Lecture Notes in Logistics
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Logistics Management

Products, Actors, Technology - Proceedings of the German Academic Association for Business Research, Bremen, 2013

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Editors

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Editors
Jan Dethloff
University of Applied Sciences
Bremen
Germany

Hans-Dietrich Haasis
ISL—Institut für Seeverkehrswirtschaft und Logistik
Bremen
Germany

Herbert Kopfer
Department of Logistics
University of Bremen
Bremen
Germany

Herbert Kotzab
University of Bremen
Bremen
Germany

Jörn Schönberger
University of Bremen
Bremen
Germany

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Preface

All areas of life in the private, economic, and public sectors are strongly influenced by and even depend on the effectiveness of logistical processes and availability of logistics systems. New and innovative logistics services are becoming practicable due to technological advance in general and in particular to new approaches for logistics management and supply chain management. On the other hand, the demand for advanced logistics services is steadily rising owing to the increased awareness of new facilities provided by upcoming technologies. Not only broadening the scope of logistics services but also the enhancement of logistics processes and their improvement in efficiency are becoming more and more important and can be realized by exploiting new technologies for logistics management and information processing.

This proceedings volume consists of selected papers presented at the conference *Logistics Management 2013* (LM 13), held at the University of Bremen and the University of Applied Sciences Bremen, Germany, from September 11 to 13, 2013. LM 13 is the continuation of a series of scientific conferences initiated by the Chair of Logistics of the University of Bremen in 1999 and aims to stimulate the exchange of ideas and discussions among scientists and practitioners about current problems, solutions, and future developments in logistics. Previous conferences were held in Bremen (1999), Aachen (2001), Braunschweig (2003), Dresden (2005), Regensburg (2007), Hamburg (2009), and Bamberg (2011). These are well documented as follows:

- Kopfer, H. and Bierwirth, C. (eds.) (1999). *Logistik Management*. Springer, Berlin.
- Sebastian, H.-J. and Grünert, T. (eds.) (2001). *Logistik Management—Supply Chain Management and e-Business*, Teubner, Stuttgart.
- Spengler, T., Voß, S. and Kopfer, H. (eds.) (2004). *Logistik Management—Prozesse, Systeme, Ausbildung*. Physica, Heidelberg.
- Lasch, R. and Janker, C.G. (eds.) (2005). *Logistik Management. Innovative Logistik Konzepte*.

- Otto, A. and Obermeier, R. (eds.) (2007). *Logistikmanagement: Analyse, Bewertung und Gestaltung logistischer Systeme*. Gabler, Wiesbaden.
- Voß, S., Pahl, J. and Schwarze, S. (eds.) (2009). *Logistik Management—Systeme, Methoden, Integration*. Physica, Heidelberg.
- Sucky, E., Asdecker, B., Dobhan, A., Haas, S., and Wiese, J. (eds.) (2011). *Logistikmanagement—Herausforderungen, Chancen und Lösungen*. Band I, II, III. University of Bamberg Press, Bamberg.

The conference is held in cooperation with the Section "Logistics" of the German Academic Association for Business Research. It has been organized and has been taking place in Bremen. Thus, the conference is coming back to the place of its first occurrence and the establishment of the conference series *Logistics Management*. Bremen plays an important role in Logistics and is well networked in the national and international commercial and scientific logistics community. A lot of logistic companies, activities, and logistic facilities are resident in the Bremen area, not to mention the Bremerhaven Container Terminal and the Automotive Terminal, which is the world's biggest point for finished vehicle transshipment. There are numerous logistics-relevant research activities and research institutes at Bremen, which are located at the University of Bremen, the University of Applied Science of Bremen, and private nonprofit foundations like ISL and BIBA. All this makes Bremen an attractive place for a *Logistics Management* conference, now and in the future.

The contributions of this conference show that logistics is making rapid progress in broadening the spectrum of services as well as in improving its effectiveness and efficiency. Both, practitioners in logistics and academia, are pushing the dynamic development of logistics which is partly documented in this proceedings volume. The papers of this volume refer to the following topics:

- Sustainability in Logistics, Supply Chain Management and Operations
- Decision Support Systems and Models in Logistics and Supply Chain Management
- Integration of Information and Product Flows in Supply Chains
- Maritime Logistics and Supply Chain Management
- Route Planning and Inventory Management
- Industry-specific Logistics Solutions and Approaches
- Education, Innovation, and Human Resource Management in Logistics

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Realizing this conference would not have been possible without the help of Bremen Research Cluster for Dynamics in Logistics (LogDynamics), Kieserling-Stiftung, Schenker AG, Sparkasse Bremen AG, STUTE Logistics (AG & Co.) KG, Wirtschaft-Wissenschaft Bremen (wiwib) and Wolfgang-Ritter-Stiftung.

We also thank all the persons involved in the operational execution of all the conference activities. Without their support, LM 13 would not have been such a success. Furthermore, we would like to thank Jan-Philip Schmidt and his team at Springer for finalizing this conference proceedings volume.

Finally, very special thanks by Jan Dethloff, Hans-Dietrich Haasis, Herbert Kopfer, and Herbert Kotzab to Jörn Schönberger for putting his heart and soul in this conference!

Bremen, April 2014

Jan Dethloff
Hans-Dietrich Haasis
Herbert Kopfer
Herbert Kotzab
Jörn Schönberger

Contents

Why Is the Transport and Logistics Sector Lacking Environmental Performance? Lessons from the Sectors of Production of Building Materials and Wholesaling

Maria Dieplinger, Peter Oberhofer and Elmar W.M. Fuerst

Abstract Sustainability has increasingly become a central business focus in times when most societies realize the harmful influence of industries on both the environment and human health. Not only policy makers demand pro-active performance from companies but also various members within supply chains expect their business partners to reduce their negative impacts on the environment and the society. Exposed to increasing competitive pressure firms are often forced to adapt their business behaviour to economic considerations. The transport and logistics sector in particular is characterized by high competition and price sensitivity. Transport is the fastest growing sector in terms of the consumption of energy and the production of greenhouse gases in the European Union. Following a multiple case study approach, the paper compares the Austrian transport and logistics sector with the sectors of production of building material and wholesaling. It aims at providing some insight as to why there are differences in the environmental performances between the sectors. This is done by identifying the specific characteristics of the transport and logistics sector concerning environmental protection and explaining the respective influencing factors. The data of each case study was analysed anonymously for each company and sector, followed by a cross-sector analysis. The findings showed that there is general awareness for sustainability across all sectors; however, the respective behaviours differ considerably. Finally, we propose implications for improving the environmental behaviour of transport and logistics companies and suggest topics for further research.

1 Introduction

Throughout the last few years, environmentally-friendly activities have become more popular in many industries. However, companies do not introduce environmental management just for fun, there needs to be some rationale for taking

M. Dieplinger (✉) · P. Oberhofer · E.W.M. Fuerst
Institute for Transport and Logistics Management, WU Vienna, 1090 Vienna, Austria
e-mail: maria.dieplinger@wu.ac.at

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decisions to go green. In all cases, managers believe that there is either a direct or an indirect advantage. Some actions improving a company's environmental performance might also raise revenues and profit; some other actions conveniently change a company's image and thus—indirectly—have a positive impact on the income situation.

In this respect, we discussed this matter with company representatives of various sectors. We put particular emphasis on environmental and ecological aspects without omitting interrelations with economic and social aspects both on the corporate and the societal levels. We therefore decided to take an in-depth look at three industries within the sectors of industrial manufacturing, transport and logistics and wholesale and retail trade (represented by the sectors C, G and H of NACE Rev. 2 and the ISIC Rev. 4 classifications) (Eurostat 2008). Taking transport and logistics as a starting point in the services sector, we added two more domains from the sectors wholesale and retail trade as well as industrial manufacturing. For the trade and industry sector one domain each was deliberately chosen. Austria offers an optimal framework for this research as the country is a full member of the European Union (one of the largest harmonised common markets with a vastly harmonised legal framework, a well-developed industry and service sector and a high degree of environmental performance.

The structure of the article is as follows: Section 2 provides information on the background and the state-of-the-art in related research examining relevant literature. Thereafter the methodological approach and the data gathered are described (Sect. 3). The results of our cross-case- and cross-sector-analyses are provided in Sect. 4 and discussed in Sect. 5. Eventually, the paper concludes by drawing conclusions and presenting some implications which can be derived on the basis of our findings.

2 Literature Review/Background

The reasons for and impacts of environmental management as a vital part of sustainable management lie in the centre of our considerations. This shall be discussed for companies of various sectors. In this respect, "environmental management" (EM) refers to objectives, decisions, organization, action, control and corrective actions within a company which are oriented at ecology and the environment (Müller-Christ 2001). At the time EM first emerged, it was regarded as hardly more than the need to comply with related rules and regulations, after some time, however, it became clear that solutions with positive effects for the company and the environment were achievable. There are manifold reasons for companies to implement EM including several general, external and internal influencing factors (Fürst and Oberhofer 2011). General factors include the size of a firm (Brammer et al. 2011) as well as its sector affiliation, as there is a correlation between a particular industry or sector and the degree of "unsustainable" processes. Furthermore, the competitive situation is highly relevant as it determines the company's capability to finance sustainable investments (Fürst and Oberhofer 2012). It also matters whether a company is operating internationally or not. Such companies are usually more eco-friendly than companies with a rather domestic focus (González-Benito and González-Benito 2010).

Regulations and stakeholder interests—e.g. requirements of customers and the general public—make up the most prominent external factors (Alniacik et al. 2011). A business's visibility is regularly related to the pressure it is exposed to (Bowen 2000). Furthermore, the position of a company within the supply chain is crucial: The closer a company is to the end-user, the more emphasis is put on sustainability and the better is their environmental performance (Walker et al. 2008). Additionally, business partners or suppliers (B2B), as well as parent companies or NGOs can substantially influence a company's environmental behaviour (Delmas and Toffel 2004). Finally, internal factors cover managers' attitudes (Ajzen 2005; Fishbein and Ajzen 1975; Fürst et al. 2011; Winn et al. 2012) as well as efficiency and profitability (Hahn et al. 2012). A surplus can be generated through the realisation of opportunities for increased revenues and reduced costs (Ambec and Lanoie 2008). Boiral et al. (2011) showed that firms committed to environmental protection tend to achieve a better financial performance than other firms. In the course of time, companies have reconstructed themselves from entities that sustainably manage resources to those that practice sustainable development. Such a fundamental change requires a holistic view of the company and its environment (Seiffert and Loch 2005).

Among the various sectors, transport accounts for 13.1 % of the global GHG emissions [24 % in EU-27 (Eurostat 2011)]. Other major sources for GHG emissions are energy (25.9 % globally, 37 % in EU-27), whereas industry (manufacturing) accounts for 19.4 % (on the global) and 22 % (on the EU-27 basis), respectively. Agriculture plays a somewhat minor role (13.5 % globally, 13 % in EU-27) (Eurostat 2011). Hence, road transport and industry are of the greatest sources of CO_2 emissions (Eurostat 2010). This clarifies that the manufacturing sector (producing goods), the wholesale and retail sector (distributing goods) and the transport and logistics sector (responsible for the transport between them) are important players in terms of environmental improvements. However, it remains unclear, whether the businesses involved see the need, are willing and able to substantially achieve fundamental environmental improvements (Thornton et al. 2008).

Following the above mentioned factors influencing the introduction and adoption of EM, study investigates the differences between three sectors. We argue that despite some general awareness and acknowledgement of the need for EM related measures, which exist in companies regardless of a specific sector affiliation, there are nevertheless differences between the sectors indicated, for instance, due to the fact that a company is exposed to various impact factors to varying degrees (González-Benito and González-Benito 2010). In contrast to other sectors, end-user pressure is very low, whereas, demands from business partners and customers (B2B) are significant. Due to their predominant upstream co-operations in supply chains (they provide rarely downstream collaborations) they are rather reactive in their nature (González-Benito and González-Benito 2006). The sectors also vary in terms of market pressure (number of market players and thus the competitive situation), average firm size, public exposure and operating area (acting nationally or internationally). As these factors have been reported as important, we investigate how—in light of differences due to specific sector characteristics—they actually influence investments in environmental measures of manufacturing, wholesale and retail as well as transport and logistics companies. On this basis we hypothesise that

- there is no significant difference in the awareness of ecological impacts and environmental management; however, there are differences in the environmental behaviour between companies of the various sectors investigated
- among the various factors that influence the implementation of environmental management, the economic factor (profitability) is the most important one, particularly under competitive circumstances
- the position and the role in a supply chain influence sustainable and environmentally-friendly behaviour
- there is a need for improvement (more measures, new solutions) of transport and logistics companies which should/will be promoted by business-to-business relations and public institutions

3 Method and Data

In order to establish in-depth analyses, a case-based approach using multiple field studies and personal interviews to identify and evaluate environmental practices of the companies and to discuss the role of profitability and other influencing factors was applied. Yin (2002) recommends to generally use six to ten cases as these provide sufficient evidence for further supporting or rejecting hypotheses, Eisenhardt (1989) recommended four to ten in this respect. Accordingly, our selection of four cases each sector complies with these recommendations.

The primary data collection was carried out through semi-structured interviews. Based on findings of the theoretical approach an interview protocol was created.

An important step in case study research is sample selecting. This decision depends on the setting, people and social processes (Miles and Huberman 1994). To keep the results from the three sectors comparable, we decided to concentrate on a certain field within each of the three sectors. Thus, we targeted large internationally operating transport and logistics companies that merely focus on freight transport and logistics. In the sector of industrial manufacturing we chose to concentrate on the production of building material. There are some large companies in Austria representing this industry and—as the cases in the field of transport and logistics—serve both national and international markets. As those two industries have in common that they are oriented at b2b rather than b2c, we stuck to this criterion and concentrated on wholesalers of food and beverages when selecting companies from the trade sector. As a consequence, we ended up with a set of twelve cases (four from each domain) which are operationally similar within their group/cluster, however largely different in other respects. These differences include for example the fact that the manufacturer produces a product which is highly relevant to the end-user, even if it is usually sold via intermediaries. The producer therefore needs to respect the end-users' requirements which—particularly for durable goods—involve considerations of sustainability. The consumer can therefore recognize the orientation of the producer without the need for a direct contact. For the other two sectors this is not the case; consumers are usually not aware of the environmental performance of a wholesaler or a transport company, and if they were they could not monitor it. Transport is a service within the supply chain; however transport does not alter the characteristics of the transported goods. Thus for the product and its quality the environmental friendliness of a lorry is irrelevant. Transport companies are, however, exposed to a general public debate as transport is blamed to be a responsible for a substantial part of emissions. Wholesalers of food and beverages are rather far from public monitoring. As most retail (supermarket) chains directly buy from producers, clients are small shops, cafeterias, restaurants, kiosks and small shops. Thus, most customers are interested in the price and the availability of larger quantities. Despite being more or less on the same level as retail trade, where the end-customer does not take notice of any EM-related measures, in the transport domain, one can at least perceive the lorry on the road.

As a next step, an expert (e.g. sustainability director or environmental manager) from each company was identified and informed by phone about the research project. To make sure that they were prepared, the protocol was sent to the respondents in advance. The interviews were conducted in late 2011 and early 2012. They lasted between 45 and 90 min and were executed personally or by phone. They were recorded and completely transcribed into written text. Additional follow-up questions were sent by email in order to clarify the contents of the interview.

The data of each case study was analysed individually for each company using a cross-case analysis. As there is no standard format for case study analysis, the researcher has to choose from a selection of approaches (Eisenhardt 1989). For organising the single case analysis we followed Yin's (2002) "Relying on theoretical proposition"-strategy and designed the case analysis based on the reviews of the literature and our hypotheses accordingly. This involved a pattern-matching technique that compares empirically-based patterns with predicted ones (Yin 2002).

For the cross-case analysis, we followed Eisenhardt's (1989) tactic of selecting groups of cases and listed the similarities and differences of each group. In a final step, the groups were evaluated in terms of their environmental behaviour and attitude. Due to its qualitative nature, this was based on argumentative interpretations (Yin 2002).

Four factors, namely Integration of sustainability, profitability, regulations and stakeholders were chosen in order to measure the environmental management performance.

4 Case Study Analysis and Findings

The “within-case” analysis was performed according to the following structure:

- Basic company description and development of environmental management
- Evaluation of different influencing factors: the role of the economical factor compared to other factors (regulations, stakeholder requests etc.)

4.1 Transport and Logistics

In the following table the “within-case” analysis of four companies from the sector of transport and logistics are presented (see Table 1).

In general, the awareness of the importance of sustainability is strong. However, significant differences between the companies analysed could be found. Company A can clearly be labelled as an “environmentally progressive” firm. It has had a holistic environmental orientation for many years. It has integrated a broad range of environmentally friendly measures covering several corporate fields. It started early to respond to customer demand and regard environmental protection as a major opportunity to be competitive in the long run. As a result, sustainability has become a key component of its corporate identity. Compared with company A the others appeared to lag behind in terms of environmental protection activities. However, they can be subdivided into environmentally “stagnated” and “ambitious” companies. Company B seems to be stagnating somewhat as—considering its size (employee number and turnover)—environmental activity appears to be poor (e.g. number of measures or projects, unsatisfactory quality of sustainability reports). Furthermore, a long-term ambition to move towards increased protection of the environment is absent. On the other hand, we could identify Companies C and D as being very ambitious concerning their environmental behaviour. They have recently initiated new steps towards a holistically orientated environmental management. Therefore, this is also strongly supported by their management boards and closely related to customer and partner requests. For Company D, on the one hand, sustainability is a relatively new topic. Due to limited resources, they are not able to realise a broad range and large number of projects immediately; however, they have introduced a strategic orientation that is based on a long-term perspective and have recently published their first sustainability report. On the other hand, Company C—after a period of stagnation, presumably due to a difficult economic situation—is ambitious to regain their title of one of the leaders in sustainable transport and logistics operations in Austria.

Table 1 Summary of cases in transport and logistics

	Key figures (worldwide)	Integration of sustainability/EM	Influencing factors		
			Profitability	Regulations	Stakeholders (customer, society, business partner)
A	• Transport and logistics service provider (road, air, sea, specialised logistics solutions)	• Board strongly supports sustainability	• Central decision criteria	• Regarded as essential	• Important influence of customers/business partners
	• Globally operating	• Incorporated into CI	• Long-term perspective	• Basis for motivation and acceleration of innovative corporate measures	• Increasing environment related customer requests
	• 96,200 employees worldwide (in Austria: 5,260)	• Sustainability has been part of corporate culture since 1990s → pioneers of EM in transport & logistics sector	• Exceptions for cost intensive EM projects → regular amortisation time can be expanded		
	• Worldwide turnover 2011: €20.30 bn. (in Austria: € 1.5 bn.)				
B	• Logistics service provider (formally state owned)	• Of minor concern due to difficult economic situation	• Central decision criteria	• Regarded as very important	• Lately, only few customer/business partner requests have been monitored
	• Focus on Austria plus Central-and South-Eastern Europe	• Listed in mission statement	• No exceptions for non-profitable projects	• Suitable for improving the overall environmental situation	• Increasing inquiries lately
	• 11,000 employees	• Ambitions towards sustainable employee behaviour			
	• Turnover 2012: €2.2 bn				

(continued)

Table 1 (continued)

	Key figures (worldwide)	Integration of sustainability/EM	Influencing factors		
			Profitability	Regulations	Stakeholders (customer, society, business partner)
C	• Specialised in European full-truck loads (family-owned)	• Support of board of directors, holistic view	• A major role	• Regarded as a decisive and necessary factor	• Customers/business partners are the driving force
	• European focus 1,484 employees	• Pioneers in sustainable logistics	• Only profitable measures are implemented		• Integration of customers into the creation of innovative sustainable solution
	• Turnover 2012: €1.55 bn	• Stagnating performance in past few years			
		• New ambitions to claim back sustainability leader in the logistics sector			
D	• Specialised in transportation and integrated logistics (family owned)	• Board supports sustainability approaches	• Central decision criteria	• Regarded as important and essential for overall improvement of the transport and logistics sector	• Customers play a decisive role
	• Globally operating • 2,300 employees • Turnover 2012: €560 m	• Foundation of "environmental association" in 2007, ISO 14001 certification in 2008/2009	• No definition of specific environmental goals, however, environmental aspects are considered in every single investment		• Customers in individual emissions calculation
		• Listed in mission statement, integration of employees (first sustainability report in 2010)			

4.2 Production of Building Materials

In the following, case study results of four companies from the sector "production of building materials" are presented in Table 2.

