measurement system, system will start the correction function regularly and get the value of A and B which are needed to calculate the insulation resistance of the cable. After the correction, the correcting circuit switch is disconnected and the electric cable is connected. This algorithm can effectively reduce the influence of floating resistance fluctuating with the external environment, and largely improve the precision of the measurement of insulation resistance.

5 The simulation and the result analysis

5.1 Filter Simulation And Analysis

In order to prove that the double T filter with the positive feedback circuit is able to filter fixed frequency noise and perform better. We conduct an experiment by the Multisim simulation software .

After simulation by Multisim, we can get the simulation results about the amplitude-frequency characteristic curve in figure 6.

The left figure stands for the amplitude-frequency of Positive Feedback Double T Filter, while the right figure stands for normal Double T Filter. By comparing the two figure, we can conclude that Positive Feedback Double T band-stop filter's band-stop filter characteristics perform excellent, and stop band is narrower. Figure 7 is the mixture picture by two curves. It shows that the amplitude amplification of 50Hz signal is -45.972 dB when using the Positive Feedback Double T Filter, while the amplitude amplification of 50Hz signal is -42.772 dB when using single Double T Filter. So Positive Feedback Double T filter based new cable insulation detection can effectively suppress the interference produced by signal whose frequency is 50Hz.

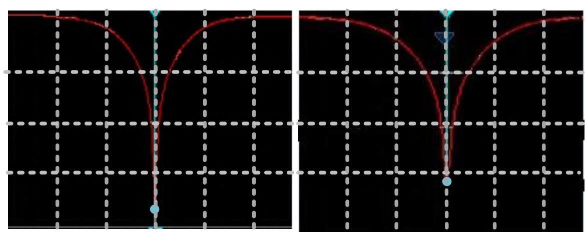

Figure 6. The amplitude frequency characteristics

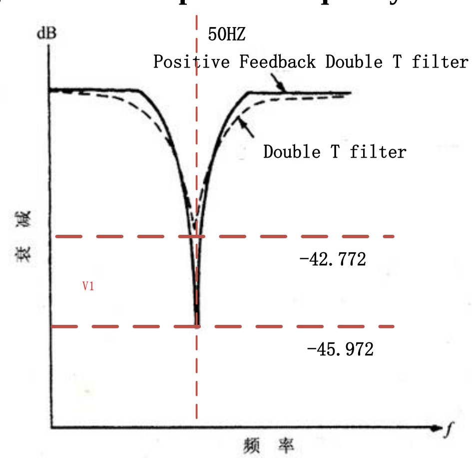

Figure 7. Amplitude frequency characteristics area chart

5.2 The experiment of measuring insulation resistance

In the experiments, we replace the insulation resistance of the cable with testing resistance and use signal generator load interference noise to simulate the interference signal in the subway train when subway train is running.LTC2484 is used in insulation detection circuit. Power supply voltage is 400V. Fluke digital multi-meter whose type is 187 was used in experiment for measuring and calibration standard table and its impedance measurement accuracy is 0.05%. The values of testing resistance were 5.1 K, 10 K, 15 K, 20 K, 25 K, 50 K, 100K, 1 M, 5 M, and 10M. The experimental results are shown in table 1,2and 3.

The experimental results in Table1 was obtained by tradition insulation testing device without filtering. The results in Table 2 were obtained by insulation testing device based on double T filter. The results in Table 3 were obtained by insulation testing device based on double T filter with the positive feedback.

Table 1. Tradition insulation testing

NO.	Grounding resistance nominal value / KΩ	Grounding resistance measured value / KΩ	Means for measuring the value of the / KΩ	Relative error%
1	5.1	5.07	4.91	3.58
2	10	10.03	9.53	4.69
3	15	14.94	13.83	7.77
4	20	20.15	18.92	5.39
5	25	24.85	22.80	8.78
6	50	49.85	45.91	8.17
7	100	99.45	95.73	4.27
8	1000	994.75	908.40	9.16
9	5000	4969.15	4762	4.76
10	10000	9939.05	9445	5.55

Table 2. Insulation testing device based on double T filter

NO.	Grounding resistance nominal value / KΩ	Grounding resistance measured value / KΩ	Means for measuring the value of the / KΩ	Relative error%
1	5.1	5.07	5.00	1.96
2	10	10.03	9.82	1.80
3	15	14.94	14.72	1.86
4	20	20.15	19.6	2.0
5	25	24.85	24.51	1.96

6	50	49.85	49.04	1.91
7	100	99.45	98.19	1.81
8	1000	994.75	981.8	1.82
9	5000	4969.15	4913.5	1.73
10	10000	9939.05	9833	1.67

Table 3. Insulation testing device based on double T filter with the positive feedback

NO.	Grounding resistance nominal value / KΩ	Grounding resistance measured value / KΩ	Means for measuring the value of the / KΩ	Relative error%
1	5.1	5.07	5.03	1.39
2	10	10.03	9.88	1.20
3	15	14.94	14.82	1.20
4	20	20.15	19.75	1.25
5	25	24.85	24.71	1.18
6	50	49.85	49.34	1.03
7	100	99.45	99.09	0.91
8	1000	994.75	986.8	1.32
9	5000	4969.15	4933.5	1.33
10	10000	9939.05	9893	1.07

Through the experiment results, it follows that insulation resistance measurement error measured by tradition detection method is bigger than that measured by double T filter based new cable insulation detection approach and the insulation resistance measurement error measured by double T filter is bigger than measured by double T filter with positive feedback .It is proved that the electromagnetic interference has a great influence on the insulation detection and can easily make the on-line insulation monitoring system unstable . We can see from table 3 that test errors remain below 1.5%, which satisfies the requirement of subway train cable insulation level. We can draw a conclusion that double filter with positive feedback based new cable insulation detection approach can effectively filter electromagnetic interference and makes the equipment working in a stable state in the course of subway running.

6 Acknowledgements

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7 Conclusion

Traditional insulation detection equipment places great emphasis on the algorithm to improve detection precision, but places little emphasis on eliminating the electromagnetic interference. Although there are many designs about shielding electromagnetic interference for every electrical module in the subway train, the cables for modules connecting are still influenced by electromagnetic interference. This paper puts forward a new scheme which combines cable insulation testing with positive feedback double T filter. The simulation experiment proves that positive feedback double filter based new cable insulation detection approach can effectively filter electromagnetic interference and makes the equipment working in a stable state in the course of subway running and measurement error is less than 1.5% when conducting the sampling measurement for insulation resistance of less than 2M, furthermore, devices can running reliably and steadily and conform to the requirements of the site.

Reference

Yankai,L.,Weidong,L.(2007).“Antijamming Electromagnetic Interference of Substation Automation System in Subway.” *BUILDING ELECTRICITY*.

Hangsheng,L.,Yingchun,X.(2000).“On-line monitoring measurement of cable insulation in microcomputer monitoring system for railway signals.” *Journal of wuhan university of hydraulic and electricengineering*, 33(6).

Yankan,L.(2007).“EMC Design in Urban Track Mass Transit System.” *BUILDING* ELECTRICITY, 26(10).

Shaolin,L.(2008).“Prevention and Protective Measures against EMI of UMT Substation.” *URBAN MASS TRANSIT*, 11(7).

Zhe,L.,Bo,M.(2013).“Design and implementation of double-T filter based on FPGA.” *Application of Electronic Technique*, 39(10).

Cuizhen,W.,Jinyuan,P.,Yunzhi,P.(2012).“Double T band-stop filter network transmission characteristics research and simulation.” *Instrumentation Technoloy*, (06).

Analysis of the Coordination of the Chengdu Metro and the Intercity Railway Ticketing Organization

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Abstract: The unification and coordination problems of the ticketing system is an important link for realizing the barrier free transfer in the city passenger transportation system. At present, the unification and coordination of the ticketing system between Metro and bus system of the major cities in our country has been basically achieved. But difficulties in the unification and coordination of the ticketing system between the high speed railway of the city region and the city track transportation have still been existed. In the foundation of the elaboration in the kind and system of the subway ticket in the domestic and foreign, it is concluded that: there are 3 kinds of subway ticketing modes, a fixed ticketing mode, multistage ticketing mode and a composite ticketing mode; in China, subway ticketing modes are classified into 2 types, as all public transport mode available and Metro special. On the base of the analysis of the demand and current situation of the unification and coordination of the ticketing system between the Chengdu Metro and Chengguan High-speed Rail, a solution is put forward. To cannel Chengguan High-speed Rail ticket real name system, using the IC card and magnetic ticket ticketing system mode, establishing a unified clearing center, to achieve the initial coordination of Chengdu Metro and Chengguan High-speed Rail ticketing. Finally, puts forward some existing problems corresponding suggestions and measures of the ticketing coordination are put forward.
Keywords: Chengdu Metro; Chengguan high-speed rail; Ticketing mode; Ticketing system.

1 Introduction

As a project of the urban infrastructure construction, the subway has become an effective way to solve traffic problems in big cities, and it has been an important symbol of the modernization of the city's traffic, and its development reflects the level of the city's comprehensive strength in a great extent.

The coordination between the various urban public transport modes in the line network, management systems and ticketing organizations has been the premise to realize the integration operation of urban passenger transport systems. Urban passenger transport systems are composed of the rail transportation system, the rapid bus transit system, the bus system and other passenger transport systems (including the car, non-motor vehicles and so on). Therefore, the realization of the seamless connection between the city rail transit and other transport systems has been the basic element of the establishment of the comprehensive transportation system in modern city. And the unification of the ticketing mode and the integration of the fare system are the keys (ZHAN Xiaoju, 2006).

2 Profiles of the subway ticketing mode and the ticket type

At present, there are no unified ticketing system models in the subway of the foreign big cities. The limited city cards of New York can be used to transfer the subway system or the bus system. And the infinite city card can be used to take the free bus for many times. In Hong Kong, the metro ticket pricing is drawn up by the meter, and they are different from adults and children. Free ride coupon is used in Tokyo metro, it can be used to take all the railway, subway and buses in the 23 district, and the unification of the ticketing system is achieved in the metro, the railway and the bus system (WANG Ke, 2007). In China, the pattern of ticket pricing is not uniform, specifically speaking, the section ticketing system adopts to Guangzhou, while the metered fare ticketing system adopts in Chengdu.

3 The subway ticketing mode form and ticketing types installation

(1) The current ticketing mode

At present, the fixed ticketing mode, the multistage ticketing mode and the composite ticketing mode are used in the domestic and foreign countries. The fixed ticketing mode is namely the single ticketing mode; the multistage ticketing mode contains the timing ticketing mode, the section ticketing mode and the metered ticketing mode; the composite ticketing mode includes the metered combining timing ticketing mode and the times combining timing ticketing mode. Advantages and disadvantages of the single ticketing mode and the multistage ticketing mode are shown in the table 1 (ZENG Qiong, 2011).

Table1. Comparison of advantages and disadvantages of subway ticket mode

Ticketing mode	Advantages	Disadvantages
Single ticketing	Easy to use, less equipment, low cost.	Cannot reflect the relationship between distance and operation cost.
Metered ticketing	Reflect fairness, increase ticket revenue, reduce government subsidies.	Difficult to manage and carry out, require the technical equipment to support.
Section ticketing	Convenient for passengers transfer, reflect the change of the Metro Center station's edge distance.	Difficult to operate in the different charging regional edge, and difficult to determine the charge standard.
Timing ticketing	Improve the subway service level, beneficial for traffic demand management	Fares and riding distance have no direct relation, unfavorable to the high cost transportation system.

(2) Subway tickets in China

The metro ticket in our country can be divided into two types by issuing mechanism: the "one card" issued by the city bus company applicable to the all buses; the "one ticket" issued by the Metro Inc only suitable for subway system. The "one ticket" include the one-way ticket, the stored value ticket and the times ticket. Automatic fare collection system (AFC system) can form some extended ticket types according to the three main kinds of tickets, through the combination of parameters, such as: the round-trip ticket, the section ticket, the regional deadline ticket, the travel ticket, and the emergency ticket.

(3) Chengdu metro ticketing mode setting

Chengdu Metro Line 1 takes the composite ticketing mode combining the timing and metering, the basic fare starting from 2 yuan, the whole section cost 5 yuan valuation for interval single car at the station, passengers for single trip can stay in the station for to 2 hours; the metro ticketing mode in line 2 are the same with the line 1, the free vertical transfer can be realized in the Tianfu Square station, the harmony and unification between Metro and metro are realized. The subway tickets have two kinds, one-way IC card and Tianfu IC card. The one-way ticket issued by Metro Inc is only applicable to subway station and only available on the sale day; Tianfu card issued by the city, including ordinary card, student card and the old card, can be applied to the city bus.

3 Subway ticketing system

The subway ticket system is composed of the AFC system, the ticketing system, the financial system, the management system etc. In the administration of subway operation, the ticketing organization is monitoring, coordinating, commanding and scheduling on the ticket flows, income flows, and the running of AFC system. The quality of ticketing organization is directly related to the operation of the company's income and economic benefit. Therefore, the effective management of the AFC system is the core of metro operation management.

The AFC system is a city rail traffic charging system based on communication network, automatic control, non-contact RF IC card, sensing and other high-techs. It can realize the fare, seat, ticketing management, liquidation, statistics and other functions, and accomplish the automatic meter and timing charging in the passenger's trip process, the efficiency and benefits are effectively improved (CHEN Yu, 2009).

3.1 Subway ticketing system management mode

Metro ticketing system generally adopts the ticket center and station ticket, namely the two level management, the center ticket management mainly takes the plan management, the specific operation to face the passenger are mainly taken by the station ticket management.

The ticket policy is the core of the center ticket management. The ticket policy sets all kinds of business's implementation rules, such as fare revenue, check the financial, settlement. Including: fare formulation principle, the fare scheme, AFC system, settlement system and so on. The fare scheme is formulated the basis fare table, while provides the basic criterion of passengers, such as time, mileage and so.

The station ticket management mainly includes three aspects, namely revenue management, ticket management and ticketing facilities management. Revenue management is mainly completed by the AFC system; ticket management is mainly to realize the ticket recycling and reusing; facilities and equipment management is to repair and maintenance the daily operation and hardware and software upgrade work for AFC system and equipment.

3.2 The station ticketing processing rules

In a one-way ticket for example, passengers should buy a tickets according to the start point and end point of the applicable fare, valid for a single use, and is to be recovered when you are outbound. The specific ticket processing rules are shown in figure 1. The one-way ticket and Tianfu card in Chengdu metro are processed by the similar rules.

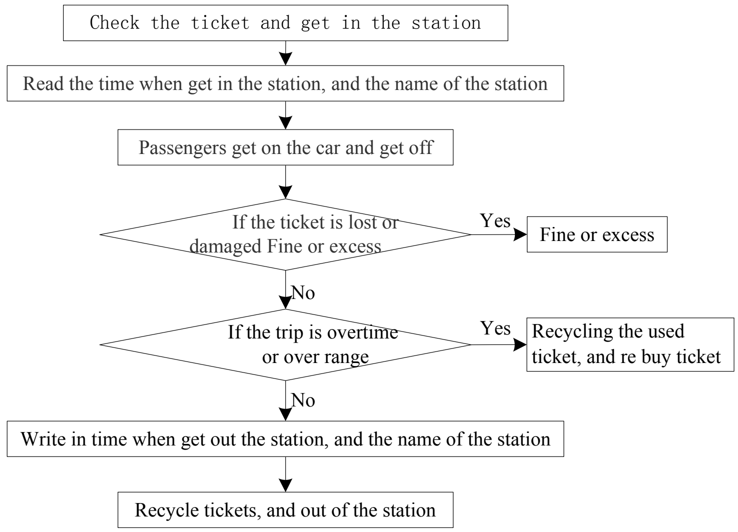

Figure 1. one-way tickets processing rules

4 Analysis of the ticketing system's coordination between Chengdu Metro and the Intercity Railway

4.1 The requirement and current status of the ticketing system's coordination

Chengguan High-speed Rail major services business and commuter passenger flows from Chengdu to Dujiangyan (Pengzhou), and it has very strong public welfare. Chengdu Metro Line 2 is introduced into the Xipu station on Chengguan High-speed Rail, ticketing system compatible for the two ticketing modes needed to be built, to achieve barrier free transfer in one stage.

Chengguan High-speed Rail has the short, the direct and the cross line passenger flows, the short distance passenger flow of XiPu Railway Station is mostly the transfer passenger flow from Metro Line 2. The current tickets use the real name system, divided into ordinary tickets and thermo sensitive magnetic tickets. Tickets are attached to the passenger's name, the identity card number, the travel time, the interval, the seat number and other information. The originating station uses the "check before wait" ticket mode, the other stations along the line use "check after wait" artificial checking or AFC mode (YANG Jie, 2010).

4.2 The solution for the coordination of the ticketing system

Since the railway CRH train tickets use the real name system, the transfer in XiPu station between the Metro Line 2 and Chengguan High-speed Rail is limited. The thermos sensitive magnetic tickets and the paper tickets are used in High-speed Rail, while IC card (Tianfu cards and single trip tickets) is used in Chengdu Metro. There are some difficulties in the realization of unification of the two ticketing systems. Therefore, a proposal to cancel the rail name ticketing system in Chengguan High-speed Rail is raised up.

(1) Cancel the rail name ticketing system in Chengguan High-speed Rail

The real name ticketing system makes the passenger ticket system complicated, making the involving problems complexity, greatly reducing the efficiency of the city bus passenger transport. As for the independent closed operation mode is used in Chengguan High-speed Rail, making passengers must purchase their tickets when out of the station to transfer to other railway in Chengdu Railway Station. If the real name system can be cancelled, it will not affect the operation of the internal other railway lines. In addition, Chengguan High-speed Rail will have big public welfare and others, so that it is more similar to the operating of urban rail transit. Therefore, cancel the real name ticketing system can be considered.

(2) Take the mode that combining the IC card and the magnetic ticket

IC card system is formed by the line ticket center, the station ticketing system and field equipment, and the ticketing mode uses the non-contact IC card, the technical standards, keys and data structures is the same with Chengdu Metro. The line ticket center should be set in Chengdu station of Chengguan High-speed rail, the station ticketing system of the station along the line should be accessed to the line ticket center (YANG Jie, 2010).

Magnetic ticketing system is composed of the regional ticket center, the station ticketing system and the field equipment, the ticket mode takes the original thermal magnetic paper ticket. All stations along Chengguan High-speed Rail ticketing system should be accessed to the area ticket center.

For the two ticketing system, the station ticket center and field equipment need to have the function to be able to identify, control, statistics, analysis.

(3) Establish the unified clearing center.

A rail transportation clearing center is required to be set by Chengguan High-speed Rail and Chengdu Metro in order to meet the need for unified the operational standards, share information in the ticketing system. The ticketing center should take unified management on the two ticketing systems, and adjusting ticketing operation mode, in order to realize distribution statistics and the financial income on both ticketing systems.

By canceling the real name ticketing system in Chengguan High-speed Rail and improving ticketing systems, using paper thermal magnetic tickets and subway IC card, the initial unity and coordination of the subway and intercity railway and between the bus system are realized.

5 Conclusions

Using the above ticketing system, although the harmonization and unification of the intercity railway and the subway are initially realized, there are still some constraints, mainly reflected in the following aspects:

① If the ticket system need integration, a lot of money for reconstruction on the related equipment update will be needed to invest and the cost of construction will be increased;

② The investment and management of ticket clearing center need operators to determine in consultation, more difficult exists in building;

③ The station using magnetic tickets and IC cards, the compatibility of automatic fare collection terminal for two ticketing modes will be needed to set.

④ Ticketing system requires real-time updates to control the number of passengers by the ticket checking system, thus reducing the probability of overcrowding of trains in the High-speed Rail.

Acknowledgement

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References

CHEN Yu. (2009). On the ticket Work Organization and Management of Urban Rail Transit. Urban Rapid Rail Transit, 22(6), 55-57.

WANG Ke. (2007). Research on Transfer between Intercity Passenger Dedicated Lines and Urban Transport (Master's thesis, Southwest Jiaotong University).

YANG Jie. (2010). Study on the Ticket Management Problems of Intercity Ticket System. Technical project of rail signal and communication, (1), 12-15.

ZENG Qiong. (2011). Research of Questions on the Intercity Railway Passenger Ticket System. Chinese Railways, (4), 73-75.

ZHAO Xiaoju. (2006). Study on the Transfer between Urban Rail Transit and Bus Transit. Changsha University of Science & Technology.

Optimization Analysis of the Energy-Absorbing Structures in a Subway Train

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Abstract: In this paper, energy-absorbing structures at the front end of the subway trains are studied through size optimization and topology optimization. To maximize the energy absorption and minimize peak impact force, the size optimization is conducted by optimization software iSIGHT and collision simulation software PAM-CRASH. Moreover, the topology optimization of energy-absorbing device is obtained by software OptiStruct. The results indicate that combining the two aforementioned optimization techniques is capable to improve the crashworthiness of the energy-absorbing structures and the passive safety of the subway train.
Keywords: Subway train; Energy-absorbing structure; Collision simulation; Optimization design.

1 Introduction

At present, the subway has been vigorously developing in many cities, because of its huge capacity and quick speed. Once a traffic accident occurs, it will cause serious casualties and property losses. Therefore, the development of collision safety technology is very necessary. The technology is divided into active safety and passive safety protection . Active safety technology refers to take positive measures to prevent the occurrence of accident. And passive protection technology is the means through good crashworthiness design and energy absorption protection system to guarantee the life safety of the driver and passengers. With the improvement of train speed, the crashworthiness design of train has become a hot topic in the current rail safety field.

The optimization design of crashworthiness problems are being studied extensively . In 1975, Bylytschko first carried out the finite element analysis on train collision, using the shell element and the explicit time integration technology. By the response surface method, Kurtaran conducted the crashworthiness of the constrained

Optimization of the cylindrical shell and the simplified train body structure. With maximum energy absorption as the optimization objective and impact load as the constraint, Fang and Jiao used the response surface method to optimize the rectangular section of the thin-walled member considering the crashworthiness.

In this paper, the optimization design of the subway train is divided into the following Firstly, considering both the energy absorption maximum and minimum peak impact force, the size of energy absorption structure is optimized using the optimization software iSIGHT and the collision simulation software PAM-CRASH. Secondly, the topology optimization of energy-absorbing device is obtained by the software OptiStruct. At the same time, the crashworthiness of this device is verified.

2 The Theory of Crash Simulation and the Finite Element Model of Train

2.1 The Basic Theory of Crash Simulation

Currently, the main collision analysis software are based on the following formulas:

The momentum equation,

$$\sigma_{ij,j} + \rho f_i = \rho \ddot{x}_i \tag{1}$$

Where ρ is the density, σ_{ij} is the stress, f_i is the volume force and $\ddot{x}_i$ is the acceleration.

The mass conservation equation,

$$\rho \ \gamma = \rho_0 \tag{2}$$

Where γ is the relative volume, ρ_0 is the initial density.

The energy conservation equation,

$$\dot{E} = VS_{ij}\dot{\varepsilon}_{ij} - (p+q)V \tag{3}$$

Where $\dot{E}$ is the current energy, $\dot{\varepsilon}_{ij}$ is the strain rate, q is viscous resistance, S_{ij} is given by $S_{ij} = \sigma_{ij} + (p+q)\sigma_{ij}$, p is the pressure given by $p = -\sigma_{kk}/3 - q$, V is the volume.

So, the equilibrium equation in the Galerkin form is

$$\int_V (\rho\ddot{x}_i - \sigma_{ij,j} - \rho f_i)\delta x_i dV + \int_{S^0} (\sigma_{ij}^{+} - \sigma_{ij}^{-})n_j \delta x_i dS + \int_{S^1} (\sigma_{ij} n_j - t_i)\delta x_i dS = 0 \tag{4}$$

By the divergence theorem, formula (4) can be written as follow:

$$\int_V (\sigma_{ij}\delta x_i)_{,j} dV = \int_{S^0} (\sigma_{ij}^{+} - \sigma_{ij}^{-})n_j \delta x_i dS + \int_{S^1} \sigma_{ij} n_j \delta x_i dS \tag{5}$$

So, the finite element discretization form is

$$M\ddot{x}(t) = P(x,t) - F(x,\dot{x}) \tag{6}$$

In which, M is the mass matrix, $\ddot{x}(t)$ is the node acceleration vector and P is the load vector. The numerical method mostly applies the explicit central difference method.

2.2 The finite element model of train

In this paper, a simplified finite element model was built. The size of element used is 25 mm, and local refinement is needed for interesting part. The length of train is 19000mm, the width is 2650mm, the height is 3785mm and the weight is 32t. The head of the train is divided into 870793 elements. Figure 1 shows the finite element model and the partial enlarged view of the front part.

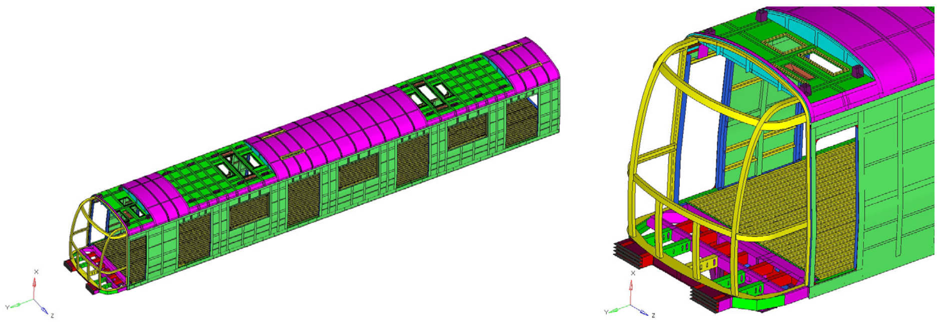
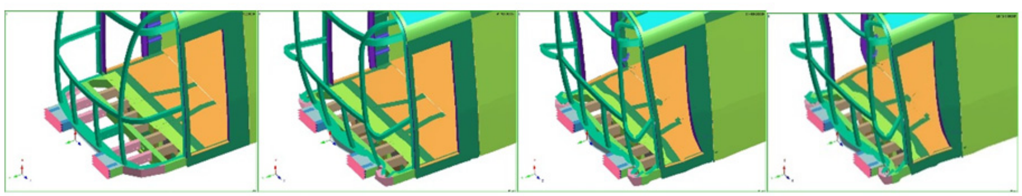


Figure 1. The finite element model

3 The size optimization of the energy absorption structure

3.1 The simulation analysis of collision

Under the working condition of fully loaded head train at a 25km/h speed impacting on a rigid wall, the simulation result of collision is gotten.



0ms 80ms 60ms 250ms

Figure 2. The deformation of front-end at the different time

From Figure 2, we can see the first level of energy-absorbing beam has been completely collapse. But the deformation of the second level is very small. Therefore, this level doesn't work.

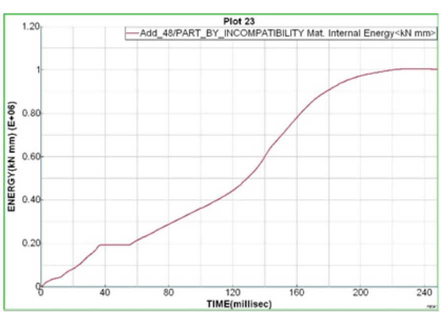


Figure 3. The sum of energy absorption

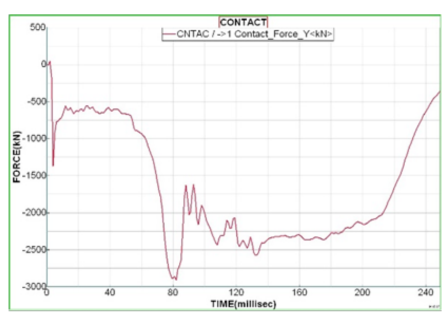


Figure 4. The history of collision force

From Figure 3, the absorbed energy curve shows the total energy absorption is 1005KJ. The peak impact force in Figure 4 is 2908KN.

3.2 The optimization model

In this paper, the following multi-objective optimization model is solved.

$$\begin{aligned} &\max E(T_1,T_2) \\ &\min F(T_1,T_2) \\ &s.t.\ 1.0 \le T_1 \le 4.0 \\ &\qquad 4.0 \le T_2 \le 10.0 \end{aligned} \tag{7}$$

Where, E is the total energy absorption by the energy-absorbing beam, F is the collision force, the design variable T_1 and T_2 are the two level's thickness of energy-absorbing beam.

				T1	T2	E	F
✔	1	1	1/1*	2.0	8.0	431040.0	2909.4
✔	1	1	2/1*	2.12	8.0	457380.0	3020.4
✔	1	1	3/1*	2.24	8.0	466940.0	3016.0
✔	1	1	4/1*	1.76	8.0	429810.0	3133.8
✔	1	1	5/1*	2.36	8.0	463880.0	3014.6
✔	1	1	6/1*	2.48	8.0	483850.0	2829.7
✔	1	1	7/1*	2.6	8.0	503800.0	2915.5
✔	1	1	8/1*	2.96	8.0	523360.0	3093.4
✔	1	1	9/1*	3.08	8.0	541030.0	3035.8
✔	1	1	10/1*	2.72	8.0	541030.0	3035.8
✔	1	1	11/1*	2.84	8.0	510440.0	2980.4
✔	1	1	12/1*	3.44	8.0	582250.0	3024.9
✔	1	1	13/1*	3.56	8.0	593620.0	2955.3
✔	1	1	14/1*	3.56	7.76	592120.0	2972.5
✔	1	1	15/1*	3.56	8.72	593490.0	2984.8
✔	1	1	16/1*	3.56	9.92	590880.0	2959.7
✔	1	1	17/1*	3.56	7.04	593660.0	2924.5
✔	1	1	18/1*	3.56	7.52	589020.0	2911.2
✔	1	1	19/1*	3.56	5.12	593930.0	2900.8
✔	1	1	20/1*	3.56	5.36	593930.0	2900.8
✔	1	1	21/1*	3.56	4.64	594380.0	2817.8
✔	1	1	22/1*	3.56	4.0	779820.0	2442.0
✔	1	1	23/1*	3.56	4.4	630550.0	2720.9
✔	1	1	24/1*	3.56	6.32	589350.0	2898.2
✔	1	1	25/1*	3.56	6.8	594580.0	2916.0
✔	1	1	26/1*	3.56	4.0	780630.0	2443.4

Figure 5. The iteration of the optimization problem

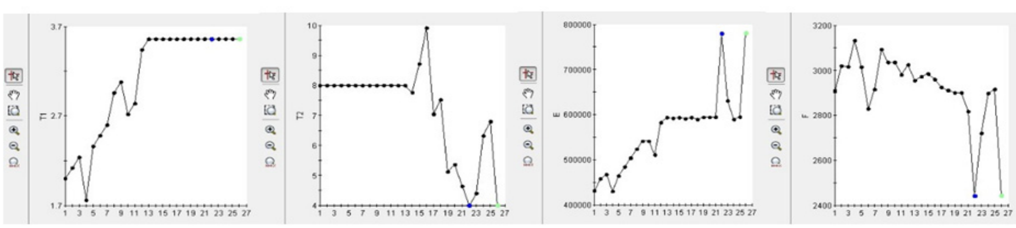
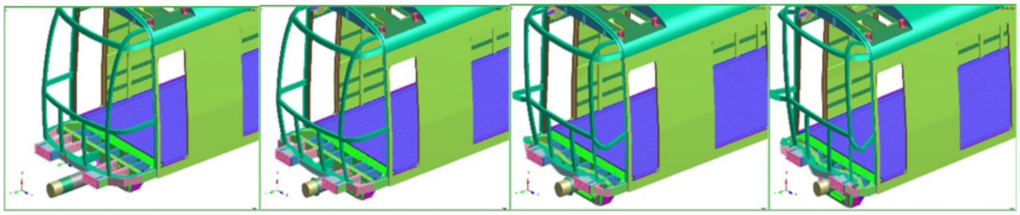


Figure 6. The iteration history of T_1, T_2, E and F

The data and curves optimization history are shown in Figure 5 and Figure 6. For the last iteration, the thickness of the first level energy-absorbing beam is 3.56 mm, the thickness of the second level is 4.0 mm, the total energy absorption is 780630J and the maximum collision force is 2443.4KN.

3.3 The optimization results

For the optimized energy-absorbing beam, the simulation result of collision can be gotten.



T=0ms T=81ms T=162ms
T=250ms

Figure 7. The deformation at different time after size optimization

As it can be seen from Figure 7, until the end of the collision, the floor didn't occur any deformation. The first level of energy-absorbing beam completely collapse, and the second level is only partly damaged. So, the optimized structure can withstand the more powerful impact. The performance of this structure is improved greatly.

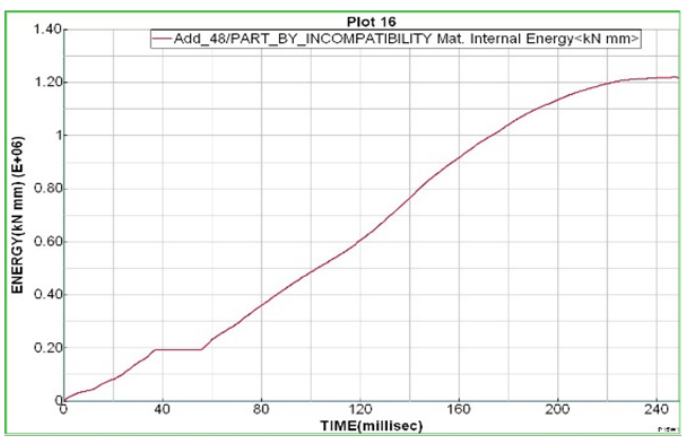


Figure 8. The total energy absorbed by the optimized energy absorption structure

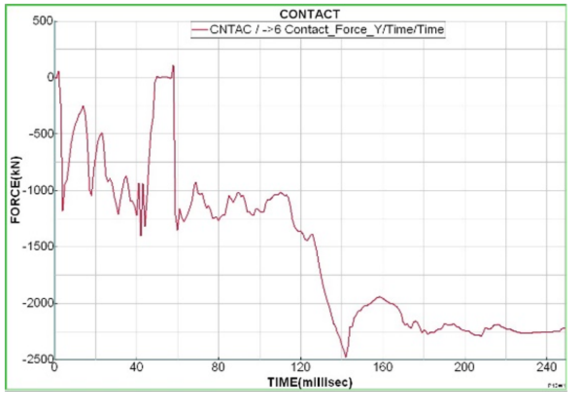


Figure 9. The curve of collision force

Table 1. Structure performance before and after size optimization

	Absorbed energy	Mass of the energy-absorbing	Peak impact force
Before	1005KJ	72.38kg	2908KN
After	1218.5KJ	62.25kg	2477.3KN
Improvement	21.2%	13.9%	14.8%

From the above curves and table, we can see the total absorbed energy is raised to 1218.5KJ and the peak impact force of collision is reduced to 2477.3KN. Furthermore, the mass of the two-level energy-absorbing beams reduced 10.13kg. So, by the size optimization, the performance of crashworthiness is improved and the lightweight design is realized.

4 Topology optimization of the second level energy-absorbing beam

4.1 The design domain and the working condition

The front end of the train is shown in Figure 10. The design domain is the second level energy-absorbing beam. By the topology optimization, the collision resistance of train is improved and the lightweight design is realized. A 3000 KN impact force is applied at anti-creeper position, when the longitudinal displacement constraint is considered.