Integration of ecological sustainability is strong in the construction sector and has been integrated in the corporate identity for many years. Despite being a central criterion for investment decisions the economic factor is not solely decisive and short term losses are accepted. This is due to the companies' long term strategic thinking. Social- (aid-) projects are often in the focus of the analysed projects. Consequently sustainability is viewed holistically (ecological, social, economic aspects). In general, customers are not regarded as a driving force in terms of environmental protection; however society (e.g. neighbours, NGOs) appears to be influential.

Differences in the environmental behaviour within our sample could be identified—particularly between large/international and smaller/national companies. Large/international companies, in our sample companies E and F, are oriented at existing regulations. Smaller companies—in our sample G and H—which are operating nationally, seem to be proactive in complying with the legal framework. In particular, smaller family owned companies, focus on innovative niches in order to stay competitive in the long run resulting in a good sustainable behaviour. This could be due to consideration of employees and descendants.

4.3 Wholesale Trade Cases

In the following, four cases from the sector of wholesale trade are presented (Table 3).

Lacking end-customer contact, companies in the wholesaling industry appeared to behave rather unsustainably. Ecological and social principles are poorly integrated in the corporate identity and little awareness has arisen recently. For companies which are part of large company groups which also include retailers with end-user contact awareness and behaviour are stronger (e.g. company C in our sample). This is mainly due to a centralized strategic decision making which transfers ideas to various group members. Nevertheless, being oriented closely at customer demands, profitability is the main driver for corporate and strategic decisions and legal framework defines the minimum standards for sustainable behaviour within the sector.

Table 2 Summary of cases in the production sector

	Key figures (worldwide)	Integration of sustainability/EM	Influencing Factors		
			Profitability	Regulations	Stakeholders (customer, society, business partner)
E	• World's largest producer of bricks	• Board strongly supports sustainability	• Central decision criteria	• Regulations have a high impact	• Important influence of all stakeholders
	• Globally operating	• Incorporated into Business Strategy	• Detailed cost-benefit analysis by experts	• Companies confronted with a variety of legal restrictions	
	• 13,000 employees worldwide (in Austria: 400)	• First attempts in 2004; first sustainability report in 2010	• Is an important factor for financial success	• Company E over fulfils the requirements	
	• Worldwide turnover 2011: €1.9 bn. (in Austria: € 89 m.)	• Holistic view: besides environmental protection strong focus on social factors (i.e. safety, health, diversity, donations to aid organizations)			
F	• World leader in building materials	• Deeply rooted in corporate identity	• The economic factor is not predominant	• Regarded as very important	• For the company all stakeholders play a decisive role
	• Globally operating	• First sustainability report in 2002	• Also high priority of social and ecological projects	• Strong orientation and compliance with legal framework	• However, is perceived mainly by society (neighbours of production side) while customers and business partners seem to be less interested
	• 68,000 employees worldwide (in Austria: 370)	• Integrated part of the company			
		• Very detailed, well documented and structured measures and concepts			
	• Worldwide turnover 2011: €15.5 bn. (in Austria: € 127 m.)	• Holistic view of sustainability including a broad variety of social and ecological projects			

(continued)

Table 2 (continued)

	Key figures (worldwide)	Integration of sustainability/EM	Influencing Factors		
			Profitability	Regulations	Stakeholders (customer, society, business partner)
G	• Specialised in wood processing and manufacturer of parquet floors (family-owned)	• Support of CEO	• A major role	• Less important due to proactive behaviour	• Customer orientation is central
	• Focus on the Austrian market	• Focus on environmental sustainability	• However long term strategic thinking; acceptance of short term losses if pay-off in long run		• Customer education and awareness raising
	• 570 employees	• Collaborations with official organisation and standardized programs			
	• Turnover 2011: € 70 m.				
H	• Building material manufacturer (cement, lime, screed); (family owned)	• CEO has supported sustainability since 2000	• High investments in sustainable (pioneer) projects	• Seems to be less important due to proactive behaviour	• Majority of customers and business partners are not interested in sustainability and sustainable products
	• Focus on the Austrian market	• Integrated part of the corporate strategy	• Acceptance of high initials investments		• Society as main driver
	• 500 employees	• Ambition to be pioneers of the sector in the long run			
	• Turnover 2011: €150 m	• Employees are a central part of their understanding of sustainability			

Table 3 Summary of cases in wholesale trade

	Key figures (worldwide)	Integration of sustainability/EM	Influencing factors		
			Profitability	Regulations	Stakeholders (customer, society, business partner)
I	• Family owned wholesaler in the food and non-food industry in Austria	• Integrated in corporate identity since 2007	• The economic factor is the central decision criteria	• Legal framework is regarded as "minimum-standard" for sustainable behaviour	• Customers and business partners demand eco-friendly behaviour
	• 740 employees	• Both, ecological and social projects are implemented			
	• Turnover 2012: €178.2 m	• Long term orientation			
J	• Group of company consisting of ten private wholesalers in Austria	• General awareness of the importance of sustainability	• Profitability is the decisive factor	• Decisive for sustainable behaviour	• Customers are not willing to pay additional costs for sustainable performance. For them low prices are most important
	• 1,120 employees	• However, not sufficiently integrated			
	• Turnover 2012: €300 m	• No sustainability report and not even information available on their homepage			
		• Strategic decisions on sustainability are not centralized—each wholesaler is responsible for their own initiatives			

(continued)

Table 3 (continued)

	Key figures (worldwide)	Integration of sustainability/EM	Influencing factors		
			Profitability	Regulations	Stakeholders (customer, society, business partner)
K	• Food- and non-food wholesale industry operating in Austria (part of an international company group)	• Awareness of sustainability—integrated in the parent corporate identity in 2008	• A major role	• Legal framework is important for sustainable behaviour	• Comparing customers of the whole company group (including both retailers and wholesalers). Customer's price-sensibility is particularly high in the wholesale industry
	• 900 employees	• First sustainability report of company group in 2009	• However, in some cases profitability is pushed into the background for the sake of product quality, safety, image, etc.		
	• Turnover 2012: €1 bn				
L	• Food- and non-food wholesaler in Austria (part of an Austrian company group)	• Little awareness of sustainability	• Decisive factor	• Orientation at legal framework	• Customer orientation through focus on product quality and organic food
	• 1,033 employees	• Not communicated in the corporate identity		• Reactive behaviour	
	• Turnover 2012: €389.70 m	• No sustainability report, only little information on the corporate website			

4.4 Cross-Sector Analysis

Across all sectors awareness of sustainability is a fact. However, the integration into the corporate strategy differs. The sector "Production of building materials" has been facing sustainability issues for many years. This is shown in broad and structured sustainability reports and the holistic approach of sustainability including a variety of social and ecological projects. In contrast, the transport and logistics sector has rather recently integrated sustainability, particularly environmental protection, into their corporate strategy; a positive trend in environmental friendly behaviour can be observed. Yet, there are still companies where sustainability is of minor concern, mainly due to a difficult economic situation. In the wholesale industry, sustainability appears not to be integrated yet, resulting in very few initiatives and poor reporting. Throughout the whole sample profitability plays a decisive role for sustainability investments. Nevertheless some exceptions particularly for social projects in the sector of "Production of building materials" can be observed. The regulatory framework is generally seen as important; particularly for the sectors of transport and logistics and wholesaling complying with regulations is a main driver for sustainable behaviour, whereas companies in the sector of "Production of building materials" go beyond compliance.

Customers and business partners strongly influence the sustainable behaviour of all companies. Customers who themselves operate in a competitive environment are not willing to pay additional costs for environmental initiatives, mainly because product and service quality does not change. We noticed that sustainable behaviour of companies in the "Production of building materials" sector is influenced by society.

4.5 Limitations

Given the empirical nature of our study, it is necessary to highlight some limitations. First, we examined only selected companies from the three sectors, and thus generalizability is limited. Second, data was collected from one (or two) source(s) inside the company: the environmental manager (and official reports). Expert bias also limited the results since personal judgment might influence outcomes. Furthermore, despite the assurance of anonymity, respondents might try to protect the companies' reputation. Moreover, we clearly put a focus on large and very large companies and their environmental behaviour. As a consequence, small firms were not at the focus of our project.

5 Discussion and Conclusion

In this paper we analysed the sustainability behaviour of companies in the transport and logistics sector by comparing them with wholesalers of food and beverages and producers of building materials. We thereby focused on the integration of sustainability into corporate identity, profitability, the (regulatory) framework and influences of stakeholders.

The findings showed that there is some general awareness of sustainability across all sectors; however, the behaviour differs considerably. Compared to the wholesalers, transport and logistics companies appeared to behave environmentally friendlier. Although both suffer from high price-pressure, customers of transport and logistics companies increasingly demand sustainable behaviour. Due to lacking financial resources for measures that do not pay off in the short run, environmental activities are generally side effects of economic decisions. This is also reflected in the strong orientation at the legal framework. Moreover, society blames transport as a main source of pollution, imposing additional pressure on companies. As a consequence, they focus on environmental initiatives rather than on social projects.

Compared with the producers of building materials, transport and logistics companies lag behind in terms of sustainable behaviour. While producers of building materials, which approach sustainability in a more holistic way, are able to pass on increased costs of related investments to the products, customers of transport and logistics services are not willing to pay additional costs. Transport is not yet covered by the EU Emissions Trading Scheme (ETS), the producers of building materials in some minor part.

For the transport and logistics sector two main developments might be responsible for further improvements of the companies' behaviour. On the one hand, there is a tendency of focal firms to take the whole supply chain of their products into account. Within these, transport and logistics companies play a major role as they are the connecting link between various players of the products' supply chain. On the other hand, carbon footprinting (calculating the CO_2 emissions of a product, service or company) has become one of the most popular methods to assess (environmental) sustainability, and carbon footprints of transport movements are relatively 'easy' to calculate and comprehensible for various stakeholders. There are various tools for assessing average emissions however the precession and accuracy of these instruments are rising constantly. Furthermore, transporting goods involves high potentials in reducing emissions through new technologies, modal shifts, increased load factors and route optimization. Moreover, transport companies, also benefit from a direct impact of energy reducing initiatives (e.g. fuel savings, drivers training) as they are correlated to expenses.

To further improve environmental behaviour in the transport and logistics sector, we suggest the support of companies by providing incentives for investments in new technologies as well as spreading training and education on environmental behaviour and communicating successful examples. In this respect an inclusion of more domains in emission trading could be helpful.

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Internal Enablers for the Implementation of Sustainable Supply Chain Risk Management Systems

Christina Tobescu and Stefan Seuring

Abstract Continuous globalization and requirements for sustainable products increases the risks for companies for reputation damages through sustainability violations in their supplier networks. Therefore effective management of sustainability risks is essential for companies. This paper aims at identifying factors that enable companies to implement an effective risk management system with regard to social, environmental and economic risks of their supply chain. A model is elaborated that represents the internal enablers that promote the development of an effective sustainability risk management system within the supplier network. Afterwards this model has been operationalized and validated by using semi-structured interviews with experts from one enterprise. It was determined that besides supply chain complexity the support of the top management is decisive for initiating and establishing necessary processes as well as for the provision of the necessary resources which in turn enables implementing an effective risk management system regarding sustainability risks from the supply chain.

1 Introduction

The continuing globalization of both goods and capital markets allows companies to build worldwide supply chains (SC). This provides tremendous benefits in terms of cost, flexibility, innovation and quality of products, so that the supplier network of a company is a decisive competitive factor. At the same time, companies are increasingly held accountable for any issues regarding environmental pollution or working conditions not only at their own production sites, but also at their suppliers'. Therefore, effective management of sustainability risks is essential for companies.

C. Tobescu (✉) · S. Seuring
Chair of Supply Chain Management, Untere Königsstr. 71, 34117 Kassel, Germany
e-mail: christina.tobescu@bmw.de

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In related literature several motivation factors are discussed that influence the efforts of a company to engage in sustainable supply chains (SSC). For instance, public and regulatory pressures are a key driver for sustainability within SCs (Lee and Klassen 2009). Furthermore, customer demands (Seuring and Müller 2008) are mentioned to play a role.

On the other side several measures taken by companies to ensure sustainability within their SCs are discussed. For example Code of Conducts are used by companies to ensure that their suppliers knows their expectations regarding social and ecological factors within the manufacturing process and the consequences of not meeting them (Awaysheh and Klassen 2010). In order to make such expectations compulsory for suppliers purchasing conditions containing paragraphs relating to sustainability are used.

Thus, different motivating factors influence companies on their decision to strive towards SSCs. In response to these companies take measures. Still, motivating factors are not the only impact. If they were the only factors decisive for the implementation of measures related to sustainability in the SC, similar companies that operate within the same industry, the same region, and are similar in size, would take comparable intensive measures in terms of their SCs. Since this is not the case, internal factors within companies might also play a role. Therefore, the goal of this work is to identify such internal factors and investigate how they are linked among each other.

This work is organized as follows: Firstly, hypotheses are derived from the relevant literature and the developed model is presented in section two. Afterwards, the used methodology is described in section three, and discussed in section four, before a conclusion and a brief outlook are given in the last section.

2 Literature Review and Model Derivation

The following section will provide a basic definition of SSC and SC risk management. Then hypothesis will be derived based on the relevant literature. They form the basic of the model then developed.

2.1 Sustainable Supply Chain Management

Several definitions of SSC management exist. In an extended literature review Ahi and Searcy (2013) analyzed given definitions and developed a common understanding. For this work, their definition of SSCs shall be adopted. Ahi and Searcy (2013) defined SSCs as:

> The creation of coordinated supply chains through the voluntary integration of economic, environmental, and social considerations with key inter-organizational business systems

> designed to efficiently and effectively manage the material, information, and capital flows associated with the procurement, production, and distribution of products or services in order to meet stakeholder requirements and improve the profitability, competitiveness, and resilience of the organization over the short- and long-term.

2.2 Supply Chain Risk Management

SC management requires a complex flow of information, materials and funds for several functional areas within and between organizations (Faisal et al. 2006). Due to the complexity of SCs there is much potential for incidents. In general SC risks can be referred to as "the possibility and effect of a mismatch between supply and demand" (Jüttner et al. 2003, 200). Sustainability risks extend this definition. According to Hofmann et al. (2013) they focus not just on mismatches between demand and supply but are "a condition or potentially occurring event that may provoke a harmful stakeholder reactions".

The special challenge of managing risks within SCs is, that in contrast to traditional risk management, not only risks from the own company have to be identified and reduced, but also across companies (Thun and Hoenig 2011). Still, purchasing organizations have the possibility to proactively try to assess the probability and impact of SC risks in advance (Zsidisin et al. 2004).

Consequently, the aim of SC risk management is first, to identify the potential sources of risk and second, to take measures to avoid or contain those risks (Jüttner et al. 2003).

Although there are different frameworks proposed in literature for achieving this goal, a systematic risk assessment process typically covers at least the following tasks (Kleindorfer and Saad 2005; Kern et al. 2012):

1. Identifying sources of relevant risks and vulnerabilities
2. Assessment of probability and impact of each identified risk
3. Risk mitigation

Based on the preceding discussion, the next section will show what promotes the emergence of an effective SC risk management system in companies.

2.3 Enablers of Sustainable Supply Chain Risk Management

Drivers and enablers are often used interchangeably. This work focuses only on enablers. Therefore the two terms need to be distinguished.

According to Gimenez and Tachizawa factors that motivates companies to adopt SSCs are drivers, while factors assisting companies to achieve this are enablers (Gimenez and Tachizawa 2012). Therefore the existence of an enabler is not enough to develop SSCs but their lack may hinder it (Lee and Klassen 2009).

Examples for drivers are legal regulation, customer demands and stakeholder pressures (Seuring and Müller 2008).

As the scope of this work are enablers, the following section presents enablers discussed within literature more in detail.

2.3.1 Top Management Support

Particularly in case companies are not exposed to external pressure by stakeholders or regulatory requirements, the orientation of management is crucial for a company's commitment to go towards SSCs (Lee and Klassen 2009). Especially the extent to which companies go towards implementing sustainability within their SCs heavily depends on the extent of managers perceiving it as opportunity or threat (Giunipero et al. 2012).

To establish sustainability in SCs effectively, it is not sufficient to occasionally incorporate sustainability in decisions. It must be included consistently in both the corporate culture and the company's goals (Pagell and Wu 2009). This in turn is only possible if the top management supports such initiatives and actions. Top management must ensure the implementation of processes, which consider sustainability throughout the entire procurement processes.

Therefore this leads to the first hypotheses:

H1a Top management support regarding SSCs ensures that the necessary SC sustainability risk management processes get implemented.

H1b Top management support regarding SSCs ensures that sufficient resources get provided to implement an effective supply chain sustainability risk management.

2.3.2 Supply Chain Complexity

For the creation of SSCs, in particular the complexity of the supply chain plays a role.

According to Vachon and Klassen (2006) the likelihood to have suppliers that do not comply with social or ecological expectations increases with the size of the supplier base.

Therefore a particularly complex SC requires an effective risk management and correspondingly also more effort. This can only be met through appropriate processes and with the corresponding resources.

In consequence, the next two hypotheses regard to the assets of the company:

H2a The complexity of the supply chain influences the provision of the necessary SSC management processes.

H2b The complexity of the supply chain influences the necessary resources to implement an effective supply chain sustainability risk management.

2.3.3 SSC Management Processes Established

Strong processes that provide guidance to employees are essential when buying companies implement SSCs (Hoejmose et al. 2013). Moreover formalized processes instruct not just suppliers but also managers in the focal company how to achieve sustainability within SCs (Awaysheh and Klassen 2010).

Based on this argument, this study postulates that:

H3a SSC management processes ensure effective social risk management within the SC of a company.

H3b SSC management processes ensure effective ecologic risk management within the SC of a company.

H3c SSC management processes ensure effective economic risk management within the SC of a company.

2.3.4 Provided Resources

In the short term the establishment of SSCs requires an investment (Giunipero et al. 2012). The buying company needs to implement new processes to ensure transparency within the SC and maybe certify them.

In addition, employees need to enhance their knowledge about implementing sustainability in the SC (Andersen and Skjoett-Larsen 2009). To achieve this, training is necessary, which in turn is also tied to financial and human resources.

Therefore, it is essential that the company provide the necessary financial and personnel resources to establish the appropriate processes for the achievement of SSCs and put them into practice.

Based on these findings, it is hypothesized that:

H4a Provided resources ensure effective social risk management within the SC of a company.

H4b Provided resources ensure effective ecologic risk management within the SC of a company.

H4c Provided resources ensure effective economic risk management within the SC of a company.

2.4 Development of the Conceptual Model

As a result of the literature review the four enabling constructs "top management support", "supply chain complexity", "processes established" and "financial and personal resources" have been identified. The relationships between these constructs have been hypothesized. The expert interviews provide two additional relationships (Sect. 3.3).

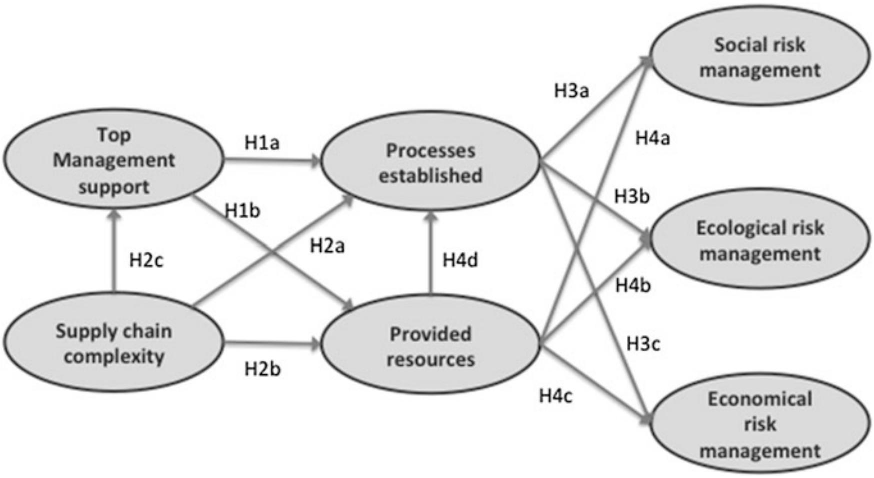

Fig. 1 Proposed conceptual model of internal enablers of effective SSC risk management

Combining the results of the literature review and the expert interviews, the model as shown in Fig. 1 is proposed.

We believe that top management is at the core of influencing SC in the model: Given certain supply chain complexity, the top management has the greatest internal lever to promote risk management regarding SSCs. It can ensure the necessary resources and initiate the processes. This allows identifying SC risks early on and mitigating them accordingly.

3 Methodology/Data Collection

For the validation of the proposed model, and for gaining further input, an expert study was performed. The methodology will be explained in the following section.

3.1 Target Group for Interviews

The automotive industry is particularly suitable for such interviews as it has a complex SC structure. The interviews were performed in a large, international company that has a strong reputation for sustainability related action.

The experts interviewed work in following divisions of the company:

- two experts were from corporate social responsibility strategy responsible for SC,
- two experts from SC management strategy responsible for sustainability,
- one expert form the product life cycle analysis and
- one chief purchasing director.

Considering different views from one single company allows for gathering a more differentiated insight into the company. Previous studies on SSC risk management have focused on cross-company data (e.g. Vachon and Klassen 2006). Therefore, the perspective in this study aims at complementing previous research by approaching one company in detail.

3.2 Research Design

The study consists of semi-structured interviews with two parts. First the experts have been asked what they believe are potential enablers for SSCs.

In a second step, the developed model and hypotheses were presented to them. They have been asked to evaluate the model whether it fits to their previously described enablers. Further they were asked to assess to what extent the proposed model is consistent with their practical observations and experiences.

Since the study refers to only one company, the number of potential interviewees was limited. Each of these interviewees had, according to their area of competence, a slightly different view of SSCs and how to ensure them. As for the particular study strategists were selected, therefore those who decide on the design of the measures in the SC, this approach allows a differentiated assessment of the main influencing views in this company. Still, this view could be different in other companies.

To ensure high content validity the constructs of the model were anchored in the literature and discussed with the experts.

3.3 Interview Findings

All presented hypotheses and the developed model were consistent with the practical experience of experts. They confirmed that the enablers and the relationships between these are suitable.

Additionally to the literature based hypotheses, the experts have stated two new hypotheses during the interviews.

Firstly, they proclaimed that the complexity of the supply chain does not only influence the processes and the financial and personnel resources provided, but also the top management. One expert argued that a higher complexity increases also the sustainability risks and therefore necessity for transparency. This in turn increases the obvious for the management that their support is necessary.

In consequence, it was concluded from the expert input:

H2c The complexity of the supply chain influence top management support for implementing SSCs

Secondly, the experts stated that the processes highly depend on the financial and personnel resources available. This leads to following hypothesis:

H4d Financial and personnel resources ensure that the necessary processes are developed and performed

Further the first draft of H1a and H1b stated that top management motivation is decisive for SSCs. Here one of the experts argued that it depends less on the motivation but rather the recognition of the necessity. Therefore H1a and H1b have been changed into "Top Management support".

4 Discussion

The developed model is in line with previous research as all identified constructs were derived from the literature. Further the result of this study, that especially top management support is an important enabler, is often mentioned in literature (e.g. Faisal 2010).

Yet, the proposed conceptual model extends previous research by considering effects of risk management in SSCs.

Previous research addressed the issues of sustainability and risk management in SCs as separate areas.

Until now three models were developed for enablers in SSCs in the literature. Lee and Klassen (2009) suggested a model that considers motivators and enablers in small and medium enterprises. Gimenez and Tachizawa (2012) deduced from the literature a model of internal and external enablers. Faisal 2010 has developed a model of the interaction among the enablers in SSCs based on a study covering three companies. Therefore, the presented model in this paper is the only one that targets the internal enablers of effective risk management in SSCs.

Furthermore, thematically similar studies, examined by a study from Andersen and Skjoett-Larsen (2009, have taken different companies into account. In this work a different approach has been taken. Experts in various positions from a single company have been questioned. As a result different points of view have been considered. This approach allows a specifically deep insight into a company.

As a first step of validation, a preliminary expert study based on a small sample group form a single company was performed. The study uses a small sample form a single company and should be replicated in a larger group in different companies and industries. This way more enablers may emerge.

Nevertheless, the presented study helped to identify a basic set of relevant enablers regarding SSC risk management, as well as provided a valuable understanding of the relationships among those enablers.

We intent to further validate the existence and influence of those factors in a future, more extensive, large-scale study this work serves as preparation. The quantification of the impact of each factor is planned for this more extensive study, providing the necessary amount of data for such quantification. Furthermore, structural equation modeling can be applied in future research to test the validity of this model.

5 Conclusions

This research proposes a conceptual model on internal enablers of a SSC risk management system.

It was determined that besides supply chain complexity the support of the top management is decisive for initiating and establishing necessary processes as well as for the provision of the necessary resources. These four enablers determine the deployment and implementation of a risk management system with regard to sustainability issues in the SC. Relationships between the enablers have been identified.

This research contributes to the understanding of the internal enablers of SSC risk management systems inside companies.

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Evaluation of Green Transport Modes for Containerized Cargo

Martin Hrusovsky

Abstract The increasing volumes of greenhouse gas (GHG) emissions from transport and the negative effects of congestion, noise and accidents lead to the search for new transport alternatives in Europe. These alternatives take into account the negative impacts of transport on environment and society in addition to minimization of the transport costs. If these additional aspects are considered, it is in many cases advantageous to use intermodal transport instead of choosing a direct transport by truck. However, this is still not the case in practice since the road transport is the most preferred transport mode in the EU. The purpose of this paper is to create an evaluation framework including various criteria for comparing different transport alternatives. The criteria combine economic factors including transport costs, inventory costs and time with external effects expressed in costs of GHG emissions, air pollution, accidents, noise and congestion. The framework is used for evaluation of transport alternatives between Vienna and Istanbul including road transport, rail transport, inland waterway transport (IWT) and short sea shipping (SSS).

1 Introduction

Transport describes any activity related to the movement of goods, persons or information which is demanded due to a spatial separation of different economic activities, such as production and consumption of goods. Transport therefore significantly facilitates the trade between the countries and supports the economic growth. However, the increasing demand for products leads to increasing transport volumes resulting in negative external effects of transport (Cole 2005).

M. Hrusovsky (✉)
Institute for Production Management, WU Vienna University of Economics and Business, Welthandelsplatz 1, 1020 Vienna, Austria
e-mail: martin.hrusovsky@wu.ac.at

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The external effects of transport negatively influence the environment and society in several ways. Firstly, transport sector belongs to the biggest producers of CO_2 and other GHG emissions responsible for global warming and climate changes. Secondly, transport negatively impacts the local population via the emissions of air pollutants and noise causing various health damages. Thirdly, the socio-economic impacts arising from accidents and congestions are important. All these negative effects can be expressed in external costs representing the costs for the society that are not paid by the responsible transport users. This leads to incorrect incentives and distortions in market equilibrium. Therefore the external costs of transport should be internalized by state interventions in form of laws, taxes or emission certificates (Maibach et al. 2008).

Since the external costs of transport are not paid by the users, they were not included in transport mode decisions in the past. Therefore companies mostly chose road transport for its relatively low costs and high flexibility which results in a very high share of the road transport on the modal split in Europe. However, if the external costs are considered, road transport might not be always the optimal alternative. Especially for containerized goods it might be convenient to use intermodal transport chains in which the goods are transported in the same transport unit by different transport modes. As a result, the concept of green transport supporting sustainable forms of transport has been introduced.

Despite the importance of external costs of transport for the society, they should not be the only factor but should rather be combined with other factors. This is also the purpose of this paper which creates a framework for evaluation of transport alternatives combining economic criteria (e.g. costs, time) with external effects of transport on environment and society (e.g. GHG emissions, accidents, congestion). The introduction is followed by a short literature review concerning green transport and calculation of external costs in Sect. 2. Section 3 presents the framework for evaluation of transport alternatives. This framework is used in Sect. 4 which compares four transport alternatives for transport of containers between Vienna and Istanbul including road transport, rail transport, IWT and SSS. Section 5 summarizes the results and concludes the paper.

2 Literature Review

Although the topic of green transport is extensively discussed in the available literature, there is no unique definition for green transport. However, most definitions are related to the minimization of negative external effects of transport. The research on external factors started in 1970s in Great Britain and was motivated by the increasing lorry traffic. At that time the studies were oriented on the reduction of emissions but did not help to reduce the traffic volume. The results highlighted the need for inclusion of additional factors for evaluation of transport (McKinnon 2010). Despite this fact, many authors include only environmental factors into the definition of green transport as found out by Carter and Rogers (2008) in their analysis about sustainable supply chain management. This is the case of Srivastava (2007) who claims that environmental aspects should be included into supply chain management for increasing the operational efficiency. However, Feitelson et al. (2001) conclude that concentration on environmental aspects does not lead to minimized external impacts of transport and more complex policies including several aspects should be introduced.

The combination of different factors is also the essential part of the concept of sustainability. In his triple bottom line concept Elkington (1999) claims that instead of concentration on economic costs companies should rather search for a balance between economic, ecological and social factors. For transport the ecological and social factors can be expressed in form of external costs including GHG and air pollution emissions, accidents, noise and congestion. In the EU these costs were estimated in various studies, such as INFRAS/IWW (2004), IMPACT (Maibach et al. 2008) or PLANCO (2007). The results of these studies are the basis for the evaluation framework presented in the next section.

3 Evaluation Framework

The evaluation framework presented in this section combines the economic factors and external factors in order to find the most sustainable way of transport. The economic factors are represented by the total logistics costs (TLC) including the transport costs and inventory costs. The inventory costs for transport and inventory holding at the final destination are influenced by the second economic factor which is the transport time. The external factors combine the impacts on environment and society and can be expressed in costs for air pollution, GHG emissions, accidents, noise and congestion. All presented cost categories are summarized in order to obtain the total sustainability costs (TSC) which can be defined as

$$\begin{aligned} TSC = {} & TLC + air\,pollution\,costs + GHG\,emission\,costs + accident\,costs \\ & + noise\,costs + congestion\,costs \end{aligned} \quad (1)$$

The economic and external factors required for the calculation of TSC are shortly described in the following sections.

3.1 Economic Factors

3.1.1 Total Logistics Costs

From the supply chain management point of view, the economic costs of transport include in addition to the direct transport costs also costs related to transport time and inventory. These costs are part of the total logistics costs concept (TLC) presented among others by Blauwens et al. (2006). TLC can be computed as

$$TLC = \textit{transport costs} + \textit{cycle inventory costs} + \textit{inventory in transit costs} + \textit{safety stock inventory costs} \tag{2}$$

The transport costs paid for transport of goods can be calculated based on the costs of each vehicle or transport prices offered by transport companies. For the cycle stock costs the order volume, the value of the goods and the holding costs are required. The inventory in transit costs depend on the speed and transport time of each transport mode. The safety stock inventory has to be held by the customer due to uncertainty of demand and lead time.

3.1.2 Transport Time

Transport time denotes the total transport time needed for transport of goods between origin and destination. In addition to the pure driving time of the vehicle, transport time includes also loading and unloading times and time needed for transhipment and waiting in terminals. The calculation of transport time for trains and short sea vessels is based on publicly available schedules which can be used as planned driving times. For the road transport several routing tools estimating the driving time according to the infrastructural limitations (e.g. speed limits, driving bans), legal restrictions (e.g. resting periods) and current traffic situation can be used (PTV 2013). In case of IWT a calculation scheme implemented by via donau (2007) including the times needed for sailing, notification, loading and unloading can be used for the transports on the Danube.

3.2 External Factors

The calculation of costs for external factors is difficult since the exact estimation of negative effects from transport is not possible. The impact of transport depends on various variables, such as geographical scope, time duration, affected population, monetary valuation and many others that are changing constantly. Therefore the results might differ significantly dependent on the methodology used.

In general, external costs of transport can be computed either as average or as marginal costs. Average costs are estimated in a top-down approach using aggregated values from national statistics. In order to obtain the costs per km, the cost function has to be simplified. For the marginal costs the bottom-up approach is applied. This approach estimates the costs based on case studies considering specific traffic conditions. However, the estimated values are difficult to aggregate in order to be comparable between the modes or countries. In most cases the results of both approaches are very similar except for noise and congestion costs. In noisy areas marginal noise costs are lower than average costs. In congested sections the marginal congestion costs exceed the average costs. Usually a combination of both approaches is used in practice (Maibach et al. 2008).

The values for external costs used in this paper are marginal costs based on the IMPACT project (Maibach et al. 2008) which were updated by Brons and Christidis (2011) to the price level of 2011. The coefficients are estimated using the impact pathway approach developed in ExternE project. This approach at first defines the relevant emissions in order to estimate their dispersion and concentration in the monitored area. Thereafter the impact of the increased concentration on the population and nature is calculated. In the last step, the impact is expressed in monetary values using the willingness to pay (WTP) and value of statistical life (VOSL) concepts (Maibach et al. 2008). The coefficients for each cost category are calculated separately for each EU country. In this paper they are used for calculation of air pollution, accident, noise and congestion costs. For the calculation of GHG emission costs a methodology based on Kranke et al. (2011) is used.

Air pollution emissions are released by vehicles with combustion engines and include gases such as particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NO_x) or sulphur dioxide (SO_2). Their amount depends on the vehicle and engine type, fuel, speed, geographical location, load factor and driving behaviour (Maibach et al. 2008). In order to obtain the air pollution costs for a certain transport, the number of vehicle kilometres (vkm) has to be multiplied by the unit cost of pollutant. Brons and Christidis (2011) estimated the costs of air pollution between 0 and 24.4 EUR/1,000 tkm depending on the transport mode and country.

The marginal accident costs describe the additional risk of accident from a new actor entering the traffic flow. They represent only the external costs that are not covered by insurance premiums which results in rather low values. They are mainly relevant for road transport and rail transport. In IWT and SSS the number and impact of accidents is very low and therefore the accident costs are negligible (Maibach et al. 2008). Brons and Christidis (2011) recommend values between 0.0 and 1.7 EUR/1,000 vkm.

Noise costs represent the negative impact of noise on human health. The impact can be expressed either in annoyance costs for disturbances and discomfort or health costs for health problems such as hearing problems, cardiovascular diseases or sleep disruptions. Marginal noise costs depend on the existing noise level, the time of the day and the affected population. They are only relevant for road and rail because IWT and SSS operations are conducted away from densely populated areas (Maibach et al. 2008). The recommended values by Brons and Christidis (2011) are between 0.6 and 5.6 EUR/1,000 tkm.

Congestion costs arise due to the insufficient capacity of the infrastructure which leads to congestion. They represent the time losses due to delays and the impact of congestion on air pollution, GHG emissions and accidents. Congestion costs are mainly relevant for the road transport and rail transport. For SSS the costs cannot be estimated due to missing detailed data about delays in ports. For IWT delays are caused mainly by waiting in front of locks but the congestion costs are negligible

(Maibach et al. 2008). In their calculations Brons and Christidis (2011) propose values between 0.1 and 5.5 EUR/1,000 vkm.

GHG are gases preventing the heat escaping from the Earth. Therefore a certain concentration of GHG in the atmosphere is necessary for life on the planet. However, since the beginning of the industrial revolution their concentrations are increasing and today GHG significantly contribute to global warming and climate changes. The most important GHG are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) (Maibach et al. 2008).

The amount of GHG emissions is calculated according to the methodology described by Kranke et al. (2011) based on the proposal of the CEN standard prEN 16258:2011. The calculation considers all six GHG and the scope of emissions is well-to-wheel including emissions from fuel consumption and emissions from fuel production and distribution. In order to obtain the amount of CO_2 emissions, the fuel consumption has to be calculated which is directly proportional to the amount of emissions. The emissions of other GHG are on average 1.05 % of the CO_2 emissions according to the calculation of the Institut für Energie- und Umweltforschung Heidelberg.

In road transport, the fuel consumption depends on the vehicle type and its engine, air and rolling resistance, road gradient, traffic situation, speed, driving behaviour and utilization. Fuel consumption factors are divided into classes according to the emission class of the vehicle and its utilization. The emission factors are 2.95 kg/l of diesel for CO_2 emissions and 3.01 kg/l for all GHG emissions.

Emission factors in rail transport differ for the electric and diesel traction. They are dependent on the gross weight of the train, type of cargo, utilization and topography. The specific energy consumption factors can be calculated as

$$EF_{Etrain} = 1.20\,\mathrm{kWh/trainkm} \times \mathrm{m}_{gross}^{0.38} \tag{3}$$

for the electric train and

$$EF_{Dtrain} = 0.326\,\mathrm{l/trainkm} \times \mathrm{m}_{gross}^{0.38} \tag{4}$$

for the diesel train with m_{gross} representing the gross weight of the train.

The factors important for the fuel consumption in IWT are the vessel type, utilization, speed of the river, speed of the vessel and the sailing direction (upstream or downstream). The calculations of fuel consumption for the Danube are based on the methodology used by via donau.

In SSS the amount of GHG emissions depends on the size and gross weight of the vessel and the type of the fuel. Vessels usually use different fuels for the main and auxiliary engines and therefore the share of each fuel on the total fuel consumption has to be known. Since the exact information is difficult to obtain, Kranke et al. (2011) propose average emission factors for different shipping lines which are also used in this paper.

The GHG emissions calculated for each transport mode have to be converted into costs by multiplying them with a price per ton. The value used in this paper is 70 EUR/t recommended by PLANCO (2007).

4 Case Study: Transport of Containers Between Vienna and Istanbul

In this section the evaluation framework presented in Sect. 3 is used for comparing the TSC of transport alternatives for containerized goods between Vienna and Istanbul. The transport includes multiple containers per week but the costs are calculated for one 40-foot container loaded with 23 t of plastics. The first alternative describes the route via Trieste which is a port in Italy often used for export of goods from Austria. Alternative 2 takes into consideration the direct transport by truck. In Alternative 3 direct transport by train between the container terminals in Vienna and in Istanbul is described. Alternative 4 combines IWT on the Danube with truck transport. The alternatives are depicted in Fig. 1. After the description of the alternatives their TSC are compared in Sect. 4.5.

At the beginning of each alternative the route and used transport modes are described. The route always starts at a container terminal in Vienna from which an empty container is taken and ends in the container terminal in Istanbul where the empty container is brought back after the delivery of goods to the customer. After that the transport time is calculated. It is assumed that containers leave the factory in

Fig. 1 Transport alternatives

regular intervals and are immediately transported to the closest terminal where they have to wait for the departure of the following vehicle. In the next step, TLC are calculated. Transport costs are either computed as costs for each vehicle and terminal or approximate transport prices are used where no detailed information about costs is available. For the road the transport costs are estimated using a standard EURO IV class truck taken from PLANCO (2007). The values for purchasing price, labour costs, insurance and fleet management are set lower due to the use of older trucks and lower wages in the Eastern Europe. Rail costs are estimated using data from PLANCO (2007) and information about infrastructure charges in each country. Although detailed data about the cost structure is missing, the results should correspond to the prices offered by transport companies. For IWT the data from via donau (2007) is used. Instead of estimating the SSS costs the approximate prices valid in October 2012 are taken. For inventory costs the holding costs rate is assumed to be 20 % of the goods value which is set to 1,450 EUR/t. It is assumed that the demand of one customer is one container per week and the goods are delivered once per week, therefore the customer has to hold 3.5 days of cycle inventory. Due to missing information about uncertainty of demand and lead time the safety stock inventory in days is assumed to be 25 % of the transport time needed in each alternative. The inventory costs include also the costs for container leasing with 2.60 EUR/day. At the end of the description of each alternative the costs for external factors are computed. More information about the calculations can be found in Hrusovsky (2013), although some values and alternatives have been updated for this paper.

4.1 Alternative 1: Intermodal Transport Vienna-Trieste-Istanbul

In the first alternative, the transport starts in container terminal in Vienna from where an empty container is transported by truck to a factory located close to the terminal. Here the container is loaded and brought back to the terminal. After that it is loaded on a train which leaves to Trieste five times per week and covers a distance of 564 km (RCA 2013). In the port of Trieste the container is transhipped to a short sea vessel which sails to Istanbul. The vessel is operated as a liner service calling at different Italian, Slovenian, Greek and Turkish ports which increases the distance to 2,944 km (Seagoline 2013). Finally, the container is brought by truck from the Ambarli port in Istanbul to a customer located 40 km away from the port and the empty container is brought back to the port after unloading.

The transport time consists of the transport time for each leg and waiting times in terminals. The truck in Vienna needs 1 h for loading the container, 0.27 h for transport to the terminal (PTV 2013) and 0.5 h for unloading the container in the terminal. Since the containers come in regular intervals and the trains leave five times a week, one container has to wait on average 0.7 days until the departure of the train. The train transport takes 3.2 days (RCA 2013) and the average waiting time in Trieste is 3.5 days since the vessel leaves once per week. The sea voyage takes 15 days (Seagoline 2013). For the last leg in Istanbul the truck needs 0.15 days which leads to average total transport time of 22 days.

The calculation of TSC starts with the transport costs of the truck in Vienna which is dedicated to the transports between factory and terminal. For the transhipment in the terminal the fees for loading, unloading and storage have to be paid. After estimation of rail costs the terminal charges for Trieste and Istanbul together with SSS costs have to be added. For the road transport in Istanbul again a dedicated truck is assumed. In addition, the inventory costs have to be added which are relatively high due to the long transport time. During the transport 1,554 kg of GHG emissions are released including also emissions from transhipment in terminals (Kranke et al. 2011). TSC are calculated in Table 1.