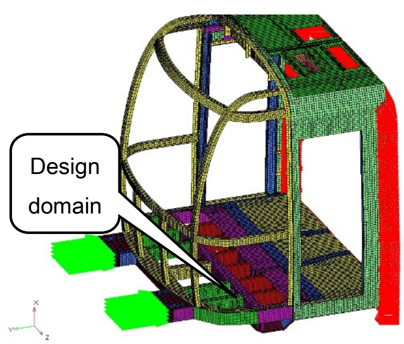


Figure 10. Topology optimization condition

4.2 The result of topology optimization

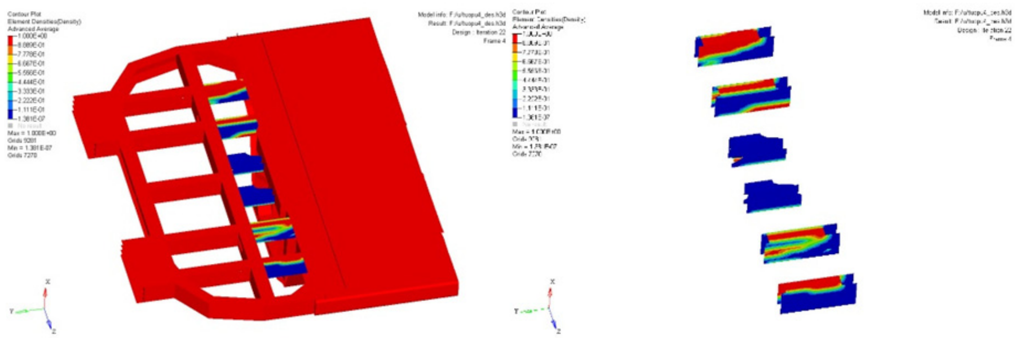


Figure 11. The result of topology optimization

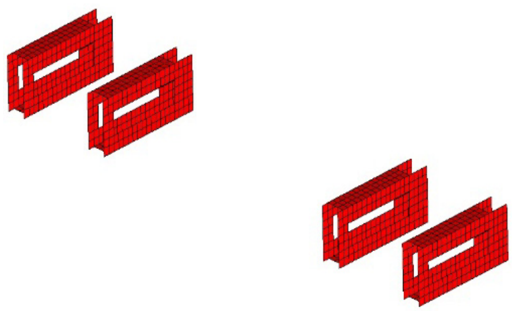
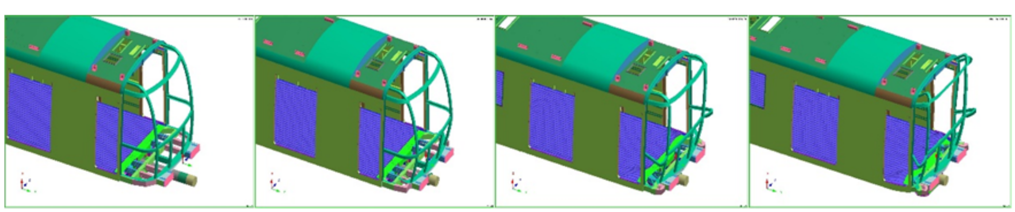


Figure 12. The redesigned energy-absorbing

In Figure 11, the red part represent the density is 1, and the blue part represent the density is 0. Other colors represent the density is between 0 and 1. We can see that the stiffness is big enough so that the two beams in the middle can be removed. Moreover, the other four beams can be designed as shown in Figure 12.

4.3 The result analysis of collision considering the redesigned energy-absorbing structure



T=0ms T=80ms T=160ms T=250ms

Figure 13. The deformation at different time after topology optimization

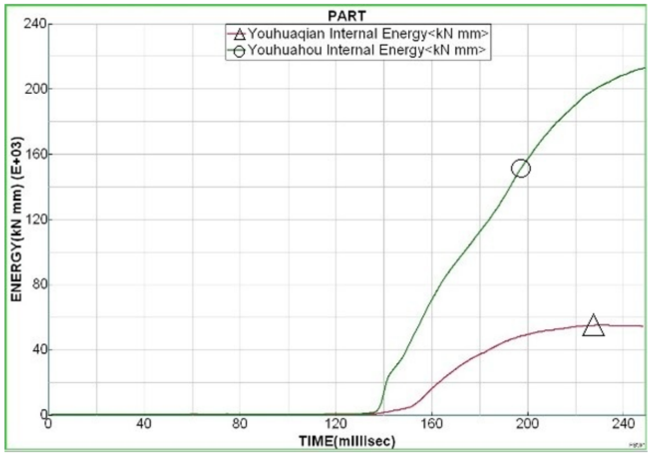


Figure 14. The total energy absorbed by the redesigned energy absorption structure

Figure 15. The curve of collision force

Table 2. Structure performance before and after topology optimization

	The absorption energy of the second level beam	Mass of the energy-absorbing beam	Peak impact force
Before	55KJ	72.38kg	2908KN
After	214.9KJ	50.3kg	2739.1KN
Improveme nt	339.8%	30.5%	5.8%

From Figure 13, we can see the first level of energy-absorbing beam completely collapse and the second level is also damaged. But the second level can absorb more energy if the impact force greater. In table 2, the absorbed energy of second level is raised to 214.9KJ and the peak impact force of collision is reduced to 2739.1KN. Furthermore, the mass of the two-level energy-absorbing beams reduced 22.08kg. So, the performance of energy-absorbing beam is improved and the lightweight design is realized.

5 Conclusion

Combining the optimization software iSIGHT and the collision simulation software PAM - CRASH, multi-objective size optimization of the energy-absorbing beams was realized. Moreover, the topology optimization method is used for the second level energy-absorbing beam by the software OptiStruct. The results show that, the crashworthiness of the energy-absorbing beam is improved and lightweight design is realized. It is suggested that the present optimization design method is capable to improve the passive safety of the railway vehicle collision.

Acknowledgement

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References

Yang Huifang. (2009). “Research on Passive Safety and Crashworthiness Optimization of CRH3 EMU.” *Dalian Jiaotong University, Master's Thesis.*

Jiménez M A, Miravete A, Larrode E,et al. (2000). Effect of trigger geometry on energy absorption in composite profiles. *Composite Structures*, 48:107-111.

Kongtian Zuo, (2004). Applied research and theory of Topology optimization in continuum structure. *Huazhong University of Science and Technology doctoral dissertation*.

Li Lan, Liu Jinchao, Wang Chengguo, Fan Zhongsheng (2008). “Digital design research of urban rail vehicle collision resistant structure”. *Rolling Stock*, 28(2), 28-32

Qian Lingxi. (1983). Engineering structure optimization design. *China WaterPower Press, Beijing*

Chen Bingzhi, Zhang Xuming, Xu Fengjun (2005). Summarized of design methods of topology optimization. *Shanxi architecture.*

Shan Qiyu (2010). Structure research of High-speed car body collision resistant. *Southwest Jiaotong University, Master's Thesis.*

Su Shengwei (2008). Application research based on topology optimization of Optistruct. *Harbin Engineering University*.1-8

Hou Shujuan (2007). Optimization design of the thin-walled components with crashworthiness criterion. *Hunan university doctoral dissertation*.

Wei Wang (2007). Optimization design of topology and size in Exhibition string than flying wing shape structure. *Northwestern polytechnical university, Master Mhesis.*

Yu Yeyi (1996). Highway transportation system security. *China Railway Publishing House*.

Urban Transit Systems' Efficiency Evaluation Model Based on DEA

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Abstract: This paper constructed efficiency evaluation model which was based on the Data Envelopment Analysis of urban transit systems from the input and output perspective. Meanwhile, this article obtained annual technological and scale efficiency and quested the solutions of urban transit systems' problem discovered in this evaluation studies through evaluating the Peking's efficiency of urban transit systems from 2003 to 2012 with this model. Thereby, this post provide the basis for improving the organization and optimization of urban transit systems furtherly. As a result, the pure technical efficiency of Peking's transit system is higher, but for achieving the best performance, it is necessary to increase investment in technology. Generally, the returns to Peking's transit systems' scale is increasing. And it has a large room to enhance.

Keywords: Urban transit; Efficiency evaluation; DEA model; Peking.

1 Introduction

The urban transit systems is not only the important urban infrastructure but also the Social Welfare Cause that is related to the national interest and people's livelihood. Currently, Public Transportation Priority has become the consensus of the metropolitan transportation development, developing energetically public transit is important channel to settle the urban traffic jam. Under the background of urban traffic congestion, the effective method to improve the urban transit systems' efficiency can be found and the degree of organization and optimization of the urban transit systems can be enhanced with this method through evaluating the transit system's efficiency and analyzing the significant factors influencing the efficiency. Significant research has been conducted by international and domestic academics in recent years, one of the most mature quantitative research methods is Data Envelopment Analysis (DEA). Attah K. Boame(2004) concluded that the average technical efficiency was about o.78 through evaluating the efficiency of Canadian urban transit systems from 1990 to 1998 with the method of DEA and analyzing the change of efficiency with the method of Tobit analysis of regression. Matthew G. Karlaftis(2004) studied the relationship among efficiency effectiveness and economies of scale of 256 transit systems of American over a 5 year time period with the DEA and frontier production functions and obtained the conclusion that efficiency and effectiveness were positively correlated and economies of scale was dependent on output. SHEN Xiaojun et al (2008) obtained the annual technological and scale efficiency and put forward of the corresponding improvement measures with the application of DEA to evaluate the efficiency of urban transit systems of Nanjing from 2000 to 2006. YANG Ming et al (2011) established the evaluation model of public transport operation efficiency with the application of DEA, analyzed the advantage and disadvantage of Changsha by comparing with others through laterally assessing the capital cities' public transport operation efficiency of 17 provinces in 2009 and analyzed its development performance of transit operation mainly through longitudinally evaluating the data of Changsha from 2001 to 2010. In home and overseas study, because of the difference of objects of study selected by scholars, which make the evaluation indicators selected in DEA model diversity and the analysis to the factors which influence the efficiency is weak. As a result, this paper will assess the urban transit systems of Peking with the channel that study and construct DEA model and propose measures purposefully through analyzing the results of assessment.

2 The evaluation model and Indicator system of urban transit systems' efficiency

Currently, there is no unified definition regarding the efficiency of urban transit systems at home and abroad, the conventional definition adopted is derived from which is based on the definition of efficiency. Economic efficiency is the degree meeting the need of people, which is afforded by social production with the usage of available resources. Generally, it often be called the resource utilization rate. Thus it can be seen that efficiency mainly exam the relationship between the input and output. The efficiency of urban transit systems, it also be called the input-output ratio of resource of urban transit systems, is a correlation between the investment to public transit and the satisfaction degree of people's need to public transit generated by the investment to public transit.

Data Envelopment Analysis is a method of efficiency rating that be in the crossing field of operational research, management science and econometrics, which was created by A. Charnes and W. W. Cooper et al (1978) who were the American famous operational research experts. Decision Making Units (DMU) is the department or unit with the multiple input and output. DEA can assess Decision Making Units' comparative validity through making sure the production frontiers and whether the DMU is on the stochastic frontier of production possibility set or not, it's a nonparametric evaluation method without the need of parameter estimates. The evaluation result obtained by picking the DEA model is independent of the effectiveness of any human factors, in other words, it is objective. This paper picks up the CCR model and C^2GS^2 model that are the mostly representative model of DEA models, the CCR model can be used to assess the scale efficiency of DMU and overall effectiveness of technical efficiency, the C^2GS^2 model can be used to assess pure technical efficiency. The C^2GS^2 model can be obtained through increasing the constraints $\sum_{j=1}^{n}\lambda_j = 1$ in the CCR model.

The specific expression of CCR model is as followed:

Assume there are n decision-making units, each decision unit has m inputs and s outputs. The input and output vector corresponding with the decision-making unit j (j=1, 2… n) are $X_j = (x_{1j}, x_{2j}, ..., x_{mj})^T$ and $Y_j = (y_{1j}, y_{2j}, ..., y_{sj})^T$ respectively. x_{ij} is the volume of investment of input i *to* decision-making unit j , $x_{ij} > 0$, $i = 1,2,...,m$, $j = 1,2,...,n$; y_{rj} is the quantity of output r *to* decision-making unit j, $y_{rj} > 0$, $r = 1,2,...,s$, $j = 1,2,...,n$.

Building the DEA validity of linear programming models of decision-making unit j:

$$\min \theta = V_D$$
$$s.t.\begin{cases} \sum_{j=1}^{n}\lambda_j X_j \le \theta X_{j_0} \\ \sum_{j=1}^{n}\lambda_j Y_j \ge Y_{j_0} \\ \lambda_j \ge 0; j = 1,2,...,n \end{cases} \quad (1)$$

After introducing the slack variables ,the model(1) becomes：

$$\min \{\theta\}$$
$$s.t.\begin{cases} \sum_{j=1}^{n}\lambda_j X_j + S^- = \theta X_{j_0} \\ \sum_{j=1}^{n}\lambda_j Y_j - S^+ = Y_{j_0} \\ \lambda_j \ge 0; j = 1,2,...,n \\ S^- \ge 0; S^+ \ge 0 \end{cases} \quad (2)$$

X_{j_0} and Y_{j_0} are respectively the index vector of input j_0 and output j_0; θ is the shrink ratio; λ_j is the linear combination coefficient of decision-making units; S^- and S^+ are slack variables. DMU_{j_0} is the necessary and sufficient condition of DEA effective, the optimal value of linear programming $V_D = 1$,and λ_j, S^-,S^+ have the optimal solution. If $\theta^* = 1$, $S^{-*} = S^{+*} = 0$ then the decision-making unit j_0 is DEA effective; If $\theta^* = 1$, S^- and S^+ exist non-zero value, then the decision-making unit j_0 is DEA weak efficiency; if $\theta^* < 1$, then the decision-making unit j_0 is DEA invalid.

This paper chooses three input indicators and one output indicator through analyzing the physical truth, which is based on the definition of urban public transport system efficiency and the application of DEA model. Input indicators: the urban transit systems includes the common input of person, vehicle, and road elements and so on. However, as the index that characterize the Labor and capital investment, the number of operating vehicles (cars) and operating range (km) directly reflects the resources investment of the public transport system, the number of operating vehicle include all of the operating vehicles of bus, rail transit and taxi, operating range is divided into bus operating mileage and rail transit operating range. Output indicators: the annual passenger traffic is the most direct reflection of the operation effect of public traffic. DEA model's input and output indicators are shown in Table 1.

Table 1. The input and out index of urban public transport system

Type	content	Code
Input indicators	Number of operating vehicles	X1
	Bus operating range(km)	X2
	Rail transit operation range(km)	X3
Output indicators	Annual passenger traffic（100 million ）	Y

3 Evaluation of public transportation efficiency of Peking during 2003-2012

In the use of DEA model, taking every year from 2003 to 2012 as a DMU (DMU1, DMU2… DMU10), then, longitudinal evaluation of efficiency of Beijing public transportation is conducted based on those DMUs. The data of all input-output indexes comes from the annual report of Beijing traffic development, as shown in Table2.

Table 2. The input of Peking public transportation during 2003-2012

Year	Operating vehicles（Car）	Operation mileages of bus（Km）	Operation mileages of rail transit（Km）	Annual passenger traffic（Million visitors）
2003	83788	17908	114	47.8
2004	73252	16823	114	56.9
2005	86715	19206	114	59.0
2006	87089	19360	114	54.2
2007	87125	17353	142	55.2
2008	89821	17857	200	66.2
2009	90330	18270	228	72.7
2010	90611	18743	336	75.9
2011	91078	19460	372	79.2
2012	92431	19547	442	83.2

Based on Table2, taking the DEAP and BBC software to analysis the efficiency of Beijing public transportation, the analysis results (Table 3) mainly contain overall efficiency θ^*, pure technical efficiency σ^* and scale efficiency S^*. Technical efficiency means the output ability of a certain input. Scale efficiency reflects the scale of the development of public transportation.

Table 3. The analysis results of the efficiency of Beijing public transportation during 2003-2012

DMU	Overall efficiency θ^*	Pure technical efficiency σ^*	Scale efficiency S^*	Scale efficiency
DMU1（2003）	0.826	1.000	0.826	Increasing
DMU2（2004）	1.000	1.000	1.000	Steady
DMU3（2005）	1.000	1.000	1.000	Steady
DMU4（2006）	0.919	1.000	0.919	Increasing
DMU5（2007）	0.901	0.969	0.930	Increasing
DMU6（2008）	0.964	0.990	0.974	Increasing
DMU7（2009）	1.000	1.000	1.000	Steady
DMU8（2010）	0.981	0.997	0.984	Increasing

DMU9（2011）	1.000	1.000	1.000	Steady
DMU10（2012）	1.000	1.000	1.000	Steady
Average	0.959	0.996	0.963	

From the analysis results in Tabe3, we found that the efficiency of public transportation of Beijing was 1 in 2004,2005,2009,2011 and 2012; this result proves the input of public transportation was properly exploited and got the maximum output. The overall efficiency was less than 1 in 2003,2006,2007,2008 and 2010 which means DEA invalid; this consequence indicates the efficiency of public transportation is low in those years.

Because of overall efficiency is equal to the multiplying of pure technological efficiency and scale efficiency in the DEA model, the DEA's invalidity in 2003 and 2006 attribute to the scale in-efficiency. It reflects that the scale of public transit is small and the returns to scale is increasing. However, the reasons making the DEA invalid also include the lower pure technological efficiency in the year of 2007, 2008 and 2010, in other words, it fails to obtain the largest output under certain conditions of investment, which concludes that public transit should be allocated reasonably and the efficiency of public transit should be enhanced. Generally, the average efficiency, average pure technological efficiency, and average scale efficiency of Peking's public transit is 0.959, 0.996, and 0.963 respectively. And the returns to scale of urban transit systems is increasing or invariable in general. It indicates that the pure technological efficiency is higher, but increasing the technological investment making the Peking's public transit achieve the best state should be supposed and the scale efficiency has a large room to promote.

4 Conclusions

Data Envelopment Analysis is a very efficient method to study the comparative validity among the departments or units of the same type and it also is a very comprehensive method to deal with the multi-objective decision-making problem in theory. Meanwhile, there is no need to estimate the parameter in advance with the usage of DEA, it is independent of the effectiveness of the unit of index selected and it has the incomparable advantage in the aspect of avoiding the subjective factors and decreasing error.

This paper established the efficiency evaluation model based on DEA and introduced the evaluation index system with the usage of this method to evaluate the efficiency of Peking's urban transit systems. Meanwhile, this article obtained the annual technological and scale efficiency and put forward corresponding improvement countermeasure tentative ideas that have practical guiding significance through comparing the Peking's urban transit systems' efficiency from 2003 to 2012 over a period of ten years. For meeting the need of future urban transit systems' development, enhancing the overall transport capacity and efficiency of urban transit systems and the urban transit systems' organization and optimization, this paper suggests that the reasonable strategies should comprehend the structural contradictions in urban transit systems exactly, coordinate the input and output of every kinds of traffic resource reasonably, integrate the existing urban traffic resources and construct the urban transit systems with high accessibility, high coverage rate and high efficiency through establishing the DEA model and empirical study.

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References

Attah K. Boame. (2004). "The Technical Efficiency of Canadian Urban Transit Systems." *Transportation Research Part E*, 40(2004):401-416.

Matthew G. Karlaftis. (2004). "A DEA Approach for Evaluating the Efficiency and Effectiveness of Urban Transit Systems." European Journal of Operational Research, 152(2004):354-364.

SHEN Xiao-jun, CHEN Jun, WANG Chen. (2008). "The efficiency evaluation of urban transit systems based on DEA model." Modern Transportation Technology, 2008, 5(6), 76-79.

YANG Ming, TANG Pan. (2011). "The comprehensive assessment of performance of Changsha's public transit operation." Highways & Automotive Applications, 2011(6), 79-83.

Compiling Operative Plans of Rail Transit Turn-Back Stations

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Abstract: It is an important task that compiling operative plans of turn-back stations in surveying, designing and operating urban rail transit projects. The quality of operative plans not only has direct effects on the results of operation management, but also reflects the rationality of turn-back station's layouts. This paper transforms the problem of trains connection in station operative plans into spliced network planning of trains with many constraints and objective functions. Based on the Windows environment, using object-oriented language Visual C++ 6.0, this paper develops the Rail Transit Station Operative Plans Compiling and Simulation System with Trains Traction Calculation. It can achieve the goal that standardized management, fine simulation and optimization, provide technical support and decision-making reference for the surveying, designing and operation departments in urban rail transit.

Keywords: Rail transit; Turn-back station; Operative plans; Spliced network planning.

With the urbanization process in China, passenger flows and traffic demands increase rapidly, especially on holidays and morning and evening rush hours. The urban road congestion problems have severely restricted the sustainable development of cities. Looking at the development of the world's major cities, urban rail transit in major cities has been the preferred solution to solving the problem of traffic congestion and achieving urban sustainable development. Since the Beijing Subway Line 1 project started in 1965 and by the end of 2014, 38 cities that including Beijing, Shanghai, Tianjin, Guangzhou, Shenzhen, Nanjing and other have been approved to construct urban rail transit; among of them 22 cities, including Beijing, Shanghai, Tianjin, have built 95 urban rail transit lines whose operating distance has been over 2900 km and will reach 6956 km by 2020. Thus, Chinese rail transit will enter a new building boom period during the Thirteenth Five years.

In recent years, with more and more rail lines put into operation, rail transit is becoming increasingly important in alleviating urban traffic congestion. Based on practical experiences in rail transit operation, we can infer that there are still some difficulties for rail transit, which are station layouts, rolling stock performance, signal control, operation level and other factors, to deal with passenger flows in morning and evening rush hours, and the turn-back capacity is the key to enhancing system capacity. Consequently, no matter in choosing station layout during the phase of project surveying and designing, or in compiling operative plans during the phase of operation and management, capacity calculations in turn-back stations become the focus, and compiling operative plans is the only way to calculating turn-back capacity. Nowadays whether in surveying and designing department, or in operation and management department, the basic solution to compiling operative plans is under traditional artificial arrangements, and supplemented by train traction calculation or using artificial experience to estimate trains running time, then to diagram station capacity by artificial means. Thus compiling operative plans not only is subject to the makers' ability and experience, but also takes a lot of time, and the accuracy of the calculation would be difficult to be guaranteed, seriously affecting the decision of station layout and operational plans. Therefore, it's of great importance to propose a compiling model for station operative plans and develop simulation software.

1 Simulation Model

The key point of compiling turn-back station operative plans is to figure out succession plans among ahead and rear trains. Thus we can transform this problem into spliced network planning of trains with many constraints and objective functions.

Based on some operation activities like train's movement, running licenses, passengers getting on and off trains and so on, station operative plans regard these operation activities as "tasks" in spliced network. According to different categories of "tasks", station operative plans' spliced network among different "tasks" is divided into "craft relations" (or called as "interlock relations") and "organizational relations." "Craft relations" refers to occupied sequences of trains determined by lines' and stations' layouts and signal designing, mainly including trains' running process from point A to point B and logic relations of signal equipment' successive activities. "Organization relations" refers to the sequence determined by train operations and passenger services, including passengers getting on and off the train and driver's cages veering.

1.1 Station operative plans network

S_i^m is the beginning time for train i to do the task m; F_i^m is the end time for train i to do the task m; D_i^m is the minimum time needed by train i to do the task m; and the set of the task's attributes is $m_i = \left(S_i^m, F_i^m, D_i^m\right)$.

As is shown in Fig.1, to describe the spliced relations between two successive tasks, Time-Interval is defined as the minimum time interval needed to do the two tasks. $F_i^m TS_j^n$ (Finish to Start) is the time interval between the end time for the train i to do the task m and the start time for the next train j to do the task n; $F_i^m TF_j^n$ (Finish to Finish) is the time interval between the end time for the train i to do the task m and the end time for the next train j to do the task n; $S_i^m TS_j^n$ (Start to Start) is the time interval between the start time for the train i to do the task m and the start time for the next train j to do the task n; $S_i^m TF_j^n$ (Start to Finish) is the time interval between the start time for the train i to do the task m and the end time for the next train j to do the task n.

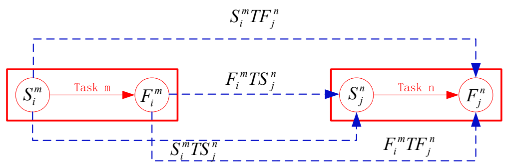

Fig.1 Sketch of spliced network relations

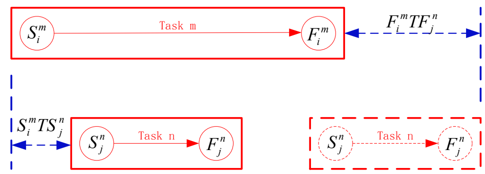

Fig.2 Sketch of mixed spliced network relations

As is shown in Fig.2, Mixed Spliced Relations is defined to describe the relations between two tasks, and it's controlled by $S_i^m TS_j^n$ and $F_i^m TF_j^n$. In other words, the start time between two tasks must keep a certain time interval, and so does the end time.

When compiling station operative plans, there must exist conflicting routes limited by interlocking relations of switches and intersecting between ahead and rear trains, which shows the two tasks can't start or be over at the same time. Thus we can transform conflicting routes of the two tasks into the spliced relations among $S_i^m TS_j^n$, $F_i^m TS_j^n$, $F_i^m TF_j^n$ and $S_i^m TF_j^n$.

1.2 Constraints of compiling station operative plans

(1) Stations must complete all the "tasks" once and only once.

Suppose that station need hand N trains, and each train i needs to do M tasks; χ_i^m represents the task m of train i whether to start or not.

$$\chi_i^m = \begin{cases} 1 & \textit{the work m of train i has started} \\ 0 & \textit{otherwise} \end{cases} \quad (1)$$

$$\gamma_i^m = \begin{cases} 1 & \textit{the work m of train i has ended} \\ 0 & \textit{otherwise} \end{cases} \quad (2)$$

$$\sum_{i=1}^{N}\sum_{m=0}^{M} \chi_i^m \gamma_i^m = 1 \quad \forall i, m \quad (3)$$

(2) Satisfy the requirements of time interval $S_i^m TS_j^n$, in other words, only when the task m of all trains i just ahead starts, can train j begin the task n.

Decision variable β_{ij}^{mn} represents the task m of train i being just ahead of the task n of train j.

$$\chi_j^n = \begin{cases} 1 & \sum_{i=1}^{N} \beta_{ij}^{mn} \chi_i^m = 1 \\ 0 & \textit{otherwise} \end{cases} \quad \forall j, n \quad (4)$$

ES_j^n represents the earliest start time for train j to do the task n. EF_j^n represents the earliest end time for train j to do the task n. Thus the earliest start time for train j to do the task n equals the task m's start time of all trains i just ahead pluses the maximum value of the time interval $S_i^m TS_j^n$. The earliest end time for train j to do the task n equals the task m's earliest start time ES_j^n of all trains just ahead pluses the minimum time needed by task n.

$$ES_j^n = MAX\left(S_i^m + S_i^m TS_j^n \middle| \beta_{ij}^{mn} \chi_i^m = 1 \quad \forall i, m\right) \tag{5}$$

$$EF_j^n = ES_j^n + D_j^n \tag{6}$$

(3) Satisfy the requirements of time interval $S_i^m TF_j^n$, in other words, only when the task m of all trains i just ahead starts, can train j end the task n.

$$\gamma_j^n = \begin{cases} 1 & \sum_{i=1}^{N} \beta_{ij}^{mn} \chi_i^m = 1 \\ 0 & otherwise \end{cases} \quad \forall j, n \tag{7}$$

Thus EF_j^n is the maximum value of the task m's start time of all trains i just ahead pluses the time interval $S_i^m TF_j^n$.

$$EF_j^n = MAX\left(F_i^m + S_i^m TF_j^n \middle| \beta_{ij}^{mn} \chi_i^m = 1 \quad \forall i, m\right) \tag{8}$$

$$ES_j^n = EF_j^n - D_j^n \tag{9}$$

(4) Satisfy the requirements of time interval $F_i^m TS_j^n$, in other words, only when the task m of all trains i just ahead ends, can train j start the task n.

$$\chi_j^n = \begin{cases} 1 & \sum_{i=1}^{N} \beta_{ij}^{mn} \gamma_i^m = 1 \\ 0 & otherwise \end{cases} \quad \forall j, n \tag{10}$$

Thus the earliest start time for train j to do the task n equals the task m's end time of all trains i just ahead pluses the maximum value of the time interval $F_i^m TS_j^n$.

$$ES_j^n = MAX\left(S_i^m + F_i^m TS_j^n \middle| \beta_{ij}^{mn} \gamma_i^m = 1 \quad \forall i, m\right) \tag{11}$$

$$EF_j^n = ES_j^n + D_j^n \tag{12}$$

(5) Satisfy the requirements of time interval $F_i^m TF_j^n$, in other words, only when

the task m of all trains i just ahead ends, can train j end the task n.

$$\gamma_j^n = \begin{cases} 1 & \sum_{i=1}^{N} \beta_{ij}^{mn} \gamma_i^m = 1 \\ 0 & otherwise \end{cases} \quad \forall j,n \tag{13}$$

Thus EF_j^n is the maximum value between the task m's end time of all trains i just ahead and the time interval $S_i^m TF_j^n$.

$$EF_j^n = MAX\left(F_i^m + F_i^m TF_j^n \middle| \beta_{ij}^{mn} \gamma_i^m = 1 \quad \forall i,m\right) \tag{14}$$

$$ES_j^n = EF_j^n - D_j^n \tag{15}$$

(6) To compact all tasks and make the operative capacity in station reach the maximum, the time interval between two successive tasks is expected to be the least. LAG_{ij}^{mn} represents the time interval between the task n's start or end time of train j and the task m's end or start time of the just ahead train i.

$$MIN\left(LAG_{ij}^{mn}\right) = \begin{cases} \left(ES_j^n - ES_i^m\right)\beta_{ij}^{mn} \chi_i^m & \forall S_i^m TS_j^n \\ \left(ES_j^n - EF_i^m\right)\beta_{ij}^{mn} \chi_i^m & \forall S_i^m TF_j^n \\ \left(EF_j^n - ES_i^m\right)\beta_{ij}^{mn} \gamma_i^m & \forall F_i^m TS_j^n \\ \left(EF_j^n - EF_i^m\right)\beta_{ij}^{mn} \gamma_i^m & \forall F_i^m TF_j^n \end{cases} \tag{16}$$

2 The optimal solution of model and the operative capacity of stations

When compiling station operative plan network, some regulations about the operative process of inbound and outbound trains need to be made. Thus suppose that stations first do inbound tasks of trains from adjacent stations or sections, then do the tasks about passenger service, and finally do the task of outbound. Meanwhile we assume the earliest start time of network plans is 0 and no task has been done; in other words, the start time for the first train to do the first task is 0 (that is $S_{i=1}^{m=1} = 0$); and then we plus some time one by one according to the task requirements and spliced relations.

Operative capacity in rail transit stations is closely related to the compiling of operative plan, which is represented by time intervals of two successive trains and divided into arrival time intervals and departure time intervals according to the differences between arriving in and departing from stations. The shorter of time intervals, the more trains handled in a unit time (usually 1 hour), and the larger of the operative capacity of stations.

$CF_{i,j}$ represents the departure time interval between two successive trains, which is the difference between the two last tasks' end time (that is $m = M$) of the former train i and the latter train j; $DD_{i,j}$ represents the arrival time interval between two successive trains, which is the difference between the two first tasks' start time (that is $m=1$).

$$CF_{i,i+1} = F_{i+1}^{m=M} - F_i^{m=M} \tag{17}$$

$$DD_{i,i+1} = S_{i+1}^{m=0} - S_i^{m=0} \tag{18}$$

$CF_{\min}$ is the minimum departure time interval, which is the maximum value among all departure time intervals （$CF_{i,j}$） between two successive trains. $DD_{\min}$ is the minimum arrival time interval, which is the maximum value among all arrival time intervals （$DD_{i,j}$） between two successive trains.

$$CF_{\min} = MAX\left(\overset{N-1}{\underset{i=1}{CF}}{}_{i,i+1}\right) \tag{19}$$

$$DD_{\min} = MAX\left(\overset{N-1}{\underset{i=1}{DD}}{}_{i,i+1}\right) \tag{20}$$

HT（headway of trains）represents the minimum tracking headway of two successive trains, choosing the maximum value among $CF_{\min}$ and $DD_{\min}$. During the compiling of station operative plans, by properly arranging the task start and end time of two successive trains, we can minimize HT namely, we get the optimal solution and also make station capacity get the maximum value.

$$HT = MAX(CF_{\min}, DD_{\min}) \tag{21}$$

HT is defined to represent how many pairs of trains received or sent by station in one hour.

$$N_h = 3600 / HT \tag{22}$$

3 Analysis of Case Simulation

According to the model above, based on the Windows environment, using object-oriented language Visual C++ 6.0, we develop the Rail Transit Station operative plan Compiling and Simulation System with Trains Traction Calculation. As is shown in Fig.3, we take this certain rail transit station as an example and simulate by means of the system. In this case, station layout is a turnaround station with one island platform and dual crossovers before the station; trains consist of 4 motor cars and 2 trail cars and their maximum running speed is 80km/h; the limited speed of switches is 35km/h; the total time for passengers get on and off the train is 90 seconds. Assuming the two turn-back tracks and platform being empty at the beginning, we can use the system to simulate the station operative plans, as is seen in Fig.4.

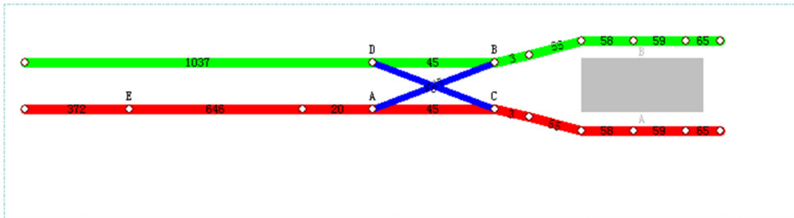

Fig.3 sketch of station yards

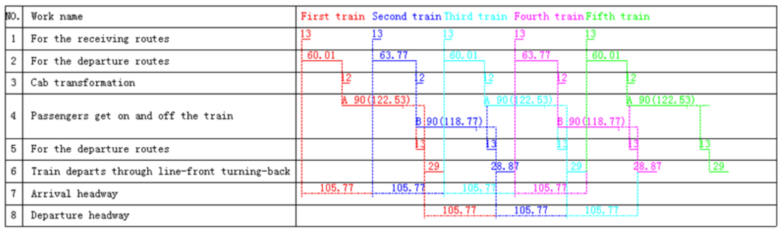

Fig.4 graph of station operative plans

According to the station operative plans obtained by simulation, the optimal operative process for this station layout is described as follows:

Step 1: The first train arrives in the station straightly through Point E and stops at Side A of the station, and then passengers get on and off the train, meanwhile apply for a lateral arrival routing and clear the signals.

Step 2: The second train arrives in through Point E and stops laterally at Side B after one tracing headway, and then passengers get off the train.

Step 3: After the second train stops, convert the switches and clear the signals. When the station dwell time is over, the first train departs laterally and Side A becomes unoccupied.

Step 4: After the first train leaves and the track circuit Point D at the before-station crossover gets unoccupied, convert the switches and clear the signals; then the third train arrives in through Point E straightly and stops at Side A of the station.

Step 5: After the third train stops, convert the switches and clear the signals, when the station dwell time is over, the second train departs straightly and the Side B of the station gets unoccupied.