4.2 Alternative 2: Truck Transport Vienna-Istanbul

In Alternative 2 the container is transported by truck directly from the factory in Vienna to the customer in Istanbul. The empty container is taken from the container terminal in Vienna to the factory where it is loaded. After that it is transported via Hungary, Serbia and Bulgaria to Istanbul covering a distance of 1,561 km. After the delivery of the goods to the customer the empty container is brought back to the container terminal in Istanbul. The transport time needed for this delivery is 3.5 days including also buffer times for border waiting times and other unexpected delays (PTV 2013). The transport costs include only the costs of the truck and the relatively short transport time leads to low inventory costs. The amount of GHG emissions is 1,844 kg and TSC are displayed in Table 1.

4.3 Alternative 3: Rail Transport Vienna-Istanbul

The third alternative considers the transport by train between terminals in Vienna and Istanbul. The transport starts again with the pick-up of empty container, loading at the factory and transport of the loaded container to the terminal. From here the trains leave four times a week travelling 1,620 km to Turkey (IFB 2013). In Istanbul the last mile of the transport is conducted by truck. The transport time of the train is 4.5 days and the average waiting time in terminal in Vienna is 0.9 days. The total transport time together with the truck transports is 5.6 days. Transport costs calculation for rail is based on PLANCO (2007) and infrastructure charges in each country. Since the main part of the transport is executed by electric train, the amount of GHG emissions is 591 kg which is low in comparison to other alternatives. TSC for Alternative 3 are computed in Table 1.

4.4 Alternative 4: IWT Vienna-Ruse-Istanbul

In the fourth alternative the IWT on the Danube to Bulgaria is considered where the containers are transhipped to truck. Although currently no regular container liner services between Austria and Romania exist on the Danube, there are various companies operating vessels on the Danube capable of transporting containers (via donau 2007). In this alternative a motorized cargo vessel with a capacity of 2,000 t and 66 TEU is used which departs once per week from the port of Vienna. The transport on the Danube is possible until the port of Constanta where the container can be loaded on vessels of different sea shipping lines. However, the transport by SSS from Constanta to Istanbul is relatively expensive as shown in Hrusovsky (2013). Therefore in this alternative the IWT to Ruse in Bulgaria combined with truck transport between Ruse and Istanbul is considered.

Before the IWT the container is again delivered by truck to the port of Vienna where it has to wait on average 3.5 days until the departure of the vessel. For the 1,428 km long trip to Ruse the vessel needs 4.5 days including the time for loading, unloading and notification at the ports (via donau 2007). After unloading in Ruse the container is taken by a truck to the customer. For the distance of 573 km 1.2 days are needed including also waiting times at the border between Bulgaria and Turkey (PTV 2013) which results in total transport time of 9.3 days. The truck used between Ruse and Istanbul is again a standard EURO IV truck used in Alternative 2 resulting in costs of 725 EUR. The costs for the vessel are based on via donau (2007) with a reduced fuel consumption of 6.9 kg/1,000 tkm calculated especially for this route. The IWT costs are with 469 EUR relatively cheap. Due to the longer distance the amount of GHG emissions is relatively high with 1,712 kg. Table 1 summarizes TSC for Alternative 4.

4.5 Comparison of Results

The calculation of TSC for each of the four alternatives is displayed in Table 1 which shows the costs for each defined cost category. As the results show, Alternative 1 with transport via Trieste has the longest distance and needs the longest transport time due to several transshipments. As a result, it leads to the highest TSC, although the sum of external costs is lower than in case of the truck transport in Alternative 2. Besides the highest external costs, Alternative 2 has also the second highest transport costs, but offers the possibility of fast transport which leads to lower inventory costs. The cheapest alternatives from the point of view of the transport costs are Alternative 3 using rail and Alternative 4 combining IWT and truck transport. Although the IWT is much cheaper, the longer distance and use of truck increase the external costs. Moreover, inventory costs are also higher in comparison to Alternative 3 because of the longer transport time. As a result, Alternative 3 is the cheapest alternative from the point of view of TSC. The main advantage of this alternative is the use of electric train on the majority of the route which leads to relatively low air pollution and GHG emission costs. The train drives

Table 1 Total sustainability costs for each transport alternative

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Distance (km)	**3,613**	**1,607**	**1,714**	**2,055**
Pure transport time (days)	18.0	3.5	4.7	5.8
Waiting time (days)	4.2	0.0	0.9	3.5
Total transport time (days)	**22.2**	**3.5**	**5.6**	**9.3**
Transport costs (EUR)	2,139	1,747	1,420	1,400
Inventory costs (EUR)	630	154	208	302
Total logistics costs (EUR)	**2,769**	**1,901**	**1,628**	**1,703**
GHG emission costs (EUR)	109	129	50	120
Air pollution costs (EUR)	341	359	194	476
Accident costs (EUR)	7	18	10	6
Noise costs (EUR)	32	62	56	24
Congestion costs (EUR)	6	126	9	46
Total sustainability costs (EUR)	**3,263**	**2,596**	**1,947**	**2,374**

directly between Vienna and Istanbul with transhipments only at the beginning and end of the route which leads to the second lowest transport time.

The comparison of external costs shows high differences between the alternatives with high importance of air pollution costs. However, it should be noted that the values are strongly dependent on the methodology and therefore the results can differ significantly for different methodologies. In order to prove the results, the external costs were also calculated with values from PLANCO (2007) and Essen et al. (2011) which came to the same order of the alternatives. However, the difference in TSC between Alternative 3 and 4 using PLANCO (2007) was only 50 EUR whereas for Essen et al. (2011) the difference was 466 EUR. Besides the external costs, the results are also dependent on the holding costs rate. In the calculation presented in Table 1, TSC of Alternative 2 become lower than TSC of Alternative 4 if the holding costs rate is higher than 53 %.

5 Conclusions

Transport activities facilitate the trade between countries which positively influences the economic growth. However, transport also causes several negative external effects which are currently not considered in the decisions about the transport mode choice. Therefore an evaluation framework combining economic and external factors of transport and computing the TSC was presented in this paper. As the results showed, whereas the transport costs of one alternative might be lower, the consideration of TSC might lead to different decisions because of lower external costs of another alternative. However, it should be taken into consideration that the results for external costs are dependent on the methodology and therefore they can vary significantly dependent on the chosen methodology.

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Evaluation of CO_2 Abatement Measures for (Bio-) Fuel Production

Laura Elisabeth Hombach and Grit Walther

Abstract A decision support framework is presented to facilitate the political decision maker by finding an emission minimal and economic reasonable long-term policy strategy for the regulation of the (bio-) fuel sector. Thus, a dynamic, bi-criteria, technology and blending model is developed to optimize economic and ecological objectives simultaneously. As result, the Pareto efficient frontier of eco-efficient solutions is calculated. The model is applied to a case study of the German (bio-) diesel market.

1 Introduction

In 2010 the transportation sector was the second largest emitter of greenhouse gas emissions in the world. Road transportation was the leading emitter within this sector, by contributing 75 % to the total emissions of this branch (IEA 2012). Several alternatives exist for the reduction of transport emissions, e.g. improvement of conventional engines, introduction of new drivetrain technologies like electric vehicles, new drivetrain concepts like modal shift by increasing the usage of e-bikes, or utilization of biofuels. However, efficiency improvement potential of conventional cars is estimated to be not more than 4 % for diesel and 2.7 % for gasoline vehicles (Mock 2010) and the total market share of new drivetrain technologies is expected to reach between 2 and 25 % (Kieckhäfer 2013) in 2030. In addition to that short-term changes to new drivetrain concepts are not likely. Thus, production and use of biofuels seems to be necessary in order to abate emissions in a short- and mid-term perspective.

While biofuels have lower emissions over the life cycle than conventional fuels, the production of biofuels causes higher costs than the production of conventional fuels due to higher process specific costs and high investments in new production

L.E. Hombach (✉) · G. Walther
Operations Management, RWTH Aachen University, 52072 Aachen, Germany
e-mail: laura.hombach@om.rwth-aachen.de

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plants (IFEU 2004; Walther et al. 2012). Therefore, biofuel production needs the stipulation by political regulations. Such political regulations have been introduced already, e.g. requiring a certain share of biofuels in total fuel demand or the fulfilment of minimum CO_2 savings compared to the usage of fossil fuels. However, political requirements were changed more than once because of low efficiency and effectiveness (e.g. low emission reduction of 1st generation biofuels, etc.) and unintended side-effects (e.g. conflict with food production).

Against that background, the aim of the paper is to develop a decision support systems that allows to analyze efficient and effective solutions for production and usage of biofuels as requested by EC (COM (2001) 264). Using these solutions, efficient and effective political strategies guaranteeing long-term planning reliability for investors as requested by EC (COM (2001) 264) will be derived in a further step.

The paper is organized as follows. In Sect. 2 the planning problem is presented. Section 3 gives an overview of political requirements for the regulation of the biofuel market. Within Sect. 4 the optimization model is described. In Sect. 5 a case study of the German diesel and biodiesel market is illustrated and first results are presented in Sect. 6. Conclusions and an outlook on future research are given in Sect. 7.

2 Framework of the Planning Problem

The production network for (bio-) fuel blends can be separated into three stages: cultivation of biomass, conversion of biomass into pure biofuel, and distribution of (bio-) fuel blends (Fig. 1). Between those stages biomass/biofuel transportation takes place.

Different kinds of biofuels (1st or 2nd generation biofuels) might be considered. Biodiesel, bioethanol and vegetable oil are 1st generation biofuels. Several kinds of biomass can be used for the production of these kinds of biofuels, e.g. rapeseed, soya or palm oil for biodiesel, rapeseed, sunflowers or palm oil for vegetable oil, and sugar beets or wheat for bioethanol (IFEU 2004). 2nd generation biofuels are for instance cellulose bioethanol and Biomass-to-Liquid (BtL)-diesel. Residual materials like straw or residual wood can be used for the production of 2nd generation biofuels (Walther et al. 2012). Concluding, less emissions result compared to 1st generation biofuels. However, production costs and investments are much higher for 2nd generation biofuels than for 1st generation biofuels (IFEU 2004).

2.1 Biomass Cultivation

Different kinds of biomass are used for biofuel production. Biomass is either cultivated in the country where the fuel production takes place, or is imported from other countries (e.g. major exporters for soya are Argentina and Brazil, while major exporters for palm oil are Indonesia and Malaysia (DBFZ 2012; WI 2007)).

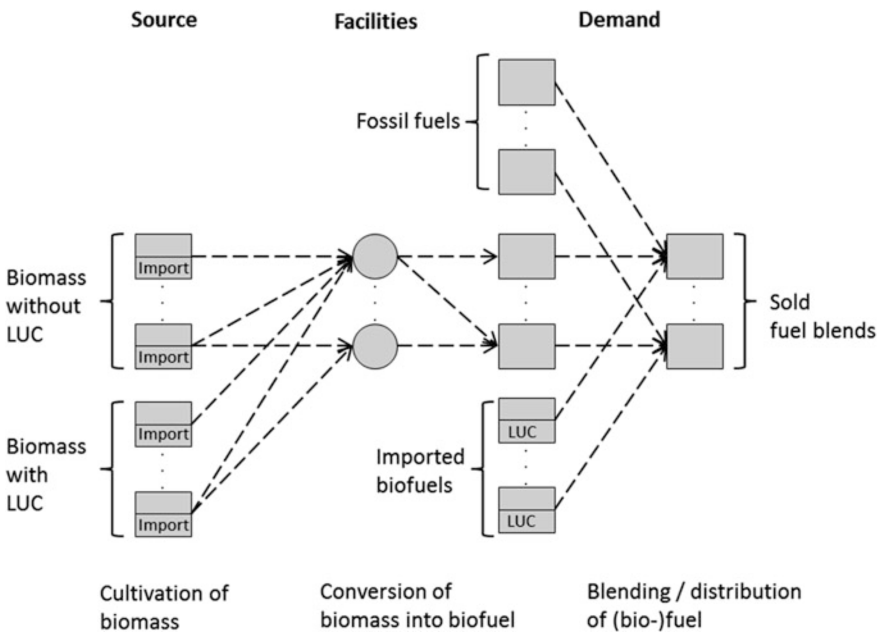

Fig. 1 Structure of the (bio-) fuel sector (LUC—land use change)

Cultivation and transportation of biomass cause emissions and costs subject to the kind of biomass, the country of cultivation and the transportation distances. If the available area for cultivation of biomasses is not sufficient, land use change (LUC) might occur. LUC often leads to increasing greenhouse gas emissions, and is diminishing the acreage that is available for food and fodder cultivation. Thereby, direct LUC (dLUC) and indirect LUC (iLUC) can be distinguished. dLUC appears if an uncultivated area is cultivated in order to grow biomass for the production of biofuel, while iLUC occurs if agricultural products grown on cultivated areas are replaced by biomass for biofuels. Often, the production of these agricultural products is moved to so far uncultivated areas. The consideration of iLUC in the ecological footprint of biofuels is a very difficult task and is controversially discussed. Thus, only dLUC is considered within the EU derivation 2009/28/EC for the calculation of the ecological footprint according to the derivation 2010/335/EU. We apply the same procedure in this paper.

2.2 *Conversion of Biomass into Biofuel*

The conversion of biomass into biofuel takes place at biofuel production plants. Technologies depend on the type of biofuel, e.g. ester interchange is used for production of biodiesel, fermentation for bioethanol, hot or cold compression for vegetable oil, enzymatic split and fermentation for cellulose bioethanol, and gasification and synthesis for BtL-diesel (Schatka 2011). Considering the capacities and process characteristics, decentralized and centralized plant concepts can be differentiated. Depending on the kind of biomass and technology there are different production efficiencies (conversion coefficients representing the input/output relation), as well as production emissions and production costs. In addition to that investments differ with regard to technologies (Schatka 2011). Currently, plants for the production of fossil fuels and 1st generation biofuels already exist whereas for 2nd generation biofuel only pilot plants exist (Schatka 2011).

2.3 Blending of (Bio-) Fuels

Fossil fuels, 1st and 2nd generation biofuels are either used in pure quality (e.g. B100), or blended (e.g. B7 or E10). While for B100 only 1st generation biodiesel is used, for the blending of B7 7 % biodiesel and 93 % fossil diesel is combined. Since (bio-) fuels have divers energy contents, energy conversion coefficients have to be considered for the blending process (FNR 2012). However, certain technical restrictions and thus blending limits exist because of limited engine compatibility with 1st generation biofuels (2009/30/EC). Currently, final fuel blends sold at service stations are a blend of fossil fuels and different kinds of 1st generation biofuels (according to political requirements e.g. 2009/28/EC). Each final fuel product has specific well-to-wheel emissions and costs in the refining process. Thus, the total emissions of the sold fuel yield from specific fuel emissions multiplied with the amount of each fuel in the blend (2009/28/EC). In the future, blending of 2nd generation biofuels or other kinds of 1st generation biofuels (e.g. based on waste material) might be necessary in order to decrease total CO_2 emissions (see for instance COM (2012) 595).

3 Political Regulations for Biofuels

In order to influence total emissions of fuels, political requirements (regulatory, market based, voluntarily/informational) can be implemented at the different life cycle phases. Furthermore, there are policies that regulate the overall life cycle. As can be seen in Fig. 2, a broad range of different policy types and applications exists within the field of biofuel regulations.

In the past, a wide portfolio of political requirements has been used in different countries. Due to unintended side-effects after implementation of some of these requirements (e.g. the food vs. fuel discussion in 2009), political requirements were often modified. For instance, required market share quotas for biofuel in the EU changed from 20 % market share until 2020 announced in 2001 (COM (2001) 264) to only 6 % market share until 2020 declared in 2009 (2009/30/EC). Concluding, past

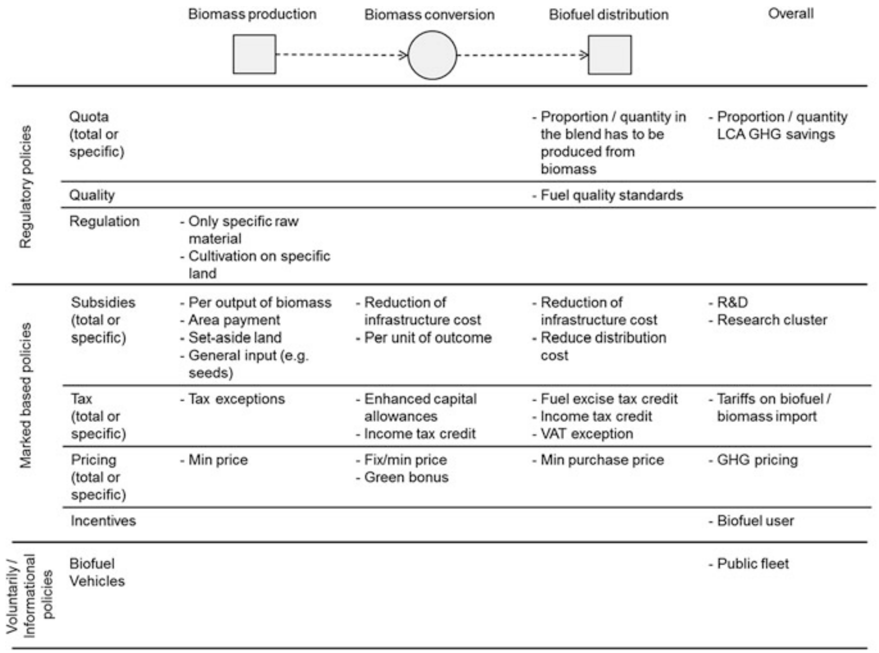

Fig. 2 Political instruments for biofuel regulation (according to Sorda et al. 2010; OECD 2008; Wiśniewski et al. 2008)

political strategies have not been time robust and thus did not ensure long-term planning reliability for potential investors in the (bio-) fuel sector. Thus, the scope of the paper is to analyze the system of (bio-) fuel production and distribution as described above with regard to the resulting trade-off between total costs and emissions. Hence, efficient solutions are determined regarding costs and emissions simultaneously.

4 Bi-criteria optimization model

In this section a bi-criteria, multi-period, technology and blending optimization model is presented that represents the system of (bio-) fuel production and distribution regarding simultaneously total costs and emissions. First, model constraints are discussed and both objective functions are described. The model is designed for one specific (bio-) fuel market (e.g. for the case study of Germany in Chap. "Carbon Efficiency of Humanitarian Supply Chains: Evidence from French Red Cross Operations"). Within this market (in the following called "producing country"), investments into production facilities are carried out to fulfill the market (bio-) fuel demand. Also, biomass and biofuel imports into the market might take place if in-land production does not fulfill the (bio-) fuel demand. Within the model, different kinds of biomass ($a \in A$), which are cultivated in certain countries ($v \in V$, where $v = 1$ denotes the producing country) are used for production of 1st and 2nd generation biofuels using different production technologies ($m \in M$, where modules $m \in M_a$ are able to transform biomass a). Furthermore, dLUC is considered regarding different area types ($d \in D$). If biomass for biofuels is grown on an area type that was not used for this kind of biomass before, area specific dLUC emissions occur (e.g. additional crop land leads to less dLUC emissions than additional forest land). In order to fulfill the demand for final fuel blends ($k \in K$), different fuels ($h \in H$) including different kinds of biofuels ($n \in H^{bio}$) and fossil fuels ($g \in H^{fossil}$) can be blended. Total costs and emissions are calculated depending on biomass type, country of cultivation, technology for (bio-) fuel conversion and (bio-) fuel blend. The model is designed for T ($t \in T$) periods.

4.1 Constraints

Total biomass available for biofuel production (b_{amnt}) is equal to biomass a cultivated in country v without dLUC (b^o_{avt}) and with dLUC (b^l_{advt}).

$$\sum_{v \in V} \left(b^o_{avt} + \sum_{d \in D} b^l_{advt} \right) = \sum_{m \in M} \sum_{n \in H^{bio}} b_{amnt} \quad \forall a \in A;\ t \in T \tag{1}$$

Total produced biofuel (y^u_{nt}) of type n results from total available biomass (b_{amnt}) multiplied with the conversion coefficient (γ_{amn}) describing the conversion of biomass a into biofuel type n using technology m.

$$\sum_{a \in A} \sum_{m \in M_a} b_{amnt} \cdot \gamma_{amn} = y^u_{nt} \quad \forall n \in H^{bio};\ t \in T \tag{2}$$

The sum of produced biofuel (y^u_{ht}), imported biofuel (the producing country cannot import its own biofuel production, $v \neq 1$) without and with dLUC ($y^o_{amhvt} + y^l_{admhvt}$) and fossil fuel ($y^f_{ht}$) multiplied with the oil equivalent factor (w_{hk}) equals fuels h blended into total blended fuel k (λ_{hkt}).

$$\left(\sum_{a \in A} \sum_{m \in M} \sum_{\substack{v \in V \\ v \neq 1}} \left(y^o_{amhvt} + \sum_{d \in D} y^l_{admhvt} \right) + y^u_{ht} + y^f_{ht} \right) = \sum_{k \in K} \lambda_{hkt} \cdot \frac{1}{w_{hk}} \quad \forall h \in H;\ t \in T \tag{3}$$

The demand of fuel blend k in the producing country $v = 1$ (D_{kt}) is fulfilled using blended fuel (λ_{hkt}).

$$\sum_{h \in H} \lambda_{hkt} = D_{kt} \quad \forall k \in K;\ t \in T \tag{4}$$

Total biomass a available without dLUC for cultivation (b^o_{avt}) and for production of biofuel that is imported into the producing country $v = 1(y^o_{amnvt}/\gamma_{amn})$ is smaller/equal then available biomass without dLUC (modeled as yield on available land (μ_a)) within a country v (O_{avt}).

$$b^o_{avt} + \sum_{m \in M_a} \sum_{n \in H^{bio}} \frac{y^o_{amnvt}}{\gamma_{amn}} \leq O_{avt} \cdot \mu_a \quad \forall a \in A;\ v \in V;\ t \in T \tag{5}$$

Total biomass a of country v available for cultivation of biomass (b^l_{advt}) and for production of biofuel for import ($\frac{y^l_{admnvt}}{\gamma_{amn}}$) with dLUC does not exceed available accessory dLUC-acreage (L_{dvt}) according to area d and yield factor (μ_a) of biomass a.

$$\sum_{a \in A} \left[\left(b^l_{advt} + \sum_{m \in M_a} \sum_{n \in H^{bio}} \frac{y^l_{admnvt}}{\gamma_{amn}} \right) \cdot \frac{1}{\mu_a} \right] \leq L_{dvt} \qquad \begin{array}{c} \forall d \in D; \\ v \in V;\ t \in T \end{array} \tag{6}$$

Total biomass (b_{amnt}) for biofuel production multiplied with the capacity coefficient ε_{am} does not exceed the available capacity (U_m) of used production facilities (z^p_{mt}).

$$\sum_{a \in A} \sum_{n \in H^{bio}} b_{amnt} \cdot \varepsilon_{am} \leq U_m \cdot z^p_{mt} \quad \forall m \in M;\ t \in T \tag{7}$$

Used biofuel within the final fuel blend (λ_{hkt}) can be limited by either lower (β_{hkt}) or upper bounds (δ_{hkt}), e.g. for technical reasons.

$$D_{kt} \cdot \beta_{hkt} \leq \lambda_{hkt} \leq \delta_{hkt} \cdot D_{kt} \quad \forall k \in K;\ h \in H;\ t \in T \tag{8}$$

Used production facilities (z^p_{mt}) must be equal or less then installed production facilities (z_{mt}).

$$z^p_{mt} \leq z_{mt} \quad \forall m \in M;\ t \in T \tag{9}$$

Installed production facilities (z_{mt}) must not exceed available facilities in period $t = 1(U^z_m)$ and new installed ones (x_{mt}).

$$z_{mt} = \begin{cases} x_{mt} + U^z_m & f\ddot{u}r\ t = 1 \\ z_{mt-1} + x_{mt} & else \end{cases} \quad \forall m \in M; t = T \tag{10}$$

x_{mt}, z_{mt}, z^p_{mt} are integer variables and only non-negative flows are permitted.

4.2 Objective Function

Within the first objective function, total emissions of the (bio-) fuel conversion and distribution system are minimized, i.e. the overall sum of emissions of refined fossil fuels (E_t^f), produced biofuels (E_t^b) and imported biofuels (E_t^I). For fossil fuels, complete life cycle well-to-wheel emissions are taken into account. For produced biofuels, specific emissions for the cultivation and transportation of the biomass (including imported biomass), potential dLUC emissions, and production emissions depending on conversion technology are taken into account. For imported biofuels land-to-wheel emissions of the country of origin are regarded.

$$\min \sum_{t \in T} \left[E_t^f + E_t^b + E_t^I \right] \tag{11}$$

Within the second objective function, the discounted profit calculated as return (R_t) minus investment (I_t) minus production payments (C_t) discounted by interest rate j is maximized. The return is calculated based on the cumulated expected sales price of the sold fuel blend. Investments for production facilities depend on used technologies. Total production payments comprise of payments for imported biomass, fixed and variable payments for biofuel production and transportation, as well as payments for imported biofuels and fossil fuels. To incorporate already existing unamortized production facilities (e.g. for 1st generation biofuels) the profit oriented objective function takes into account the book value of existing facilities in $t = 1$ (BV) as payment.

$$\max \sum_{t \in T} [R_t - I_t - C_t] \cdot (1 + j)^{-t} - BV \tag{12}$$

Due to restricted space, the objective functions will not be presented in detail. An overview of the components of both objective functions is given in Table 1. Thereby, the decision variables that drive the costs and emissions (e.g. material flows of biomass and biofuel, conversion processes) are listed in the left column, while the interrelation of each driver with costs and emissions is described in the two columns at the right. In the two objective functions shown in Table 1, each driver is multiplied with specific cost/emission factors.

To solve this bi-criteria optimization model, an ε-constraint approach is used. According to the mixed integer character of the model the exact ε-constraint method for bi-objective optimizations problems from Bérubé et al. (2009) is implemented.

Table 1 Structure of the objective functions

Driver	$\max \sum_{t \in T} [R_t - I_t - C_t] \cdot (1+j)^{-t} - BV$	$\min \sum_{t \in T} \left[E_t^f + E_t^b + E_t^I\right]$
b^l_{advt}	Payment for biomass with dLUC	Emission for biomass cultivation with dLUC
b^o_{avt}	Payment for biomass without dLUC	Emission for biomass cultivation without dLUC
x_{mt}	Investment	
y^l_{admnvt}	Payment for biofuel import with dLUC	Life cycle emission for biofuel import with dLUC
y^o_{amnvt}	Payment for biofuel import without dLUC	Life cycle emission for biofuel import without dLUC
b_{amnt}	Variable payment for biofuel production	Emission for biofuel production
y^f_{gt}	Payment for fossil fuel	Life cycle emission for fossil fuel
y^u_{nt}		Emission for biofuel usage
z^p_{mt}	Fix payments for biofuel production	
D_{kt}	Revenue for sold final fuel blends	

5 Case Study

In the case study, the German diesel blend and pure biodiesel (B100) market is analyzed. For the production of the diesel blend, fossil diesel, rapeseed oil, 1st generation biodiesel and 2nd generation BtL can be blended. Pure biodiesel consists of 1st generation biodiesel only. Different kinds of biomass can be used to produce 1st generation biodiesel and 2nd generation BtL. Rapeseed, soya beans or palm oil can be transformed into 1st generation biodiesel and residual wood/energy crops as well as straw into 2nd generation BtL. Rapeseeds are used in order to produce rapeseed oil too. Rapeseed, residual wood/energy crops and straw are cultivated in Germany. Soya beans are imported from Argentina and palm oil from Malaysia. Additionally 1st generation biodiesel produced from soya or palm oil can be imported. If the yield of the existing agricultural land for biomass cultivation is not sufficient to fulfill biomass demand, additional land may be used for the cultivation of biomass and dLUC might appear (renew D5.01.03 2008; renew D5.01.07 2008; StatBA 2012; WI 2007, 2008; BMELV 2012). Prices for the different kinds of biomass are calculated based on forecasts of OECD (2012) and renew D5.3.6 (2008). For emissions from dLUC, the standard value from Biograce (2011) is used.

An average production facility for 1st generation biodiesel and rapeseed oil is considered. To produce 2nd generation BtL bioliq or Carbo-V facilities with average capacity can be used. Investments, fixed and variable production payments are considered for all facilities (Schatka 2011; DBFZ 2012). Modeling of biomass conversion is done using conversion coefficients representing input/output relations (Schatka 2011; Biograce 2011). In Germany, 51 production plants for 1st generation

Table 2 Blending coefficients

	Biodiesel (%)	BtL (%)	Rapes. oil (%)	Source
Diesel equivalent	90	97	96	FNR (2012)
Max. blending percentage into diesel	7	100	10–100	Dena (2013)

biodiesel and 77 plants for rapeseed oil production exist already. For 2nd generation BtL, only pilot plants are installed so far (FNR 2012; Walther et al. 2012).

On the demand side, a market forecast for diesel blend as well as pure biodiesel based on (MWV 2011; UFOP 2012) is used. If produced 1st generation biodiesel does not meet 1st generation biodiesel demand, additional 1st generation biodiesel from soya beans produced in Argentina or from palm oil produced in Malaysia can be imported. Besides maximal blending amounts due to technical restrictions, different blending equivalents of blended fuels must be considered for the blending process (see Table 2).

Historical price development data of diesel blend and biodiesel are taken from StatBA (2012) and UFOP (2012). Import tax for biodiesel is set to 6.5 % (Sorda et al. 2010).

According to fuel type, life cycle phase, production technology and biomass, different emissions appear. Emission coefficients are taken from 2009/28/EC and renew D5.2.10 (2008). A planning horizon of 20 years (starting 2013) is applied.

6 Results

In this section the first results of the case study for the German (bio-) diesel blending market are presented. The optimization model contains 1,997 constraints and 7,855 variables, of which 168 are integer. To solve the model a CPLEX 12.4 solver was used. The optimization time for 10,721 iterations was 2,382.74 s.

In Fig. 3 the efficient frontier for the diesel blending and pure biodiesel market is shown. Considering the shape of the curve the trade-off between the profit and emission oriented objective functions becomes apparent. To reach the maximal emission reduction potential, three production facilities for 2nd generation BtL have to be installed (Carbo-V) blending 33 % biofuels (26 % from 2nd generation BtL; 7 % from 1st generation biodiesel) into the final diesel blend. Biofuel share within the final diesel blend can’t reach 100 % due to biomass and blending restrictions. If those restrictions are dropped, 100 % 2nd generation BtL is used in the final diesel blend and 11 production plants would have to be installed in an emission optimal solution. According to the efficient frontier, a decision maker is able to find a solution which is Pareto efficient with regard to the trade-off between ecological and economic objectives.

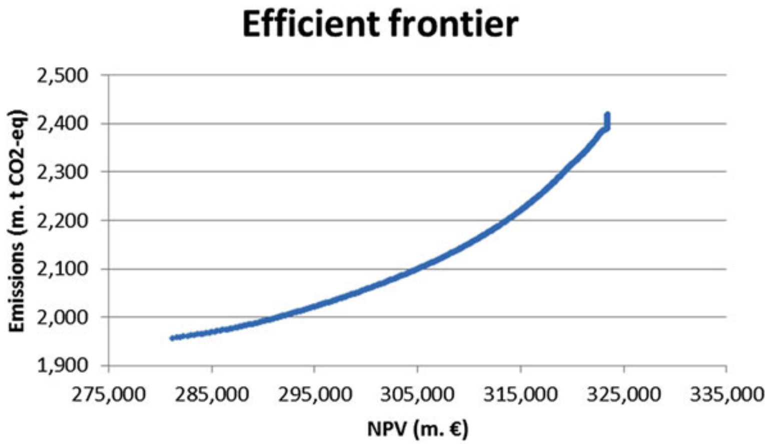

Fig. 3 Pareto efficient frontier of the German blended diesel and pure biodiesel market

Concluding, it is apparent that by using the profit and emission oriented decision support model, Pareto efficient solutions can be found.

7 Conclusion and Outlook on Future Research

In this paper a bi-criteria decision support model for the analysis of the (bio-) fuel sector according to economic and ecological goals was developed and first results of a case study for the German (bio-) diesel market were presented.

In further research the design of political strategies (e.g. dynamic parameter values for specific political regulations) will be implemented. Furthermore, the model will be extended, to solve not only the demand of one single country (e.g. Germany) but of an assembly of countries (e.g. the EU). Also, the uncertain characteristics of the forecasted parameter values will be regarded, e.g. using robust models in order to take into account the unknown environmental development.

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Carbon Efficiency of Humanitarian Supply Chains: Evidence from French Red Cross Operations

Peter Oberhofer, Edgar E. Blanco and Anthony J. Craig

Abstract Sustainability is identified as a major gap in humanitarian logistics research literature. Although humanitarian supply chains are designed for speed and sustainability is of minor concern, environmentally-friendly behavior (e.g. through reduction of transportation emissions and avoidance of non-degradable materials) should be a long-term concern as it may ultimately affect more vulnerable regions. The purpose of this paper is to illustrate how greenhouse gas emissions can be measured along the supply chain of common relief items in humanitarian logistics. We analyze the CO_2 emissions of selected supply chains using Life Cycle Assessments based on data provided by the French Red Cross. We calculate the CO_2 emissions of relief items from 'cradle to grave' including production, transportation, warehousing and disposal. Using these calculations, we show that transporting relief items causes the majority of emissions; however, transportation modes may not always be changed as the main purpose of humanitarian supply chains is speed. Nevertheless, strategic and efficient pre-positioning of main items will translate into less transportation and thus reducing the environmental impact. The study also shows that initiatives for "greening" item production and disposal can improve the overall carbon efficiency of humanitarian supply chains.

Keywords Humanitarian logistics · Sustainability · Environment · Carbon efficiency · Relief items · Carbon footprint · Life cycle assessment

P. Oberhofer (✉)
Institute for Transport and Logistics Management, WU Vienna, Welthandelsplatz 1, 1020 Vienna, Austria
e-mail: peter.oberhofer@wu.ac.at

E.E. Blanco · A.J. Craig
Center for Transportation & Logistics, MIT, 77 Massachusetts Avenue, E40-276, Cambridge, MA, USA
e-mail: e.blanco@mit.edu

A.J. Craig
e-mail: t.craig@mit.edu

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1 Introduction

Over the past few decades, sustainability has become a global issue. In humanitarian research, and particularly, in humanitarian logistics research, embedding sustainability in relief operations it is gaining importance as natural catastrophes are often amplified by human impact on the environment. Although humanitarian supply chains and operations are designed for speed and sustainability is of minor concern, environmentally-friendly behavior should be a long-term concern as it may ultimately affect more vulnerable regions.

The purpose of this paper is to evaluate the environmental efficiency of supply chains of main relief items, taking into account specific characteristics and difficulties of humanitarian logistics. We aim at illustrating how carbon efficiency along humanitarian supply chains can be measured, identifying the most harmful processes and propose implications to support environmental sustainability thinking in humanitarian logistics. We compare major and minor operations as well as proactive and reactive supply chains and aim at recommending areas for improvement. The analysis includes the evaluation of the environmental impact of various disposal scenarios of the relief items. Calculations of carbon efficiency are based on Life Cycle Assessment (LCA) methodologies using data of the French Red Cross from their response operations in the 2010 Haiti earthquake and floods in Mozambique and Reunion Island in 2011. We considered the environmental impact of the relief items from 'cradle to grave', including production, warehousing, transportation and disposal.

The remainder of this paper is structured as follows: Sect. 2 is a literature review of the research topic. Sections 3 and 4 present the methodological approach and the case studies. In Sect. 5 we analyze the data and show the environmental impact results. Finally, Sect. 6 discusses the findings and closes with concluding remarks.

2 Literature

Humanitarian aid comprises a mixed array of operations and covers both disaster relief and continuous support for developing regions (Kovács and Spens 2007). The term "disaster relief" is generally connected to foreign interventions following sudden catastrophes, such as natural disasters (floods, earthquakes, etc.) or man-made disasters (terrorist attacks or nuclear accidents) with the intention of supporting affected locals (Long and Wood 1995). In general, actions have to fulfill the principles of humanity, neutrality and impartiality to constitute a humanitarian operation (Tomasini and Van Wassenhove 2009).

A variety of institutions are involved in relief operations. The main actors are non-governmental organizations (NGOs), such as the Red Cross, which coordinate and 'operate' relief operations. Governmental organizations are mainly responsible for providing financial funds, while business organizations produce and sell relief items. Additionally, private donors, media and military are important players in relief operations (Kovács and Spens 2007).

Various authors define different numbers of (time) phases of relief management (Cottrill 2002; Lee and Zbinden 2003); in general, they can be summarized as a phase of preparation, an immediate response phase and reconstruction (Kovács and Spens 2007). A high degree of preparation is usually performed in areas with a high risk of catastrophes (e.g. Caribbean Sea). Here, evacuation plans are developed beforehand and items are often pre-positioned. In less developed countries, however, the magnitude of disaster consequences is amplified due to poor living conditions, infrastructure and construction (Kovács and Spens 2007; Thomas 2003). Where possible, many relief agencies have pre-purchasing agreements with suppliers for the most commonly needed items, such as drugs, sheetings or blankets. As speed is essential for humanitarian aid operations, lead time reduction needs to be further considered in contracts with these producers (Tomasini and Van Wassenhove 2009).

Being confronted with very specific conditions, humanitarian supply chains significantly differ from 'normal' business supply chains (Kovács and Spens 2007). Main characteristics of humanitarian supply chains can be summarized as follows: ambiguous objectives of different actors, limited resources (human, capital, infrastructure), high uncertainty, urgency and politicized environment (Tomasini and Van Wassenhove 2009). By contrast, most business supply chains usually deal with a determined set of partners and a more or less predictable demand (Kovács and Spens 2007; Tomasini and Van Wassenhove 2009). As most logistics departments track their goods, there is important data, covering various aspects from supplier-effectiveness, costs and speed of response to information management that can be analyzed for post-event learning (Thomas and Kopczak 2005).

Despite the fact that humanitarian supply chains are designed for speed and flexibility, and that environmental sustainability is of minor concern, environmentally-friendly behavior has to secure a certain standard of living in general, and in affected regions in particular, in the long run. Kovács and Spens (2011) identify sustainability—both in practice and in research—as a major gap in humanitarian logistics. Besides economic and social aspects, environmentally-friendly behavior is important as climate change remains one of the utmost challenges. Moreover, sustainable 'exit strategies' need to focus, among others, on reducing transportation emissions and avoiding of degradable materials for humanitarian products. Reverse logistics, for instance, is identified as an important topic that is yet to be researched (Kovács and Spens 2007).

A literature analysis revealed that humanitarian logistics has gained in importance as a subject of academic research over the past few years. Various topics are addressed, such as inventory management, vehicle fleet optimization, the identification of learning areas for business supply chains or analyses of trends and gaps (Kovács and Spens 2007, 2011; Pedraza-Martinez and Van Wassenhove 2012). Although authors have repeatedly called for more academic research on environmental sustainability in humanitarian logistics (Kovács and Spens 2011; Pedraza-Martinez and Van Wassenhove 2012), there is still very little research. Carbon efficiency of humanitarian supply chains, in particular, is a main research area lacking detailed empirical work.

3 Research Design and Methodological Approach

A case-based approach using multiple field studies to analyze the carbon efficiency of humanitarian supply chains was chosen. As there is little evidence of carbon footprinting calculation aiming at evaluating the product life cycle of relief items, this study is both exploratory and explanatory in its nature. The case study approach is common in purchasing and supply management research (Dubois and Araujo 2007).

'Carbon Footprinting' is one of the most widely dimensions measured when addressing environmental sustainability. A widespread definition was offered by Wiedman and Minx (2008) stating: "The Carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product." (Wiedmann and Minx 2008). Besides environmental impact quantification, Carbon Footprinting enables emission management and evaluation of mitigation measures (Carbon Trust 2012).

In order to measure the carbon footprint of a product from 'cradle-to-grave' a Life Cycle Assessment (LCA) was performed. "The assessment includes the entire life cycle of the product, process or activity economic passing extractions and processing of raw materials, manufacturing, transportation and distribution, use/re-use/maintenance, recycling and final disposal" (Society of Environmental Toxicology and Chemistry (SETAC) 1990). LCA methods go beyond most carbon footprint calculations. For transportation, not just direct emission from fuel combustion, but also indirect emissions (e.g. emissions related to the upstream production of the fuel, vehicle production and disposal, etc.) are included. LCAs are very data-intensive, and the data often defines the success of the Assessment (Curran 1996). Following the guideline of the European Environmental Agency (1997), we conducted the LCA study in four major steps: (1) Goal and scope definition, (2) Detailed life cycle inventory (LCI), (3) An assessment of the potential impacts (4) Result Interpretation.

Based on data from the French Red Cross on three disaster relief operations, our goal was to calculate the CO_2 emissions of three commonly used relief items from 'cradle to grave' including production, transportation, warehousing and end-of-life waste disposal.