Step 6: After the second train leaves and the track circuit Point D at the before-station crossover gets unoccupied, convert the switches and clear the signals; then the fourth train arrives in through Point E laterally and stops at Side B of the station.

Step 7: After the fourth train stops, convert the switches and clear the signals, when the station dwell time is over, the third train departs laterally and the Side A of the station gets unoccupied.

Step 8: After the third train leaves and the track circuit Point D at the before-station crossover gets unoccupied, convert the switches and clear the signals; then the fifth train arrive in through Point E straightly and stops at Side A of the station.

From here to Step 5 forms a cycle.

From Fig.4, we can conclude the minimum departure headway ($CF_{\min}$) and arrival headway of this station layout is 105.77s; the minimum tracing headway is $HT = MAX(105.77,105.77) = 105.77$ s; and the number of receiving and sending trains in one hour is $N_h = 3600 / HT = 34$ pairs.

4 Conclusions

The quality of operative plans for turn-back stations directly restricts and influences the choice of turn-back stations' layouts in the survey and design phase and the determination of running plans in the operation and management phase. The paper transforms the problem of compiling station operative plans into spliced network planning with many constraints and objective functions. The Rail Transit Station Operative Plans Compiling and Simulation System with Trains Traction Calculation is developed to achieve the standardization, refinement and optimization of urban turn-back station operative plan compilation. The paper sets a certain turn-back station as an example to simulate and prove the feasibility of the model, providing technical support and decision-making reference for the surveying, designing and operation departments in urban rail transit.

References

HUANG Zhi-ming,SUN Jian-xiong,LI Jian-yu(2007).Study on simulation algorithm of metro train opertaion.Electric Locomotives & Mass Transit Vehicles,2007(3):56-57.

LU Gong-yuan,YAN Hai-feng,XIAO Lei,YANG Kui(2013). Study on Modeling and Simulation System of High-speed Railway Station Opertation.RAILWAY TRANSPORT AND ECONOMY,2013(05):37-42.

YANG Bing(2002).Analyzing the Models for Spliced Network Planning.JOURNAL OF NORTHERN JIAOTONG UNIVERSITY,2002(05) :84-88.

ZHOU Meng,DU Zhi-da(2012).Calculation Methods for Multi-dependency Network with Maximum Time Lags.Journal of Engineering Management,2012(04) :67-71.

UML Modeling and Development of an Urban Rail Transit Network Passenger Travel Process

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Abstract: Improve urban rail transit system's operation efficiency, guarantee the operation scheme's economical, reasonable and effective has important significance to ensure the city passenger transport system's whole performance work normally. This paper from the view of network level, put train operation process simulation with passenger travel process simulation together, research the microcosmic simulation problem of urban rail transit network passenger transport process, use the unified modeling language to describe the simulation system's analyze, design and realize; and take Suzhou rail transit network planning in 2015 as an example, achieve its' passenger travel process's microcosmic simulation. The microscopic simulation technology, can recur the whole network passenger transport process, achieve elaborate statistical time and efficiency index, and to lay a solid foundation for the operation scheme's analysis, decision-making and evaluation.
Keywords: Urban rail transit; Unified modeling language; Passenger travel process; Microcosmic simulation.

1 Preface

Network operation is the inevitable developing trend of urban rail transit. Lines in the network interconnected by transfer station, make different lines' passenger transportation activities correlative, interact, and variety, therefore, compared with the single line condition, rail transit network operation are more complicated in passenger flow distribution forecast, transportation plan making, event emergency treatment and other aspects. In order to achieve network transport organization's optimal management, it is especially important to grasp the passenger flow's time-space distribution laws, master the interaction relationship between sections, stations, trains and passenger flows in the network from the nerwork level.

This paper suggest to build system entity model, establish the rail transit passenger travel process simulation system, using UML tools to describe the system's analysis, design and development, and take Suzhou rail transit network planning in 2015 as an example, achieve its' passenger travel process's microcosmic simulation. The system can provide effective auxiliary decision-making tools and methods to network passengers' distribution analysis and forecasting, transport scheme's optimization, emergency resources' optimal allocation and etc.

2 Modeling analysis based on UML

Here to describe system analysis by use case diagram and activity diagram, to describe system design by class diagram, sequence diagram and state diagram, to describe system development by component diagram.

2.1 System analysis

The system's user include network basic information administrator and simulation valuator. Basic information administrator is responsible for various data management needed by simulation, such as: network structure basic data, train operation data, station time and passenger flow data, etc. Simulation valuators used the 'simulation parameters management module' to invoke the basic data, after setting up the relevant parameters, start the passenger transport process simulation calculate. Figure 1 show its use case diagram.

'Passenger travel process simulation calculate' is the core use case of the system, its function describe as table 1 shows, other use cases are provide basic data and control parameters for this use case. 'Network basic information manage' use for edit rail network's topological structure, and the line, station, section's attribute information and etc. 'Train operation process calculate' use for calculate various lines' train operation time-distance data under specified operation scheme. 'Station time manage' use for set the passengers' time distribution consumed during the get in, outbound and transfer process. 'Station passenger flow data manage' use for set the station's get in passenger's total number, time distribution and destination stations' distribution.

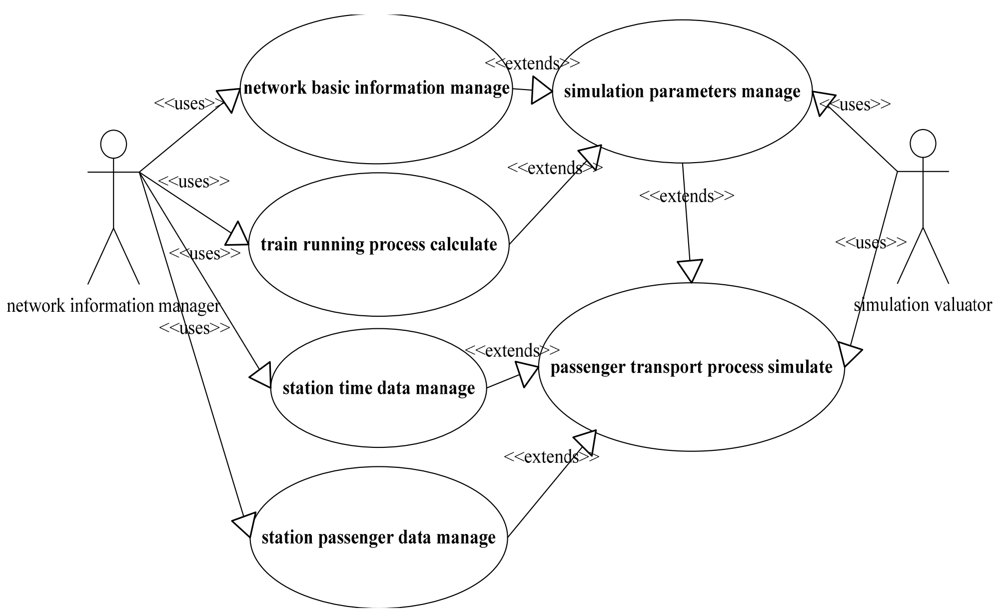

Figure 1. passenger travel process simulation system use case diagram

Table 1. 'passenger travel process simulation calculate' use case's function description

Function	Detail information
describe	Based on the basic data and setting parameters, simulate passenger travel process in network
input	Network basic data, train running time data, station time data, station passenger flow data, simulation control parameters
output	The whole passenger travel process, index statistics about network transportation
precondition	Full data about basic information and control parameters
post-condition	Passenger transport organization scheme's evaluate and optimize
specification	If parameters is full, complete passenger transport process simulation calculate automatically

Figure 2 shows the simulation system's activity diagram, describes the algorithm process of 'passenger travel process simulation calculate'. According to the given simulation parameters and basic data, the system get the simulation start time and end time automatically. Simulate calculate begin from the start time moment, move forward step by step according to the setting time step, until arrived the end time moment and stop simulation.

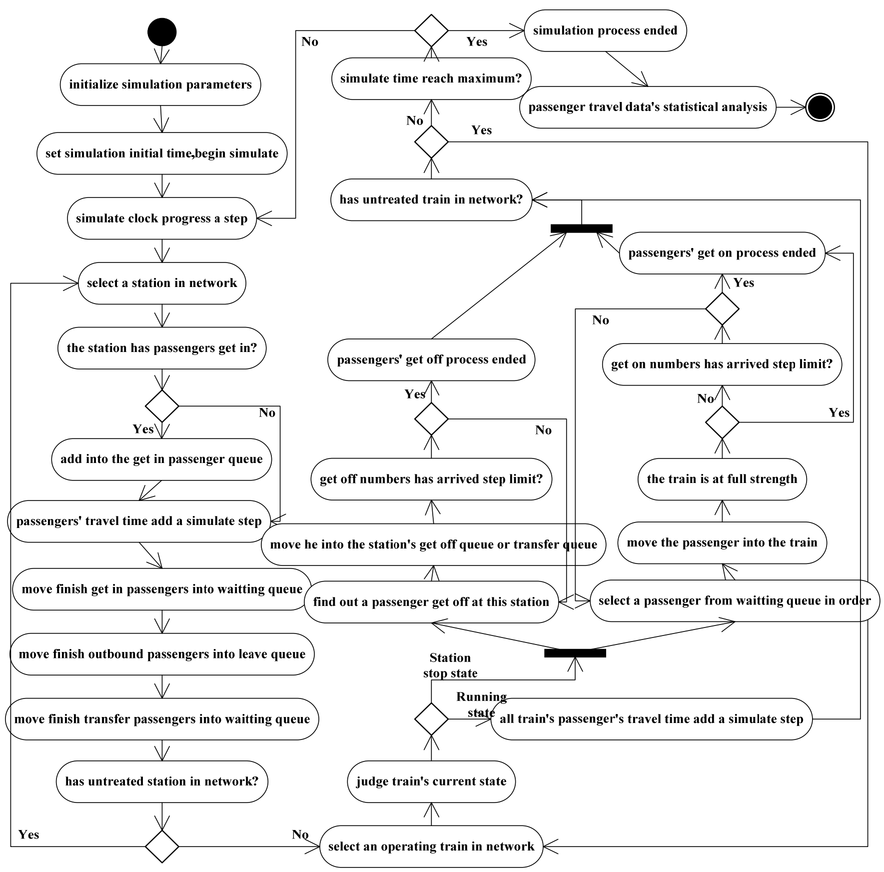

Figure 2. simulation system's activity diagram

The following contents are calculated in each simulation step:

(1) passenger's status update in each station within the network.

With the simulation clock's progress, stations will have new passengers to get in and add to arrival queue. While passengers in stations which are entering, leaving and transferring, their current state may change with time, therefore need to check the update. At the same time, in order to meet later index calculation, station passengers' relevant time need to add a step.

(2) each running train's status update within the network.

According to the time-distance data, train's position and operating mode will change along with the simulation time progress. If train's current mode is running, need to update the passenger's travel time inside the train; if train's state is stop at station, need to exchange passengers with the stop station.

2.2 System design

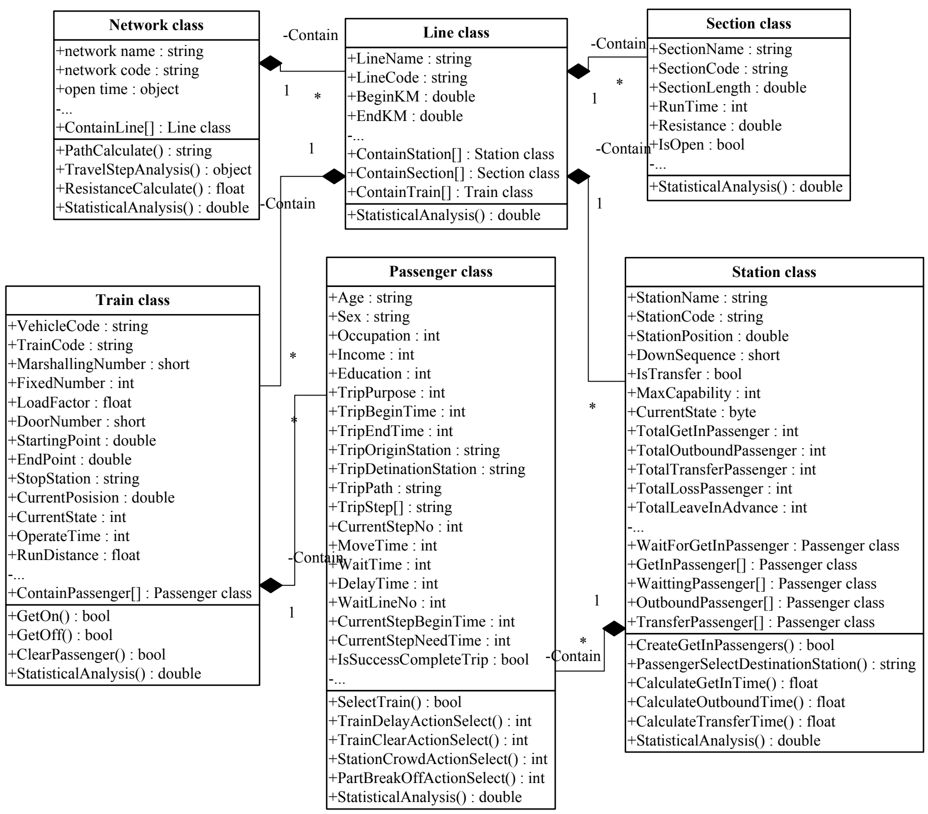

Figure 3. simulation system's class diagram

From the network transport activity's main participants we know, the simulation system's class mainly include: passenger, train, station, section, line and network. According to the passenger transportation process simulation requirements, design the simulation system's class diagram as shown in figure 3. Among them, the passenger class is the core of the system, its design may not only reflect the passenger's individual characteristics, but also meet the requirement of travel process drive and key parameters statistics. Further more, simulation system contains a large number of passenger individual objects, these individual objects have different behavior choice and motion characteristics when confront different situations, this will be reflected by the estimate algorithm inside the class's operation function.

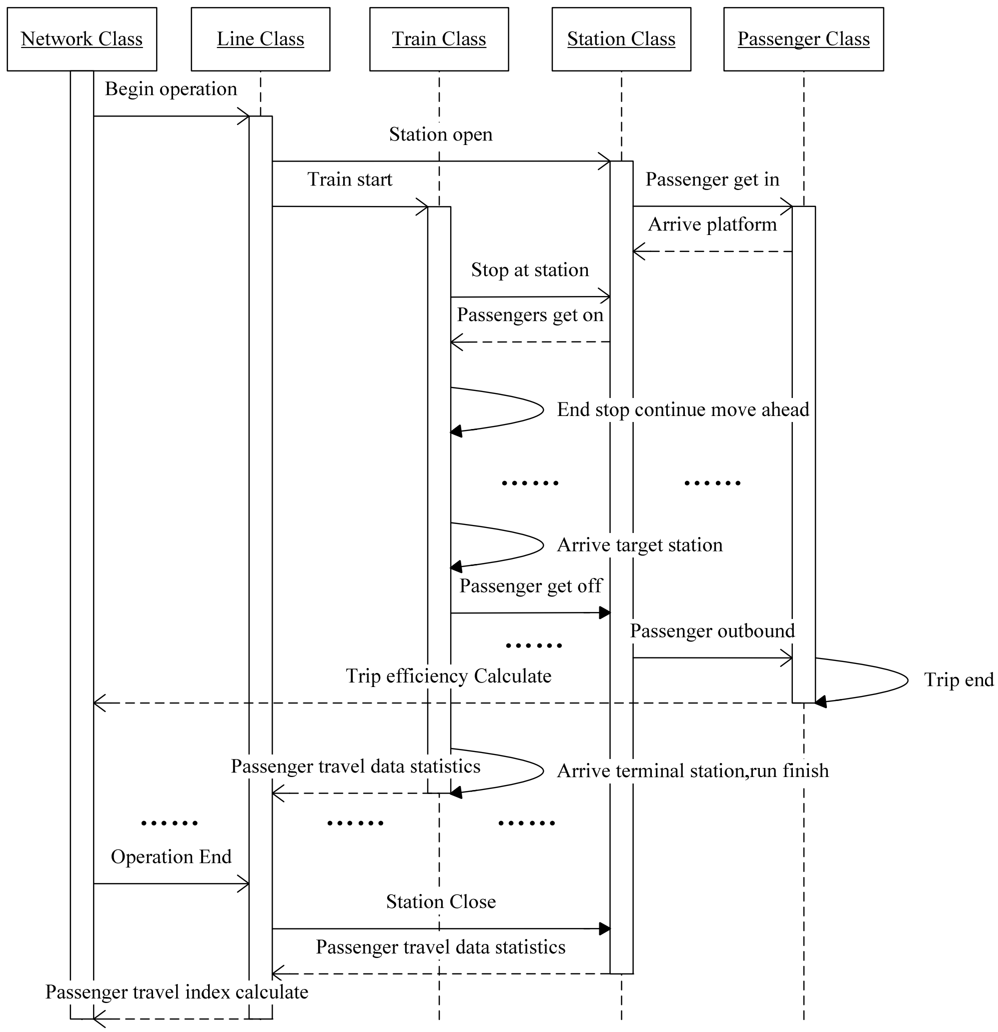

Figure 4. passenger travel process simulation sequence diagram

During the simulation process, the main work is train object and station object's status update and passengers exchange between them, while network object and line object mainly used for general control and statistical analysis, its sequence diagram as shown in figure 4. Train object's life cycle start from origin station depart, end after reach the destination station and complete clear passengers. Passenger object's life cycle start from reach origin station, end after leave rail transit system. Line object and station object create from its opening operation, and logout when its stop operation. Network object's life cycle throughout the whole simulation process, and is the global control object.

Figure 5 is the station object's state variation diagram. Stations are initialized according to the simulation parameters, open in specified simulation time. In each simulation step, statistic the total number of passengers in the station, and set the station's state to temporary closed or limit passenger flow or normal operation according to the statistical result. The cycle continues until the simulation time arrives the operation end time, station closed.

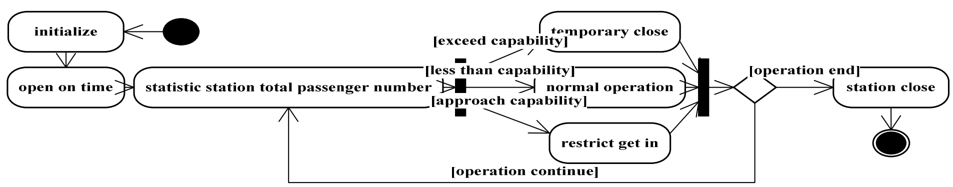

Figure 5. station object's state diagram

Figure 6 is the train object's state variation diagram. When the system clock arrive running time the train object is created, according to time-distance data train runs on the designated route. When train stop at station, execute passengers get off operation first. If the train has not arrive destination station, execute passengers get on operation, then continue run forward. Otherwise train running ended, object logout.

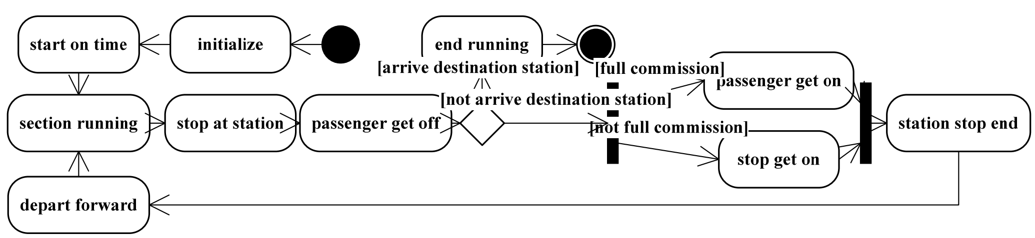

Figure 6. train object's state diagram

Figure 7 is the passenger object's state variation diagram. When passenger begin to travel, passenger object created. Then according to the trip requirement, transfer in sequence between train object and station object, until reach the destination station, outbound and leave, object logout.

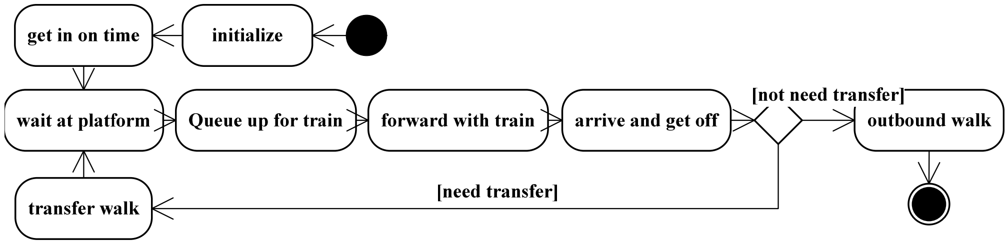

Figure 7. passenger object's state diagram

2.3 System development

As shown in figure 8, the simulation system contains two function module, include seven components. ‘Information management module’ mainly for system administrators use, consist by five components which are network basic information management, OD path and impedance calculation, train running time calculation, station time data management and station passenger flow data management. Each component provides two interfaces: edit interface and retrieve interface, edit interface provide function for manage basic data, retrieve interface provide data for simulation calculate. ‘Simulation calculate module’ mainly for simulation evaluator use, consist by simulation parameters manage component which use for simulation parameters and result's manage and setting, and passenger travel process simulation calculate component which use for execute simulation calculate and result analysis.

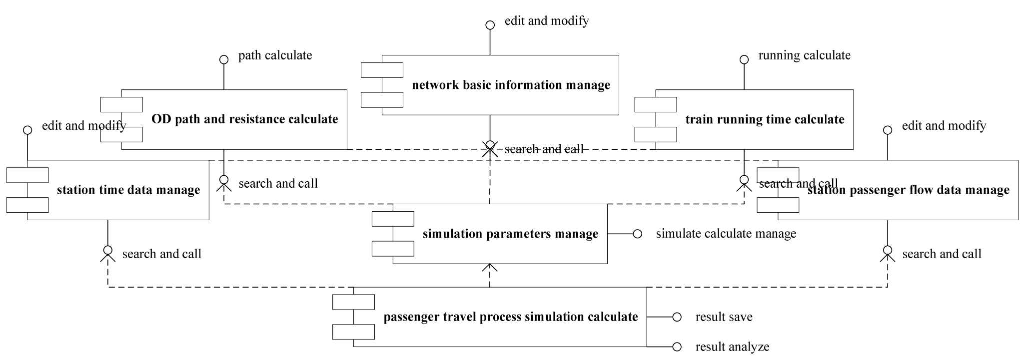

Figure 8. passenger travel process simulation system component diagram

3 Passenger travel process simulation example

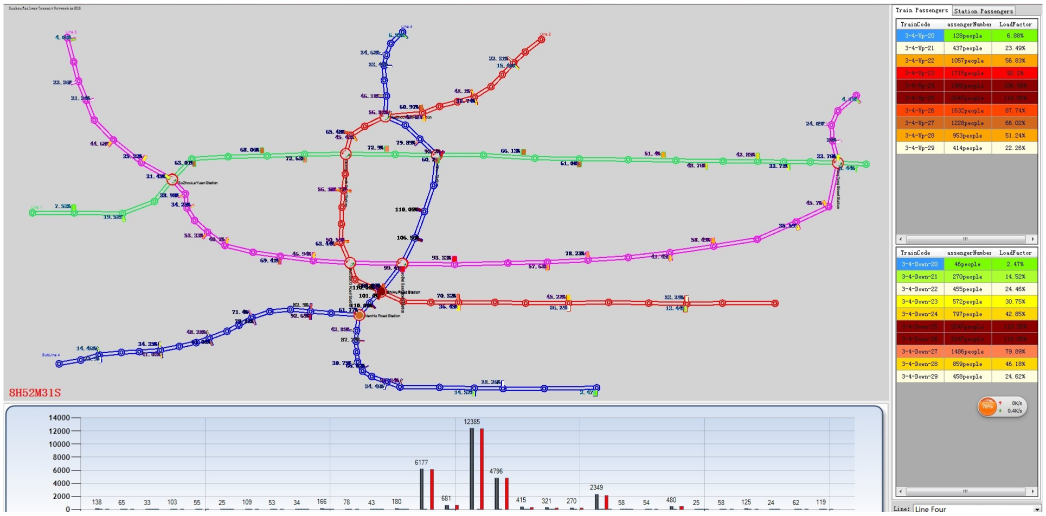

Figure 9. SuZhou 2015 planning network passenger travel process simulation screenshots

Take SuZhou rail transit 2015 planning network for example, through assumption lines basic data and passenger flow data, conduct simulation calculate, the result shows as figure 9 and figure 10. Figure 9 is the network passenger travel process microcosmic simulation's animation screenshots, in which can clearly show each line's train position, each train's load factor, each station's passenger number and other data's changing process. Figure 10 shows a station or a train's passenger number variation along with time. Through microcosmic simulation, can clearly recur network passenger travel process, and has important reference to master passenger flow's network distribution, grasp the system's bottleneck and weakness.

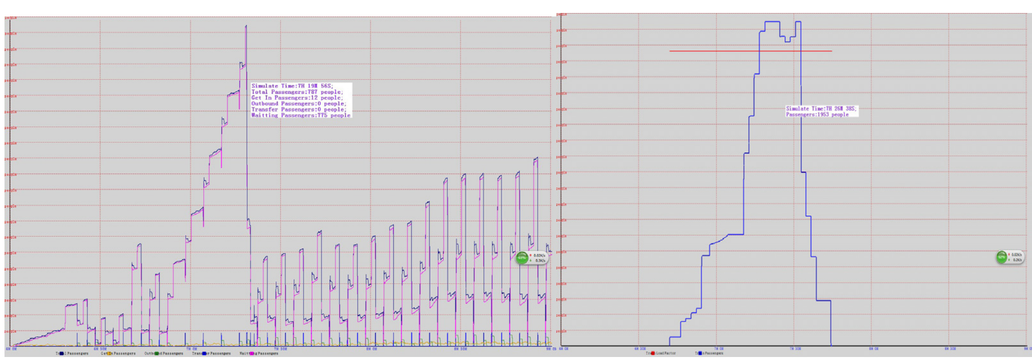

Figure 10. station passenger number change trends graph (left) and train passenger number change trends graph (right).

4 Conclusions

This paper put train operation process simulation with passenger travel process simulation together, build urban rail transit network passenger travel process simulation system, use the unified modeling language to describe the simulation system's analyze, design and realize; and take Suzhou rail transit network planning in 2015 as an example, achieve its' passenger travel process's simulation calculate, verified the system's validity. The system can provide effective aid decision making tool to promote rail transit system's efficiency.

Because the rail transit passenger travel process involve many technologies, the system this paper build although realize the passenger transport process simulation, but simplified dispose in many details, such as station passengers' move process, passengers' get on and off's rule, emergency treatment and so on. These aspects are the objects that need to do further study, in order to make the system's simulation results conform with reality more.

Acknowledgements

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References

GAO Peng, XU Rui-hua.(2010). Event-driven simulation model for passenger flow in urban mass transit station. Systems Engineering—Theory & Practice,30(11):2121-2128.

Ken Lunn. (2003).Software Development with UML，Palgrave Macmillan Limited.

Wang Zhiqiang, He Jiahang.(2013). Multi-train Operation simulation in the case of Train Fault Disposal. Urban Mass Transit Research, 16(1):19-23.

XU Rui-hua, LUO Qin, GAO Peng. (2009).Passenger Flow Distribution Model and Algorithm for Urban Rail Transit Network Based on Multi-route Choice. Journal of the China Railway Society, 31(2):110-114.

Optimization Method Study for Capacity Coordination between Urban Rail Transit Lines

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Abstract: In this paper, it analyzed the variation of waiting passengers in transfer station platform, and a model was obtained to calculate the number of waiting passengers, the number of passengers who had got on trains and the remaining passengers in transfer sites when trains arrived and left the transfer station during the coordination period. In the model, the case that passengers could not board on the first arrival train they encountered was considered. Based on the calculation model, an optimization model was established. The optimization model took maximizing the total number of passengers that departed as the target during the coordination period in the transfer station, and took the maximum waiting passengers not exceeding the capacity of each site as the constraints. Using the calculation model and the optimization model, a case was analyzed under the condition that passengers transferred unevenly between two inter-lines. The research can provide a reference for urban railway network coordination.
Keywords: Urban rail transit; Calculation model; Optimization model; Transfer station; Coordination.

1 Introduction

With the increase of urban rail lines, network-oriented operation model is being formed, the corresponding passenger traffic is also showing a leap -growth. As a bridge between lines, the operation of transfer station has an important impact on the operational efficiency and quality of the entire rail network. Therefore, improving the service capability and quality of the transfer station is a very important issue.

Liu (2011) proposed a method to solve the mismatch of transport capacity between lines and the restriction of transfer station capacity through restricting passenger flow and operating with skip-stops. Wang (2011) analyzed the impact of traffic density mismatch between intersecting lines to the number of waiting passengers and stranded passengers and the residence time. Wang (2013) analyzed a calculation method under the condition that different arrival intervals of trains from two different lines corresponded to the different aggregation. Xu (2013) described the changes of waiting passengers in an ordinary station through establishing a probabilistic model. Yan (2008) calculated the operation intervals through balancing the travel satisfaction of passengers against the interests of enterprises. Zhao (2011) analyzed the passenger flow volume variation of ordinary station, and a method was obtained to calculate the maximum number of passengers through analyzing the number of passengers arriving, boarding and alighting.

There are few studies about the impact of transport capacity mismatch between lines and transfer stations in the existing literature. Firstly, in this paper we analyzed the necessity of capacity during peak hours for particular lines coordination. Then we established a model to calculate the number of waiting passengers in the transfer station, and proposed an optimization model of line capacity coordination on this basis. Finally, a case was used to analyze the impact of adjusting operation intervals and carrying capacity to the result of coordination under the condition that passengers transfer unevenly between two inter-lines.

2 Analysis and Research Hypothesis

This paper mainly analyzes the problem that transfer directions are not balanced, caused by the commuters. Taking the morning rush hour for example, a lot of people take suburban rail rushing into the city from suburb, and transfer in the transfer station intersected with the urban ring, while there are less passengers in the opposite direction .In this case, as the main connecting line, the urban ring is greatly impacted. In addition, the operational capacity and the station capacity are limited, and it's easy to be stranded. So it needs further study to avoid congestion in the transfer station.

Describing the variation of passenger flow accurately is the precondition for the coordination of inter-line capacity. In order to analyze the relationship between operational capacity configuration and requirements, this paper ignores the impact of passengers getting off the train and evacuation procedure, only takes the variation of waiting passengers in the transfer station into consideration.

This article discusses the situation that the transfer station is an intermediate station of the intersecting lines. There are four operational directions at the transfer station when two lines intersected. Respectively, l_{11} and l_{12}, l_{21} and l_{22} represent the up and down direction of line l_1 and l_2 .Assume that:

(1)Trains on each line operate balanced.

(2)In the same direction, the transfer passenger flow from outside the station subjects to the same Poisson distribution.

(3)In the same direction, the transfer passenger flow brought in the transfer station subjects to the same Poisson distribution.

(4)No passengers transfer between the up and down directions on the same line.

3 Computing Model for Transfer Station's Waiting Passengers

This paper only analyzes the variation and calculation method of waiting passengers in one station for the reason that each station shares the same calculation method. This paper mainly analyzes the calculation method of line l_{21}.

3.1 Analysis for waiting passengers on the line l_{21}

Depending on the operating characteristics of the train, passengers' arrival and departure regularities on line l_{21} are shown in Figure 1.The arrows above the time axis represent the times that passengers getting off the trains on line l_1 arrive at l_{21} in transfer station, while the arrows below the time axis represent the times passengers taken away from the transfer station on l_{21}. On the line l_2, D_2 is the dwell-time in the transfer station; t_i-D_2 is the times that the i^{th} train reaching the transfer station on line l_{21}, t_i is the leaving time. h_1 and h_2 are the intervals between trains on line l_1 and l_2.

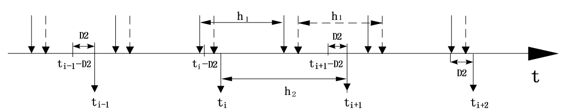

Figure 1. Passenger's arrival and left time in l_{21} platform

The number of passengers inside the station on line l_{21} is increasing during the time period t_{i-1} to t_i-D_2. After the i^{th} train stops and opens the door, the number of passengers in the station is decreasing till this train closes the door and leaves this station, the leaving time is t_i, and then the next cycle starts in the same way. Therefore, the waiting passenger flow in the station on line l_{21} shows a cyclical variation. According to the variation characteristics of passenger flow, the extent of congestion about the transfer station can be reflected by calculating the number of waiting passengers when the train arrives on line l_{21}, and the remaining waiting passengers $SY_i^{l_{21}}$ after this train leaves the transfer station. Furthermore, the operational efficiency can be reflected by calculating the actual number of passengers transported from the transfer station.

3.2 Calculation model of waiting passengers on line l_{21}

Firstly, we gave the relationship between parameters as in formula (1).

$$\begin{cases} PD_{t_i-D_2}^{l_{21}} = SY_{i-1}^{l_{21}} + DD_{(t_{i-1},t_i-D_2)}^{l_{21}} \\ XN_{t_i}^{l_{21}} = PD_{t_i-D_2}^{l_{21}} + DD_{(t_i-D_2,t_i)}^{l_{21}} \\ SJ_i^{l_{21}} = \min\{XN_{t_i}^{l_{21}}, FN_i^{l_{21}}\} \\ SY_i^{l_{21}} = XN_{t_i}^{l_{21}} - SJ_i^{l_{21}} \end{cases} \tag{1}$$

Where $PD_{t_i-D_2}^{l_{21}}$ represents the number of waiting passengers when the ith train arrives at the transfer station on l21; $SY_{i-1}^{l_{21}}$ represents the number of remaining waiting passengers on l21 after the (i-1)th train leaves; $DD_{(t_{i-1},t_i-D_2)}^{l_{21}}$ represents the number of arriving passengers during the dwell time period (ti-1,ti-D2); $XN_{t_i}^{l_{21}}$ represents the total number of passengers that need to take the ith train before it leaves the transfer station; $SJ_i^{l_{21}}$ represents the actual number of passengers aboard during dwell-time period of the ith train; $FN_i^{l_{21}}$ is the operating capacity of the train, which is the number of empty seats after passengers get off the train.

$DD_{(T_a,\tau)}^{l_{21}}$ is calculated by formula (2):

$$DD_{(T_a,\tau)}^{l_{21}} = ZW_{(T_a,\tau)}^{l_{21}} + HC_{(T_a,\tau)}^{l_{21}} \tag{2}$$

Set $[T_a, T_b]$ to be the operational period, $\tau \in [T_a, T_b]$, $ZW_{(T_a,\tau)}^{l_{21}}$ is the random arriving passengers from outside the station on line l_{21} during the time period (T_a,τ); $HC_{(T_a,\tau)}^{l_{21}}$ represents the transfer passengers from line l_1 to l_{21} during (T_a,τ).