4 Case Study: Carbon Efficiency of Humanitarian Supply Chains (French Red Cross)

The Red Cross subdivides items according to the Emergency Response Units (ERU), differentiating between Logistics, IT & Telecommunication, Water & Sanitation, Medical Help, Relief and Base Camp IFRC (2013a). The focus of our analysis is on three relief items for personal use or housing (IFRC 2013b):

- Item No. 1 is a woven blanket (100 % cotton, 1.2 × 1.8 m, light, weight: 250 g/m^2) that is packed in triple corrugation cardboard boxes (H: 0.5 × W: 0.4 × L: 0.6 m) for shipping.
- Item No. 2 is a woven plastic sheeting (4 × 60 m, weight: 198 g/m^2) consisting of high-density polyethylene (HDPE) with low-density polyethylene (LDPE) coating on both sides. The tarpaulins are wrapped as cubic bales (dimensions: ca. 800 mm × 600 mm × 150 mm) for shipping.
- The jerrycan (item No. 3, foldable, 10 L, weight: 0.14 kg) is blow-molded and made of low-density polyethylene plastic (LDPE) including an injection molded screw cap. It is packed in a plastic bag (polyethylene, 5 g) for shipping.

According to the French Red Cross, the selected three items provide a good insight into their relief operations.

The carbon footprints were measured in CO_2-equivalents (referred to as CO_2e throughout this paper). CO_2e is the amount of CO_2 that would cause the same time-integrated warming influence (radiative forcing), over a given time horizon, as an emitted amount of a long-lived greenhouse gas (GHG) (e.g. methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), etc.) or a mixture of GHGs (IPCC 2007) and has broadly been accepted as a reporting unit (Carbon Trust 2012). The emissions were calculated by using the SimaPro software tool (PRé 2013) based on information about sizes and weight of item materials, packaging, involved production processes, transportation mode and warehouse location. To calculate emissions SimaPro uses default data of emissions from raw material extraction, manufacturing, transportation, energy and disposal default data from Ecoinvent, a leading supplier of life cycle inventory data of renowned quality offering science-based, industrial, international LCA data and services (Ecoinvent 2013). For each emission generating activity data was collected regarding the amount of emissions generated and the quantity of relief items involved in the activity. In this manner the emissions can be allocated to the items and processes in order to determine the carbon footprint of the respective items produced, stored, transported and disposed. The final emission factors were calculated on the basis of one individual item including packaging proportionally.

For data that was not directly available from the French Red Cross, estimates were made from secondary data sources. Emissions from warehousing are caused by consumption of fuel oil, natural gas and electricity. Based on information from the U.S. Energy Information Administration (2003), which provides average values based on used space (m^3), we calculated the emissions according to the metrics of the shipped item units and the duration of storage. Depending on the location of the warehouse, the emission factors from energy consumption were adopted according to information from Greenhouse Gas Protocol (WRI 2012), and the French Environment and Energy Management Agency (ADEME), as energy mixes can vary significantly from country to country. Emission calculation for transportation was based on the weight of the shipments, the distance from origin to destination and the main transportation modes used. For disposal, we differentiated between recycling, landfill and incineration. Emissions were calculated using information from SimaPro and the U.K. Department for Environmental, Food and Rural Affairs (2012).

Data from the French Red Cross included detailed information about relief operations of a ‘major’ crisis caused by the earthquake in Haiti (HT) in 2010, and two ‘minor’ crises, caused by floods in Mozambique (MZ) and Reunion Island (RE) in 2011. For the selected relief items, it specifies the quantity of sent items, the location (city) of production and warehouses for temporary storage, main transportation modes used, last mile distances as well as disposal options used. A total of 25,083 items (6,630 blankets, 3,993 pieces of plastic sheeting and 14,460 jerrycans) are included in the analyses of the Haitian operation, and 10,250 (2,010 blankets, 2,100 pieces of plastic sheeting and 6,140 jerrycans) in the analysis for the minor operations in Mozambique and Reunion Island. The selected items are mainly produced in Turkey, Pakistan or China on a ‘make-to-order’ scheme. Depending on time pressure and the availability of pre-positioned relief items, the goods are transported either by ship or plane from various distribution warehouses. Last miles are covered by trucking.

For the Haitian case, the operation can be divided into three phases (similar for all major crises). In the first phase (from outbreak of crisis up to two months) the initial shipments are sent from the different pre-positioned stocks nearby the intervention zone owned by the French Red Cross (e.g. Guadeloupe). The pre-positioning strategy allows cutting intervention timelines, costs (transport via sea vs. air) and emissions (as a side effect). The supply chain can be considered as proactive in this phase. Besides, air shipments from Paris quicken the French Red Cross support, as its main concern is that of minimizing response time whereas costs or emissions are not considered. Planes (mostly Iliouchines, capacity: 100 t) are chartered and loaded at full capacity; however, back hauls are mainly empty. In the second phase (from 2 to 4 months) the supply chain evolves from proactive to reactive due to stock shortage at different levels (manufacturers, distributors). To cut response time, items at different stages in the supply chain need to be transported mainly by plane. Additionally, different sourcing solutions need to be introduced. Due to the stock-out situation of preferred suppliers in Turkey and Pakistan, items are mainly obtained from China. In a third phase, a parallel supply chain with larger volume and longer lead times is introduced, thus allowing sea transport. It is still reactive but optimized in terms of costs (and emissions). Besides, (continuous) air transportation is used to balance out missing items.

Operations for minor crises can mainly be covered by pre-positioned stocks on sea transport. If necessary, air transportation supports the operation. In general, suppliers are able to provide products on a normal scheme.

5 Results

The totality of all items included resulted in emissions of about 2,380 t CO_2e. Which is equivalent to annual emissions of 469 passenger cars (U.S.) or 61,370 trees to sequester the emissions (U.S. Environmental Protection Agency 2013). Accounting for 56 % of all emissions, transportation has the by far strongest impact, followed by item production (39 %). In all analyzed operations, 'no action' to dispose of the used relief items was assumed, resulting in emissions of 41,100 kg CO_2e (2 %), while warehousing accounted for 59,600 kg CO_2e (3 %).

5.1 Analysis "Major Versus Minor Operations"

25,083 items were included in the analysis of the relief operation in Haiti (major crisis), out of which a total of 1,974 t CO_2e was emitted (equivalent for annual emissions of 389 passenger cars (U.S.) or 50,900 trees to sequester the emissions). Of those, 65 % can be assigned to transportation, 32 % to item production, 2 % to warehousing and 1 % to disposal. On average, one item resulted in 79 kg CO_2e and the share of emergency shipments in our case study was 54 %.

10,250 items were included in the analysis of the minor operations (Mozambique and Reunion Island), which resulted in a total of 388,500 kg CO_2e (equivalent for annual emissions of 77 passenger cars (U.S.) or 10,000 trees to sequester the emissions). Here, item production (310,500 kg CO_2e) accounted for 80 % of the emissions, while 16 % of the emissions were due to transportation, 1 % to warehousing and 4 % to disposal. On average, one item resulted in 38 kg CO_2e. The share of emergency shipments was 38 %.

5.2 Analysis by Item, Strategy and Type of Crisis

By focusing on selected supply chains of the three items separately, we aim at analyzing emissions within the logistics operation in detail. We differentiate again between major (Haiti, HT) and minor operations (Mozambique, MZ/Reunion Island, RE) as well as pre-positioned stock and emergency shipment.

Looking at the example of a blanket within the Haiti operation, significant results can be observed (Table 1). While item production causes 85 % of the emissions in the pre-positioning strategy, it accounts for only 12 % in the reactive supply chains. This is due to the enormous emissions from transportation in reactive supply chains (87 %) which rise up to 102 kg CO_2e for a blanket on average. Emissions from warehousing, however, are higher in the pre-positioning strategy, its share generally being very low.

Table 1 Emissions caused by a blanket

Blanket											
		Strategy	Item production		Transport		Warehousing		Disposal		
			kg CO_2-eq.	%	kg CO_2-eq.	%	kg CO_2-eq.	%	kg CO_2-eq.	%	Total
Major	HT	Pre-positioned stock	13.15	85	1.4	9	0.5	3	0.46	3	15.5
	HT	Pre-positioned stock	13.15	85	1.6	10	0.3	2	0.46	3	15.4
	HT	Pre-positioned stock	13.15	85	1.6	10	0.3	2	0.46	3	15.5
		Mean	*13.1*	*85*	*1.5*	*10*	*0.3*	*2*	*0.5*	*3*	*15.5*
	HT	Emergency shipment	13.15	15	74.1	84	0.1	0.1	0.46	1	87.8
	HT	Emergency shipment	13.15	9	130.7	91	0.0	0.0	0.46	0	144.3
		Mean	*13.1*	*12*	*102.4*	*87*	*0.1*	*0*	*0.5*	*0*	*116.1*
Minor	MZ	Pre-positioned stock	13.15	89	1.0	7	0.2	2	0.46	3	14.8

Jerrycans cause relatively high emissions from warehousing in prepositioning strategies (66 % of emissions). Emissions from production, transportation and disposal are rather low. Again, an increase in transportation emissions can be observed in reactive supply chains.

Compared to blankets and jerrycans, the high emissions caused by plastic sheeting stem from production and disposal (Table 2) resulting in the highest average of total emissions per item among the three analyzed items (134 kg CO_2e). This is mainly due to its composites (HDPE and LDPE), which are relatively emission-intensive in production and disposal (6 kg CO_2e). As could be observed for a blanket, production accounts for the majority of emissions in pre-positioning strategies (88–90 %), while emissions from transportation makes up 77 % in reactive supply chains.

In order to highlight the impact of the strategy applied, the following figure should illustrate differences in emissions between pre-positioned stock and emergency shipment, taking the example of a piece of plastic sheeting in the Haitian case (Fig. 1).

Emissions per item from emergency shipment rise up to 624 kg CO_2e while pre-positioning an item causes only 152 CO_2e. Particularly emissions from transportation increase significantly in emergency shipments compared to the use of pre-positioned stock (mainly due to air transportation). Main findings are similar for major and minor operations. In general, minor operation can mainly be covered by pre-positioned stock, explaining lower average emissions when comparing “major vs. minor operations”.

5.3 Analysis of Emissions from Disposal and Evaluation of Scenarios

Generally, items are left with the locals beyond the time of the agencies’ active relief operations. However, serious environmental impacts are connected to the end-of-life cycle of the items as many affected countries lack facilities to handle used items. For all analyzed operations ‘no action’ (landfilling) for item disposal was selected resulting in total emissions of 41,100 kg CO_2e Disposing of plastic sheeting (with ‘no action’) are most harmful with 6 kg CO_2e per item, while a blanket causes disposal emissions of 0.5 CO_2e and a jerrycan 0.02 CO_2e. In the following we evaluate the following scenarios: (1) recycling in response area (provision of facilities necessary), (2) transportation of items to Europe (Paris) and recycling ‘at home’, (3) incineration in response area.

Recycling all items properly would cause emissions of 7,000 CO_2e, equaling a reduction of 83 %. However, this would require proper facilities in the response areas which are rarely existent. Building these facilities would result in high costs for donors and expenses for educating locals. Back hauls of used items to countries which provide adequate recycling facilities would be a second option. A fictitious

Table 2 Emissions caused by a piece of plastic sheeting

Plastic sheeting											
		Strategy	Item production		Transport		Warehousing		Disposal		Total
			kg CO_2-eq.	%	kg CO_2-eq.	%	kg CO_2-eq.	%	kg CO_2-eq.	%	
Major	HT	Pre-positioned stock	134.0	88	6.5	4	5.7	4	6.04	4	152.2
	HT	Pre-positioned stock	134.0	88	6.5	4	5.8	4	6.04	4	152.3
	HT	Pre-positioned stock	134.0	88	6.5	4	5.9	4	6.04	4	152.4
		Mean	*134.0*	*88*	*6.5*	*4*	*5.8*	*4*	*6.0*	*4*	*152.3*
	HT	Emergency shipment	134.0	21	482.8	77	0.9	0	6.04	1	623.8
Minor	MZ	Pre-positioned stock	134.0	90	5.0	3	4.5	3	6.04	4	149.5
	MZ	Pre-positioned stock	134.0	90	5.0	3	4.5	3	6.04	4	149.5
		Mean	*134.0*	*90*	*5.0*	*3*	*4.5*	*3*	*6.0*	*4*	*149.5*
	MZ	Emergency shipment	134.0	23	449.4	76	1.5	0	6.04	1	590.9

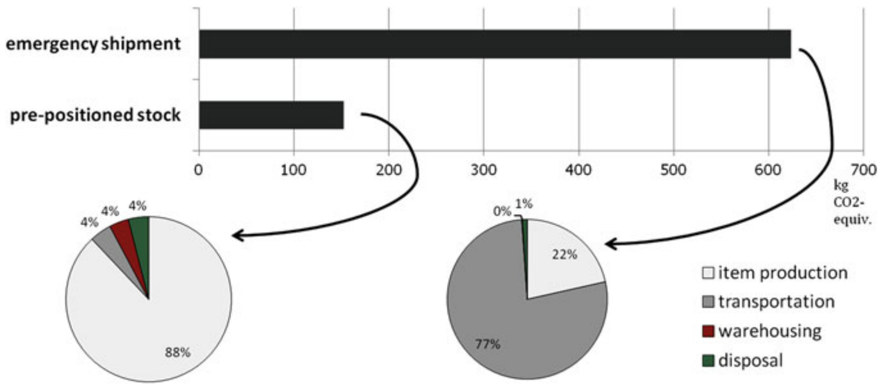

Fig. 1 Emissions from emergency shipment and pre-positioned stock of a piece of plastic sheeting in the Haitian operation

scenario in which all items would be transported back to Paris via ocean transport as main transportation mode and by recycled there would result in total emissions of 42,500 kg CO_2e Although this scenario almost equals the amount of emissions from 'no action' (41,100 kg CO_2e) it could improve the overall situation when using free ocean transportation capacity from non-balanced trade flows. If capacities allow only a part of the items to be hauled back, carbon-intensive items, such as plastic sheeting, should be prioritized. Nevertheless, costs and organizational expenses would increase in such a scenario. Eventually, incineration would result in emissions of 996,100 kg CO_2e (increase of 2,400 % compared to status quo). This option should strictly be avoided and it is therefore necessary to communicate proper handling of used items to both locals and aid staff.

6 Conclusions

In this paper, we analyzed the carbon efficiency of selected humanitarian supply chains of main relief items by performing life cycle assessment and calculating the carbon footprint of three main relief items based on data from French Red Cross relief operations of 2010 and 2011. Looking at the total emissions, transportation is responsible for a majority of the emissions in the analyzed humanitarian supply chains. However, due to its central significance and high importance, it is unreasonable and impossible to "cut" transportation as speed within the supply chain is most vital to save lives. Nevertheless, we found that a well-organized network is capable of reducing the impact on the environment as well as the risk of man-made amplification of future catastrophes. Particularly, pre-positioning items at strategic locations proofed to be a key element in saving CO_2 emissions in our analysis as these pro-active supply chains reduce the enormous emissions from air transportation. This would go hand in hand with cost reduction as expensive air transportation could be saved. Consequently, from both an environmental and a strategic economic perspective a focus should be on efficient distribution of pre-positioned stock of relief items as this will save both time, emissions and costs.

Besides, item production accounted for a large amount of emissions in our analysis. In "pre-positioned" supply chains production processes of all three items clearly made up the major part of the emissions. Innovative methods and new technology to improve environmental performance of manufacturers and suppliers can improve the carbon efficiency of supply chains. Humanitarian aid operations should use their "buyer power" to encourage better environmental management on manufacturers or include environmental requirements in tender offers. Another option could lie in the acquisition of certain international certification (e.g. ISO/ EMAS) as a prerequisite for being able to participate in Red Cross tender offers.

Finally, we demonstrated how alternative disposal scenarios reduce carbon emissions and support the sustainable redevelopment of the affected regions in the long run. Although having relatively little impact—compared to transportation and warehousing—improving waste management needs to be an area of focus by relief organizations. Firstly, there is a general lack of action in terms of waste management, and therefore there is high potential for improvement. Moreover, improving item disposal influences affected areas positively and directly without negatively influencing speed or effectiveness of supply chains and can directly be performed by relief organizations. The following strategies need to be evaluated: Investment in (portable) facilities as well as the construction of recycling facilities at the respective locations should be considered from an economic perspective as it certainly pays off in the long run. Besides, a focus should be on the coordination of logistic flows to enable back-hauling used items to countries with adequate recycling facilities for. Here, empty miles from unbalanced transportation routes could be used. Incineration should be avoided from a GHG perspective.

Donors (mostly governments) demand direct results of operations (e.g. number of people reached by healthcare programs or hygiene promotion activities, number of households provided with shelter, number of established water and sanitation facilities). Initiatives to reduce emissions, however, have (only) indirect impacts which are hard to calculate. Nevertheless, they are capable of reducing the carbon footprint of supply chains both globally and locally in affected areas in particular, and therefore might prevent the amplification of natural catastrophes and support a sustainable redevelopment of damaged areas.

This paper therefore aims at raising awareness for environmental sustainability of humanitarian operations and proposes implications for various players: On the one hand, the results provide support for decision makers who coordinate logistic flows in humanitarian aid operations (e.g. sustainability aspects could be integrated into decision support systems). On the other hand, we point out that awareness for environmental aspects of humanitarian aid operations should be raised and that education is needed. This should focus on (1) locals by educating them on how to minimize negative environmental impact and how to handle used items correctly to support a sustainable reconstruction of “their” environment (e.g. collecting and avoiding of incineration for specific items), (2) relief agencies who can reduce emissions of various (logistics) processes through strategic planning (e.g. pre-positioned stock) in tandem with increasing speed and efficiency of supply chains and (3) donors who provide funds and, so far, have regarded environmental sustainability as a minor aspect of humanitarian aid due to a lack of direct results.

Although effort was put on high quality and reliability of calculations and research, some research limitations have to be acknowledged. Due to the limited numbers of cases and data from one organization (French Red Cross), the research might lack external validity. Moreover, we only focused on three specific (main) relief items with long life-cycles, so results for other items—particularly for items which need special treatment such as cooling or have shorter life-cycles (e.g. medical goods or nutrition)—may deviate. This could be analyzed and compared in further research. Due to missing information some assumptions for the LCA calculation had to be made. Drayage on the road for transportation processes from manufacturers to warehouses or between various warehouses was not taken into consideration—this aspect was only considered for last mile transportation at the response area. Missing information on energy mixes for some countries (e.g. Guadeloupe) was adapted. Finally, emission factors used were generally based on default data (Ecoinvent) which can cause deviation.

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Return Management for Remanufacturing

A Review of Quantitative Models in Reverse Logistics and Their Assumptions Regarding Product Returns

Carolin Witek

Abstract Production systems which include remanufacturing induce complex planning problems for manufacturers. One major challenge is correctly forecasting the date when used products will return, how many used products will return, and in which condition the returned products will be. Based on a review of current literature, this paper aims to identify gaps in academic research regarding the modeling of product returns for remanufacturing. It will focus on quantitative models, in which the quantity of returned products is either a decision variable (DV) or directly depends on other decision variables, such acquisition prices, i.e., the quantity of products returned can be influenced by decision makers. Subsequently, we will propose a new approach to incorporate consumers into Closed Loop Supply Chains (CLSC), in order to more precisely forecast product returns. The proposed voucher system, a time-dependent buy-back-offer on the part of the Original Equipment Manufacturer (OEM), is designed to influence consumers' return behavior. Finally, using game theory for quantitative modeling, this approach will permit a closer examination of the problems regarding dynamic production planning with remanufacturing options.

1 Introduction

In order to contend with society's rising environmental consciousness and increasing legal regulations regarding extended producer responsibilities, companies have to search for new ways to deal with their products as these near their end-of-life. Remanufacturing is the recovery process which is defined as the total disassembly of products, the cleaning and testing of reusable parts, as well as the repair of defective parts. Items, which are as good as new and can be used, e.g., in new product line assemblies, are the result of this process (Ijomah et al. 2007). Especially with durable

C. Witek (✉)
Lehrstuhl für BWL, Insb. Industrielles Management, Fakultät Wirtschaftswissenschaften, 01062 Dresden, Germany
e-mail: Carolin.Witek@tu-dresden.de

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goods, remanufacturing can be a profitable recovery option (Thierry et al. 1995). A common assumption is that remanufacturing costs are less expensive than manufacturing products from raw materials (see, e.g., Mukhopadhyay and Ma 2009). Considering production systems with remanufacturing options, both Original Equipment Manufacturers (OEMs) and third party remanufacturers (3Ps) face numerous of complex planning problems (Guide Jr and Jayaraman 2000), for example, underscore the difficulties associated with the disassembly, the balance between demand and returns, and the requirements of reverse logistics networks. Yet, the primary challenges remain the forecasting of when used products will return, how many of these products will return, and what the quality of the returned items will be. The worse the quality of the returned products, the higher the remanufacturing costs will be. In this case, other recovery options may have to be considered. For this reason, an active return management, which ensures the right amount of returns, at the right time, and in the right condition, should play a primary role in the planning of remanufacturing processes.