Assume that the random arriving passenger flow outside the line l_{21} subjects to Poission flow, the intensity to be $\delta^{l_{21}}$, then it has:

$$E(ZW_{(T_a,\tau)}^{l_{21}}) = (\tau - T_a) \cdot \delta^{l_{21}} \tag{3}$$

And $HC_{(T_a,\tau)}^{l_{21}}$ can be calculated as formula (4):

$$HC_{(T_a,\tau)}^{l_{21}} = HC_{(T_a,\tau)}^{l_{11}\to l_{21}} + HC_{(T_a,\tau)}^{l_{12}\to l_{21}} \tag{4}$$

Where, $HC_{(T_a,\tau)}^{l_{11}\to l_{21}}$ represents passengers transfer from line l_{11} to l_{21}; $HC_{(T_a,\tau)}^{l_{12}\to l_{21}}$ represents passengers transfer from line l_{12} to l_{21}, shown as formula (5) and (6).

$$E(HC_{(T_a,\tau)}^{l_{11}\to l_{21}})=\begin{cases}0 & T_a\le\tau<t_{cs}^{l_{11}}+t_{hc}^{l_{11}\to l_{21}}\\ \lambda^{l_{11}\to l_{21}}\cdot[floor(\frac{\tau-t_{cs}^{l_{11}}-t_{hc}^{l_{11}\to l_{21}}}{h_1})+1] & t_{cs}^{l_{11}}+t_{hc}^{l_{11}\to l_{21}}\le\tau\le T_b\end{cases} \quad (5)$$

$$E(HC_{(T_a,\tau)}^{l_{12}\to l_{21}})=\begin{cases}0 & T_a\le\tau<t_{cs}^{l_{12}}+t_{hc}^{l_{12}\to l_{21}}\\ \lambda^{l_{12}\to l_{21}}\cdot[floor(\frac{\tau-t_{cs}^{l_{12}}-t_{hc}^{l_{12}\to l_{21}}}{h_1})+1] & t_{cs}^{l_{12}}+t_{hc}^{l_{12}\to l_{21}}\le\tau\le T_b\end{cases} \quad (6)$$

Where, $t_{cs}^{l_{11}}$ and $t_{cs}^{l_{12}}$ respectively represents the time that the first train arrives at the transfer station on line l_{11} and l_{12}. $t_{hc}^{l_{11}\to l_{21}}$ and $t_{hc}^{l_{12}\to l_{21}}$ respectively represents the time it takes transfer passengers to reach the transfer station in the corresponding direction. Both of them take average statistics. $\lambda^{l_{11}\to l_{21}}$ and $\lambda^{l_{12}\to l_{21}}$ are the passenger volume intensities transferring from each train in both direction on line l_1 to l_{21}.

The time t_i each train leaves the transfer station on line l_{21} meets the equation (7).

$$t_i = t_{cs}^{l_{21}} + D_2 + (i-1)\cdot h_2 \qquad i=1,2\ldots N \quad (7)$$

Where, $t_{cs}^{l_{21}}$ represents the arrival time of the first train on line l_{21}, N is the number of combined trains on line l_2.

The initial arrival times $t_{cs}^{l_{11}}$ 、 $t_{cs}^{l_{12}}$ 、 $t_{cs}^{l_{21}}$ in each direction satisfy the formula(8).

$$T_a\le t_{cs}^{l_{pq}} \le T_a+h_p \qquad p=1,2;\quad q=1,2 \quad (8)$$

Where, h_p represents the running interval of line l_p.

Based on the analysis above, both the expected value of waiting passengers in the transfer station $E(PD_{t_i-D_2}^{l_{21}})$ and the expected value of actual traveler flow of each train on l_{21} $E(SJ_i^{l_{21}})$ can be obtained using iterated inference. Similarly, the formulae of $E(PD^{l_{pq}}_{t_i-D_2})$ and $E(SJ^{l_{pq}}_i)$ (p=1,2; q=1,2) in other direction can be obtained.

4 Optimization Model of Capacity Coordination Adjustment

For the whole transfer station, the target of the coordination and optimization is to maximize the number of passengers taken away *SJ*, which is tallying up all the values of traveler flow in each direction, shown in formula (9).

$$\text{Obj.}\quad \text{Max}\quad SJ=\sum_{i_1=1}^{N_1}E(SJ^{l_{11}}_{i_1})+\sum_{i_2=1}^{N_2}E(SJ^{l_{12}}_{i_2})+\sum_{i_3=1}^{N_3}E(SJ^{l_{21}}_{i_3})+\sum_{i_4=1}^{N_4}E(SJ^{l_{22}}_{i_4}) \tag{9}$$

Where variable(N_1, N_2, N_3, N_4) is the number of trains on line l_{11},l_{12},l_{21},l_{22} during the study period. Otherwise, the maximum number of waiting passengers $\max(E(PD^{l_{pq}}_{t_i-D_2}))$ (i=1,2…N;p=1,2;q=1,2) must be not exceeding the maximum number the platform can hold, described by (10)~(14).

$$\max(E(PD^{l_{11}}_{t_{i_1}-D_1}))\le C^{l_{11}}_{\max}\qquad i_1=1,2\ldots N_1 \tag{10}$$

$$\max(E(PD^{l_{12}}_{t_{i_2}-D_1}))\le C^{l_{12}}_{\max}\qquad i_2=1,2\ldots N_2 \tag{11}$$

$$\max(E(PD^{l_{21}}_{t_{i_3}-D_2}))\le C^{l_{21}}_{\max}\qquad i_3=1,2\ldots N_3 \tag{12}$$

$$\max(E(PD^{l_{22}}_{t_{i_4}-D_2}))\le C^{l_{21}}_{\max}\qquad i_4=1,2\ldots N_4 \tag{13}$$

$$t_{N_1}\le T_b;\; t_{N_2}\le T_b;\; t_{N_3}\le T_b;\; t_{N_4}\le T_b \tag{14}$$

Where $C^{l_{pq}}_{\max}$ is the maximum number that the platform l_p can hold in the q[th] direction. D_1 is the dwell-time on line l_1 in the transfer station while D_2 is the dwell-time on line l_2 in the transfer station.

Formula (9) ~ (14) describe the coordination optimization model in transfer station of cross lines. But the optimization model is in accordance with constraints (1)~(8); the adjusting parameters are the train headway time interval (h_1,h_2) and the carrying capacity of the i[th] train $E(FN_i^{l_{pq}})$. $E(FN_i^{l_{pq}})=\mu^{l_{pq}}$ (p=1,2;q=1,2) can be derived according to the assumptions. In the following, we discuss the coordination optimization schedule between cross lines by example when the numbers of transfer passengers in opposite directions are seriously imbalanced during the peak-hours.

5 Case Study

We chose the morning peak-hour 7:00~8:00 as the coordination period. The transfer passengers in each direction were shown in table 1 and the data were transfer passengers from the rows transferring to the corresponding columns.

Table 1. Transfer passengers

	l_{11}	l_{12}	l_{21}	l_{22}
l_{11}	--	--	214	231
l_{12}	--	--	252	224
l_{21}	105	132	--	--
l_{22}	121	125	--	--

Two coordination schemes were considered. One was to adjust the train headway time interval h_1 on line l_1, the other one was to adjust the carrying capacity of trains $\mu^{l_{2j}}$ (j=1,2) on l_2. The two schemes were discussed as follows.

5.1 Coordination of headway time interval

According to table 1, trains on l_2 brought passengers away from the transfer station while trains on l_1 brought passengers in the transfer station. Therefore, the smaller h_2 was, the better it is to evacuate passengers. Assuming that h_2 to be 180s, the smallest headway time interval, we considered adjusting h_1, the headway time interval on l_1, to optimize the transfer passengers in the transfer station. Denote the initial time 0 by 7:00, then the coordination period T was 3600s. The initial data were set as follows: Intensities of passengers arriving at the transfer station from each direction $\delta^{l_{ij}}$ = 0.5, $\mu^{l_{ij}}$=500, $t_{cs}^{l_{11}}=t_{cs}^{l_{12}}$=80s, $t_{cs}^{l_{21}}=t_{cs}^{l_{22}}$=120s, $C_{\max}^{l_{ij}}$=700, D_1=D_2=40s, the walking time in transfer station in all directions was 90s.

Through simulation, we could get the variation trend of the maximum number of waiting passengers in the transfer station and the total number of passengers taken away during the period, as shown in figure 2 and figure 3. In figure 2 and figure 3, x-coordinate represented headway time interval h_1(s), while y-coordinate represented waiting passengers. Figure 2 showed that as with h_1 increased, waiting passengers in the two opposite directions on l_1 increased, while waiting passengers in the two opposite directions on l_2 decreased. In order to meet the constraint that the number of waiting passengers must be not exceeding the maximum number the platform can hold in all transfer stations, the headway time interval h_1 was in accordance with constraint (15). hl and hu were shown in figure 2.

$$\text{hl} \le h_1 \le \text{hu} \tag{15}$$

According to the initial parameters, we could calculate that hl was 225s and hu was 260s. As shown in figure 3, when h_1 decreased, the total number of passengers taken away from the transfer station increased within the range of [hl,hu]. Considering a variety of disturbance when the train ran, if h_1 was too small, we should consider the risk that waiting passengers in the transfer station on l_2 may exceed the capacity. Considering all these factors, we could select $h_1$to be 240s, so the number of waiting passengers in each station was: 405(l_1 up-line), 495(l_1 down-line), 663(l_2 up-line), 495(l_2 down-line).

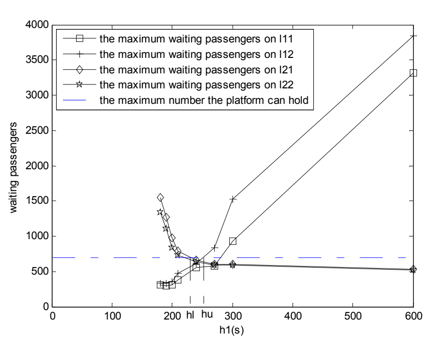

Figure 2. Relationship between waiting passengers and h_1

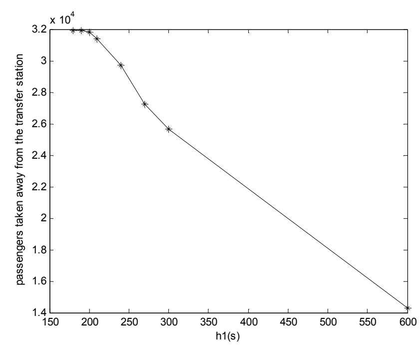

Figure 3. Relationship between depart passengers and h_1

5.2 Coordination of the carrying capacity of trains

As the main transfer direction was from l_1 to l_2, so we could adjust the carrying capacity of trains on l_2. Assuming that h_1=h_2=180s, the other parameters to be invariant. Through simulation, the effect the carrying capacity of trains on l_2 had on the number of waiting passengers could be obtained. For the sake of convenience, list the two parameters in figure 4. The effect that the carrying capacity of trains on l_2 had on the number of passengers taken away from the transfer station was shown in figure 5. In figure 4 and figure 5, x-coordinate represented the carrying capacity after passengers getting off the train $\mu^{l_{21}}, \mu^{l_{22}}$ *(unit)*, while y-coordinate represented the number of waiting passengers. The number of waiting passengers in transfer station on l_1 was not affected, so it was not discussed any more.

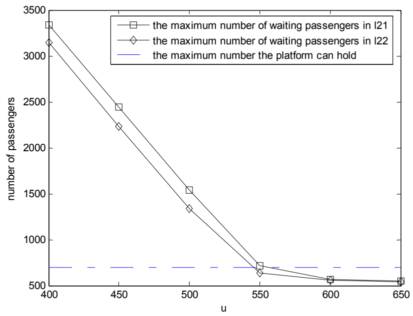

Figure 4. Waiting passengers change with $\mu^{l_{21}}$ 、 $\mu^{l_{22}}$

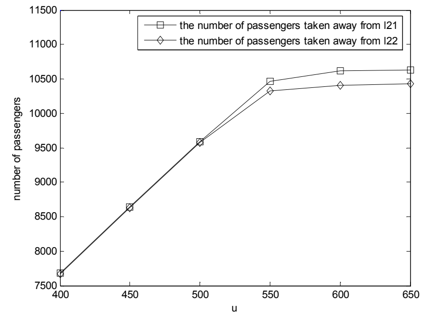

Figure 5. Depart passengers change with $\mu^{l_{21}}$ 、 $\mu^{l_{22}}$

Figure 4 and 5 showed, within some range (as shown in the figures: $\mu^{l_{21}} \leqslant 550, \mu^{l_{22}} \leqslant 550$),the variation of carrying capacity had a great effect on the maximum number of waiting passengers in the corresponding transfer station and the total number of passengers taken away. Therefore, it is an effective method to optimize the number of waiting passengers by increasing the carrying capacity of the trains in the main transfer directions. The coordination of carrying capacity can be achieved by replacing another type of train or changing train marshalling.

6 Conclusions

In this paper, it analyzed the variation trend of waiting passengers in transfer station platform, the interactions of parameters described by formulae, and models to calculate the number of waiting passengers and the passengers taken away from the transfer station are obtained. Based on the calculation model, a coordination optimization model was established. The optimization model took improving the efficiency of the transfer station as the target, and took the maximum waiting numbers in each transfer platform not exceeding the capacity of the platform as constraints. Finally, a case was analyzed under the condition that the number of transfer passengers in opposite directions were imbalanced, so the adjust schemes were provided, and the effect that train headway time interval adjusting and train carrying capacity adjusting had on waiting passengers in the transfer station and the service efficiency was obtained.

References

Liu, L. H., Jiang, L.(2011). "Research on the method to control passenger for urban rail transit". Railway Transport and Economy, 33(5),51~55.

Wang, C. C., Liu, J. H., Zhu, X.(2011). "Passenger Flow at Rail Transit Station Transfer in Different Rates of Traffic Flow". Urban mass transit research, 37~39.

Wang, F., Sun, Q. X., Mao B. H. etc.(2013). "Calculation Model for Passenger Assembling on One-platform-transfer Station Based on Timetable Coordination". Journal of Transportation Systems Engineering and Information Technology, 13(3),163~169.

Xu, X. Y., Liu, J., Li H. Y., etc.(2013). "Probabilistic model for remain passenger queues at subway station platform". Journal of Central South University of Technology, 3: 837-844.

Yan, B.(2008). "The Optimization Model of Train Headway Time in Urban Rail Transit". Urban mass transit research, 6,53~57.

Zhao, Y. G., Mao, B. H., Yang, Y. Z., etc.(2011). "Methods of Calculating the Maximum Assembling on Urban Rail Transit Platforms". Journal of Transportation Systems Engineering and Information Technology, 11(2),149~154.

Research on the Urban Rail Traffic ATS Simulation System

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Abstract: Communication Based Train Control System (CBTC) is different from the traditional train control system. It controls the train in high-Precision Positioning by the continuous, high- speed and two-way train-wayside data communication. Automatic Train Supervision (ATS) is an important subsystem of CBTC to control the train in high-speed and normal operation. This paper introduces the system structure and functional requirements of the ATS system. Then this paper particularly designs and realizes functions of train working diagram, routing judgment, train route control, automatic generation of train number and train operation adjustment. Such this paper builds Comprehensive experiment simulation platform.
Keywords: Urban rail traffic; Automatic train supervision; Running simulation.

Automatic control system of urban rail transit (ATC) consists of Automatic Train Protection (ATP), Automatic Train Operation (ATO) and Automatic Train Supervision (ATS). Based on the design principle of fail-safe, ATP is responsible for the safety in the process of train running. ATP raises the train running level and Control train automatic driving including arrivals and departures of trains, automatic reentrant. ATS is the command center of the ATC system. The main effect of ATS is to command and supervision of train operation. The three subsystems cooperated to achieve complete functions of ATC system. The relationship between ATS, ATO and ATP shows in figure1.

1 Summary of ATS

According to the train operation plan, the ATS system compiles train schedule and organize train operation in accordance with train diagram. ATS gathers and displays the real time information of train number, actual running time, condition of route, station information and train position. Such ATS gives supports to dispatch and command of Urban Rail Transit.

The ATS simulation system is communication Based Train Control System (CBTC). The ATS simulation system can realize functions of the real time information of train and station, editing train working time schedule, route control, automatic turn-back running, automatic generation of train number, train withholding in station platform and train jump stopping and preservation and print of the simulation data.

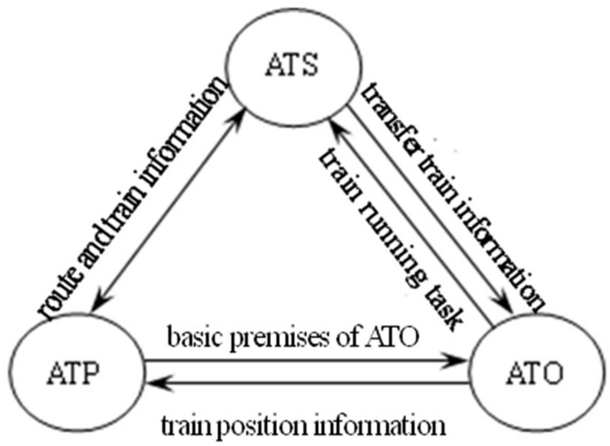

Figure 1. Relationship between subsystem of ATC

2 Drawing Train Working Diagram

Urban Rail Transit train timetable is realized by train working diagram. The train working diagram shows the relationship of time and space of train running. It stipulates the interval occupied order of each train, the train running time in the section, the train arrival and departure time, station dwell time，turnaround time of turn back station, train routing and leaving and arriving car depot. It can directly display the train’s state of running time in the section, stopping and passing of station. Such train working diagram is the base of organization of train operation.

Train working diagram of Urban Rail Transit contains plan operation diagram and actual train diagram. The actual train diagram is produced from the train’s arriving and departing time of automatic searching. The two operation diagram are distinguished by different colors. The plan operation diagram is one minute diagram. The transverse axis is equally divided into one minute. The longitudinal axis is equally divided by the train running time in the section, as Figure2 shows. The elements of drawing train diagram include the train running time in the section， station dwell time, residence time of turn back station, turn-back departure interval, operation time of car depot, time interval between trains spaced by automatic block signals and time interval for two trains despatching in succession in the same direction.

The simplest method of drawing train working diagram is to find out the starting and arrival point. The two points are connected to form a line. The method is simple.

Since there are many stations and running lines, the work load is large. The train running time in the section and station dwell time are relatively fixed in drawing. So the system can directly draw up and down direction line. If the running line is different the generated line, it can be fine adjusted.

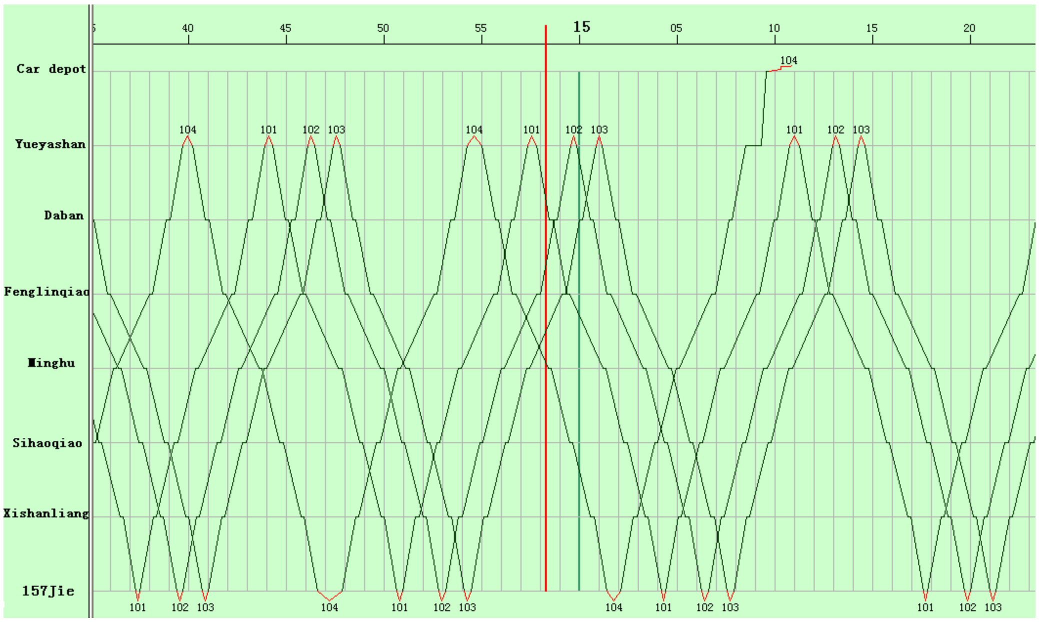

Figure 2.Plan operation and actual train diagram

The drawing process of the train working diagram.First, starting station was determined. Secondly, destination station was determined. The ATS simulation system generates running line according to the predetermined time standard. Last, the line can be adjusted according to the practical operation.

During drawing train working diagram, the destination station should be selected by the train operation plan. The operation routing depends on the destination station. The operation routing contains long locomotive routing and short locomotive routing. The turn-back station of long locomotive routing is the terminal station of the line. The turn-back station of short locomotive routing is the appointed intermediate station of the line. During drawing short locomotive routing running line, the ATS simulation system should judge the conditions of the locomotive routing(Figure3).The form of reentrant contains station-front and station-end turning-back(Figure4,5).

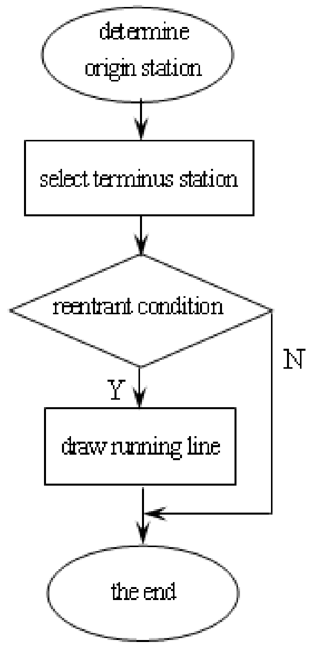

Figure3. Drawing line flowchart

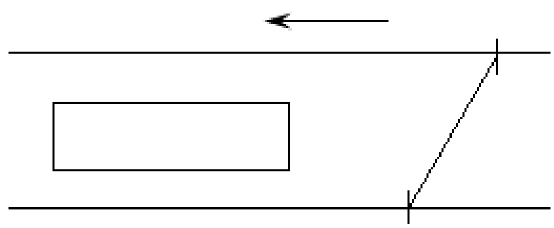

Figure4. Station-front turning-back

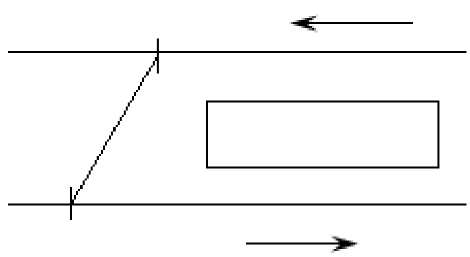

Figure5. Station-end turning-back

3 Train route control

The moving block system is one of development directions of signal system for urban rail transit. The train runs in accordance with train diagram. The train running route includes auto railway route and manual route. Normally, the train route is auto railway route. Its control process shows as Figure6. According to the requirement of work the ATS simulation system can artificially control the switch and route. The artificial control of switch contains conversion of switch normal position and reverse position, individually lock and unlock. The manual route can be controlled by choosing start-stop signal. Also the route can be cancelled and released.

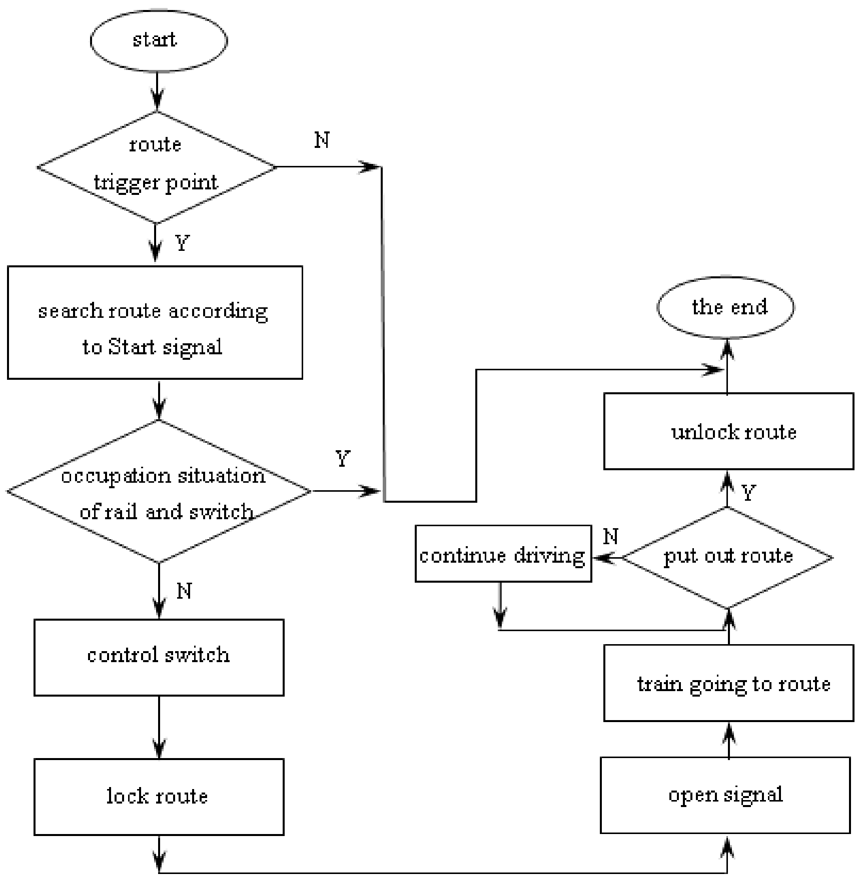

Figure 6. Auto railway route control flow chart

4 Train withholding in station and station jump stopping

The train directly passes through the station without stopping and carrying passengers. The ATS simulation can realize the train withholding in station by selecting the train in the dialog box.

The train jump stopping refers that the train departure from station after increasing the station operation time in order to achieve the purpose of train interval equilibrium. The ATS simulation can realize train jump stopping by selecting the station in the dialog box.

The application of ATS simulation platform meeting the requirements of the laboratory of soft and hard platform interface has stronger practicability. The results can provide some theoretical and implementation reference for the building of Urban rail transit relevant experimental platform.

References

Zhao Genmiao, Chen Yongsheng(2004). " Design and Implementation of ATS Simulation Training System". Urban Mass Transit.2004(01):55-57.

Sun Zhiyong, Chen Yongsheng(2012). "Design and implementation of metro train movement for the ATS simulating training system ".Microcomputer & its Applications.2012(14):7-9.

Zhang Yanpeng, Dang Jianwu. "Design of ATS Timetable Management System for Urban Mass Transit". Urban Mass Transit.2013(10):48-52.

Zou Leibin. "The Design and Implement of General Model of Urban Track Transportation ATS Simulation Train System". Tongji University Master thesis.2008(01).

Wang Xianyu. "The Research and Implement of ATS Simulation System Interactive Development Platform". Tongji University Master thesis.2006(03).

Suspended Monorail System: A New Development of an Urban Rail Transit System with Low Passenger Capacity

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Abstract: China has entered the booming stage of urban rail transit. Suspended monorail system, which belongs to urban rail transit with low traffic volume, is under development. Adaptability and technical feasibility of suspended monorail are analyzed on the basis of train capacity, technical features and construction cost. Operational features of symmetrical suspended monorail systems in Germany and Japan are introduced. Capacity adaptability of the monorail is calculated under four-parameter combined cases, which are vehicle size, seat layout, train marshalling and capacity principles. The trains with width 2.4m ~2.6 m and marshalling cars 2~3, are suggested in domestic. Compared to modern tram, BRT, and metro, the monorail has unique advantages in technology, engineering construction and cost, and it becomes new development of urban rail transit. Learn from development of mid-low speed maglev traffic, and the monorail will be successfully brought to market.
Keywords: Suspended monorail system; Train capacity; Technical feature; Function orientation; Domestic application.

1 Introduction

Rapid and large-capacity public transport with electric energy power and by wheel/rail running mode is referred to as urban rail transit. Beginning with the opening in 1863 of Metropolitan Railway in London, urban rail transit has developed more than 150 years. 170 cities in 50 countries and regions all over the world have opened rail transit and operating mileage is over 10,000 km.

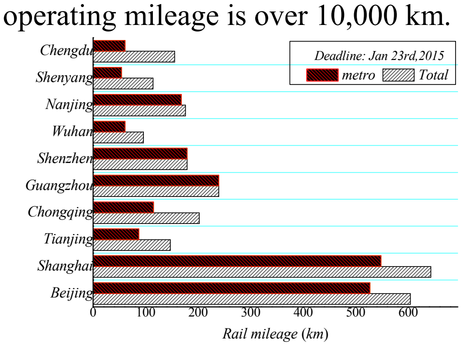


Figure 1. Statistics of urban rail traffic mileage in China

China has entered into a stage of vigorous development of urban rail transit. According to the data from China Association of Metros in early 2015(China Association of Metros), mileage of urban rail transit are counted in Figure 1. Mileages of Beijing and Shanghai rank the first and proportion of metro traffic mileage reaches more than 80%. Modern tram and straddle monorail are operated. Mid-low speed maglev, suspended monorail and automated people mover systems (APM) (Figure 2) are also developed gradually.

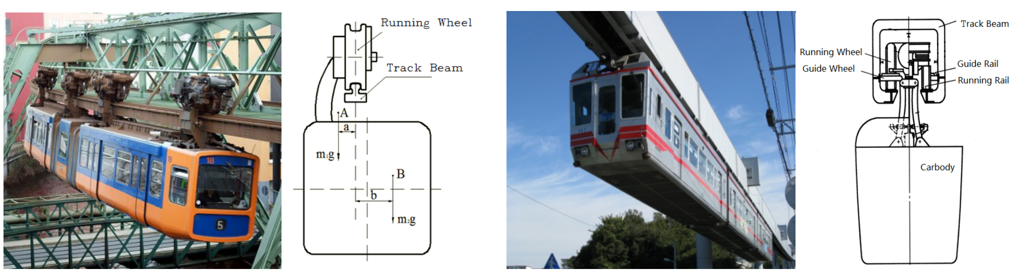
Guangzhou Metro (A-type vehicle) Shenyang Tram Chongqing straddle monorail

Zhuzhou mid-low speed maglev Chiba suspended monorail Guangzhou APM system

Figure 2. A variety of urban rail transit system

2 Presentation of suspended monorail system

On the basis of different design principles, two suspended monorail systems, asymmetric type and symmetric type, are developed (Figure 3).



(1) Asymmetric type (2) Symmetric type

Figure 3. Two types of suspended monorail

Famous monorail lines, Wuppertal line in Germany and Ueno zoo line in Japan, are applied the asymmetric type. Originated from design thoughts of German engineer Eugen Langen in 1894, this type takes advantages of double flange guide technology, moment balance principle and steel wheel/rail contact. Some deficiencies, such as excessive flange wear and passenger unilateral ride, limit its application.

Symmetric type, which is originated from France SAFEGE, uses rubber tires running in an enclosed track beam. It has contributed to reduce operating noise, improve ride comforts and decrease effect of severe weather. This type is promoted heavily by Mitsubishi Heavy in the world's longest suspended monorail line-Chiba monorail. Along with technical progress of rubber tires, advantages of symmetric type gain international acclaim. Therefore, symmetric type is study object of this article.

3 Adaptability and technical feasibility analysis of suspended monorail

3.1 Train capacity analysis

Combined with operating and train features of Japan Chiba and Germany Dusseldorf monorail systems, train capacity is analyzed in Table 1. Capacities of the two systems are not high. The seats are in a symmetrical layout and passengers can move freely. Standing capacity principle of the two system is calculated as being 3~4 person/m^2, which belongs to comfortable standard (SHEN Jingyan,2007). Based on operation schedule of Chiba monorail, passenger flow volume at peak hour for one-way traffic is less than 2500.

Table 1. Train capacities of suspended monorails in Japan and Germany

		Chiba urban monorail in Japan	Duesseldorf Sky Train in Germany
Manufacturer		Mitsubishi Heavy	H-bahn
NO. of Driver's Cab		2	0
NO. of Vehicles		2	2
Vehicle Size length * width*height (m)		14.8*2.58*3.085	8.232*2.334*2.623
Vehicle Capacity (person)	Seating	30	16
	Standing	48	54
	total	78	70
Operation scene			

Table 2. Factors for train capacity analysis

Factor	Classification	Factor	Classification
Vehicle Size length * width (m)	9 *2.2	Number of Vehicles	2
	11*2.4		3
	15*2.6		4
	19*2.8		5
	22*3		
Seat Layout	Metro seat	Capacity principles (person/m^2)	4
	Bus seat		5

Vehicle size, seat layout, train marshalling and capacity principles of urban rail transit in China (Table 2) are introduced to analyze domestic capacity adaptability.

Train capacities under different types of seat layout and standing capacity principles are calculated with the size, such as carbody thickness, door width, wheelchair area, and so on. The train in this paper applies symmetrical design and driver's cab is considered in the lead and tail vehicle. At present, standing principle of 5 person/m2 is applying in some domestic cities for better comfort.

Some results are shown in Figure 4 and Table 3. As vehicle width and numbers increase, so do the train capacity. An excess of vehicle width or numbers will give rise to high cost on engineering construction and maintenance. Narrow track and slender beam column have obvious advantages on decreasing engineering cost and environmental influence.

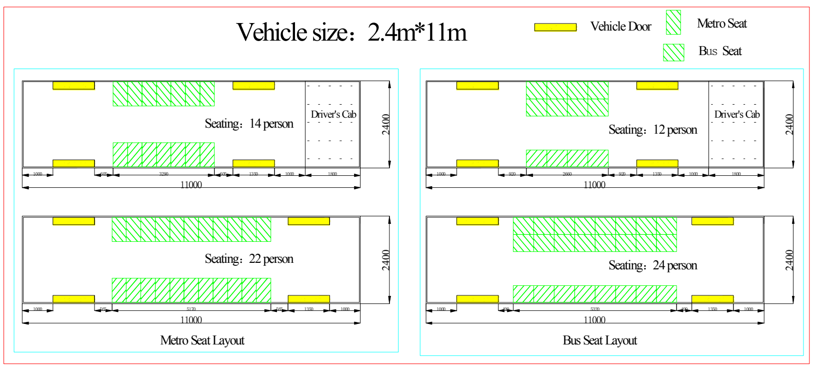


Figure 4. Seat layout of a vehicle (size: 11m length and 2.4m width)

Table 3. Calculation results of train capacity

			Metro seat layout				Bus seat layout			
Case I: 4 person/m^2	Vehicle No.		2	3	4	5	2	3	4	5
	Vehicle width	2.2m	96	159	222	285	96	159	222	285
		2.4m	140	226	312	398	142	227	312	397
		2.6m	228	359	490	621	222	348	474	600
		2.8m	328	510	692	874	318	494	670	846
		3m	420	650	880	1110	406	629	852	1075
Case II: 5 person/m^2			Metro seat layout				Bus seat layout			
	Vehicle No.		2	3	4	5	2	3	4	5
	Vehicle width	2.2m	110	182	254	326	110	182	254	326
		2.4m	162	260	358	456	164	261	358	455
		2.6m	262	412	562	712	246	386	526	666
		2.8m	376	585	794	1003	354	550	746	942
		3m	484	749	1014	1279	454	703	952	1201

Considering length of the station platform of Chiba monorail, which is built for 2~4 vehicles, the capacity is partial to the result for conditions of case II, vehicle width from 2.4m to 2.6m, and vehicle number from 2 to 3. The value for 3 vehicles with 2.4m width is close to that for 2 vehicles with 2.6m width, as shown in gray areas in Table 3. And it is appropriate. On the basis of 14 pairs of train operated from 8:00 to 9:00 am in Chiba line and high population density in China, a hypothesis, that pairs of operating train at peak hour is 20, is made. For the train with 2.4m width and 3 marshalling cars, passenger flow volume at peak hour is about 5000 under the hypothesis.

3.2 Technical features analysis

Urban public traffic develops seven categories: metro system, straddle monorail, suspended monorail, modern tram, maglev system, automated guideway transit and BRT. Modern tram and BRT system have the same capacity with suspended monorail. Technical features of the three systems are compared in Table 4. Suspended monorail has remarkable features of high punctuality, low impact on the environment, good city landscape, litter effect on ground resources and transportation. Due to feature of elevated transit, rescue services for train faults are difficult(ZHOU Meiyan,2014). There are some rescue measures(Figure 5). If train failure appears in a single line and it can’t move any more, a rescue train should be sent to fault location and passengers can be evacuated to the rescue train from the front door, or evacuated to ground by vertical evacuation passageway, such as rope, slide, aerial ladder and so on. If there are double track lines, passengers can be evacuated from the side door.

Table 4. Technology features of suspended monorail, Modern Tram and BRT

		Suspended Monorail	BRT	Modern Tram
Line condition	Grading	10%	6%	6.5%
	Minimum curving radiu(m)	30	24	For steel wheel: 18 For rubber tire: 11
Operation indicators	Running speed (km/h)	20-30	15-30	15-25
	Train punctuality	High，not affected by the ground traffic congestion	High, affected by the weather	Low, affected by ground traffic congestion and weather
	Rescue situation	difficult	easy	easy
Environment effect	Noise(dB)	<65	75	For steel wheel:70 For rubber tire: 65
	Waste gas	No	Serious	No
	Landscape	Elevated running, Good vision and landscape	Ground and elevated running, General vision and landscape	Ground running, limited vision and landscape

Figure 5. Rescue measures of suspended monorail systems

3.3 Engineering construction and cost features analysis

Engineering construction and cost features of suspended monorail, modern tram, and BRT are compared in Table 5(ZHOU Meiyan,2014). Suspended monorail possesses advantages of low construction difficulty. All parts, including track beam, beam column and so on, use batch production and site construction is simple. So construction time is the shortest. Cost per kilometer of suspended monorail is about 120~150 million. Except the station, all parts of monorail require litter ground space. If lines change the route or remove, the parts can be moved easily and previous engineering cost should not be wasted.

Table 5. Construction and cost of suspended monorail, modern tram and BRT

	Suspended Monorail	BRT	Modern Tram	Metro
Construction period	1-2 year	1-2 year	2-3 year	4-5 year
Construction time	Prefabricated structures, Site assembly，< 1 year	Site construction, 1-2 year	Site construction, 2-3 year	Site construction, 4-5 year
Cost (hundred million RMB/ km)	1.2-1.5	0.3-0.5	0.8-1.5	5-8

4 Function orientation of suspended monorail system

Function orientation of suspended monorail system is summarized as follows:

(1) Passenger flow volume at peak hour is about 5000 and it belongs to urban rail transit with low traffic volume.

(2)It can be used as a supplement of urban rail transit in big cities or the main line in medium cities, or a traffic line between the central city and satellite towns.

(3)It can be built as internal transportation tools for airport terminals, large business districts and economic development zones.

(4)It can be designed for city landscape sightseeing.

(5)It is adapted to the district that ground traffic becomes saturated and underground construction condition is special. Cities with rich buried relics, abundant spring water, or special soft soil, are suitable for suspended monorail.

5 Domestic application and development advice of suspended monorail system

A proposal of NPC &CPPCC Sessions 2012, advice to alleviate urban traffic congestion phenomenon by suspended monorail system(Qin Wu,2013), was made. Some cities, such as Tianjing, Shanghai, Hefei, Jinan, Qingdao, Guiyang and Wenzhou, show clear intentions to construct suspended monorail or are carrying out feasibility studies. At present, preliminary planning mileage for suspended monorail transit in China is close to 300 km.

Primary key to promote suspended monorail system in China is to nationalize its design and manufacturing technology. The promotion way can learn from the implementation of mid-low speed maglev traffic in domestic. Firstly, test lines or test running lines are built to prove and master the technology of suspended monorail. And then, tests for homemade equipment are carried out and improved equipment can be manufactured. Further development potential of suspended monorail in domestic cities should be excavated. Then whole-set equipment of suspended monorail system can be brought to the market maturely.

Acknowledgement

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References

China Association of Metros. (2015-1-27) .'News: General situation of 2014 China's urban rail transitlines'.

QIN Wu, WANG Lin.(2013). Analysis of Applicability of Hanging Rail Transit System. *Journal of Tianjin Vocational Institutes*, 15(3):75-80.

SHEN Jingyan.(2007).On the carriage passenger capacity and the crowdedness involved.*Urbdan Rapid Railtransit*,20(5):14-18.

ZHOU Meiyan.(2014).Application and Development of the Suspension Type Sky Train. *Foreign Rolling Stock* ,51(2):10-14.

Application of Pedestrian Microscopic Simulation Technology in Researching the Influenced Realm around Urban Rail Transit Stations

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Abstract: Under the background of urban rail transit's rapid development, urban rail transit station， as the only connection of urban space and rail transit， undertakes the responsibility of traffic organization and passenger volume distribution. Influenced urban realm around station becomes the focus of the optimization of the sustainable urban development. Pedestrian Microscopic Simulation method establishes the comprehensive dynamic behavior rules in a part of urban space through simulating the behavior law by digital tools， in which can explain the internal demand and motive mechanism of the development and change of urban space fairly well by digital representing and analyzing relevant laws. After that, the research with the realm as the carrier analyzed the demand of each simulation level and the choice of simulation parameters based on analyzing the walking connection behavior characteristics, and then further established the methodology system of pedestrian microscopic simulation. At last the research taking the study of influenced urban realm around typical station for sample explored the application method of optimizing of urban space and traffic organization based on Anylogic platform.
Keywords: Urban rail transit; Optimization of traffic organization; Influenced urban realm around station; Walking connection behavior; Pedestrian microscopic simulation.

1 Introduction

In transportation design and analysis Pedestrian Microscopic Simulation are common. The different behaviors of pedestrians can be simulated based on different mathematic models. In urban design, by digital simulation of individuals and the interaction between them in the urban area, Pedestrian Microscopic Simulation illustrates the bottom-up dynamic mechanism and process of urban space development and introduces the technology into urban design, optimizing and updating to a great extent, so as to effectively improve the ability of problem-solving of urban design on the micro level. In urban design, the natural conflict between human demands and space requirements are prioritized. Among features related to behavior law has become the key element relating to urban space. It is a key point in future research on urban space features.

Currently, the social force model is perhaps the best known. In 1995, physicists Helbing and Molnar first proposed its embryonic form, and later published a model in the journal Nature in 2000. The social force model can simulate the self-organization process of pedestrians, and thus vividly reflect behavior features of the pedestrian flow. Representative software includes Anylogic, SimWalk and NOMAD, etc.

It is a quite challenging and very urgent problem to organize stations and the surrounding urban space from the micro perspective. Applying the Pedestrian Microscopic Simulation technology to the urban design of Influenced Urban Realm around Station is the current application of self-organization planning. Among various self-organization planning methods abroad, multi-individual simulation centered on Pedestrian Microscopic Simulation is a practical and increasingly mature method. There have been successful examples regarding multi-rail transit and comprehensive development of surrounding urban environment based on the technology in several countries and regions including Hong Kong, Japan and the UK.

2 Research and application foundation

2.1 Simulation requirements of Pedestrian connection behavior

This research focuses on the influence of a station on the urban space based on pedestrian timings. The Influenced Urban Realm around Station refers to a certain urban space around a specific station, in which various behaviors of individuals will be influenced by this station. From the 1950s, the research on pedestrian behavior features shifted from macro features to micro ones. Pedestrian Micro behavior Three-Level Theory proposed by Hoogendoorn and Bovy from Delft University of Technology in the Netherlands divided pedestrian micro behavior into three levels (Hoogendoorn S. P., P.H.L. Bovy, 2004), namely strategy level, tactical level and operational level, corresponding to the psychological decision-making process of pedestrians, and received relatively wide recognition. Referring to the Three-Level Theory, pedestrian behavior features in the micro simulation can also be divided into the perception level, option level and action level (Figure 1). Different levels have different simulation requirements (Hu Mingwei, Shi Qixin, 2009; Jia Hongfei, Yang Lili, Tang Ming, Meng Dan, 2009).

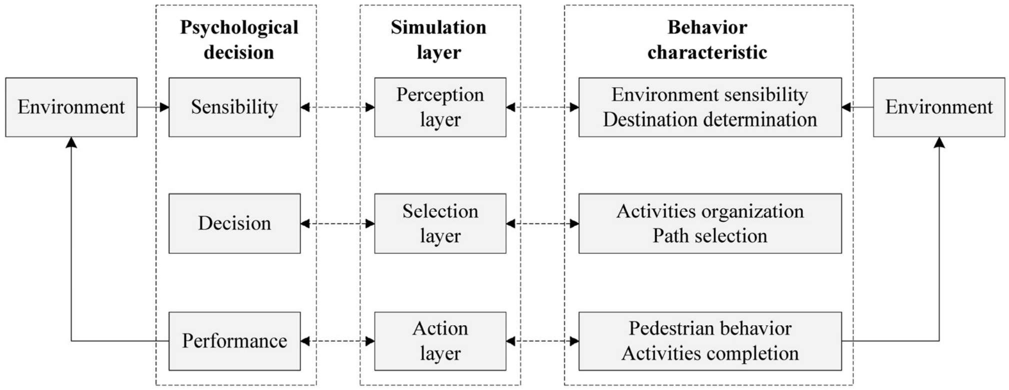

Figure 1. The relationship between psychological decision and behavior simulation

2.2 Characteristic parameters of pedestrian connection behavior

Pedestrian behavior feature parameters can be divided into macro and micro parameters. According to the area of urban design, together with current studies by relevant scholars, the simulation requirements level and the simulation feasibility of every parameter were summed up (Helbing D., Farkas I., Vicsek T, 2000).

In the specific simulation process, it is impossible and not necessary to take all behavior feature parameters into consideration (Zhang Guobin, 2009). Therefore the simulation parameter needs to be simplified to some extent, as long as the major features of pedestrian connection behavior can be demonstrated. As for the requirements of the simulation, some simulation parameters are preserved or eliminated. Finally, walking speed, space requirements, walking influenced scope, accelerated speed, destination, active link, turning actions, queuing, waiting, and facility influence are included in the major parameters of simulation.

3 Applications for pedestrian micro-simulation technology

Exploring the methodology for introducing Pedestrian Microscopic Simulation into the micro process of urban design is a key stage in connecting urban space and rail transit. The application of the technology consists of three stages, namely urban survey, survey statistics and simulation analysis. This research chose Anylogic7.0 as the software platform and used the social force model to conduct the pedestrian micro-simulation study (Figure 2).

Liziba station on the Chongqing light rail network's Line 2, is located by the Jialing River in the city's central Yuzhong District. It is housed within a large residential tower block. The station is on the 6th floor due to the hilly local landscape. Exit B of the station connects to an upper road running along a ridge behind the building at 6th floor level while Exit A is down on the first floor. The station is close to residential areas and bus stops with a large population flow, complicated traffic routes and unusual space.

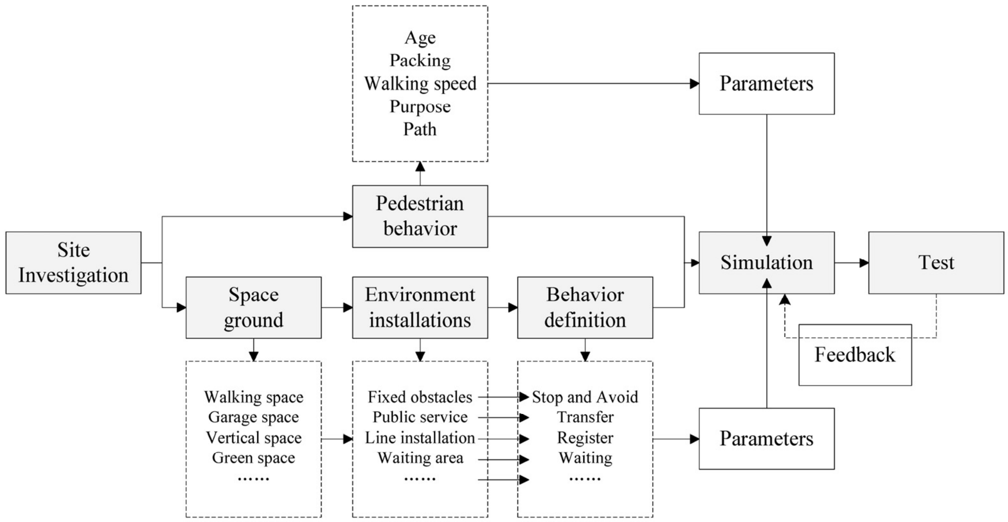

Figure 2. Simulation Process of Anylogic

3.1 Survey of urban information

According to the requirements of the research and software simulation, the survey consists of two major parts: physical environment and pedestrian behavior (Figure 3). There are four major aspects:

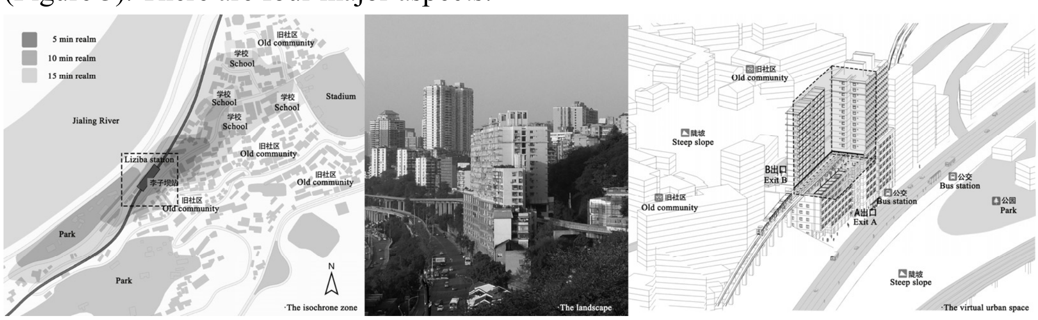

Figure 3. The isochrone zone and landscape of Liziba station

(1) Work out the isochrone zone, so as to identify the simulation scope and the urban elements.

(2) Establish the mathematical model. In this way, the base map of the simulation region is generated and all functional regions are identified.

(3) Calculate the traffic volume and the pedestrian component ratio at every key point in the simulation region according to the record.

(4) Survey the movement, capacity of buses and taxis within the simulation region, so as to identify the operational ability of this transferring method.

3.3 Simulation analysis

Anylogic provides a visualized simulation observation mode, enabling designers to better grasp the micro behavior of pedestrians. However, Anylogic does not provide a section mode. Hence, the section simulation effect of Liziba Station is drawn according to the simulation result, reflecting some problems. Please refer to Figure 4 for the pedestrian flow simulation result of urban design on a micro-level. The following conclusions can be drawn in line with the pedestrian flow figures of Liziba Station and surrounding pedestrian channels (Figure 4).

Figure 4. The pedestrian simulation flow diagram and present situation of Influenced Urban Realm around Liziba Station

Comparing the Anylogic simulation results and real scene images they can be seen to be very close indicating that Anylogic can go on to help improve pedestrian flows. Based on the above analysis of the simulation results, below are several recommendations for the Influenced Urban Realm around Station at Liziba and for further simulation:

(1) Broaden the width of stairways connecting Liziba Station platform and hall.

(2) Given that the function of the station hall is ensured, the collecting and distributing space at the station hall level can be enlarged via the subsidiary room so as to control pedestrian density at Exit A efficiently.

(3) Try best to cut down parking spaces along the street to the north side of Exit B, and enlarge the walking area for pedestrians to improve access for nearby residents.

(4) Creating a platform bridge by making use of the height differences of the station and vertical transportation at Exit A could separate pedestrians from vehicles, and eliminate security risks without adding a new line.

In summary, recommendations from the analysis of the Influenced Urban Realm around Liziba Station can solve the problems established in the first simulation. Should they did not achieve expect, analysis shall be carried out for the new problem with optimization again. This research is only the first exploration of pedestrian simulation method, in the hope that solution of microcosmic problems can facilitate the optimization in the Influenced Urban Realm around Station from macro level.

4 Conclusions

Here we may draw the following conclusions.

(1) The rapid expansion of cities and dramatic increase in complexity is undeniable. What should be ensured is that people's physical condition and behavioral competence will not be altered negatively due to the expansion of cities, nor will they see significant cultural / societal changes. While paying attention to urban macro system question, we shall also pay attention to the minutiae of the quality of people's lives.

(2) By exploring pedestrian micro simulations, the method of "simulation-optimization-re-simulation-re-optimization" was created. It has updated the methodology of urban design, perfected the appraisal system of urban design based on digital tools, and contributed refinements to urban design on a micro level. Meanwhile, by introducing Pedestrian Microscopic Simulation into urban design, this method has been applied in wider aspects, broken through its original traffic auxiliary analysis field, made a marked and positive effect on space comparison and rational decisions regarding urban design.

Acknowledgement

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References

Helbing D., Farkas I., Vicsek T. (2000). "Simulating Dynamical Features of Escape Panic." *Nature*, 7.487-490.

Hoogendoorn S. P., P.H.L. Bovy. (2004). "Pedestrian Route-Choice and Activity Scheduling Theory and Models." *Transportation Research Part B*, 38.169-190.

Hu Mingwei, Shi Qixin. (2009). "Comparative Study of Pedestrian Simulation Model and Related Software." *Journal of Transport Information and Safety*, 4.122-127.

Jia Hongfei, Yang Lili, Tang Ming, Meng Dan. (2009). "Micro-characteristics and Modeling Requirement of Pedestrians in Muti-modal Transport Hub ." *Journal of Transportation Systems Engineering and Information Technology*, 2.17-22.

Zhang Guobin. (2009). "*Pedestrian traffic behavior and microscopic simulation research on station square of synthetical Passenger transport hub.*" Beijing Jiaotong University, Bei Jing.

Influence Law of Urban Rail Transit Delay Propagation under Network Operation

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Abstract: Network operation perplex train delay and passenger flow delay which are the two typical representations of delays. Several train diagram models were set up to analyze train delay propagation characteristics and passenger flow affect. The most prominent characteristics is network dynamic property, and main factors are utilization of carrying capacity, distribution of delay and location of delay. Therefore computer simulation is applied for a case study of Shanghai Metro's Line 2 to find the influence law of these factors. Firstly, the simulation results help summarize several challenges of delay propagation for Urban Rail Transit (URT) Organization. Secondly, it is found that Operation Reliability is an important indicator of Urban Rail Transit Organization. The mutual effect between delay propagation and carrying capacity has been mainly reflected in actual URT Organization. Lastly, this paper provides URT with strategies to deal with these influence relation.
Keywords: Urban rail transit; Train delay; Network operation; Delay propagation; Computer simulation.

1 Introduction

Stochastic events will happen to URT to affect the normal operation，whose results are train delay and passenger flow delay in general. Under the condition of network operation, these delays propagate in its own line and others which has transfer relation to the line, meaning spread in the whole network, due to the complex network scale and structure, various train operation modes and complicated passenger flow distribution. Therefore, networked delay propagate is more complicated and needs more attention.

2 Literature review

Researches about URT train delay at home and abroad can be summed up as four aspects: generation mechanism, propagation characteristics, influence factors, network reliability. Several classic results are as follows:

YUAN J et al. (YUAN J et al., 2007) proposed a stochastic model of train delay propagation in stations to estimate the knock-on delays. The stochastic variations of track occupancy times were modelled with conditional probability distributions. The model can be applied for optimizing the station capacity utilization. XU Ruihua et al.

(XU Ruihua et al., 2006) analyzed several characteristics of train delay propagation and established the train delay simulation model of Urban Mass Transit, then found the related influencing factors of train delay and the spread of delay propagation. WANG Zhiqiang et al. (WANG Zhiqiang et al., 2009) designed a URT network's simulation analysis model and network's connection reliability evaluation index. JIANG Zhibin et al. (JIANG Zhibin et al., 2012) proposed a simulation model and found some passengers may get benefits from the short delay, but large initial train delay may result in not only knock-on train and passenger delays along the same line or the entire rail transit network.

Simulation techniques can be used to study train delay. XU Ming et al. (XU Ming et al., 2004) illustrated the modeling-method, the structure design, the function realization, evaluates parameters of a train operational delay simulation system. Besides, many institutions have researched train delay and the reliability of train diagram, etc. through microscopic simulation, developed some simulation systems (such as RailPlan, RailSys, OpenTrack, RailSim, RECIFE, etc.).

In contrast to the above, this paper takes the network operation into account, and analysis the influence law of URT delay propagation.

3 Delay propagation law in network operation

3.1 Propagation characteristics of train delay

Initial train delay may occur in a station or a section, then it may trigger joint delays to other trains because of connectivity of line and network.

(1) Rapidity and directness

The most lines of URT's only have two main tracks. The interval and buffer time between trains are both small. Therefore, train delay will spread more directly and rapidly, which can be illustrated by figure 1.

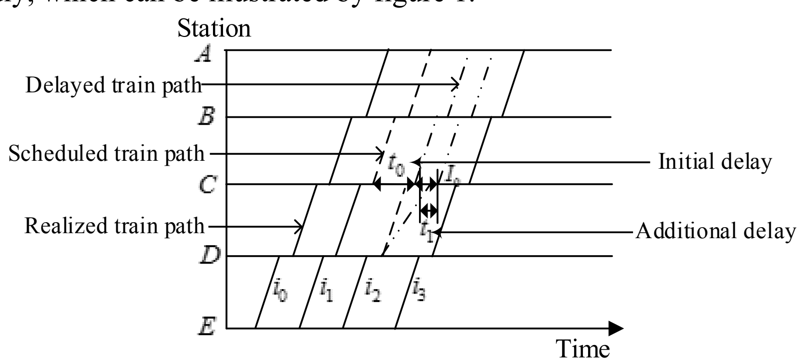

Figure 1. The train delay propagation rapidly and directly

(2) Two directions

1) Propagation forward: When some train delay happens, the forward train may be detained at forward station for a while to reduce the interval between the two trains, which can be illustrated by figure 2(a).

2) Propagation backward: Expect for spreading backward in same direction, train delay may still spread in another direction, because the rolling stock is used by cycling. When a train is delayed in one direction, it may still delayed when it starting at the circulation station unless the delay is eliminated completely by buffer time.

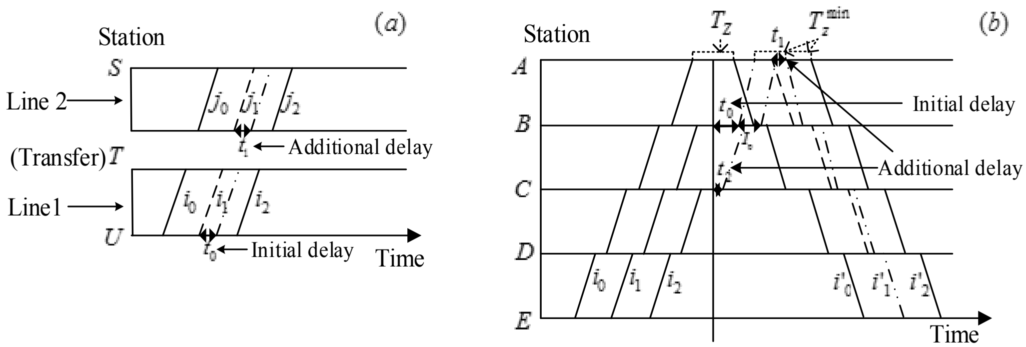

Figure 2. Examples of forward propagation (a) and counter propagation (b)

(3) Network propagation

Lines connect each other through the transfer station in network. When a train is delayed in a line, thus may lead to a lot passengers transferring to other lines to keep away from the delay, if there have delay until so this is a diffusion phenomenon in network.

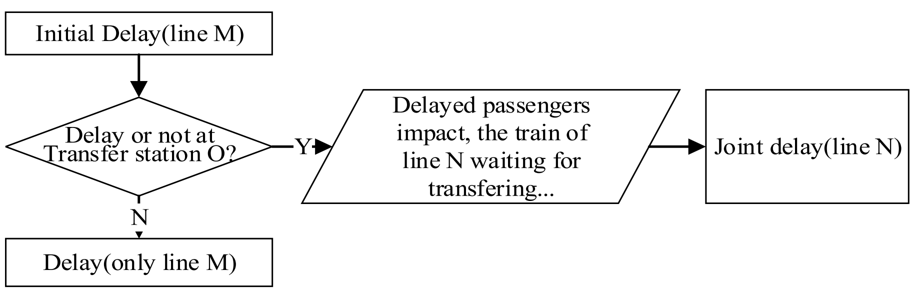

Figure 3. Network propagation process

(4) Network dynamic property

There is a buffer time between two trains in general, the length of buffer time determines the propagation speed and absorbed level of delay. If buffer time is smaller than initial train delay, the delay will spread dynamically in network, which means initial delay will be absorbed gradually, or second delay may be caused by relevant circumstances. 'Adjustment time' can be defined to describe the above adjustment process of delay, it begins with initial delay occurs, end in recovering plan operation.

3.2 Characteristics of passenger flow affected

Passenger flow will be affected by train delay. A travel time (T) including walking time into stations (t_w^i), all of waiting time($\sum t_w$), all of riding time($\sum t_r$), transferring time (t_w^t), and walking time out stations (t_w^o), among which waiting time and riding time are susceptible to train delay.

$$T = t_w^i + \sum t_w + \sum t_r + t_w^t + t_w^o$$

(1) Stage Differences

Riding time delay changes with the train delay, while waiting time delay or not is indicated by arrive time and train departure time.

(2) Dynamic change

The passengers' once waiting time or once riding time delay does not always lead to total travel time delay. For example, a train may accelerate to smooth over the waiting time delay. Besides, a passenger may transfer another train more quickly and reduce waiting time when the former train has a small delay, so he can arrive his destination punctually.

(3) Passive delay

Because of the influence of train delay and delay adjustment measures, the travel time delay is passive for each passenger. Especially, some trains have high load factors at rush hours of URT network, and Transfer stations have large passenger flow, they board the first transfer train hardly and are easy to be delayed. This situation is common in recent years.

4 Delay propagation simulation

4.1 Simulation design

The RailSys software is adopted to simulate Shanghai Metro line 2's train operation environment and operation mode, where stochastic delay is set according to delay analysis parameters (Table 1). 50 times simulation experiments are run to get relative indicators more accurately.

Table 1. Delay analysis parameters

A~Capacity utilization ratio	B~The delay distribution	C~ The initial delay location
A1~ 85.7%	B1~0min:2min:5min:10min = 90:8:2:0	C1~station XJD
A2~ 90.4%	B2~0min:2min:5min:10min = 90:6:2:2	C2~station PPS (busy)

4.2 Simulation results

There are schemes comparison according to the simulation results (Figure 4):

Scheme 1:（A1B1C1 and A2B1C1）the influence of different capacity utilization

For improved capacity utilization ratio in A2B1C1, high train density leads to more serious delay propagation than A1B1C1. We can see that initial delay (arrival delay and departure delay) at station XJD in A2B1C1 is longer. What's more, the train running speed can’t increase and the stop time can’t shorten because train operation interval is short.

Scheme 2:（A1B1C1 and A1B2C1）the influence of different delay distribution

The delay distribution is described by the proportion of various delay time, 0min means there is no delay. For A1B2C1, The delay time growth and the propagation scope increases observably, which means 2% 10min delay has a great influence. Because the long distance between HQA and SHR, the trains keep a higher speed running a long time, so the delay are absorbed greatly. However, the delay becomes severe because of higher train density and shorter section distance since NJX.

Scheme 3:（A1B1C1 and A1B1C2）the influence of different delay location

The initial delay occurs at a busy station (PPS) in A1B1C2, then we can see the delay disappears more slowly than A1B1C1, because there are more trains in these sections during the Adjustment time, so the buffer time is less and not enough to absorb the delay.

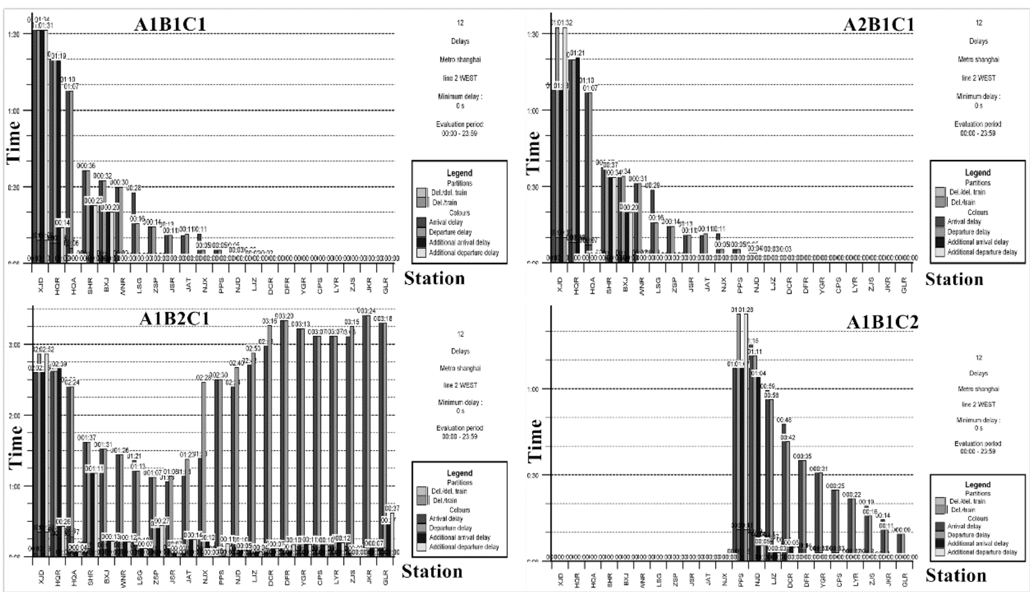

Figure 4. Delay propagation simulation results

5 Conclusions

(1) It is observed that higher capacity utilization ratio means greater challenges. In the event of a train delay, Operation Reliability will be effected. Therefore, capacity utilization ratio should keep within a certain range. The dot in figure 5 expresses the best capacity utilization ratio for reliable operation.

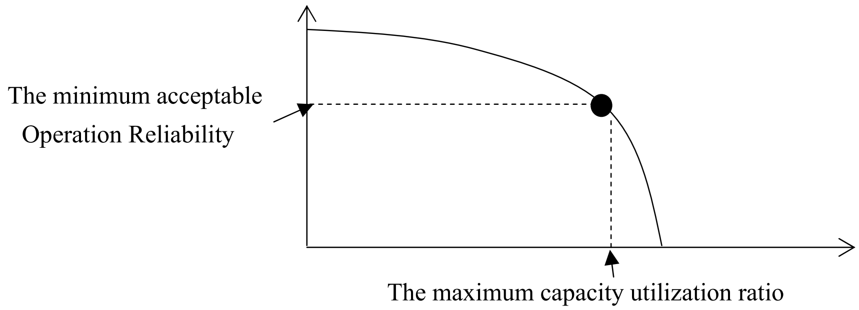

Figure 5. The reliability of capacity utilization and Operation Reliability

(2) It is also observed that large delay has greater influence, so we should avoid it in the process of URT Organization.

(3) There are some strategies to deal with these influence relation: 1) a certain amount of buffer time is necessary for dealing with stochastic delay. 2) Do a good job in prevention of early warning, reduce the possibility of emergency delay. 3) Optimize operation organization work and security the train operation order of busy stations or sections.

6 Recommendations for Future Research

The passengers' route choice behavior is important to future study so that it can be replicated in microscopic simulation models to represent more realistic train operation conditions.

Acknowledgement

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References

HIGGINS A, KOZAN E. (1998). "Modeling train delays in urban networks." *Transportation Science*, 32(4):346-357

JIANG Zhibin, XU Ruihua, Xie Chao. (2007). "Train delay propagation simulation in rail transit system." *(ICTE'2007).*ASCE: 789-794

JIANG Zhibin, LI Feng, XU Ruihua, GAO Peng. (2012). "A simulation model for estimating train and passenger delays in large-scale rail transit networks." *Journal of Central South University*, 12:3603-3613.

NIELSEN O A, LANDEX A, FREDERIKSEN R D. "Passenger Delay Models for Rail Networks." *Schedule-Based Modeling of Transportation Networks: Theory and applications*, 2008, 46: 27.

WANG Zhiqiang, XU Ruihua. (2009). "Reliability Simulation Analysis of Urban Rail Transit Networks Based on Complex Network." Journal of System Simulation, 2009, 20:6670-6674.

XU Ming, JIANG Zhibin, XU Ruihua. (2004). "Train Operational Delay Simulation System for Urban Mass Transit." *Urban Mass Transit*, 7(6): 35-38

XU Ruihua, JIANG Zhibin, SHAO Weizhong, ZHU Xiaojie. (2006). "Simulation Study on Train Characteristics of Urban Delay and Propagation Mass Transit Systems." *Journal of the China Railway Society*, 28(2), 7-10.

YUAN J, HANSEN I A. (2007). "Optimizing capacity utilization of stations by estimating knock-on train delays." *Transportation Research Part B: Methodological*, 41(2): 202-217

Urban Rail Simulation Platform Control System Design Based on Fault Detection

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Abstract: According to the design requirements of CBTC simulation platform, the fault injection model of track-side equipment carries out research, at the same time, the circuits are designed and the software are tested on dynamic simulation sand table. In this article, the operation principles, fault characteristics and trigger mechanisms of the track-side equipment such as the responder, emergency shutdown button, signal light and turnout are analyzed and designed. And the feasibility of fault injection model is verified by testing the fault injection. The fault diagnoses and emergency command abilities of Railway operating training staff are trained by the fault injection, at the same time, it also provides some services for the teaching and training.
Keywords: Urban rail; Simulation; Fault simulation; Control system.

1 Introduction

Urban Rail Traffic Control Laboratory is a laboratory construction project of Southwest Jiaotong University Emei Campus Ministry of Education to improve the basic conditions of school. The Urban Rail Traffic Control Laboratory consists of five training platforms, including the urban rail operation simulation platform based on the simulation of the urban rail transit operation sand table, the equipment operation platform which is based on the train operation control system and network traffic technology, the management and control integration simulation training platform based on station signal control system and ISCS underlying hardware and software technology, ATS signal interlock simulation training platform based on train signal supervision system and DCS system, and control system coordination and dispatching training platform based on the simulation environment under abnormal conditions.

The design concept of Urban Rail Operation Simulation Platform is to simulate train track, train reversal, etc. process in urban rail traffic. Through simulating urban rail abnormal operating conditions, train the analyzing and solving capability of students for emergency, emergency plan, and typical case. Currently, the control system of sand table only can do simple control for signal equipment, without detection feedback function. Owing there is no detection feedback function, control system does not know whether the control is in place, all kinds of setting fault in sand table cannot be returned back to the interlock host, and cannot simulate the rail operation under abnormal conditions.

The prerequisite of setting fault on the sand table is reading back signal equipment status. The feature of the control system in the paper is that it can periodically collect the signal equipment status information, deliver the change of status back to the interlock host, and simulate the rail operation under abnormal condition by the fault injection.