This paper will begin with an analysis of current research literature regarding remanufacturing. More specifically, it will focus on quantitative models in CLSCs with remanufacturing options and the assumptions in these models concerning product returns. Thereafter, we will propose a new approach to modelling product returns, which incorporates consumers as active agents in CLSCs. The aim of this approach is to encourage consumers to return products in a predictable time-frame, quantity and quality for an OEM with remanufacturing options. This allows the OEM—in combination with game theory methods—to perform simultaneous production planning of both new and remanufactured products in CLSCs (see Pescht and Buscher 2011).

2 Literature Review

This section will examine academic research articles in the field of remanufacturing. An important question here is how product returns are incorporated and modelled in quantitative models with regard to remanufacturing options. Additionally, the current section will provide the literature search process, as well as an overview of related reviews. Finally, it will present a detailed analysis of the reviewed papers, with emphasis on their assumptions regarding product returns, the specific focus of their research, optimization target and process ownership.

2.1 Related Literature Reviews

A direct result of the large increase in research done in recent decades on CLSCs and product recovery is a substantial spike in the number of literature reviews published in the last two years in the area of remanufacturing. This subsection will present an overview of current review papers and their main findings. In addition, we will underscore the differences between these findings and our work.

Akcali and Cetinkaya (2011) analyze about 120 research papers with regard to inventory problems and production planning of CLSCs. They first classify the models into deterministic and stochastic models and subsequently focus on inventory and production control policies. In contrast to our review, Akcali and Cetinkaya (2011) do not limit their survey to remanufacturing, but instead include related research disciplines noted above. As a result, one of their main findings calls for taking more practical aspects into account, such as more realistic cost structures, improved exposition of the interactions between new and remanufactured products, or dependencies between demand and returns. Another work closely related to ours is the literature review and analysis by Junior and Filho (2012). This review provides an answer to the question, how much research was done between 2000 and 2009 on the subject of major challenges in remanufacturing based on Guide Jr (2000). The majority of the 86 papers analysed consider problems in inventory management, and focus on the uncertainty of the timing and quantity of returns, as well as the need to balance returns with demand. In addition to production planning and control activities, they classify the papers according to major complication issues, the subsystems of processes, and the types of research. One of the most recent survey papers on remanufacturing issues is Krikke et al. (2013). Based on a literature review, the authors derive ten key propositions for return management in forward and CLSCs. Subsequently, they run a global web survey (ca. 3,500 questionaries sent out, 250 returned) to support or confute their suppositions. One interesting find is that only 25 % of products sold come back as end-of-life products (EOLs) to OEM supply chain agents, and even less as end-of-use products (EOUs). EOLs are products whose life cycle is close to its end, thus their technology is so obsolete that there is practically no market for remanufactured products (Guide Jr and van Wassenhove 2009). EOUs are products which have no remaining value to their owners, but which are still functional and contain relatively up-to-date technology. Another interesting statistic from this survey is that 45 % of EOLs and EOUs are driven by legal regulations and economic viability. Summing up, they found that the main assumptions in research literature correspond with practical experience.

In contrast to the reviews above, this paper will analyse how returns are incorporated in quantitative models with remanufacturing processes. In the majority of the models examined, specific kinds of products are not mentioned, but rather product branches such as telecommunications or consumer electronics. Additionally, this paper will focus on the dual role of the consumer in CLSCs. In CLSC, the consumer not only demands products, but also supplies used products for recovery processes.

2.2 Method

Academic research papers were found by searching in data bases (licensed by SLUB Dresden) including SciVerse ScienceDirect (SV), as well as Academic Search Complete, Business Source Complete and EconLit with Fulltext (all via

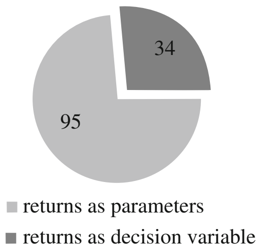


Fig. 1 Returns in quantitative models (n = 126)

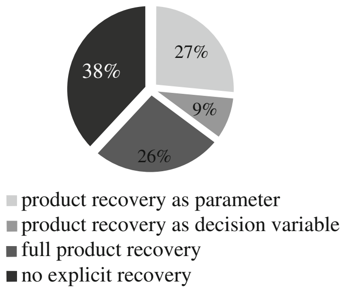


Fig. 2 Product recovery (returns are DV) (n = 34)

EBSCO Host). The first search term was "remanufacturing" (Results: SV: 1664, EBSCO: 1693). Due to the vast number of results, the search was limited with the search terms "product return" and "closed loop supply chain" (Results: SV: 386, EBSCO: 15). Furthermore, only papers with quantitative models were considered, which explicitly treat remanufactured products as the result of recovery processes. Papers which focus on refurbished or recycled products are not included in this review. Having established this as base, a further search was done by examining the references in reviewed papers.

In total 126 research papers from academic journal were found to be reviewed regarding their assumptions about product return modelling (Fig. 1). About three quarters of them assume, that product returns are known (parameters) or can be easily derived from other set parameters. This review is restricted to models in which returns are defined as decision variables (n = 34). Because remanufacturing research is not a niche research field, not all papers could be considered for this undertaking. Yet, despite these limitations, we are confident that this review provides a representative, up-to-date general survey of the current research on remanufacturing issues with returns as decision variables (Fig. 2).

2.3 Data Analysis

We begin of our analysis by briefly mentioning a few basic statistics. Figure 3 shows which journals have published the most research papers on the subject of remanufacturing options. Quantitative-leaning journals like *The International*

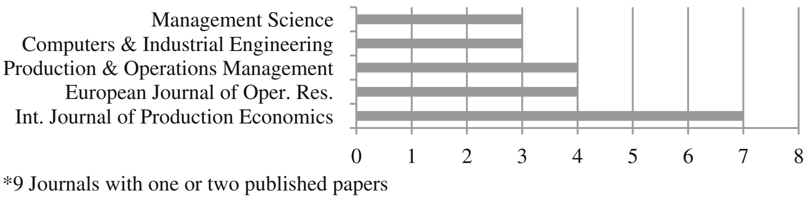


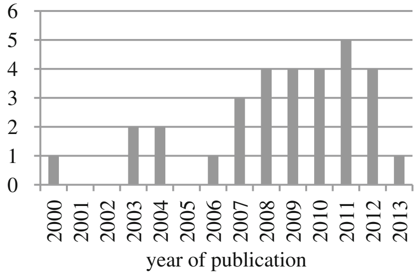
Fig. 3 Quantity of publications per academic journal

Journal of Production Economics as well as the *European Journal of Operational Research* published the majority of papers analyzed here. Because of two special issues on remanufacturing published in 2006, *Productions and Operations Management* is ranked third.

Research on remanufacturing in the European Union was brought into focus with the Europe-wide research project REVLOG (1997–2002) about Reverse Logistics. At the beginning of the century (esp. in 2001) numerous papers were published in the areas of inventory as well as production planning and control (typical authors: Van der Laan, Teunter, Inderfurth, Richter). However, these papers all deal with returns as given parameters (deterministic or stochastic). Research on active return management, i.e., where returns are decision variables, began about 10 years ago. This development is readily identifiable in the increase of publications since 2006, which explicitly search for optimal return quantities or flows (Fig. 4). The majority of this research with returns as decision variables focuses on production planning of new and remanufactured products, the pricing of these products, as well as on network optimization (Fig. 5).

Lastly, statistical properties are examined regarding the ownership of remanufacturing processes. 23 papers treat a single manufacturer, who is able to produce both new and remanufactured products. We denote such process owners as OEMs, since in practice this is usually an OEM. 3Ps indicate pure remanufacturing companies, which are discussed in 12 papers (3 in collaboration/competition with OEMs). Quantitative models with remanufacturing, which regard returns as

Fig. 4 Publications per year (n = 34)



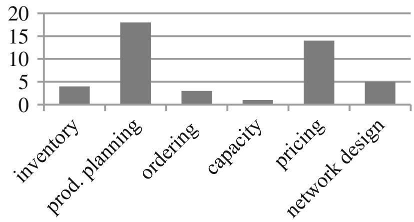


Fig. 5 Quantity per research focus (n = 34)

parameters usually aim for cost minimization. However, if returns are considered as decision variables, a proactive return management is set in place. Thus, 24 papers aim for profit maximization based on optimal return and remanufacturing decisions.

2.4 Assumptions Regarding Product Returns in Quantitative Models with Remanufacturing

In this section we examine the assumptions concerning product returns according to several impact factors. Table 1 includes all papers reviewed and incorporates product returns as decision variables as well as their assumptions related to returns and other classification characteristics listed above. First, a preliminary analysis designates the models as either “Stochastic” (or deterministic) and “Dynamic” (or static). Models which are denoted as stochastic work with uncertain parameters and/or decision variables. In dynamic models, these parameters and/or decision variables change over time. It is important to point out, that all models reviewed thus far have been static ones. This highlights a significant gap in current academic research. It is also worth mentioning that whenever product returns are modeled as decision variables, financial incentives frequently play an important role (Table 1 “Incentives”). Half the papers reviewed assume that returns depend on some kind of incentives such as trade-in-rebates or buy-back-prices, which are offered by the process owners or collection centers. A typical structure of such problems is that return quantities and acquisition prices are determined by and for various quality classes. Generally, such models also assume an unrestricted supply of returns. Table 1 “Quality” and “Unlimited availability” shows which models assume quality dependency (e.g., quality classes or price-quality-functions), and which assume unrestricted supply of used products.

In order to examine the availability of potential returns, it is necessary to analyze the relation to sales resp. demand, too. In Fig. 6 the “Demand” row illustrates if there is a relationship between demand and returns, which is often modelled as restriction of return quantity on sales in former periods or by quotas from current demand. Furthermore, in contrast to given external return parameters, where additional assumptions regarding recovery quantities are often made (e.g., with

Table 1 Research papers and characteristics

Author, Year	Assumed impact factors on product returns and model characteristics						Additional Assumption for recovery			Other impacts	Optimization target	Process owner	Research Focus
	Stochastic	Quality	Incentives	Demand	Unlimited available	Dynamic	Full recovery	Recovery as parameters	Recovery as decision variable				
Aras and Aksen (2008)			x								p	OEM	N
Bakal and Akcali (2006)			x								p	3P	P
Bayindir et al. (2003)				x	x						c	OEM	I
Chen and Chang (2012)											p	OEM,3P	L,P
Galbreth and Blackburn (2006)								x			c	3P	L
Galbreth and Blackburn (2010)		x		x	x			x			c	3P	L
Geyer et al. (2007)				x				x			p	OEM	L
Gu et al. (2008)			x								p	OEM	P,N
Guide Jr. et al. (2003)		x	x		x		x				p	3P	P
Hammond and Beullens (2007)			x					x			p	OEM	L,P
Hong and Yeh (2012)			x	x							p	OEM	P
Jaber and Saadany (2009)				x			x				c	OEM	L
Karakayali et al. (2007)		x	x								p	OEM	P
Kaya (2010)			x								p	OEM,3P	L
Klausner (2000)			x	x						x	p	OEM	P
Kleber et al. (2011)			x	x							p	OEM	I,L,P
Li et al. (2009)			x					x			p	3P	P
Lu and Bostel (2007)								x			c	OEM	N
Mukhopadhyay and Ma (2009)					x			x			p	OEM	L,O
Mutha and Pokharel (2009)					x			x			c	OEM	L,O
Nakashima et al. (2004)				x				x			c	3P	I

(continued)

Table 1 (continued)

Author, Year	Assumed impact factors on product returns and model characteristics						Additional Assumption for recovery			Other impacts	Optimization target	Process owner	Research Focus
	Stochastic	Quality	Incentives	Demand	Unlimited available	Dynamic	Full recovery	Recovery as parameters	Recovery as decision variable				
Ovchinnikov (2011)									x		p	OEM	L,P
Robotis et al. (2005)		x			x						p	3P	L,O
Robotis et al. (2012)				x			x				p	OEM	L
Rubio and Corominas (2008)				x					x		c	OEM	C
Saadany and Jaber (2010)		x	x	x							c	OEM	L
Savaskan et al. (2004)				x			x			x	p	3P	N
Savaskan and van Wassenhove (2006)							x			x	p	OEM	N
Shi et al. (2010)	x		x				x				p	OEM	I,L
Shi et al. (2011a)	x		x		x		x				p	OEM	L,P
Shi et al. (2011b)	x		x		x		x				p	OEM	L
Teunter and Flapper (2011)		x	x		x				x		c	OEM	L
Wei and Zhao (2013)			x								p	OEM	P
Wu (2012)					x		x				p	OEM,3P	P

Optimization target: *p* profit maximization, *c* cost minimazation
Process owner: *OEM* Original Equipment Manufacturer (able to produce new and remanufactured products), *3P* third party (produce only remanufactured products)
Research focus: *I* inventory, *L* lot sizing, production planning, scheduling, *O* ordering from ext. supplier, *C* capacity, *P* pricing, *N* network design

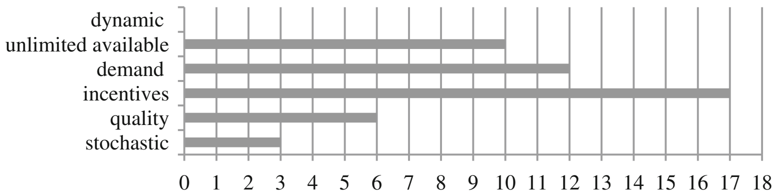


Fig. 6 Assumed impact factors on returns (in n = 34 publications)

disposal options), models with returns as decision variables usually assume either a full recovery, a specific recovery quota (often stochastic), or they do not make any further assumptions. Only three of the reviewed papers deal with separate product recovery decision variables (Rubio and Corominas 2008; Teunter and Flapper 2011; Ovchinnikov 2011).

As indicated, the review of current research literature reveals a number of gaps in the modelling of product returns with regard to remanufacturing issues. First of all, uncertainty in the quality of used products is not taken into consideration, unless different quality classes are assumed (often coupled with the unrestricted supply of each class). Secondly, the timing of returns is not considered, due to the fact, that these models are static. However in a more general review, we were able to find dynamic models with given returns for specific time periods. Thirdly, the consumer is rarely viewed as both the purchasor of new products as well as the supplier of used. Shi et al. (2010, 2011a, b) and Saadany and Jaber (2010), model return quantities as an inverse demand function of used products. Shi et al. (2010, 2011a, b) do not consider the quality of used products, in contrast to Saadany and Jaber (2010), who correlate price and return quantity with the quality of used products, where only used items with a better than defined quality level are accepted. Other products are disposed of immediately. The following approach to modelling product returns, with time dependent financial incentives, aims for a dynamic modelling, that will reduce both the uncertainty regarding the quality of used products, as well as the uncertainty in the timing of returns.

3 Incorporating Consumer in CLSCs (Vouchersystem)

Due to the gaps found above, a new approach in the modelling of product returns will be proposed in this section. As indicated above, the consumer is traditionally considered as a decision taker in (original forward) supply chains. This is in contrast to remanufacturing in CLSCs, where all agents should be regarded as active decision makers. Thus consumer behavior must be regarded in the same way like any other SC-agent behavior. In order to simplify things, we assume consumers to be rational thinking agents, whose aim is profit maximization, which can, for example, be expressed with utility functions based on consumer surplus. When consumers are viewed as passive agents, researchers often assume a given demand or demand functions. In this approach, consumer utility will be considered for a products entire use span. This includes consumer surplus from the point of purchase, as well as the remaining value left at the end of the useful product life.

Obsolete products often remain of value to consumers, be it as a secondary device, gifts for friends or family, or as stock for spare parts [for IT-equipment see a study of (Herrmann et al. 2008)]. Additionally, the majority of people simply do not know what to do with or how to dispose of used products. This leads to high transaction costs for the consumer. Thus, trying to convince consumers to return products at a predictable time, quantity and quality would seem to be an almost insurmountable task, considering that one must also deal with the remaining value of the product and transaction costs. However, if one regards consumer as a rational agent, financial incentives for returning used products become an option. Voucher systems appear at first glance to be an attractive realization of this concept, but only if they are as simple as possible. Several voucher systems have already been proposed in the literature. Hallmann and Jäger (2010), for example, propose a quality dependent voucher system, where a refund is offered at the point of replacement and linked with a good quality of the used product. Klausner (2000) investigates take back offers and observes the return of end of life products, which could not be remanufactured at all. Our proposal is a time-dependent buy-back-offer on the part of the OEM for customer with EOUs. The unique feature of this system is that consumers know at point of sale they can return the product after its useful life, and get back a guaranteed refund. Hence, the consumer has the opportunity to include this information in his or her buying decision and individual utility. In this system there is only one restriction, namely, the latest return date. This must be set by the OEM, based on, for example, to the typical useful life of a product.

Such a voucher system, with a guaranteed refund, has two main advantages. First of all, vouchers increase the usefulness of the product for consumer since they no longer have to think about what to do with used items. Vouchers linked to financial incentives can increase consumers' willingness to pay, and thus increasing demand (more in Pescht and Buscher 2011). Secondly, time-dependent vouchers emitted by OEMs (which is logically, because they are linked to new product sales), results in increased planning certainty regarding the timing, quantity and quality of returns. Thus, such vouchers function as a kind of mail-in-rebate. The time dependency also increases the likelihood that the vouchers will be redeemed. Marketing research has shown, that vouchers or coupons are often redeemed at the beginning or at the end of their validity (Inman and McAlister 1994). Because the validity of the voucher is correlated with the average useful life of the product and thus, the value of the product to the consumers is low, making the return of the EOU a more attractive option for consumers. This is intensified by the linked refund consumers receive for their used products. According to Davis et al. (1998), the likelihood of returning a product increases with the simplicity of the process. Hence the fewer the restrictions, the more consumers will be willing to return their used product. Thus, a second important characteristic of the program is the "no questions asked" policy. Finally, there is no need to buy a new product while returning the old one, although this can be used for demand predictions.

One possible drawback with this voucher system could be problems with the quality of the used products. However, because of the time dependency, products should on average be in a good condition. Of course, exceptions due occur as a result of heavy or unusual use, but for this reason OEMs normally develop their products for a longer life than the average useful time. It follows, that if the time validity is set according to the average useful life, the quality of the product should be sufficient for remanufacturing. For example, mobile phones are changed on average every 18 months (Franke et al. 2006). The OEM could set the validity for taking back the old phone at 24 months. This way, consumers will most likely have no remaining value left in their old phone, and will want to buy (or have already bought) a new one. However, the OEM could use the processors, batteries and touch screens for remanufacturing, since their condition is still acceptable.

4 Conclusions

Our literature review of quantitative models regarding product returns for remanufacturing revealed a number of gaps in current academic research. The subsequent analysis examined the lack of dynamic models in production planning and control with active return management.

The reason given in the most cases was the complex problem of forecasting product returns at the right time, in right amount and under adequate conditions for remanufacturing. In order to overcome these uncertainties, we proposed a new approach that creates incentives for consumers in order to increase their willingness to return end-of-use-products. This approach, combined with a game theoretical framework, provides a basis for modeling EOU product returns.

The major challenge with this approach is setting the buy-back-price and duration of the buy-back-offer. If the buy-back-price is too low, consumers remain unaffected and will frequently keep the product as a second device or sell it privately. If the duration of the coupon is too long, the quality of the returned EOU products may be too low. One possible method for setting suitable buy-back-prices would be to base them on comparable prices at Second Hand Markets (see e.g., Thomas 2003 or Anderson and Ginsburgh 1994). The combination of lower transaction costs due to the no-questions-asked-principle, in conjunction with prices based on Second-Hand-markets sales, should make it possible to overcome the private-sale-effect.

We conclude that due to the central role of CLSCs, consumers need to be incorporated into supply chains, and regarded as active agents for whom profit maximization is a key motivating factor. Pescht and Buscher (2011) propose a model which illustrates how this approach can be used to forecast product returns. In a simplified scenario, they describe a two-person game with a vertical supply chain, where a monopolistic OEM and consumers act as rational players. Taking into consideration the behavior and motivation of the other player, the goal is to maximize profit. Among the manufacturing options for new products, the OEM can remanufacture returned products and sell them next to new products. However, for remanufacturing, the OEM needs adequate product returns. In order to forecast these returns, a holistic view at the planning horizon is required. After determining the Nash-equilibrium, optimal prices and quantities can be derived. With the assumption of full recovery, which is reasonable as a result of the time-dependent take-backs, return quantities based on given financial incentives can also be derived. By analyzing consumer behavior and incorporating consumers as active agents into closed loop supply chains, it is possible to manage product returns more precisely. A time dependent buy-back option and game theoretical modeling enables us to predict and overcome problems in dynamic production planning with remanufacturing options.