2 The control system and interface

The signal equipment such as the signal light, turnout, departure indicator and emergency shutdown button are used on the sand table. The signal equipment on the sand table is mainly concentrated in the station and small part is on the rail line. The most of data is switch signal and the amount of data is small. The design of control system interface should consider the following factors: the rate of information, data format, interference immunity, the wiring convenience of the sand table, real-time, expansibility and other factors. The RS-485 interface uses differential signal and has strong interference immunity, easy networking and cheap price. In addition, the interface can transport between long distance, and the communication speed can meet the need of control and detection. The RS-485 is suitable as a communication interface between the control system and the interlock host. The control system structure is shown in Figure 1.Multiple control system is connected to the interlocking host via RS-485 bus and the interlock host could check the logical relationship of signal equipment and access to the operating control center(OCC) for unified management. The control system consists of three parts, including signal light drive and detection, turnout drive and detection, interface and protocol. Departure indicator and emergency shutdown button can be completed by using signal light drive and detection circuit.

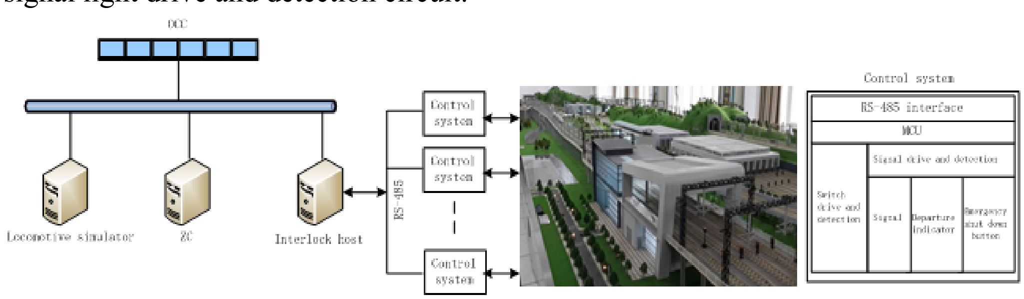
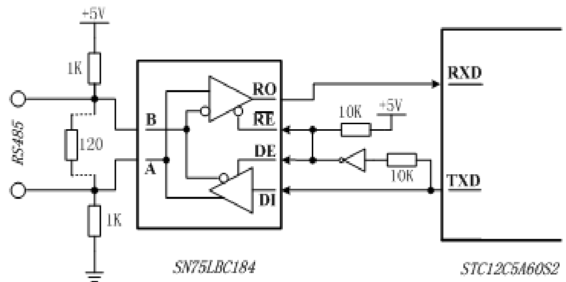


Figure 1. The control system structure

The communication interface and protocol are shown in Figure 2.The differential transceiver SN75LBC184 has transient voltage suppression, does not need external chip protection circuit. The RS-485 network terminal uses 120 ohm resistor terminal. The RS-485 interface of each node is always in the state of receiving data, the interface switches to transmit mode when sending data to the interlock host. The MCU of control system uses STC12C5A60S2, and the RS-485 interface is connected to the UART interface of MCU. When the MCU transmits data to the RS-485, only need to operate the UART interface.



	interlock host ->sand table	sand table ->interlock host
byte 0	SYN(0xAB)	SYN(0xCD)
byte 1	address	address
byte 2	CW	CW
byte 3	data length	data length
byte 4	data 0	data 0
byte 5	data 1	data 1
byte ···	······	······
byte n-1	check	check

Serial data frame format

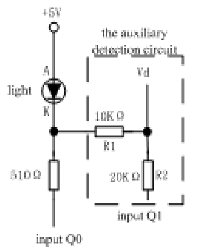
Figure 2. The communication interface and protocol

RS-485 uses half-duplex communication mode, and the data transmits in serial mode. The structure of data includes synchronization character, address, the data length, data and check. In order to distinguish the direction of data flow, data frame synchronization character from the interlock host to the sand table uses 0xAB, from the sand table to the interlock host uses 0xCD.Address is a unique address curing in control system, stores in the EEROM region of STC MCU. Command word contains reading and writing the address, reading and writing the turnout status, reading and writing the signal status, writing the departure indicator status, and reading the emergency stop button status. The third byte of data frame determines the data length, and the last byte is check word.

3 Signal light drive and fault detection

The number of signal lights on the sand table is large, and the signal light uses various colors of light emitting diodes. The driving circuit is generally connected with a resistor. Signal detection is mainly to detect signal lamp in normal status, short circuit status, open circuit status or the ground status. LED has a different pressure drop when the lighting, red or yellow is between 1.8V and 2.5V, green is between 2.7V and 3.5V. When the signal voltage drop is in the range of LED lighting, you can explain that the signal is lighting and normal. If the signal is not normal, we determine light is in short circuit, open circuit, or ground fault condition.

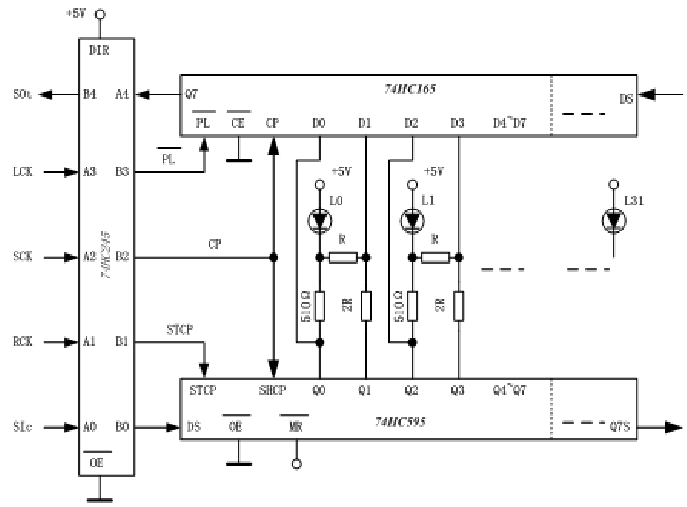
The input level threshold of flipping CMOS gate circuit is always half of power , and with power fluctuates. According to this feature, when we design for the auxiliary detection circuit, the voltage drop determination signal is converted to a logical value determination. The signal light auxiliary detection circuit is shown in Figure 3(a).Owing the number of lights is particularly much, so we design a signal light driving and detection card for each 32 lights. The card uses the SPI bus cascade as shown in Figure 3(b).The control data is sent from the serial input and parallel output shift register 74HC595, and the test data is looped back from the parallel input and serial output shift register 74HC165.The shift register is fabricated by CMOS process, every two manage a signal light.



(a)signal auxiliary detection circuit

status	input		output		state vaule
	Q0	Q1	D0	D1	
normal	0	0	0	0	0xF8
	0	1	0	1	
	1	0	1	1	
	1	1	1	1	
short circuit	0	0	0	1	0xFA
	0	1	0	1	
	1	0	1	1	
	1	1	1	1	
open circuit	0	0	0	0	0xF0
	0	1	0	0	
	1	0	1	1	
	1	1	1	1	
ground	0	0	0	0	0x50
	0	1	0	0	
	1	0	1	0	
	1	1	1	0	

(c)light working state vaule



(b)signal light control and detection card circuit

Figure 3. Signal light drive and detection circuit

The signal light control and detection card circuit is shown in Figure 3(b).When the signal light L0 is controlled, the control data will be sent to the Q0 terminal of 74HC595.If the Q0 terminal outputs high level, the light will be turned off. And the low level will make light on. When detecting the signal light L0, enter 00B, 01B, 10B and 11B four kinds of logical values to Q0 and Q1 terminal. Then read back the logical value from D0 and D1 terminal. Four kinds of logical values from the low to the high combines into a byte, the byte is equipment state value. As shown in Figure 3(c), the equipment state value of light is different. Through the equipment state value, we can determine the fault condition of signal light. The control method of the remaining signal light is similar to above method, the light x is managed by Q_{2x}, Q_{2x+1}, D_{2x} and D_{2x+1}.

4 Turnout drive and fault detection

The switch machine uses the push-pull electromagnet, electromagnet magnetic will make the switch locking. A switch drive and detection card can manage four switches, the board uses SPI bus. The data of switch drive outputs by parallel port 74HC595, acquisition data and fault data are sent to the 74HC165 parallel port. The turnout control and detection circuit is shown in Figure 4.The turnout drive signal is Q0 pin of 74HC595.Through the control of combinational logic circuit, the coil current of L293D switch machine is in forward, reverse or no current.

The detection of the turnout uses non-contact optoelectronic switch, and the location and anti-location both install one separately. When the turnout is moved, it will drive the turnout linkage mechanism, and when the turnout linkage mechanism reach reliably one side of location (anti-location) detector, the detector will output location (anti-location) pulse signal. The location (anti-location) detection circuit uses firstly inverter 40106, resistors and capacitors to constitute TTL inverter and RC oscillator, and the output square wave signal drives the infrared light emitting diodes. To generate different frequency pulses, the resistor of the location (anti-location) detection circuit will be set different values, therefore, the pulse input of location (anti-location) are distinguished by the frequency. After the infrared receiver diode receives the signals, the signals are modulated and outputted to the MCU to identify, and then the identified turnout states are sent back to the main control card by the D0 port of the 74HC165.

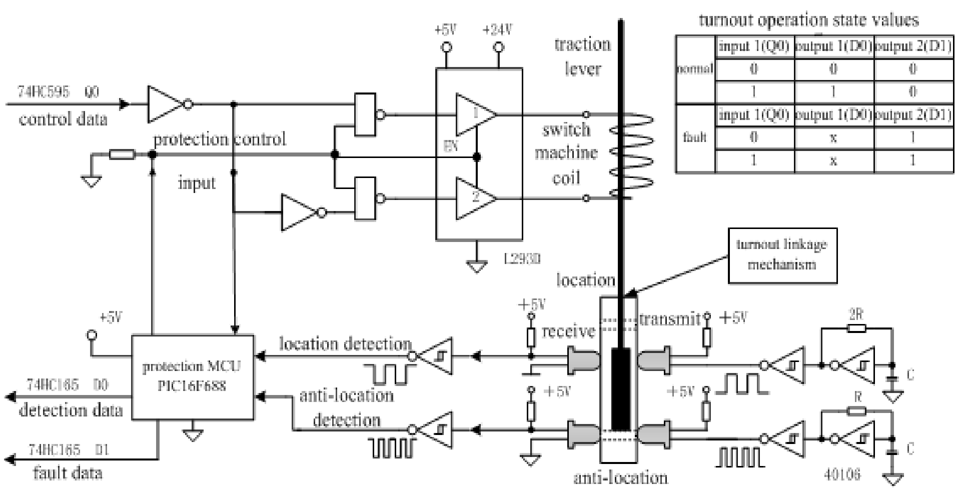


Figure 4. Turnout control and detection circuit

Due to the coil of switch machine is drove by DC power, the coil impedance is small. So the switch machine can not be supplied power for a long time, otherwise it will burn the coil or driver chip L293D.Through the comparison of the control data and the detected data, identify the turnout is in place or not. In order to cut off power of switch machine coil, achieve the purpose of protecting MCU. The detection data and fault data are returned back to the main control card by the D1 port of the 74HC165.

5 The control system fault injection and test

A sand table has many lines, a line has many control systems, they are arranged in a control cabinet. Every control system is connected to the interlock host by the RS-485 bus. A set of control system contains a main control card, many signal machine driving and detecting cards and turnout driving and detecting cards, and manage one station or more adjacent stations. Each control system contains main control card, signal machine driving and detecting card, turnout driving and detecting card, and they are cascade connected through SPI bus. The main control card is responsible for communication, outputting control signals and reading back detection data. And the signal machine driving and detecting card manages signal machine, departure indicator and emergency stop button. The turnout driving and detecting card is responsible for managing the turnout. The physical diagram of control system is shown in Figure 5.

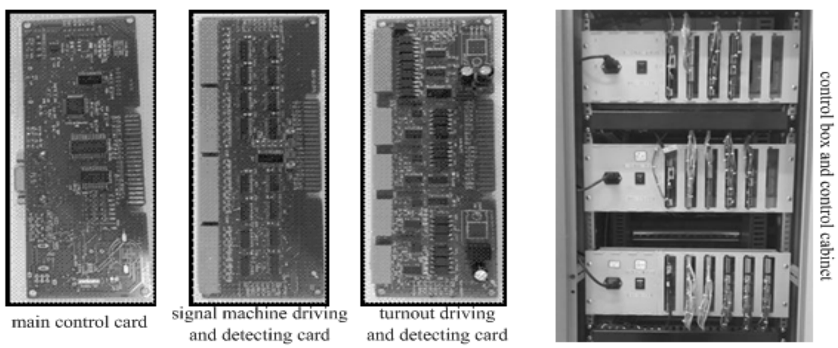


Figure 5. The physical diagram of control system

Through controlling and detecting the signal equipment on the sand table, all aspects of urban rail operation simulation software are reflected truly. The simulation software can make students master all aspects of urban rail operation quickly, and verify the logic relation of interlock parts. The urban rail operation condition is shown in Figure 6. Many groups of students study and practice in the line, prove that the control system is reliable and feasible.

Figure 6. The urban rail operation condition

6 Conclusions

The urban rail simulation laboratory could simulate many kinds of abnormal condition, and provide specific practices for the all professional students. For the students of signal profession, the lab could train many abilities of students, such as interlock logic relationship, the system signal control, communication, equipment failure identification, etc. For the students of operation management profession, it could provide vertical and horizontal linkage training based on various normal and abnormal situations in the positions such as operation coordination, emergency command center, control center, station, train, etc. The control system relies entirely on the self-exploration, self-development, from easy to difficult, in the last it is improved gradually. Compared with the similar laboratory, the laboratory focuses more on training. It is an important reference for training students which study in railway transportation, railway signal or other profession in laboratory construction.

Acknowledgement

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References

Bu B, Yu F R, Tang T. Method to improve the performance of communication-based train control (CBTC) systems with transmission delays and packet drops//Intelligent Transportation Systems (ITSC), 2014 IEEE 17th International Conference on. IEEE, 2014: 762-767.

International Conference on System Simulation and Scientific Computing (5, 2002, Shanghai). Proceedings of Asian Simulation Conference, the 5th International Conference on System Simulation and Scientific Computing (Shanghai): November 3-6, 2002, Shanghai, China. Internat. Acad. Publ., 2002.

Li Bai.(2014).Research on Urban Rail Transit Network Command Center Information Platform. Procedia - Social and Behavioral Sciences.

Motion Simulation of a Vessel Based on Standard Environmental Conditions and Dynamic Assessment

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Abstract: The motion simulation of vessel play a very important role in the maritime full mission simulator, which can show the user some kinds of simulation environment in the fixed sea and meteorological conditions. The purpose of this paper is to decide the way of vessels motion in the fixed sea and meteorological conditions by use of the real-time hydrological and meteorological information, and the dynamic assessment of the security situation of vessels can be done at the same time.

Keywords: Vessel motion simulation; Simulator; Sea state; Dynamic assessment.

1 Introduction

With the rapid development of marine economy, marine disasters, caused by heavy weather especially sea wind, fog and the derived bad sea condition (storm surges, waves, current etc.), happen frequently and are more and more prominent to maritime security.

Usually, seaman deals with the bad weather mainly based on experiences, and takes action according to the meteorological information obtained by NAVTEX. The purpose of this paper is to show the ship motion in bad weather by simulator to the user, and decide the security situation of vessels in bad weather by use of the real-time hydrological and meteorological information. So as to provide accurate safety information for the ships.

In china, (Huang, 2001) has done some research on the ship motion in the dynamic environment, and is very helpful for my research.

2 The model of storm force in the state of underway

2.1 model analysis of ship by force

The most serious failure state for the ship underway is to capsize. It is generally believed that the ships are influenced mostly in the horizontal state, so this study is based on the situation of crosswind.

Just as (G Bulian,2004) described, the roll motion of the ship affected by crosswind and wave can be expressed as the equation:

$$(J_{xx} + J_{add}) \cdot \ddot{\emptyset} + D(\dot{\emptyset}) + \Delta \cdot \overline{GZ}(\emptyset) = M_{wind,tot}(\emptyset, t) + M_{waves}(t) \qquad (1)$$

J_{xx}: ship moment of inertia in air, J_{add}: added moment of inertia, $D(\dot{\emptyset})$: general damping moment, Δ: ship displacement, $\overline{GZ}(\emptyset)$: restoring lever, $M_{wind,tot}(\emptyset, t)$: total instantaneous moment due to wind, $M_{waves}(t)$: total instantaneous moment due to waves.

For the sake of calculation convenience, the effects of wind is divided into two parts, the mean wind and the instaneous wind, when the ship is exposed to wind, the constant wind can only reduce the ability of ship against external gust effect; while the gust is the mainly cause of capsizing.

The heeling moment $\overline{M}_{wind}$ due to the wind can be expressed in the formula:

$$\overline{M}_{wind} = \frac{\rho_{air} \cdot \overline{V}_w{}^2 A_L C_y (H_w + H_{yd})}{2} \quad (2)$$

Where, ρ_{air}: air density, $\overline{V}_w$: mean wind speed, Hw: distance from the waterline of the center of aerodynamic pressures, Hyd: distance from the waterline of the center of hydrodynamic pressures, Cy: drag coefficient, AL: lateral projected area.

For the influence of mean wind, we can approximate changes the ship's GZ curves as follow. First of all, the mean wind made the stable position of the ship shifts fromΦ0 to ΦS. In consideration of the changes of stable position, the GZ value at the windward side becomes and the stability vanish angle becomes larger, while in the lee side shows the GZ value and stability vanish angle becomes smaller. The capsizing generally occurs at the lee side, so here only the lee side considered.

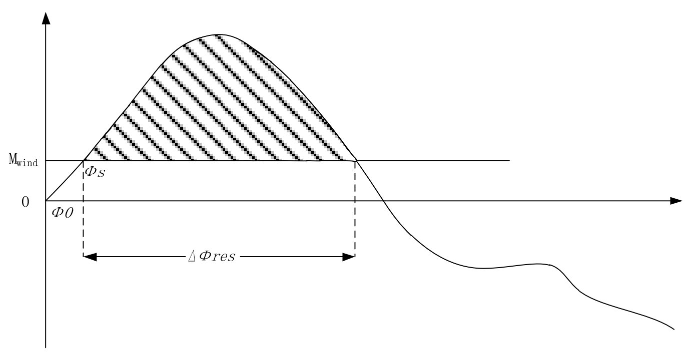

Fig.1 GZ curve schematic diagram and relevant parameters

2.2 Wind spectrum and wave spectrum analysis

The wind and the waves are all irregular random process. The effects of wind and wave on the ship can be most directly exhibited by the wind wave spectrum. This paper assumes that waves are fully developed by the effect of the wind, so the mutual relationship exists between the wind and the waves.

Because the wind direction is steady, this wind spectrum only includes the instaneous wind, and is described by Davenport spectrum:

$$S_{wind}(\omega) = \frac{K\overline{u}_{10}^2}{\omega} \acute{\chi}^2 (1 + \acute{\chi}^2)^{-\frac{4}{3}} \quad (0 \le \omega \le \infty) \quad (3)$$

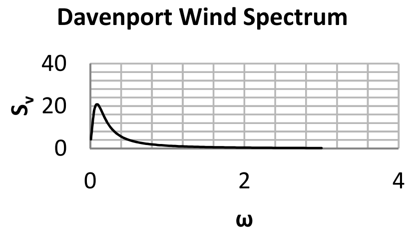

Fig.2 the davenport wind spectrum

Where, K: instaneous wind coefficient, and K=0.003, $\bar{u}_{10}$: mean wind velocity, ω: the frequency of instaneous wind and $\acute{\chi}$=600ω/π$\bar{u}_{10}$.

The sea elevation in metres is modeled using the spectrum recommended by the international towing tank conference（ITTC）as follow：

$$S_{wave}(\omega) = \frac{A}{\omega^5} exp\left(-\frac{B}{\omega^4}\right) \quad (4)$$

Where, A=8.10*10-3g2,B=3.11/$H_{1/3}{}^2$.

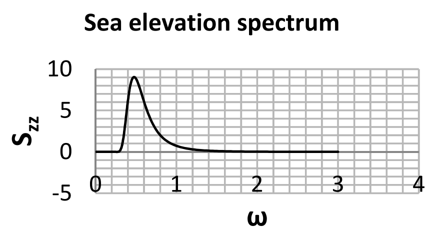

Fig.3 the sea elevation spectrum

3 The model of safety judgement for ship at sea

Through alternating the GZ curve, the mean wind influence upon ship is excluded, the movement of the ship will be irregular at the effect of the irregular waves. According to (Peng,1989). The spectrum of ship motion can be expressed as follow:

$$S(\omega) = \frac{\omega^4}{g^2} \frac{x_\theta{}^2}{(1-\wedge_\theta{}^2)^2 + 4\mu_\theta{}^2 \wedge_\theta{}^2} (S_{wind}(\omega) + S_{wind}(\omega)) \quad (5)$$

Where, ω: the encounter frequency of the ship, here $\omega = \omega_0 \left(1 + \frac{\omega_0}{g} \vartheta cos\theta\right)$, g: acceleration of gravity, x_θ: effective wave slop, $\wedge_\theta$: specific value of the encounter frequency and wave frequency, μ_θ: effective drag coefficient。

The roll angle standard deviation σ_x and the roll velocity standard deviation $\sigma_{\dot{x}}$ can get from the spectrum of ship motion:

$$\sigma_{\dot{x}}^{\ 2} = \int_0^{+\infty} \omega^2 S_x(\omega) d\omega \tag{6}$$

$$\sigma_x^{\ 2} = \int_0^{+\infty} S_x(\omega) d\omega \tag{7}$$

According to the characteristics of the wave spectrum, the motion of the ship around the steady position under the action of beam wind can be considered to be Gauss course. Assume that ship's capsizing accord with Poisson distribution, ship capsizing probability of exposure in a particular environment for a period of time can be got according to the Poisson equation. The capsizing probability of ship can be expressed as follow:

$$P = 1 - exp\left(-\frac{T_{exp}}{2\pi}\frac{\sigma_{\dot{x}}}{\sigma_x} exp\left(-\frac{1}{2}\left(\frac{\Delta\Phi}{\sigma_x}\right)^2\right)\right) \tag{8}$$

The probability of occurrence of different levels for different ship sailing under different wind conditions can be got by calculating.

4 Introduction of the system

4.1 system working principle

System workflow roughly as follows:

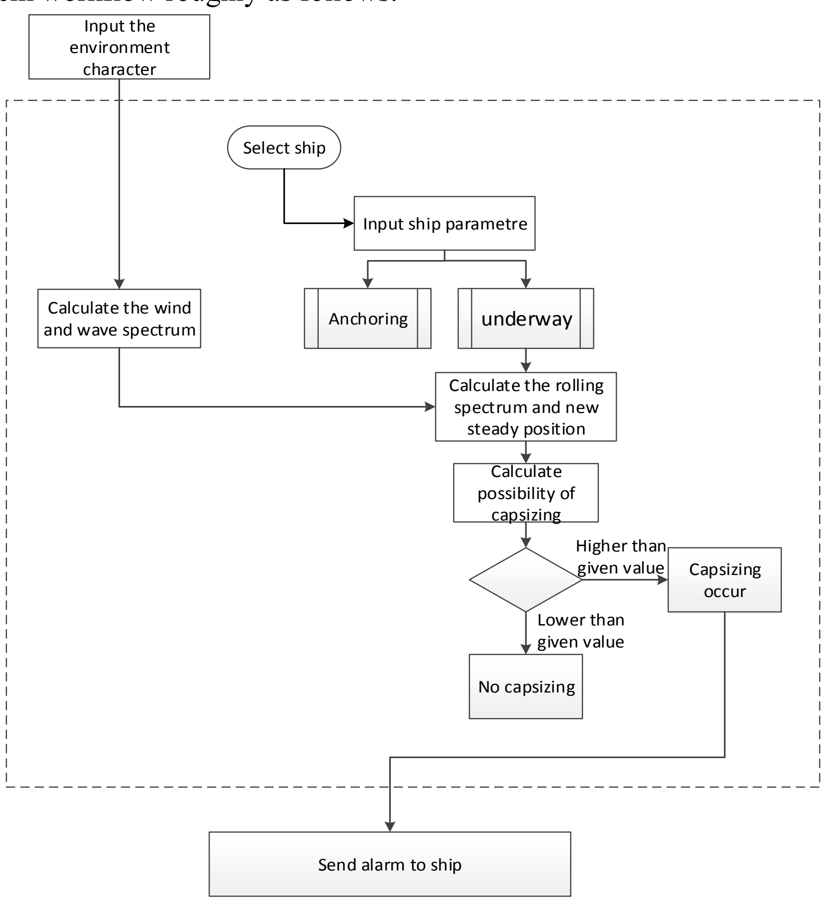

Fig.4 System work flow

Through the information platform and real-time observation we can get the environment information, and the detail of the ship is easy to get. Combining the ship location, ship detail and environment character, the possibility of capsizing can be got, and the danger degree of the ship is easy to judge.

Fig.5 Technical renderings of ship motion in the simulator

4.2 Practical application of the system

This system can be used in maritime supervision department or Shipping Co which often has ship sailing in the heavy sea area. Combining with a communication system, a computer processing, the system can be used alone, for route selection, navigation state monitor, reference for meteorological navigation; And the system can be used, together with the ENC system, radar system, AIS system, as additional calculation unit of ship monitoring or information display system. It is easy to judge ship in danger, and complete safety status monitoring and alarm of a series of ship. According to the calculation result, the safety navigation advice can be given.

5 Result and discussion

The methods of calculating the probability of capsizing of ship navigating in heavy sea area is studied in this paper. When the relevant departments predicts the ship is in danger, safety information can be conveyed to the ship in danger by the public communication network, the VHF or satellite equipment. Damage to the personnel, ship and cargo can be avoided. This system has positive significance to the navigation safety and navigation order of heavy sea area.

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References

G Bulian, A Francescutto. (2004). “A simplified modular approach for the prediction of the roll motion due to the combined action of wind and waves.” *SAGE*, 1, pp.189-211.

Huang Yanshun. (2001). “Calculation of the capsizing probability of a ship at beam wind and sea.” *Journal of Tianjin university*, 34, pp.189-211.

Liu Xiaofeng. (2009). “Analysis of factors affecting the safety of anchoring.” Dalian: *Dalian maritime university press*.

Ni Jianbin, Zhang Jingmin. (2009). “The application of comprehensive safety assessment method in the maritime safety regulation.” *China Water Transport*, 7, pp.38-52.

Peng Shengying. (1989). “Ship seakeeping basis.” Beijing: *National defense university press*.

XiangYang, Zhu Yonge, Chen Guoquan. (2000). “Risk analysis and evaluation of comprehensive security.” *China Ship Survey*, 2, p.38-41.

Yang Linjia, Yang Zuochang, Yu Yang. (2005). “Ship dragging anchor alarm system.” Dalian: *Journal of Dalian maritime university*, 31, pp.29-31.

Reform of a Load Balancing Mechanism for a Railway Freight Vehicle

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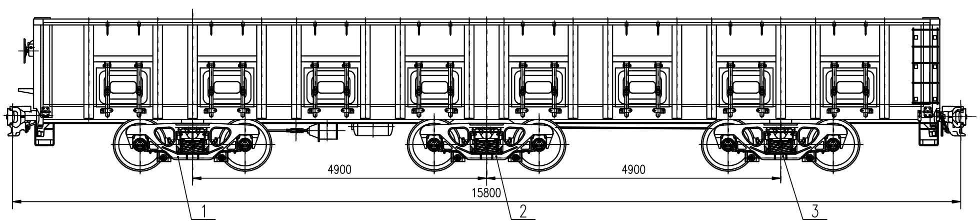
Abstract: To achieve uniform distribution of loads over three bogies, we use two sets of load balancing mechanisms at the underframe of car body. The practical tests show that the load balancing mechanism has two problems: low efficiency, the difference between vertical forces at both ends being equalised reaches about 25%; response latency, the force at the passive end is always slightly delayed, which affects the uniform load effect when the vehicle operates at high speeds. This paper gives the principle and stress analysis of the railway freight vehicle load balancing mechanism, and provides the methods to improve the efficiency of the mechanism.
Keywords: Railway; Freight vehicle; Uniform load; Mechanism; Efficiency.

1 Introduction

Generally, the car body of railway freight vehicle is supported by two bogies and each bogie has two wheel set. The structure of the vehicle can be regarded as two-stage simple supported beam with uniform load, i.e., car body-bolster and bolster-wheel set (Zhao, W. H., 2000). To improve the vehicle loading, especially the concentrated loading capacity in the middle, a vehicle is developed with three bogies this year, named three-point support vehicle, as shown in Figure 1(Lin, J., 2003).

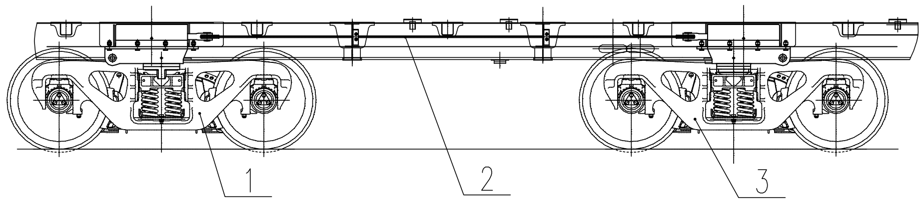


1—The bogie in Position 1, 2—The bogie in Position 2, 3—The bogie in Position 3

Figure 1.Three-point support railway freight vehicle

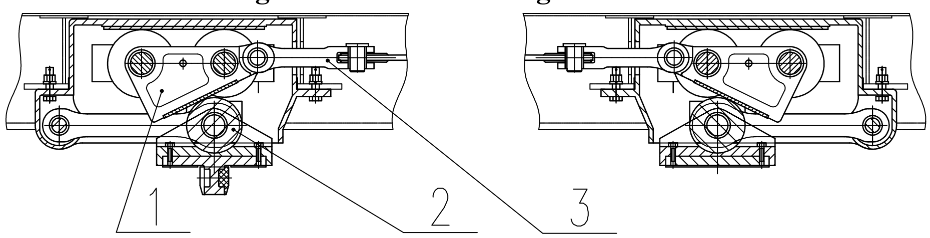
2 The problem in it

In order to achieve uniform distribution of loads over three bogies, the load balancing mechanism can be set at the underframe of car body, distributing even load on the bogie in the middle of the vehicle and the one at one end. There are two sets of load balancing mechanisms and vertical forces act on two side bearers of each bogie respectively. As simple force analysis shows, the bogie in the other end of the vehicle can get the same load as that two bogies. The load balancing mechanism is shown in Figures 2 and 3(Cao, Y., 2007).



1—The bogie in Position 2, 2—Load balancing mechanism, 3—The bogie in Position 3

Figure 2. Load balancing mechanism



1—Inclined wedge, 2—Roller, 3—Brace

Figure 3. Structure of load balancing mechanism

The load balancing mechanism is a kind of mechanism with inclined wedges. Although the load balancing mechanism can achieve uniform distribution of loads theoretically, it has two problems by testing:

(1)low efficiency, the difference between vertical forces at both ends being equalised reaches about 25%;

(2)response latency, the force at the passive end is always slightly delayed, which affects the uniform load effect when the vehicle operates at high speeds (Hu, H. P., 2010).

3 Force analysis of load balancing mechanism

The 1:1 effect of load balancing mechanism based on the present design theory can be obtained, after the detailed analysis of the present load balancing mechanism and the deduction of theoretical formula. However, the system working efficiency in practice manifests that a component of the load must be applied to overcome the friction of wedges and the initial elastic deformation of the braces. Therefore, uneven distribution of loads and latency are the inevitable results (Wang, F.D., 2003).

The equivalent force diagram of load balancing mechanism is shown in Figure 4, and the meanings of the symbols in the figure are shown as follows:

α_1 and α_2- the inclined wedge angle;

β_1 and β_2- the friction angle of the friction surface;

μ-the equivalent friction coefficient (the approximate value is 0.044, β=2.52°);

L_0- the distance between rollers in two horizontal planes;

x1 and x2- the horizontal distance;

L – the length of the brace.

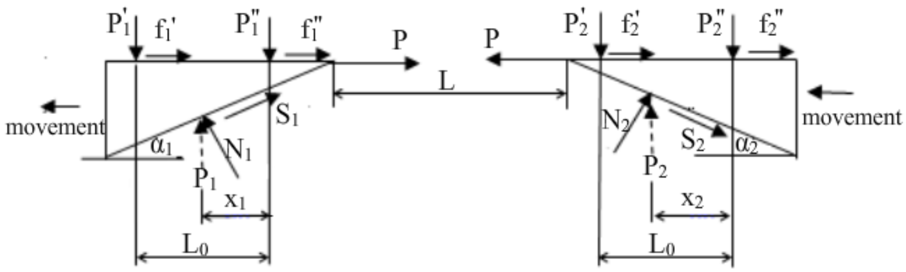


Figure 4.the equivalent model of load balancing mechanism

The end on the left is set to be active here. When dynamic load P_1 is transferred from the side bearers in active end to wedges, N_1 acts on slop, driving the left mechanism to move left. The brace pulls the right mechanism to the left after completing elastic deformation, driving the side bearers at the right end which is also the passive end to move down to complete motion for uniform load, and vice versa.

The following are fundamental formulas:

$$\mu = \tan\beta \tag{1}$$

$$f_i = \mu_2 P_i \tag{2}$$

$$S_i = \mu_1 N_i \tag{3}$$

$$P_i = P_i' + P_i'' \tag{4}$$

$$P = P_1 * \tan(\alpha - \beta_1) - (P_1' + P_1'') * \tan\beta_2 = P_2 * \tan(\alpha + \beta_1) + (P_2' + P_2'') * \tan\beta_2 \tag{5}$$

(1) The brace elastic deformation has the following expression

$$\Delta L = \frac{PL}{EF} \tag{6}$$

The symbolic meanings in the above formulas are as follows:

μ_i - the friction coefficient;

f_i - the equivalent friction in horizontal plane;

S_i - the friction in slop;

N_i - the normal pressure (KN);

P_i - the vertical force acting on a single wedge;

P- the tension of the brace in the process of load balancing(KN);

E - the elasticity modulus (216×109 N/m^2);

F - the cross-sectional area of the brace ($50\times14mm^2$);

ΔL- the anount of brace elastic deformation.

Taking 275(KN) which is the experimental data value of P1 into the formula (5), the tension of the brace can be got: P=109.77(KN).

The brace elastic deformation can be obtained by taking P into the formula (6): ΔL=2.99(mm).

Vertical displacement of the side bearers may be lost, because of the deformation. The displacement: $2.99\times\tan26^\circ=1.46\text{mm}$.

According to the calculation on geometry size of actual product, when the displacement of the passive end is 35.1 mm, the load acting on the corresponding side bearer is 221 KN and, in this case, the equivalent stiffness is:221/35.1=6.3 KN/mm.

That is, the load that is equal to 6.3×1.46=9.19 KN is offset in vertical direction.

(2) The analysis of friction resistance

The friction resistance of the mechanism is from respectively the friction between the roller and the plane and that between the roller and the shaft. By comprehensive consideration, in this scheme, equivalent friction coefficient is taken and the value is larger than that under pure rolling and smaller than that under pure sliding. So, the value 0.04 is taken.

(3) Delay load balancing mechanism of action

The mechanism is complicated and has many links. There exist friction and clearances between the parts of hinge, which influences the response speed. The friction of the damping device and the elastic elements are also the reasons of response latency.

4 The methods to improve the property of load balancing mechanism

Through the above analysis, the following aspects can be changed to improve the efficiency of the load balancing mechanism and reduce lag:

(1) The corresponding lag caused by the elastic deformation can be reduced by increasing the cross-sectional area of the brace;

(2) To reduce equivalent friction coefficient, several methods can be taken such as increasing the diameter of the roller and improving the lubrication conditions between the inner hole of the roller and the shaft;

(3) Because it is hard to change the friction characteristics of materials, we enhance the efficiency by changing the wedge angles. The inclined wedge angle is optimized, the normal pressure is reduced and the resistance is also declined in the process of load balancing.

It is necessary to analyze the relationship between the inclined wedge angle and the efficiency. The ratio of the inclined wedge angle to the forces acting on side bearers at both ends is the function of α, and, to improve load balancing effect, we discuss the influence on the effect resulting from adjusting the wedge α.

According to formula (5), the ratio of P_1 to P_2 is determined by formula:

$$\frac{P_1}{P_2} = f(\alpha) = \frac{\tan(\alpha+\beta_1)+\tan\beta_2}{\tan(\alpha-\beta_1)-\tan\beta_2} \qquad (7)$$

So, the equivalent friction coefficient (sliding and rolling) is 0.044 and the value of the equivalent friction angle is $\beta_1=\beta_2=\beta=2.520°$.

According to formula (7), the monotonicity of the tangent function determines $f(\alpha)>1$. Only under the condition that friction is not taken into account, i.e., $\beta_1=\beta_2=\beta=0$, the equation $f(\alpha)=1$ can be got, that is to say the force is transmitted in accordance with 1:1 and the efficiency equals 1.

With the friction condition given by formula(7), the ratio of the input force to output force acting on the present mechanism is $f(26°)=1.505$. That is to say, the ratio of the output force to input force is its reciprocal: $1/f(26°)=1/1.505=0.664$, i.e., the value of the efficiency is 0.664. The relationship between the wedge angle α and the force ratio $f(\alpha)$ can be got by programming calculation using the MATLAB software shown in Table 1. As α increases, the ratio $f(\alpha)$ reduces and the uniform load rate of the system is improved.

Table 1. The relationship between $f(\alpha)$ and α and η and α（μ=0.044）

α（°）	25.	26.	27.	28.	29.	30.	31.	32.
$f(\alpha)$	1.53	1.505	1.48	1.46	1.45	1.43	1. 42	1.4
η(%)	20.88	20.15	19.47	18.85	18.27	17.74	17.25	16.79
α（°）	33.	34.	35.	36.	37.	38.	39.	40.
$f(\alpha)$	1.39	1.38	1.37	1.36	1.34	1.34	1.34	1.33
η(%)	16.37	15.98	15.61	15.27	14.96	14.67	14.40	14.14

According to Table 1 , when α increases from 26° to 37°, the ratio of the output force to input force rate increases from $P_2/P_1=1/1.505=0.664$ to $1/1.34=0.746$. However, when α increases to 37°, the pressure angle of the roller increases much and the general working efficiency of the system will be lower. Therefore, on the premise of keeping the inclined wedge structure symmetrical, it is hard to meet the requirement for the perfect uniform load only by changing the inclined wedge angle.

As a result, in the three optional measures, the first one and the third one should be combined. Because the third would enlarge the horizontal tension, increasing the load acting on the brace, it is necessary to increase the cross-sectional area appropriately to avoid the influence that the initial elastic deformation has on the systematic response. The choice about whether to use the second measure is made according to the practical situation.

5 Conclusions

As to the problems including low efficiency and response latency existing in the load balancing mechanism of three-bogie railway freight vehicle, the force analysis reveals that the efficiency and the latency are relevant to the inclined wedge angle and the dimensions of the brace and the roller, and that the reasonable design can improve the mechanism efficiency and reduce action delay. In the practical design, to get the optimal comprehensive effect, some factors should be taken into consideration such as the installation space, the internal force in the mechanism and the strength and abrasion loss of every part.

References

Cao, Y.(2007). "The Scheme Design of 100t-Weighted 3-pivot Freight Cars." Mechanical Engineer, (6)121-122.

Cui, D. G., Yu, L. Y. and Lu, K. W.(2008). "Study and Application of Frame Brace Bogie Technology for Railway Freight Cars with Increased Speeds and Higher Loading Capacities." Journal of the China Railway Society, 30(2):65-70.

Hu, H. P. and Liu, F.G.(2010). "The Technical Studies on Three Fulcrums of Railway Freight Wagon." Locomotive and Rolling Stock Technology, 10(4):7-9.

Lin, J.(2003). "Present Conditions of Freight Car Bogies in Our Country and Prospects." Rolling Stock, 41 (8):11-14.

Song, F. S. and Cao, Z. L.(2000). "A Report on Investigation into Railway Freight Car Bogie." Rolling Stock, 38(8):1-10.

Wang, F.D., Li, Q. and Miao, L. X.(2003). "Study on Distribution of Dynamic Load on Cross Sustaining Device for Speed Increased Freight Car Bogies." Journal of Beijing Jiaotong University, 27(1):28-31.

Yu, G. C., Liu, Z.M. and Wang, W. J.(2004). "Research on the Life of Cross Sustaining Device for the Speeding-Up Freight Car Bogies." Journal of Beijing Jiaotong University, 28(1):104-107.

Zhao, W. H. (2000). "Development of the Under Cross-Braced Bogie of Freight Car with axle load of 25t." *Rolling Stoc*k, 38(8):25-27.

Application of an Optimal Control Algorithm on ABS for an Electric Vehicle

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Abstract: Promotion of pure electric vehicle (EV) has become a trend, of which the braking performance is very important. In this paper, by using a family of curves of the relationship between adhesion coefficient and sliding rate of an electric vehicle on different roads, to elect the sliding rate corresponding to the peak value of adhesion coefficient, and then the mathematical models of EV braking process are established and the dynamics differential equation is obtained. According to the optimal control theory, appropriate state vector and control vector based on the dynamic mathematical model of vehicle-road system are selected, and a quadratic performance index of the minimum error between actual output and expected output with the minimum energy consumption of the hydraulic braking system in time domain are proposed as well. Typical working condition parameters are selected as the initial condition to calculate series of control parameters of the optimal control model by Riccati matrix algebra equation. In MATLAB/simulink vehicle anti-lock braking system model is established, and by simulation graphs of wheel velocity response show that, the wheel velocity can satisfy the slide requirements well by using optimal feedback control algorithm for EV with more advanced ECU system.
Keywords: Electric vehicle; Braking performance; Sliding ratio; Optimal control.

1 Introduction

To address the two urgent issues nowadays of protecting the environment and achieving energy sustainability, it is of strategic importance on a global scale to replace oil-dependent vehicles with electric vehicles (Cheng Lin et al.,2014), and the promotion of electric vehicle has become a prevalent trend increasingly. The development of the electric vehicle also focus on the theme of safe, energy saving, and environmental protection. How to apply modern control theory and technology to improve the performance of active safety for electric vehicles has been the research hotspot in automotive filed for several years.

The braking performance is directly related to the safe running of the electric vehicle, automobile anti lock braking system (ABS) can make full use of the adhesion between tire and road surface, so as to shorten the braking distance, improve automobile braking performance, and handling stability, which has become an indispensable part of automobile brake system. Similar to the braking system of traditional vehicle, but more accurate control algorithm should be adopted in electric vehicles because of its more advanced and mature electric control system.

2 Mathematical modeling of ABS

2.1 Tire Modeling

The tire model is a mathematical model which describes mechanical properties of road-tire. In practical application, it is difficult to draw a formula which describe effects of various physical parameters of tire on adhesion coefficient. A tire model called "Magic Formula" proposed by Pacejka is widely used, because almost any tire parametric curves can be fitted by adjusting parameters of "Magic Formula", and it is usually written as equation (1):

$$\varphi(s) = \varphi_0 + D\sin\left\{C\arctan\left[Bs - E\left(Bs - \arctan\left(Bs\right)\right)\right]\right\} \tag{1}$$

Where φ_0 is the static friction coefficient of tire, and commonly $\varphi_0 = 0$, D is the peak factor, C is the curve shape factor, B is the stiffness factor, E is the curvature factor, and s is the slip ratio, $s = 1 - \omega r / u_a$. In this pepper different sets of parameters above are chosen to simulate three kinds of typical working conditions of dry asphalt pavement, mud road, and ice snow covered pavement (Table1).

Table 1. Parameters of different typical working condition

Typical working conditions \ Parameters in Magic Formula	D	C	B	E
Dry Asphalt Pavement	0.8	2.4	4	0.9
Mud Road	0.6	2.4	5	0.9
Ice Snow Covered Pavement	0.15	2.4	6	0.9

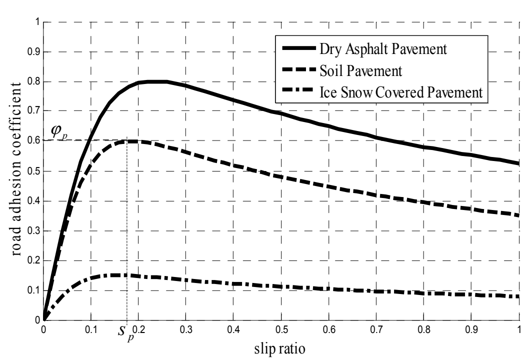

Figure 1. Adhesion coefficient-slip ratio curves of three different road surface

The adhesion coefficient-slip ratio curves (figure 1) shows that tire adhesion coefficients reach the peak value in the sliding rate about 0.2 in three different road conditions. Therefore, the proposed control algorithm should make the slip ratio to maintain at around 0.2 to prevent the wheels from locking to the greatest extent.

2.2 The vehicle dynamics model

If the rolling resistance and aerodynamic resistance are ignored, the vehicle single wheel model after simplified is shown in figure 2. (Yu Fan,2005),of which the mass of the single wheel model is m, the wheel rolling radius is r_d, the moment of inertia of the wheel is I_w, the wheel angular velocity is ω, the vehicular velocity is u_a, the wheel velocity is u_ω, the braking moment is T_b, the rolling resistance moment is T_f ,the ground normal force is F_z, and the ground tangential braking force is F_{xb}.

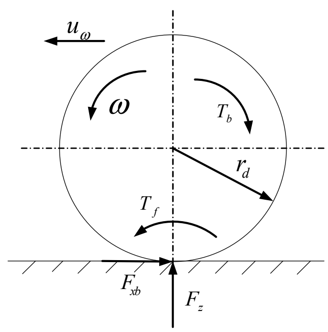

Figure 2. Braking mechanics model of the single wheel

From figure 2 the dynamics equations of vehicle braking can be obtained as follows：

$$m\dot{u}_\omega = -F_z\varphi(s) \tag{2}$$

$$I_w\dot{\omega} = -T_f - T_b + F_z r_d \varphi(s) \tag{3}$$

$$T_b = \alpha P(t) \tag{4}$$

Where $P(t)$ is hydraulic brake pipe pressure, α is a constant value.

3 Design of optimal control algorithm for ABS

In the control system, the wheel angular velocity ω and the wheel angular acceleration $\dot{\omega}$ are chosen as the state variables, the wheel velocity u^* ($u^* = 0.8u_a$) corresponding to the peak value of $\varphi - s$ curve is chosen as expected output. Therefore it is necessary to design tracking system, so that the actual output of control system is the tracking value of expected value, and the tracking follower can be designed as a integral form as follows:

$$I = \int_0^t \left(\omega r - u^*\right)\mathrm{d}t = \int_0^t \left(u_\omega - u^*\right)\mathrm{d}t \tag{5}$$

Where $u_\omega = \omega r$ .What is different from the conventional algorithm(Cui Shengmin, 2008) is that a first-order integrator is substituted for a second-order integrator.

Take derivative of the equation (3), and substitute equation (1) and (4) into it, such equation can be obtained:

$$\ddot{u}_\omega = \frac{F_z r_d^2}{I_w}\dot{\varphi}(s) - \frac{\alpha r}{I_w}\dot{P}(t) \tag{6}$$

Where $$\dot{\varphi}(s) = \frac{48\cos\left[\frac{12}{5}\arctan\left(\frac{2s}{5}+\frac{9\arctan(4s)}{10}\right)\right]\left[\frac{18}{5(16s^2+1)}+\frac{2}{5}\right]}{25\left[\left(\frac{2s}{5}+\frac{9\arctan(4s)}{10}\right)^2+1\right]}$$

it is complicated to solve, in order to increase the computing speed, $\dot{\varphi}(s)$ can be simplified as (LI Gang,2012):

$$\dot{\varphi}(s) = -\frac{\varphi_p}{s_p}\frac{r_d\dot{\omega}}{u_a},(s \le 0.2) \tag{7}$$

Organize all equations above, matrix form of the state space equation of ABS is obtained as follows:

$$\dot{\mathbf{X}} = \mathbf{AX} + \mathbf{B}U + \mathbf{E}d \tag{8}$$
$$\mathbf{Y} = \mathbf{CX} \tag{9}$$

Where

$$\mathbf{A} = \begin{bmatrix} -\frac{\varphi_p}{s_p}\frac{F_z r_d^2}{I_w u_a} & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix},\ \mathbf{B} = \begin{bmatrix} -\frac{\alpha r_d}{I_w} & 0 & 0 \end{bmatrix}^{\mathbf{T}},\ \mathbf{E} = \begin{bmatrix} 0 & 0 & -1 \end{bmatrix}^{\mathbf{T}}$$

$$\mathbf{X} = \begin{bmatrix} \dot{u}_\omega & u_\omega & I \end{bmatrix}^{\mathbf{T}},\ \mathbf{C} = \begin{bmatrix} 0 & 1 & 0 \end{bmatrix}, U = \dot{P}(t), d = u^*,\ \mathbf{Y} = \omega r = u_\omega .$$

In order to control the hydraulic system with minimum energy consumption, and minimize the error between actual output and expected output during the process of braking, quadratic performance index (eq.10) is chosen (B.-C.Chen,2014):

$$J = \int_0^{\infty} \left(\mathbf{X}^{\mathrm{T}} \mathbf{Q} \mathbf{X} + U^{\mathrm{T}} \mathbf{R} U \right) \mathrm{d}t \tag{10}$$

Where $\mathbf{Q}$ and $\mathbf{R}$ are the weighting matrices for state deviations and input effort, respectively.

$$\mathbf{Q} = \begin{bmatrix} 1 & & \\ & 1 & \\ & & 10^5 \end{bmatrix}, \quad \mathbf{R} = 1$$

The optimal control law of this system is as equation(11) according to optimal control theory:

$$U^* = -\mathbf{R}^{-1}\mathbf{B}^{\mathrm{T}}\mathbf{L}\mathbf{X} = -\mathbf{K}\mathbf{X} \tag{11}$$

The $\mathbf{L}$ in feed back gain matrix can be obtained by Riccati formula (eq.12).

$$-\mathbf{L}\mathbf{A} - \mathbf{A}^{\mathrm{T}}\mathbf{L} + \mathbf{L}\mathbf{B}\mathbf{R}^{-1}\mathbf{B}^{\mathrm{T}}\mathbf{L} - \mathbf{Q} = 0 \tag{12}$$

4 Simulation results

With the parameters shown in Table.2, the proposed algorithm is evaluated by using MATLAB/Simulink, and the dynamic responses of electric vehicle are shown in the following Figures.

Table.2 Parameter conditions in control algorithm

F_z	350Kg	α	600
r_d	0.3m	s_p	0.2
I_w	$12\,\mathrm{Kg}\cdot\mathrm{m}^2$	φ_p	0.8

In order to observe the character of wheel velocity u_ω tracking the expected wheel velocity u^* corresponding to the peak value of $\varphi - s$ curve, two typical conditions of speed u_a at 30Km/h and 60Km/h are selected. The response process of u^* and brake oil pressure can be illustrated in Figure 3 and Figure 4, respectively.

In figure 5 illustrates that, the proposed algorithm of using a first-order integrator mainly can not only reduce the computational complexity of solving the Riccati matrix equation significantly, but also have a more rapid response quality than the conventional algorithm of using a second-order integrator.

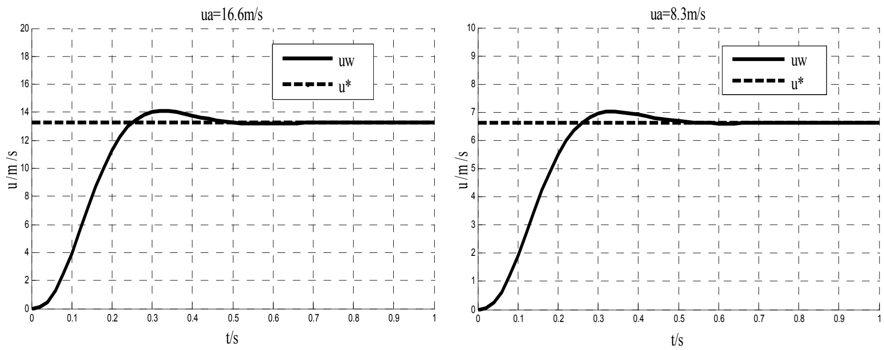

Figure 3. Response of wheel speed

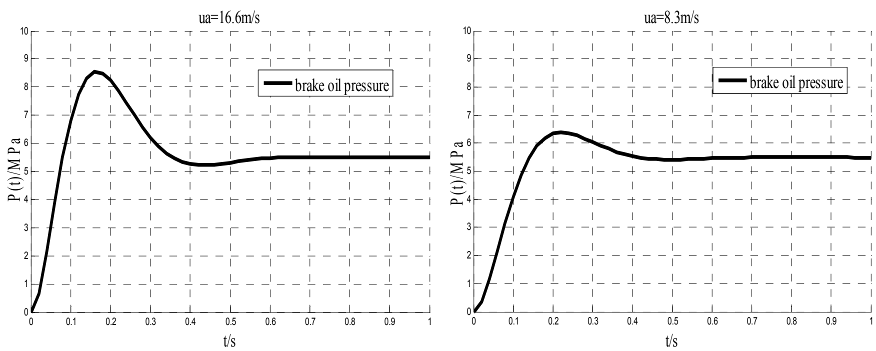

Figure 4. Response of brake oil pressure

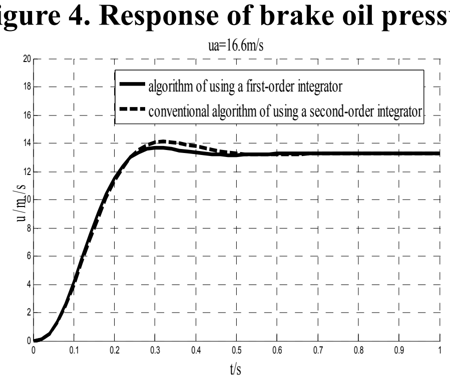

Figure 5. Comparison of effects of two kinds of control algorithm

5 Conclusions

As can be seen from the simulation graph, wheel velocity u_ω can track the expected wheel velocity u^* quickly with reasonable error by controlling the brake oil pressure during driving the EV at one speed. Therefore the slip ratio of wheel is about 0.8, and then larger braking-force coefficient can be obtained for EV.

The proposed algorithm can achieve a good anti-lock braking performance, but mathematical model of ABS is demanded to be as precise as possible and high performance real-time computing system is required. However, compared with the traditional fuel-consumption vehicles, EVs are often equipped with more advanced ECU system, this control algorithm has better practical application value for EV.

Acknowledgement

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References

B.-C. CHEN and C.-C.KUO (2014) "Electronic stability control for electric vehicle with four in-wheel motors." *International Journal of Automotive Technology*, 15(4),575-576

Cheng Lin and Xingqun Cheng (2014). "A Traction Control Strategy with an Efficiency Model in a Distributed Driving Electric Vehicle." *The Scientific World Journal,* http://dx.doi.org/10.1155/2014/261085

Cui Shengmin (2008). "Chap 5: ABS of vehicle" *System Control technology of modern automotive* . Beijing, 145

LI Gang and ZONG Changfu (2012). "Integrated control for X-by-wire electric vehicle with 4 independently driven in-wheel motors" *Journal of Jilin University(Engineering and Technology Edition)*, 42(4),798

Yu Fan and Lin Yi.(2005). "Chap 18: Examples of vehicle system modeling, simulation, and controller in MATLAB environment" *Vehicle System Dynamics,* Beijing, 294

Physical Model Selection in Numerical Simulation and Structural Optimization of a Locomotive Traction Motor's Air Cooling Channel

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Abstract: In this paper, two methods are used to deal with air cooling channel's entrance. One method is connecting the Axial-flow fan. The other uses circular cross section of the guide tube as the air inlet. This paper analyzes Axial-flow fan's influence to the numerical calculation results of air cooling channel and puts forward a method to build simplified and reasonable physical model in the simulation calculation of the locomotive traction motor's air cooling channel. Then structure optimization of air cooling channel is proposed to ensure uniform flow distribution of each outlet.

Keywords: Locomotive traction motor; Air cooling channel; Axial-flow fan; Structural optimization.

1 Introduction

As the power source of locomotive, traction motor's good heat dissipation is vital to ensure smooth and safe operation of locomotive. This requires cooling ventilation system to have reasonable structure and layout method. In the simulation calculation of air cooling channel by fluid analysis software FLUENT, selecting the calculation area reasonably is the important premise to realize accurate simulation. A cooling ventilation system for locomotive traction motor takes environmental air into the lead axial-flow fan, after the fan impeller rotating speed, cooling air gets into the entrance of cooling air channel through the guide tube, air flows through three sub channels, then cools three traction motors.

The simulation calculation that connecting the Axial-flow fan to the cooling channel can realize accurate simulation of locomotive traction motor's air cooling channel. But complicated Axial-flow fan structure makes modeling more difficult and the number of elements and nodes increases obviously. So it is necessary to make further study for the selection of the simulation computation area of cooling air channel. This paper compares the results between the whole model with Axial-flow fan and the simplified cooling air channel.

The simulation results show that the flow rate distribution of the original three air outlets are uneven, difference between each outlets exceeds the design requirements due to the unreasonable layout of internal baffles and the seriously blocked channel's corner. Therefore, it is necessary to optimize the structure of the air cooling channel to ensure uniform flow distribution among sub channels without increasing air resistance greatly.

2 Physical model and System parameters

2.1 Physical model

Method 1 is the whole model with Axial-flow fan, as shown in figure 1. Cooling air channel has an inlet and three outlets, above the air inlet are guide tube and Axial-flow fan .Cooling air gets into the system though the entrance of Axial-flow fan and flows out through three air outlets. The Axial-flow fan is cancelled in method 2, using circular cross section of the guide tube as the air inlet.

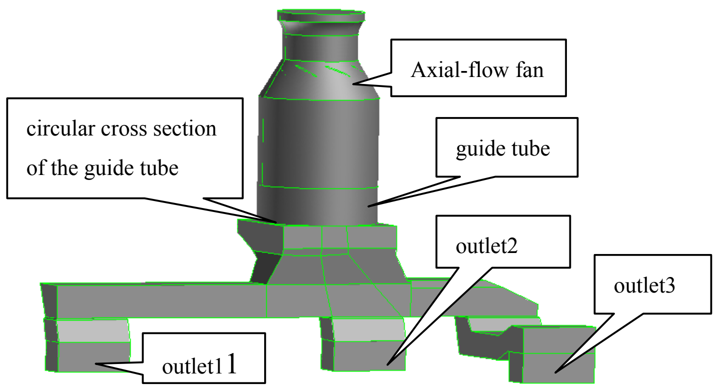

Figure 1. Whole model with Axial-flow fan and cooling channel

The performance parameters of Axial-flow fan: Rotational Speed n=2950 r/min, ventilation rate Q=330 m3/min, pressure P=3600 Pa. performance and structure parameters of air cooling channel: resistance of channel entrance P=400 Pa，size of channel entrance Φ=810 mm, three outlets of air cooling channel face to the motors respectively, each outlet size 220 mm × 520 mm，back pressure 2300 Pa. Size of circular cross section of the guide tube D=810 mm, d=524 mm.

2.2 Meshing

Due to the complexity of the fan model structure, structured grid is difficult to achieve when the flow field area dispersed, this flow field area is divided into tetrahedron and pyramid grid in tgrid method with FLUENT pretreatment software GAMBIT, the air cooling channel area is divided into many blocks, the well-shaped areas are dispersed into structured hexahedron grid. Other areas are dispersed into unstructured tetrahedral grid because of its strong adaptability characteristics. The girds around the blades need to be refined to adapt the complex flow situation. There are 3.9 million elements and 0.8 million nodes in method 1, 0.46 million elements and 0.11 million nodes in method 2. Discrete grid models are shown in figure 2.

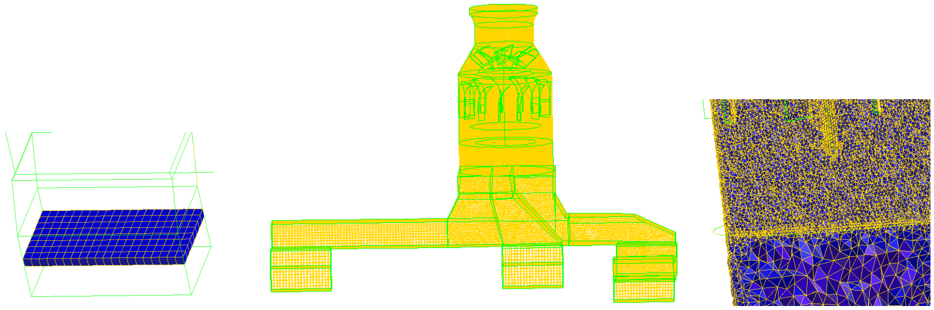

Figure 2. Finite elements of the whole model and Local amplification view

3 Numerical calculation method and boundary conditions settings

3.1 Numerical calculation method

Because of the temperature rise is small between the outlet and inlet and the velocity of fluid is slow, the compressibility of the gas is not obvious, viscous force is dominant, and this traction ventilation system flow field is treated as incompressible viscous fluid. The master equation choices the three-dimensional turbulent navier-stokes equations, using SIMPLE algorithm to solve the equation which can solve the problem of velocity and pressure coupling. Calculation model uses the standard k - epsilon turbulence model, the near wall region is treated as standard wall function method. As it belong to the internal fully developed turbulent flow, turbulence intensity and hydraulic diameter are suitable to be the turbulence parameters.

3.2 Functional zoning and boundary conditions settings

Axial-flow fan is belong to the rotating machinery, the moving fluid near rotating impellers shows the transient features in the fixed reference system. By using the motion reference system for processing, the case of transient flow field can be translated into steady situation. Traction ventilator part adopts the multiple reference frame model (MRF) in the process of calculation. MRF model is often used in this situation that the interaction is not obvious between stator and rotor. The moving fluid near rotating impellers is set as moving area and other areas are static areas in method 1. After importing the mesh model into FLUENT, the wall of rotating impellers is set as moving, rotational speed is 2950r/min, the wall is static relative to the surrounding fluid.

Inlet boundary conditions both in two methods are velocity inlet, and ensured to have the same flow 330 $m^3/\min$, speed direction perpendicular to the entrance surface. The outlets of the cooling air channel in this paper are limited to have the ruled pressure, so they are set as pressure outlet, the value is 2300 Pa.

4 Calculation results analysis

Both the two methods are conducted on the workstation with 32 G of memory, 8 core CPU, faster 2.4 GHz, the calculation results are reached the second order convergence accuracy.

4.1 Comparison and analysis of flow flied

The inlet static pressure and mass flow of each sub duct achieved from two methods are listed in table 1. Figure 3 shows the velocity pathlines from two methods. Figure illustrates that the internal flow states of air channel are basically identical between the two methods. The velocity gradient of airflow changes slowly in the sub duct1, velocity changes evenly, backflow occurs at the corner between the air duct and sub duct 2; the velocity of air in sub duct 2 increases firstly and then decreases; the velocity of air at the entrance changes evenly, but when the gas flow from the vertical to horizontal direction, the section of sub duct 3 becomes smaller suddenly, blocking phenomenon occurs. Table 1 lists the flow distribution situation, the mass flow values of each sub duct achieved from two methods have a little change, but less than 0.1 kg/s.

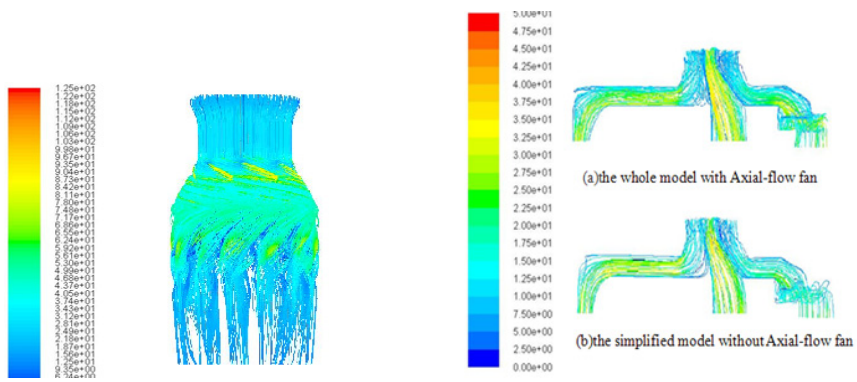

Figure 3. Pathlins of the two methods

Table 1. Static pressure at the inlet and the flow distribution among sub ducts

	Inlet static pressure （Pa）	Mass flow (kg/s)		
		Outlet1	Outlet2	Outlet3
Method1	3190	1.68	3.24	1.82
Method2	3160	1.77	3.18	1.80

4.2 Comparison and analysis of velocity and pressure at the inlet

Figure 4 shows velocity vector of inlet and outlets achieved from two methods, both velocity magnitude and distribution are almost the same, the inlet velocity of sub duct 2 is larger than sub duct1 and sub duct3. On both sides of the entrance of Sub duct 2 appears a small amount of horizontal air flow; Static pressure value and distribution achieved from two methods are almost the same and static pressure value of inlet is listed in table 1.

According to the analysis above, the inside flow of the cooling air channel tends to be consistent between the model connecting the Axial-flow fan and the simplified model using circular cross section of the guide tube as the air inlet. This is because that, the cross section that air flow through increases gradually from the bottom of the guide to the cooling air channel inlet, The gas disturbance, velocity and pressure distribution inequality problems caused by guide vane rotating improved fully through the tube, so there is almost no influence to the air flow in the air cooling channel, Axial-flow fan's influence to the numerical calculation results is little in the simulation calculation of locomotive traction motor's air cooling channel.

5 Structural Optimization of air cooling channel and Calculation results analysis

The simulation results show that the flow rate distribution of the original three air outlets are uneven, difference between each outlets exceeds the design requirements. Because of the sub duct 2 is the shortest, its air flow rate is larger than both outlet1 and outlet 3 apparently, the difference up to 45%. Therefore, it is necessary to optimize the structure of the air cooling channel to ensure uniform flow distribution among sub ducts.

Firstly, enlarging the fillet to make the flow diffused smoothly; secondly, the baffle 1 near the inlet moves to the baffle 2 20 mm, the baffle 3 moves to the baffle 2 30 mm: Then, separating sub duct1 and sub duct2 to enlarge the fillet corner of subduct2; lastly, optimizing the baffle shape between sub duct2 and sub duct3, it means reducing the cross-section of the outlet 2 and increasing the cross-section of the outlet 3. The original model and optimized model are shown in Figure 5.

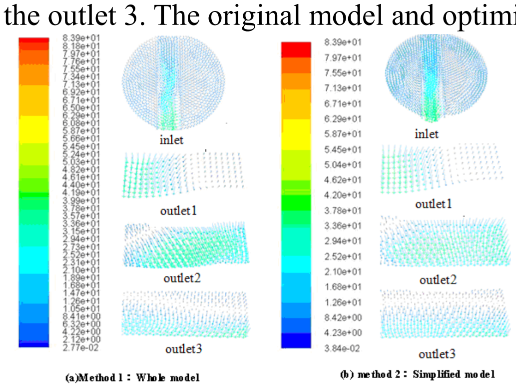

Figure 4. Velocity vector for cooling Channel's inlet and outlets

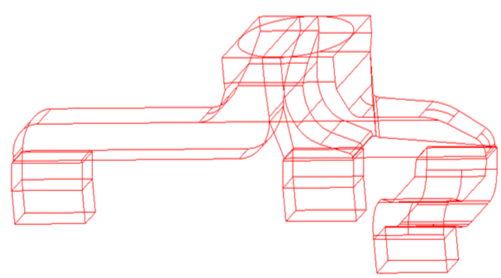

Figure 5. Optimized structure of air cooling channel

Based on the above optimization model, re-establish the grid model and simulate. The grid division method, the mathematical model selection and boundary condition settings are consistent with the original method. Static pressure at the air duct entrance and the flow distribution among sub ducts of original method and optimization method are listed in table 2, the maximum difference of mass flow is

Less than 10% among three outlets of the optimized air cooling channel. Figure 7 shows velocity vector of outlets achieved from the optimization method. The figure shows that flow rate among sub ducts of optimized channel is more uniform and backflow phenomenon is less clear.

Table 2. Contrast of static pressure at the inlet and the flow distribution

	Inlet static pressure （Pa）	mass flow (kg/s)			maximum difference of mass flow
		outlet1	outlet2	outlet3	
Original method	3187	1.7	3.2	1.8	48.%
Optimization method	3312	2.2	2.4	2.16	9%

6 Conclusions

My conclusions are as follows:

(1) In the simulation calculation of locomotive traction motor's air cooling channel with the model that using circular cross section of the guide tube as the air inlet, computational scale, the number of iterations reduce greatly and computation time reduces to 1/5 of the whole model. The inside flow of the cooling air channel tends to be consistent to Axial-flow fan's. So it can be removed to get simplified and can reduce the modeling work, improve the computational efficiency.

(2) By enlarging the fillet, adjusting the baffles, reducing the cross-section of the outlet 2 and increasing the cross-section of the outlet3, the air flow rates of three ducts trend to be identical, the difference is less than 10%, which meets the requirement of air cooling channel design strictly.

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References

HAN Shu-lin and DU Li-ming. (2010) “Optimization design and numerical simulation of flow field of air duct of blower for CKD7B locomotive” *Diesel Locomotives*, Da Lian, 436(6): 11-15

LUO Meng and SUN Li-ping. (2013） “Numerical calculation and optimization of locomotive traction motor’s air cooling channel” *Diesel Locomotives*, Da Lian, 470(4): 33-36

WANG Wei and LIUYan-yan. (2009) “Numerical analysis and optimization on flow of air passage in traction motors blower for locomotive” *Diesel Locomotives*, Da Lian, 421(3): 20-22

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Structural Improvement of a Lifting Platform for a Multi-Function Operation Car

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Abstract: The FEM of car body steel structure is established on the basis of the structure characteristics analysis for the Multi-function operation car. Since the lifting platform is one of the main equipments of the Multi-function operation car, emphatically analyses the lifting platform's strength. The results show that the original structure design of the lifting platform is not reasonable. Then, a series of improvement schemes are proposed, and each kind of improvement scheme is calculated and analyzed. Finally the lifting platform's strength of the improvement Multi-function operation car meets the requirement.
Keywords: Lifting platform; Strength analysis; Structure improvement.

1 Introduction

The Multi-function operation car is the specialized equipment, used for the repair and maintenance of electrified railway and high-speed passenger special railway catenary. The car is equipped with aerial work bucket, the lifting platform, wire shifting device and the catenary detection system. It can be used for comprehensive testing, inspection and maintenance of high voltage catenary line and line facilities, also can be used for the repair and maintenance of the high-altitude facilities of the railways, bridges and tunnels [1]. The roof's lifting platform is one of the main equipment to achieve the above functions. Since the lifting platform of the Multi-function operation car carrying weight, and revolve radius of the rotating arm is large, so its structure strength safety is especially important. In this paper, the finite element model of whole car is established and the strength of the lifting platform is analyzed. Then according to the calculation results, the lifting platform structure is improved.

2 Introduction of Lifting Platform Structure

Two operation equipments are equipped on the roof of the Multi-function operation car: One is lifting operation equipment on the roof lifting platform which is at the "B" end roof of car ; The other is aerial work bucket mounted on the installation base which is a thin-walled cylindrical tube structure, connecting the roof and under frame, at the "A" end roof of car. The Multi-function operation car body steel structure is shown in Figure 1. The roof lifting platform is mainly composed of 120mm ×103mm transverse and longitudinal channel steels and 8mm thick sealing plates. The transverse channel steels connect with the top side beams, and the longitudinal channel steels are uniformly distributed in the middle of the transverse channel steels; Equipment installation seat is arranged at the central of roof lifting platform, connecting with the transverse and longitudinal channel steels; Sealing plate tiles on the top skins of the operation platform. The partition column which is just under the middle lifting platform connects with the transverse channel steel. Angle steel, Z-sharp steel and channel steel are used to connect the roof lifting platform and other parts of the roof .The structure of roof lifting platform is shown in figure 2.

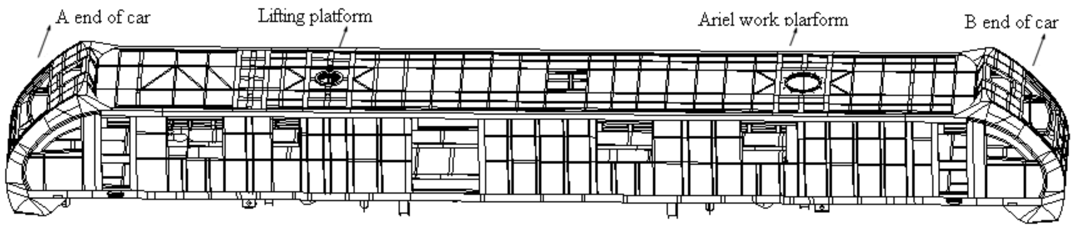
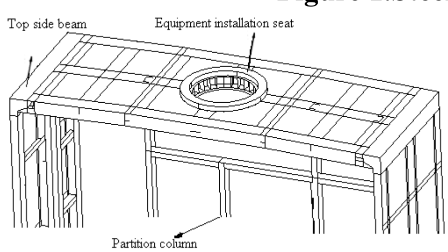


Figure 1.Steel structure of car body



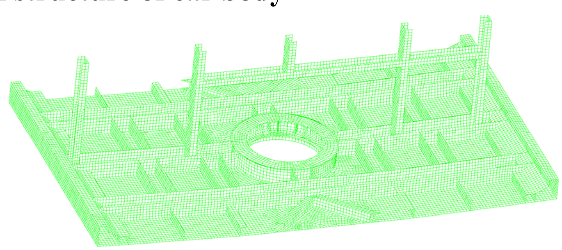


Figure 2.Structure of lifting platform

Figure 3.Local finite element model of lifting platform

3 Finite Element Modeling and Calculation Results Analysis

3.1 Finite element modeling

The FEM model of the carboy is established based on the geometric model. The majority of car structures are meshed by using the shell element, individual structures are meshed by using solid element such as crane blocks, equipment installation seat. The car body is divided into 1.1 million nodes, 1.24 million elements. The local finite element model of roof lifting platform is shown in figure 3.

3.2 Load and constraint conditions

While working the car body suffers the vertical load applied on the rotating arm of the lifting operation equipment and aerial work bucket in addition to the dead weight and weight of load. The operation rotating arm can rotate 360 degrees. From the barycenter of lifting rotation arm to the center of mounting seat surface, the vertical height is 550mm, the radius is 1668mm, and the concentrated load on the barycenter is 25kN; The vertical distance and the horizontal distance between center of gravity of aerial work rotating arm and mounting seat surface are respectively: 2844mm and 970mm, and the concentrated load on barycenter is 59kN. The vertical constraints are applied on the bolster where the cylinder jacks the car.

3.3 Calculation results analysis

The material for Multi-function operation car body is Q345B steel, the material properties are as follows: elastic modulus is 210GPa, Poisson's ratio is 0.3, and the density is $7.85\times10^{-6}\,kg/mm^{-3}$. According to the standard TB/T 1335-1996 *railway vehicle strength design and test standard*, the allowable stress of material is 216 MPa[2]. The lifting platform strength is calculated, and the maximum stress is 450 MPa at the intersection of the transverse channel steel and side beams , as shown in figure 4.

Further analysis of the results is that the maximum stress of the transverse and longitudinal channel steel that nearby the equipment installing seat is 323 MPa on the edges of web plate of steel diagonals. Nearby the aerial work platform, the maximum stress of car body is only 71 MPa. Occurs at the first window corner of the "A" end of car, the stress nephogram is shown in figure 5.

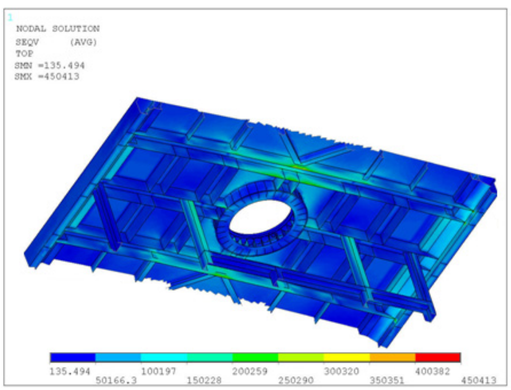


Figure 4.Lifting platform stress nephogram

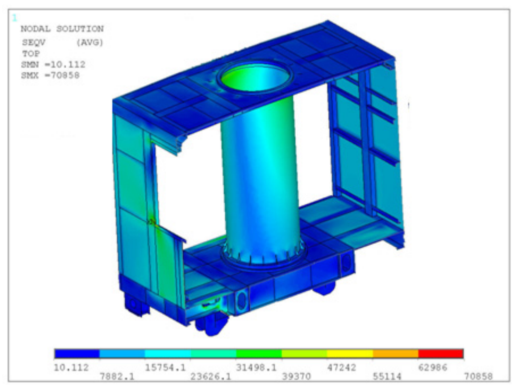


Figure 5.Aerial work platform local stress nephogram

4 Improvement of lifting platform

According to the calculation results, although aerial work platform's rotating arm suffers greater load than the lifting platform, it meets the strength requirements due to using a thin-walled cylindrical tube mounting seat which connects the roof and under frame. If the lifting platform is also using this structure, it is bound to increase the weight of steel structure of car body. Therefore the lifting platform structure should be improved without using a thin-walled cylindrical tube mounting seat. Comprehensive analysis of car body structure's characteristics and stress distribution, specifically identified the following three kinds of improvement projects.

4.1 Improvement scheme 1

Because bending resistant ability of opening channel steel is weak, channel steel connected to the equipment installation seat is changed into rectangular steel. The stress distribution of improvement lifting platform is shown in figure 6. The maximum stress occurs at the intersection of transverse channel steel and side beam, stress value is 330Mpa. Stress values of the rectangular steel around the equipment mounting seat have fallen to below the material allowable stress. But the stress values of the longitudinal channel steel connected with the rectangular steel still exceed the allowable material stress.

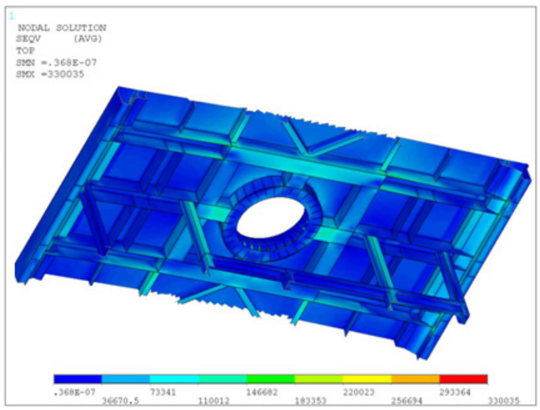


Figure 6.Stress nephogram of lifting platform in scheme 1

4.2 Improvement scheme 2

Compare with the calculation results of the original structure and the improvement scheme1, we can see that the improvement scheme by changing the cross-sectional form of lifting platform is feasible. In addition, the maximum stress of the original structure and improvement scheme1 occurs at the intersection of transverse channel steel and side beam. So the stress concentration here is most serious, the structure should be improved. Improvement schemes are as follows: Replace the open channel steel under lifting platform by the rectangular steel; the lower part of equipment mounting seat closed by 8mm steel plate; Change sealing plate thickness from 8mm to 10mm on the top of equipment mounting seat. Keep the 20mm distance between the horizontal rectangular steel with the top side beam. The improvement lifting platform structure is shown in figure 7. Then the lifting platform strength is calculated and analyzed. Its maximum stress is 262MPa, Occurs at the position where the horizontal rectangular steel connects the bevel edge of side beam. But the other parts of lifting platform stress are lower than the material allowable stress. The improvement structure of lifting platform has relatively high strength, except the position where the horizontal rectangular steel connects the bevel edge of side beam. Finally, we just need to do local improvement.

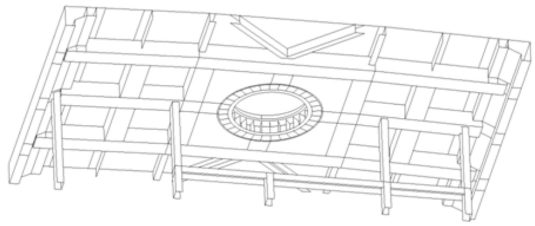
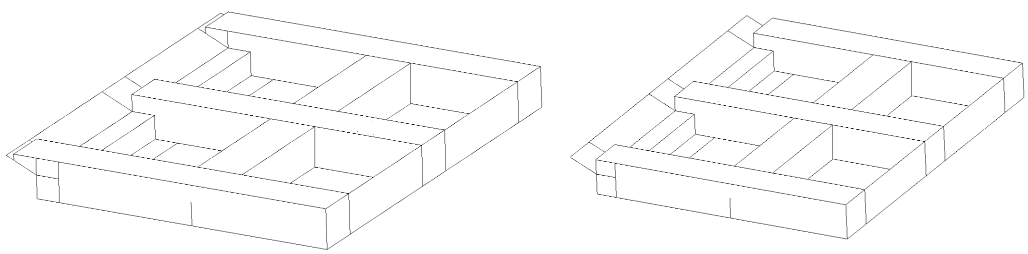


Figure7.Structure of lifting platform in scheme 2

4.3 Improvement scheme 3

For the local position above specific improvements are as follows: Remove part of the horizontal rectangular steel connected to the bevel edge of side beam. The local structure is shown in figure 8. The maximum calculated stress of the improvement lifting platform is only 111MPa, as shown in figure 9. The calculation results show that the lifting structure of improvement scheme 3 is more reasonable and the stress distribution is more uniform. It can greatly reduce the maximum stress value.



(a) Beam structure in scheme 2 **(b) Beam structure in scheme 3**

Figure8.Comparison diagram of local structure of lifting platform

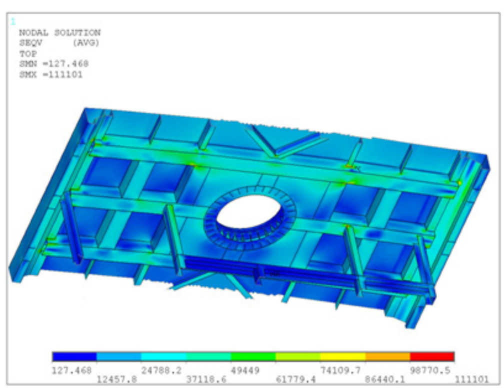


Figure9.Stress nephogram of lifting platform in scheme 3

5 Conclusions

By the analysis of the finite element strength on the lifting platform, the calculation results show that the original lifting platform structure of Multi-function operation car is not reasonable. According to the calculation results, a series of improvement schemes are put forward .Finally a reasonable scheme of lifting platform is proposed which meets the mechanical properties. While in the improvement process, the rules obtained are as follows: Aiming at the stress concentration, the relatively weak local structure should reinforce without changing the overall structure as far as possible; Bending resistance of the open channel steel is weak, if the structure is subjected to a large torque, rectangular steel should be used. The results of this study provide some reference for the design of Multi-function operation car body in future.

Acknowledgement

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References

Ministry of Railways of the People's Republic of China.(2006)TB/T 2810-2006 "Technical specification for electrified catenary inspection & Maintenance railway working car ". *China Railway Publishing House*. Bei Jing.

Ministry of Railways of the People's Republic of China.(1996)TB/T 1335-1996 "Code for strength design and test evaluation of railway rolling stock". China *Railway Publishing House*. Bei Jing.

YU Lei, SUN Li-ping ,HUANG Yin-hua and WEI Jing-qi.(2010) "Analysis of strength and local stress concentration for railway overhaul car body". *Diesel Locomotives* ,Da Lian, 439(9):4-7.

ZHANG Jin-qun. (2010) "Strength analysis of car body for GCY300 rail car" .*Diesel Locomotives*,Da Lian, 433(3):26-28.

Optimization Plan of Refrigerated Container Refueling Strategies in Transit

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Abstract：Containerization and multimodal transport are the development direction of railway cold-chain transportation. The increasing market demand also put new requirements on railway cold-chain transportation. The fact that China is a country covering vast territory with backward cold-chain transport equipment restricts the range of railway refrigerated freight transport. Therefore railway cold-chain transportation lost its comparative advantage that combined large freight volume and long transport distance. For solving this problem, railway transportation department uses 45ft integrated diesel-electric refrigerated container as cold-chain carrier, at the same time, adopts stop and refueling strategies in transit to extent continuous refrigerating time. Due to China’s railway cold-chain transportation is still in early stages, the location of gas stations along the route is uncertain and the refueling plan is lack of scientificity, the efficiency of railway refrigerated container transportation can be improved obviously. For extending the depth of railway cold-chain transportation and promoting the development of containerization and multimodal transport, this paper considers the features of railway cold-chain transportation in China and the method of using 45ft integrated diesel-electric refrigerated container. By setting the minimum cost as the objective function and involve other constraint condition in railway cold-chain transportation, this paper gives a optimization plan of refrigerated container refueling strategies in transit based on dynamic programming. Based on the research results on optimization plan, railway transportation department can reduce the time of refueling-stop and number of gas station which are unnecessary to reduce the cost of railway container freight station building, improve the efficiency and quality of railway cold-chain transportation.
Keywords: Refrigerated container; Railway cold-chain; Refueling strategies; Dynamic programming.

1 Introduction

The current container used in railway cold-chain transportation is 45ft integrated diesel-electric refrigerated container adapted to the features of China’s railway transportation. Compared with traditional railway mechanically refrigerated containers, Hobbs J.E, Young L.M.(2000)referred, it is more in line with the characteristics of modern refrigerated logistics, and through container multimodal transportation, can implement no-gap cold-chain transportation, which is good for extending the depth of railway cold-chain transportation, promoting the development of containerization and multimodal transport. However, the continuous cooling time is confined in 10 days during transit due to the limit of diesel-electric refrigerated container fuel tank volume, according to Xie R.H, Liu G.H, Qu R.G.(2007). This can be a important problem in the development of railway cold-chain transportation. When face to long distance transport (4000km and more, for instance) or in intermodal transportation with multiple reloading, require to continuous cooling time is out of reach for current refrigerated containers and traditional train operation organization. Zhou,J (2009) referred that this situation makes railway cold-chain transportation lost its comparative advantage that combined large freight volume and long transport distance. In this situation, establish a thorough refrigerated container refueling strategies in transit become most important. It is necessary to ensure the extension of refrigerated container refrigeration time, to ensure the quality of the goods, but also to control costs and reduce the number of stops to ensure the timeliness of cargo transport.

2 Problem statement

Railway transportation's comparative advantages are low transportation cost, large freight volume, and long transportation distance and low energy consumption. For extend the cooling time of refrigerated container, refueling during transit is necessary and unavoidable.

If we take refueling at every container station as refueling plan, the generalized cost will be large, and the travel speed must be decreased, furthermore, is harm to the efficiency and quality of railway cold-chain transportation. As we all know, different refueling strategies lead to different influence on railway refrigerated container transportation, as figure below shows.

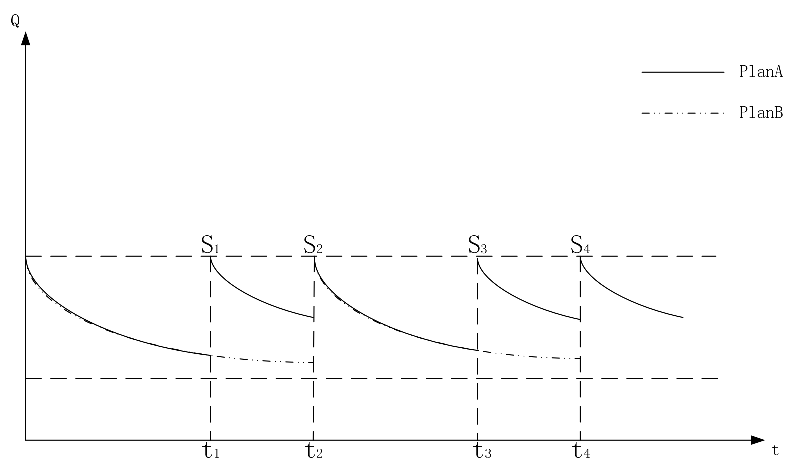

Figure 1. Influences of difference refueling strategies

In Figure 1, the curves describe fuel consumption of refrigerated container during transit. With refueling plan A, we must stop the train 4 times at S_1, S_2, S_3 and S_4, while with plan B, we only need stop twice at S_2 and S_4. The conclusion is obvious that take different strategies will bring change in operation cost and quality.

So in this paper, we focus on making optimization plan of refrigerated container refueling strategies in transit through building a dynamic programming model.

The following chat describes the detailed parameter of the container in research which is extensively used by China railway tielong container logistics co., LTD.

Table 1. Detailed parameter

External dimensions（L×W×H）	13716mm×2438mm×2896mm
Internal dimensions（L×W×H）	12716mm×2294mm×2554mm
Maximum gross weight	30480 kg
Dead weight	7000——7180kg
Container Internal Volume	74.5 m^3
Fuel tank volume	543L
The shortest continuous cooling time	About 240 hour
Charging voltage	380V
Range of temperature control	-29 $^{\circ}C$ ~+27 $^{\circ}C$
Ambient temperature	-40 $^{\circ}C$ ~80 $^{\circ}C$
Airtightness（m^3/hr.）	≤7
Hot leakage rate（KCAL/hr. $^{\circ}C$）	≤41.3

Assumption 1. For better researching, we make train with refrigerated container running route abstracted as a one direction line. The speed of train is *v*, and $\sum l_i$ denotes the transport distance, $\{S, E\}$ denotes the set of sections. The number of container transaction stations that can conduct refueling operation is $r-1$. The origin stop and destination stop are denoted by S_0 and S_r, $S=\{s_i | i=1,2,\ldots,r-1,r\}$

is set of container transaction stations on operation line, $E=\{e_i \mid i=1,2,\ldots,r-1,r\}$ is set of operation sections and $l(e_i)$ is length of section e_i.

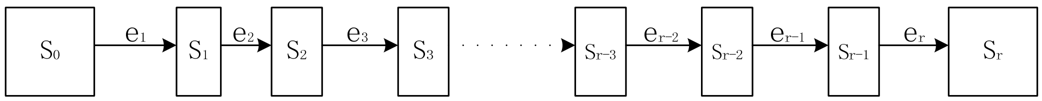

Figure 2. Abstract description of the train operation

Assumption 2. The factors which can influence the cooling effect and energy consumption during the railway cold-chain transportation are complex which involve the temperature difference between day and night, different temperature, humidity, and wind speed when in different regions, etc. However, these are all not the research focus here. Therefore, we see these influence factors as constant and make no influence on refrigerated container transportation.

Assumption 3. Different freights make no different on transportation condition.

Assumption 4. The refueling operation time, additional time for stopping and starting, and other operating time at every container station along operation route are fixed.

3 Dynamic programming models

The refrigerated container refueling strategies in transit can be seen as dynamic programming because it can be a good method to describe the process of transportation which involved many variables changing with different stages. And we take the different sections train running as different stages, the diesel quantity remaining as status variable. The choice of refueling strategies can be a multistage decision process. For observing dynamic programming's principle of optimality, we make minimizing the cost (penalty cost) as our model's objective. As the optimum strategy of whole process, it must observe the following principle: no matter what status or strategy before, for the status resulted from previous strategy, the rest strategies must consist in the optimum strategy.

By making cost as indicator, we can build an indicator recursive equation between adjacent two stages. During status transition, once it reached a certain status of a stage, the later process is only depended on the status at this moment, and independent of the previous statuses or strategies. It observes the ineffectiveness theory.

3.1 Refrigerated container diesel consumption model

In order to study refrigerated container fuel consumption and refueling, we use inventory theory to build refrigerated container diesel consumption model. For sampling the influential factors, we make some assumption as follow.

(1)The refrigerated container in transit consumes diesel at a speed which is a time related function.

(2)The refueling operation time is same at different station.

(3)Precooling and the change of external environment are out of consideration.

(4)Set reasonable minimum diesel storage. When the diesel quantity remaining in fuel tank is less than the minimum diesel storage, the train must refuel.

(5)The refueling strategies use (s,S) strategy, which means we must set q_{min} as minimum diesel storage and q_{max} as maximum diesel storage (it usually uses the 95% of the maximum capacity of the tank, Q).

3.2 Stage division in model

The stages in dynamic model are beginning with the train leave or pass one station, and end up with arriving the next station. Through this way, we can division the train route into a set of separate phases and number them. In different stage, we can make different strategy to control the whole process of transportation. When i=1 , we think the dynamic model is in stage 1, and when i=2 , in stage 2,and so on. The i=r is the last stage.

3.3 Status and status variable

Based on the assumption we made before, the diesel quantity remaining in fuel tank is the only variable which is time-varying. They are various in different stages and make effect on making refueling strategies.

So we make the diesel quantity remaining in fuel tank when a train arrives one station as the status variable and use q_i to denote the status of stage i ,that is the diesel quantity remaining in fuel tank of refrigerated container at station i . $f(t)$ is the diesel consumption function, which is time related.

$$q_0 = q_{max} = Q*0.95 \tag{1}$$

$$q_1 = Q - \int_0^{\frac{l_1}{v}} f(t)dt \tag{2}$$

3.4 Decision variable

$X_i = \{x_{ij} \mid j = 0,1\}$ is allowed decision variable set in stage i ,and $x_{ij} = 0$ denotes the train with refrigerated container will pass the station i without refueling;

$x_{ij} = 1$ denotes the train will be refueled.

$X = \{x_i | i = 1, 2..., r-1, r\}, x_0 = 0$ is a set of every decision variable at every station from origin stop to destination stop. We can know this set of variable is a set of 0-1 discrete variables.

3.5 Quality indicators

Solving dynamic programming problem means finding an optimum strategy under a specific situation. In this model, we take the relevance between around two stages and the actual characteristics of the refrigerated container transportation into consideration, use refuel and stop cost, rate of damaged goods, dwell time, the diesel quantity remaining in fuel tank and consumption in next stage as quality indicators of status transition. These indicators are determined by status variable and decision variable in previous stage. So, they are changing following q_i and x_i, denoted by $d_i(q_i, x_i)$,the function calculator as follow.

$$d_i = \left(q_i - x_i \int_0^{\frac{l_i}{v}} f(t)\,dt - \int_{\frac{l_i}{v}}^{\frac{l_{i+1}}{v}} f(t)\,dt - q_{min} \right) * \mathrm{C}_i * b_i * t_i^{\Delta} \qquad (3)$$

The part in bracket makes there is no possible that the diesel quantity remaining in fuel tank is less than the minimum diesel storage when train is in the next section under present status and decision. The three parts after bracket make sure the cost, rate of damaged goods and dwell time are minimum.

The refueling cost contains two parts, one of them is refueling operation cost c_{oc} and another is oil cost.

$$C_i = c_{oc} + p_{dplp} * (Q - q_i) \qquad (4)$$

p_{dplp} is the diesel price per liter.

3.6 Status transition equation

If q_i describes the status of stage i , and the decision x_i is made, the status of this stage will transit into the next stage. We use status transition equation to describe this process, which explains the relevance among the status q_{i+1} of stage

$i+1$, q_i of stage i and decision variable x_i at stage i. The status transition equation is as follow.

$$q_{i+1} = x_i Q + (1 - x_i) q_i - \int_0^{\frac{l_{i+1}}{v}} f(t)\, dt \tag{5}$$

3.7 Indicators recursion equation

The optimal process indicator in the back of previous stage is needed when calculate the next stage's optimal process indicator, and there is functional relationship between the two indicators, which named indicators recursion equation. The equation is as follow and $h_i(q_i)$ denotes the optimal process indicator.

$$\begin{cases} h_i(q_i) = min\{h_i(q_i, x_i) | x_i \in X\}, i = 1, 2 \ldots r-1, r \\ h_i(q_i, x_i) = d_i(q_i, x_i) + h_{i-1}(q_{i-1}) \\ h_0(q_0) = 0 \end{cases} \tag{6}$$

3.8 Mathematical expression of the dynamic programming model

We give the mathematical expression of the dynamic programming model as follow.

$$\begin{aligned} &(DOP)\ min\, h = \sum_{i=0}^{r} h_i(q_i(x_i), x_i) + h_0 \\ s.t \quad & q_{i+1} = x_i Q + (1 - x_i) q_i - \int_0^{\frac{l_{i+1}}{v}} f(t)\, dt \\ & x_i = 0,1 \end{aligned} \tag{7}$$

Table 2. Variables in dynamic programming

q_{min}	minimum diesel storage
q_{max}	maximum diesel storage
q_i	status of stage i
Q	maximum capacity of the tank
X_i	allowed decision variable set in stage i
X	set of every decision variable at every station
x_{ij}	decision variable
$d_i\left(q_i, x_i\right)$	quality indicators
$f\left(t\right)$	diesel consumption function
C_i	Refueling cost in stage i
b_i	rate of damaged cargo in stage i
t_i^{Δ}	Dwell time in stage i
c_{oc}	refueling operation cost at station i
p_{dplp}	diesel price per liter
$h_i\left(q_i\right)$	optimal process indicator in stage i

4 Integrated assessment model

4.1 Time Constraints

Transit time usually means the average transport time-consuming in transportation of goods from the starting point to the end point. Average transport time-consuming influences transport cost in two different ways.

(1) The loss of value of the goods because of limited pot life (for example, fruits, vegetables, sea food, etc.) and sensitive time value (for example, newspaper, fashionable dress, etc.).

(2) Occupancy cost of capital by the value of goods in transit performance. For goods of high value goods or big freight volume, it is good for improving the rate of capital turnover and utilizes to shorten the cargo transportation time.

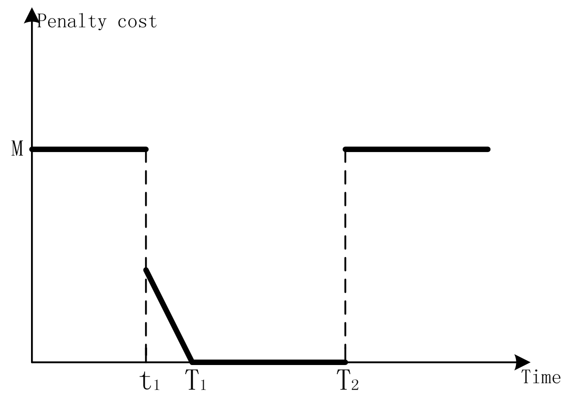

Figure 3. Penalty cost under mixed time window

We adopt the mixed time window limit in this paper. Mixed time window is mixed up with hard and soft time windows in transport service. When the delivery time is within (t_1, T_1), goods can be accepted but the carrier must bear penalty cost. When it is earlier than t_1 or later than T_2,the penalty cost will be an infinite. When the delivery time is within (T_1, T_2),the goods will be accepted without penalty cost.

Under mixed time window, when the arrival time of train with refrigerated containers is within (t_1, T_1), the penalty cost is denoted by f_{pc} in which a function of time related is consisted of the warehousing fee(reefer container electricity costs, container bit administrative expenses,etc.) paid by railway cold-chain transportation department because of early arrival. For an economic results pursuing enterprises, it is obvious uneconomical. The penalty cost function under mixed time window as follow.

$$G(t) = \begin{cases} M, & t < t_1 \\ f_{pc}(t - t_1), & t_1 \le t < T_1 \\ 0, & T_1 \le t \le T_2 \\ M, & t > T_2 \end{cases} \quad (8)$$

The time in this model are consisted of two parts: the running time in section

e_i ,which can be calculated by section length l_i and train speed v; the refueling operation time t_i^{Δ} at station i.

4.2 Rate of damaged cargo constraints

Cold-chain transportation cargo has perishability and special temperature requirements. Thus there would be different levels of cargo damage. In practice, the influential factors of the rate of damaged cargo could be very complex and contain many variables in consideration. For being convenient to study, the rate of damaged cargo is abstracted into a time related unary function $b_i(T_i)$ as fallow.

$$b_i(T_i) = \int_0^{T_i} g(t)dt \tag{9}$$

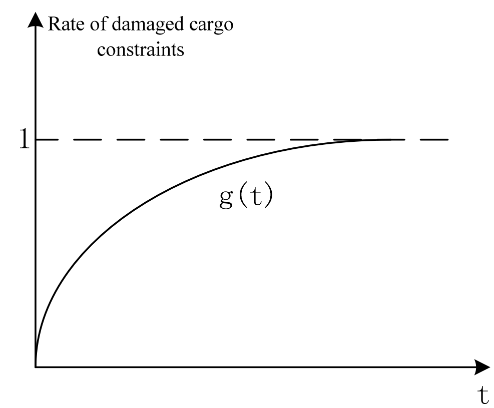

Figure 4. Rate of damaged cargo function

T_i is the travelling time consumed when train arrived the station i. When making railway cold-chain transportation contract, the rate of damaged cargo should be restricted in a specific range. So, when we build the model, the rate of damaged cargo should be taken into consideration—must be or less than a specific ratio β. For value the rate of damaged cargo and the cost in the same way, we define $C\left(\sum_{i=0}^{r} b_i\right)$ as the function to turn cargo damage to penalty cost.

4.3 Objective function

As a profit aimed enterprise, the railway transport sector should make sure that maximum profit and minimum cost. So, based on this principle we build objective function contains transport and refueling cost, which means, under same freight rate, railway transport sector can increase profit by decreasing cost.

The main costs are as follow.

(1)The refueling cost at container transaction stations. In order to facilitate the research, in model, we fix the refrigerated container refueling operation cost at different station, and the refueling cost is depend on refuel quantity. p_{dpl} denotes the diesel prince per liter.

(2)Time penalty cost. It is a function of time related is consisted of the warehousing fee (reefer container electricity costs, container administrative expenses, etc.) paid by railway cold-chain transportation department because of early arrival.

(3)Cargo damage penalty cost. It takes time as variable and converts the rate of damaged cargo into cost for measuring the transport efficiency and quality. Cargo damage penalty cost should be the less the better.

4.4 Integrated assessment model

By using dynamic programming, we have a set of initial refueling-stops strategies $X=\{x_i \,|\, i=1,2...,r-1,r\}$. After that, we need to validate if they can meet the time window' require or the cost limits. If they are all satisfied, then the initial strategies set is the optimized result, otherwise, it must be under modification. By make some through stations to stopping stations or in turn, we try to get another feasible solution and then validate the new solution in the same way and so on. The assessment model can be expressed in mathematical way as follow.

$$\begin{aligned} &min\ F = C\left(\sum_{i=0}^{r} b_i\right) + h_{(DOP)} + G(t) \\ &s.t \qquad t_1 \le \sum_{i=0}^{r} t_i^{\Delta} x_i + \sum_{i=0}^{r} \frac{l_i}{v} \le T_2 \\ &\qquad\quad \int_0^{\sum t_i^{\Delta} x_i + \sum \frac{l_i}{v}} g(t)dt \le \beta \end{aligned} \tag{10}$$

5 Optimization algorithm for refueling strategies

Our final optimization model is combined dynamic programming model and integrated assessment model, its mathematical expression is as follow.

$$
\begin{aligned}
& min\ F = C\left(\sum_{i=0}^{r} b_i\right) + h_{(DOP)} + G(t) \\
s.t \quad & (DOP)\ min\ h = \sum_{i=0}^{r} h_i\left(q_i\left(x_i\right), x_i\right) + h_0 \\
& q_{i+1} = x_i Q + (1 - x_i) q_i - \int_0^{\frac{l_{i+1}}{v}} f(t)\,dt \\
& t_1 \le \sum_{i=0}^{r} t_i^{\Delta} x_i + \sum_{i=0}^{r} \frac{l_i}{v} \le T_2 \\
& \int_0^{\sum t_i^{\Delta} x_i + \sum \frac{l_i}{v}} g(t)dt \le \beta \\
& x_i = 0,1
\end{aligned} \tag{11}
$$

Through iterative analysis calculating, we can get the optimization result. In addition, if an initial solution can't meet the time and cost constrains, the problem is no solution for that the initial solution is already the least time consumption strategy.

Step1: Determine the section length l_i , the train speed v , the initial diesel quality in refrigerated container oil tank Q and diesel storage bound q_{min}, q_{max};

Step2: Solve the dynamic programming problem by sequential method and get a initial solution X^1;

Step3: Put X^1 into assessment model and check if it meets the constraints and calculate F^1;

Step4: If X^1 is feasible, stop calculating and X^1 is the final result and the optimization plan;

Step5: If X^1 can't meet the constrains, find at which station the least $d_i(q_i, x_i)$ appear, then adjust the decision variable x_i (from 0 into 1 or in turn). Turn to step2 and get a new solution X^2;

Step6: Put X^2 into assessment model and turn to step3 till get the final solution.

6 Conclusions and recommendations for future research

This paper built a dynamic programming model based on railway cold-chain transportation and tries to optimize the refueling stopping strategy. For decreasing the cost and time consumption, the method in this paper has a certain value. This model can be used in making refueling plan of railway cold-chain transportation, and reduce unnecessary stopping. However, because of lacking of specific data, the assumption in this paper and the function defined are not accurate in a certain extent, which needs further study in the future.

Reference

Hobbs J. E, Young L.M. (2000). Closer vertical co-ordination in agri-food supply chains A conceptual framework and some preliminary evidence. *Supply Chain Management*, 5(3), 131~142

Xie R. H, Liu G.H, Qu R.G. (2007). The simulation and experimentation on the temperature field of railway refrigerated car. In:IIR/IIF eds. *The 22nd International Congress of Refrigeration,* Beijing, China:IIR/IIF.

Zhou, J. (2009) "Study on the development and operation of refrigerated container transportation in China".