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A Manufacturer-Retailer Supply Chain with Fuzzy Consumer Demand

A Vertical Cooperative Advertising and Pricing Model

Gerhard Aust

Abstract In this paper, we apply fuzzy set theory to a single-manufacturer single-retailer supply chain, where both players try to determine their optimal pricing and advertising decisions. The interaction between manufacturer and retailer is analyzed by means of a Stackelberg game. Moreover, a vertical cooperative advertising program is considered, which represents a financial agreement where the manufacturer offers to share a certain fraction of his retailer's advertising expenditures. Even though this topic gained substantial interest in recent years' operations research literature and studies reveal that results strongly depend on demand parameters, most analyses are limited to deterministic model formulations. Here, fuzzy set theory has the advantage that it is not only able to incorporate the uncertainty of demand parameters into analysis. Furthermore, it enables us to take into consideration the experience of decision makers, which is often not expressed numerically, but rather in vague linguistic terms.

Keywords Game theory · Fuzzy set theory · Supply chain management · Vertical cooperative advertising · Pricing

1 Introduction

Vertical cooperative advertising programs are financial agreements between manufacturers and their retailers on the sharing of advertising expenditures (cf. Crimmins 1984). In most cases, this financial assistance is offered by manufacturers, who thereby intend to increase the retailers' advertising in order to generate sales (cf. Somers et al. 1990). Reasons for this form of cooperation can be manifold: Besides cheaper access to local media or better knowledge of local markets, mainly the different effects of manufacturer's and retailer's advertising are mentioned.

G. Aust (✉)
TU Dresden, Fakultät Wirtschaftswissenschaften, 01062 Dresden, Germany
e-mail: gerhard.aust@tu-dresden.de

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That means, manufacturers use their advertising campaigns primarily to build up brand image, while retailers' advertising aims on generating immediate sales (cf. Hutchins 1953; Young and Greyser 1983).

Therefore, vertical cooperative advertising programs are very common in practice. Empirical data clearly show an increasing trend, e.g., from \$15 billion which were spent for such programs in the United States of America in 2000 up to \$50 billion in 2008 (cf. He et al. 2012; Nagler 2006). However, Nagler's study reveals that manufacturers mostly set their participation rates to 50 % or 100 % instead of conducting an appropriate analysis on the optimum percentage.

This gap between importance and theoretical background in approaching cooperative advertising has motivated many researchers to study related questions, especially the determination of advertising expenditures and prices of the different echelons of a supply chain. Thereby, the findings of the different analyses reveal that results as optimal participation rate, prices, spending on advertising, or the profit split within the supply chain strongly depend on the underlying demand function as well as on the assumed parameters (see Aust and Buscher 2011).

However, as a result of uncertain consumer behavior, demand and advertising effectiveness parameters are often unknown in practice. Stochastic models based on probability distributions may be of avail in some cases, but they require extensive historical data, which is often not available to decision makers. At this point, the fuzzy set theory proposed by Zadeh (1965) may be a promising instrument, as it is able to incorporate the experience of decision makers, which is usually expressed in linguistic terms like *low*, *medium*, or *high* price sensitivity. Hence, our scope is to propose how fuzzy set theory can be applied to vertical cooperative advertising models.

The remainder of this article is organized as follows: In Sect. 2, we first introduce some basic concepts of fuzzy set theory. In the next section, we develop a mathematical model of a single-manufacturer single-retailer supply chain with fuzzy demand and advertising effectiveness parameters (3.1) and apply a Manufacturer Stackelberg game to that model (3.2). As a result, we derive closed-form solutions for the players' prices, advertising expenditures, and profits, which are further analyzed in Sect. 4. The paper is concluded with a short summary of the main findings and some open topics for future research.

2 Fuzzy Set Theory

In this work, we will only give a brief introduction into fuzzy set theory and calculation rules for fuzzy variables which are necessary for the following analysis. For a more formal introduction and the relevant definitions and axioms, we refer the reader to Zadeh (1965) and Nahmias (1978), or to the comprehensive books of Liu (2009, 2013). A more summarized but still formal discussion can be found in Zhou et al. (2008).

Let ζ and η be two independent and nonnegative fuzzy variables, $f(\cdot)$ a function, $\mathrm{Pos}(\cdot)$ a possibility measure of a certain event, and φ a possibility value with $0 < \varphi \le 1$. According to Liu (2009), we can define the φ-pessimistic value ζ_φ^L and the φ-optimistic value ζ_φ^U of fuzzy variable ζ as follows:

$$\zeta_\varphi^L = \inf\{r|\ \mathrm{Pos}\{\zeta \le r\} \ge \varphi\} \text{ and } \zeta_\varphi^U = \sup\{r|\ \mathrm{Pos}\{\zeta \ge r\} \ge \varphi\}. \tag{1}$$

Hence, the φ-pessimistic value ζ_φ^L is the greatest lower bound that fuzzy variable ζ will reach with a possibility of φ, while the φ-optimistic value ζ_φ^U is the least upper bound that ζ will reach with a possibility of φ. ζ_φ^L and ζ_φ^U can now be used to calculate the expected value $E[\zeta]$ of ζ (cf. Liu and Liu 2003):

$$E[\zeta] = \frac{1}{2}\int_0^1 \left(\zeta_\varphi^L + \zeta_\varphi^U\right) \mathrm{d}\varphi. \tag{2}$$

Table 1 gives an overview of calculation rules for φ-optimistic and φ-pessimistic values as well as for related expected values, which will be used later on during calculus. Thereby, x and y denote normal real-valued numbers, which are also called *crisp numbers* within the context of fuzzy set theory (cf. Liu 2013).

After this consideration of general fuzzy variables, we turn our attention to triangular fuzzy variables, which are solely used in the following. These fuzzy variables are of the shape $\tilde{\zeta} = (x, y, z)$ and consist of three crisp numbers $x < y < z$. According to Eq. (1), the φ-pessimistic and φ-optimistic values of a triangular fuzzy variable are (cf. Zhao et al. 2012b):

$$\zeta_\varphi^L = y\varphi + x(1-\varphi) \text{ and } \zeta_\varphi^U = y\varphi + z(1-\varphi). \tag{3}$$

Table 1 Calculation rules for fuzzy variables

Operation	φ-pessimistic value	φ-optimistic value	Source
Scalar multiplication ($x > 0$)	$(x\zeta)_\varphi^L = x\zeta_\varphi^L$	$(x\zeta)_\varphi^U = x\zeta_\varphi^U$	Liu and Liu (2003)
Scalar multiplication ($x < 0$)	$(x\zeta)_\varphi^L = x\zeta_\varphi^U$	$(x\zeta)_\varphi^U = x\zeta_\varphi^L$	Liu and Liu (2003)
Addition	$(\zeta+\eta)_\varphi^L = \zeta_\varphi^L + \eta_\varphi^L$	$(\zeta+\eta)_\varphi^U = \zeta_\varphi^U + \eta_\varphi^U$	Liu and Liu (2003)
Multiplication	$(\zeta\cdot\eta)_\varphi^L = \zeta_\varphi^L \cdot \eta_\varphi^L$	$(\zeta\cdot\eta)_\varphi^U = \zeta_\varphi^U \cdot \eta_\varphi^U$	Zhao et al. (2006)
$f(\cdot)$ with $f'(\cdot) > 0$	$(f(\zeta))_\varphi^L = f(\zeta_\varphi^L)$	$(f(\zeta))_\varphi^U = f(\zeta_\varphi^U)$	Zhou et al. (2008)
$f(\cdot)$ with $f'(\cdot) < 0$	$(f(\zeta))_\varphi^L = f(\zeta_\varphi^U)$	$(f(\zeta))_\varphi^U = f(\zeta_\varphi^L)$	Zhou et al. (2008)
Expected value	$E[x\zeta + y\eta] = xE[\zeta] + yE[\eta]$		Liu and Liu (2003)

By means of Eq. (2), we can derive the following expression for the expected value of a triangular fuzzy variable:

$$E[\tilde{\zeta}] = \frac{x + 2y + z}{4}. \tag{4}$$

3 A Manufacturer-Retailer Supply Chain Model with Fuzzy Consumer Demand

The first mathematical model on cooperative advertising in a manufacturer-retailer supply chain was proposed by Berger (1972). In the following, many different extensions have been published, prevalently with game-theoretic analyses. We refer the reader to a recent review of Xie and Zhang (2011), where relevant articles are summarized. Although one can realize an increased interest in this field in recent years, there are only few stochastic approaches (see, e.g., Chen 2011; He et al. 2011; Tsao and Sheen 2012), while most authors consider deterministic models. However, to the best of our knowledge, no application of fuzzy set theory to a cooperative advertising model yet exists. Therefore, we take on a deterministic model formulation recently published by Aust and Buscher (2012), which is simplified in order to ensure mathematical tractability, and transform the parameters of the demand function as well as the advertising effectiveness into fuzzy parameters. Similar approaches of applying fuzzy set theory to supply chain models, which are not related to cooperative advertising, can be found in, e.g., Zhou et al. (2008), who consider fuzzy demand and manufacturing cost in a two-echelon pricing game. This model is further expanded to a manufacturer-duopoly (see Zhao et al. 2012b) or a retailer-duopoly (see Zhao et al. 2012a).

3.1 Model Formulation

We consider a single-manufacturer single-retailer supply chain, which is illustrated in Fig. 1. This supply chain sells one product to the customer market, which demands a quantity D of the product. For each unit, customers pay a retail price p to the retailer, who, for his part, pays a wholesale price w to the manufacturer. The consumer demand $D(p, a)$ depends both on the retail price p and on the retailer's advertising expenditures a. Please note that we do not consider manufacturer's advertising expenditures in order to simplify our analysis (see, e.g., Karray and Zaccour 2006; Yang et al. 2013; though, the distinction between manufacturer and retailer advertising is a common assumption, which can be found in, e.g., SeyedEsfahani et al. 2011; Xie and Wei 2009). However, the manufacturer has the possibility to participate in his retailer's advertising expenditures by means of a cooperative advertising program. Here, we assume that the manufacturer decides on a participation rate t, with $0 \leq t < 1$ (see Table 2 for a listing of symbols used in this article).

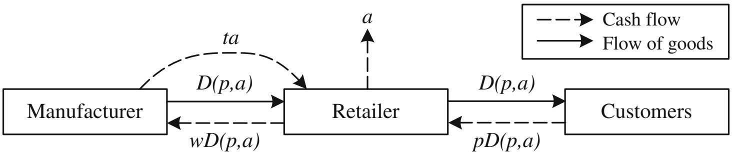

Fig. 1 Manufacturer-retailer supply chain

Table 2 List of symbols

Variables		Parameters	
m	Manufacturer's margin	$\tilde{\alpha}$	Base demand
w	Retailer's margin	$\tilde{\beta}$	Price sensitivity
a	Retailer's advertising expenditure	$\tilde{k}_r$	Advertising effectiveness
t	Advertising participation rate		
Π	Profit	$h(\cdot)$	Price demand function
D	Demand quantity	$g(\cdot)$	Advertising demand function

With respect to the cash flows in Fig. 1, we can set up the profit functions of the manufacturer (Π_m) and the retailer (Π_r):

$$\Pi_m = wD(p, a) - ta \tag{5}$$

$$\Pi_r = mD(p, a) - (1 - t)a. \tag{6}$$

Here, m denotes the retailer's margin, which can be calculated via $m = p - w$. As stated above, customer demand depends both on retail price p and advertising expenditures a. Thereby, one can distinguish a price-induced demand component $g(p)$ and an advertising-induced demand component $h(a)$. Following Kunter (2012) and Yan (2010), we assume a linear price demand function

$$g(p) = \tilde{\alpha} - \tilde{\beta}p, \tag{7}$$

where $\tilde{\alpha}$ and $\tilde{\beta}$ are fuzzy parameters. In detail, $\tilde{\alpha}$ describes the initial base demand, i.e., the customer demand which occurs for $p = 0$, while $\tilde{\beta}$ can be interpreted as customers' price sensitivity. In order to ensure a non-negative demand quantity, we set $\mathrm{Pos}(\{\tilde{\alpha} - \tilde{\beta}p < 0\}) = 0$.

Concerning advertising demand, we apply a square root function, which corresponds to the widely spread advertising saturation effect (see, e.g., Kim and Staelin 1999; Zhang and Xie 2012):

$$h(a) = \tilde{k}_r\sqrt{a}. \tag{8}$$

The fuzzy variable $\tilde{k}_r$ determines the effectiveness of advertising expenditures. We assume that advertising affects demand like a multiplicator (cf. Thompson and Teng 1984). With this multiplicative relationship between price and advertising demand, we can now formulate the extensive total demand function as well as the profit functions of both players:

$$D(p,a) = g(p)h(a) = (\tilde{\alpha} - \tilde{\beta}p)\tilde{k}_r\sqrt{a}, \tag{9}$$

$$\Pi_m(w,t) = w\left[\tilde{\alpha} - \tilde{\beta}(w+m)\right]\tilde{k}_r\sqrt{a} - ta \tag{10}$$

$$\Pi_r(m,a) = m\left[\tilde{\alpha} - \tilde{\beta}(w+m)\right]\tilde{k}_r\sqrt{a} - (1-t)a. \tag{11}$$

3.2 A Manufacturer Stackelberg Equilibrium

For our analysis of the supply chain interaction, we use a Stackelberg game, where the manufacturer obtains the channel leadership, while the retailer acts as a follower. That means the manufacturer has perfect knowledge of the retailer's reaction on his own decision and is therefore able to take this reaction into consideration when determining wholesale price and cooperative advertising participation rate. Mathematically, we first have to calculate the retailer's response functions by solving the following optimization problem:

$$\begin{aligned} \max_{m,a} \quad & E[\Pi_r(m,a)] \\ \text{s.t.} \quad & \text{Pos}(\{\tilde{\alpha} - \tilde{\beta}(w+m) < 0\}) = 0 \\ & m, a > 0. \end{aligned} \tag{12}$$

Please note that we assume that both players try to maximize their expected profits $E[\Pi_r]$ and $E[\Pi_m]$. Another possible objective could also be the φ-optimistic values $\Pi^U_{r\varphi}$ and $\Pi^U_{m\varphi}$, respectively, which can be seen as the maximum profits the players could realize with at least possibility φ. In contrast, the φ-pessimistic values $\Pi^L_{r\varphi}$ and $\Pi^L_{m\varphi}$, respectively, stand for the minimum profits the players could achieve with at least possibility φ (see Zhou et al. 2008). Therefore, we first have to determine the expected profit function of the retailer:

$$
\begin{aligned}
E[\Pi_\mathrm{r}] &= E\Big[m[\tilde{\alpha} - \tilde{\beta}(m+w)]\tilde{k}_\mathrm{r}\sqrt{a} - (1-t)a\Big] \\
&= \frac{1}{2}\int_0^1 \Bigg[\Big(m[\tilde{\alpha} - \tilde{\beta}(m+w)]\tilde{k}_\mathrm{r}\sqrt{a} - (1-t)a\Big)_\varphi^U \\
&\quad + \Big(m[\tilde{\alpha} - \tilde{\beta}(m+w)]\tilde{k}_\mathrm{r}\sqrt{a} - (1-t)a\Big)_\varphi^L\Bigg]\,\mathrm{d}\varphi \\
&= \frac{1}{2}\int_0^1 \Bigg[m\Big(\tilde{\alpha} - \tilde{\beta}(m+w)\Big)_\varphi^U \big(\tilde{k}_\mathrm{r}\sqrt{a}\big)_\varphi^U - (1-t)a \\
&\quad + m\Big(\tilde{\alpha} - \tilde{\beta}(m+w)\Big)_\varphi^L \big(\tilde{k}_\mathrm{r}\sqrt{a}\big)_\varphi^L - (1-t)a\Bigg]\,\mathrm{d}\varphi \\
&= \frac{m\sqrt{a}}{2}\int_0^1 \Big[\,[\tilde{\alpha}_\varphi^\mathrm{U} - \tilde{\beta}_\varphi^\mathrm{L}(w+m)]\tilde{k}_{\mathrm{r}\varphi}^\mathrm{U} + [\tilde{\alpha}_\varphi^\mathrm{L} - \tilde{\beta}_\varphi^\mathrm{U}(w+m)]\tilde{k}_{\mathrm{r}\varphi}^\mathrm{L}\Big]\,\mathrm{d}\varphi - (1-t)a \\
&= \frac{m\sqrt{a}}{2}\int_0^1 \Big[\tilde{\alpha}_\varphi^\mathrm{U}\tilde{k}_{\mathrm{r}\varphi}^\mathrm{U} - \tilde{\beta}_\varphi^\mathrm{L}\tilde{k}_{\mathrm{r}\varphi}^\mathrm{U}(w+m) + \tilde{\alpha}_\varphi^\mathrm{L}\tilde{k}_{\mathrm{r}\varphi}^\mathrm{L} - \tilde{\beta}_\varphi^\mathrm{U}\tilde{k}_{\mathrm{r}\varphi}^\mathrm{L}(w+m)\Big]\,\mathrm{d}\varphi - (1-t)a \\
&= m\sqrt{a}\Bigg[E[\tilde{\alpha}\tilde{k}_\mathrm{r}] - \frac{w+m}{2}\int_0^1 \Big(\tilde{\beta}_\varphi^\mathrm{L}\tilde{k}_{\mathrm{r}\varphi}^\mathrm{U} + \tilde{\beta}_\varphi^\mathrm{U}\tilde{k}_{\mathrm{r}\varphi}^\mathrm{L}\Big)\,\mathrm{d}\varphi\Bigg] - (1-t)a. \\
&= m\sqrt{a}\big[E[\tilde{\alpha}\tilde{k}_\mathrm{r}] - \Psi(w+m)\big] - (1-t)a,
\end{aligned}
\tag{13}
$$

with Ψ being defined as follows:

$$
\Psi = \frac{1}{2}\int_0^1 \Big(\tilde{\beta}_\varphi^\mathrm{L}\tilde{k}_{\mathrm{r}\varphi}^\mathrm{U} + \tilde{\beta}_\varphi^\mathrm{U}\tilde{k}_{\mathrm{r}\varphi}^\mathrm{L}\Big)\,\mathrm{d}\varphi. \tag{14}
$$

In order to determine the retailer's response functions, we have to calculate the first order partial derivatives with respect to m and a:

$$
\frac{\partial E[\Pi_\mathrm{r}]}{\partial m} = \sqrt{a}\big[E[\tilde{\alpha}\tilde{k}_\mathrm{r}] - \Psi(w+m)\big] - \Psi m\sqrt{a} \tag{15}
$$

$$
\frac{\partial E[\Pi_\mathrm{r}]}{\partial a} = \frac{m}{2\sqrt{a}}\big[E[\tilde{\alpha}\tilde{k}_\mathrm{r}] - \Psi(w+m)\big] - (1-t). \tag{16}
$$

Setting Eqs. (15) and (16) to zero and eliminating m from $a(m, w, t)$ leads to:

$$
m(w) = \frac{E[\tilde{\alpha}\tilde{k}_\mathrm{r}] - \Psi w}{2\Psi} \tag{17}
$$

$$
a(w,t) = \frac{\big(E[\tilde{\alpha}\tilde{k}_\mathrm{r}] - \Psi w\big)^4}{64\Psi^2(1-t)^2}. \tag{18}
$$

Thereafter, we now consider the manufacturer's decision problem given by:

$$\begin{aligned} \max_{w,t} \quad & E[\Pi_{\mathrm{m}}(w,t)] \\ \text{s.t.} \quad & m = (E[\tilde{\alpha}\tilde{k}_{\mathrm{r}}] - \Psi w)/2\Psi \\ & a = \left(E[\tilde{\alpha}\tilde{k}_{\mathrm{r}}] - \Psi w\right)^4 / 64\Psi^2(1-t)^2 \\ & \mathrm{Pos}(\{\tilde{\alpha} - \tilde{\beta}(w+m) < 0\}) = 0 \\ & w > 0, 0 \le t < 1. \end{aligned} \tag{19}$$

The manufacturer's expected profit function $E[\Pi_{\mathrm{m}}(w,t)]$ can be determined analogously to the retailer's expected profit given in Eq. (13). Hence, we derive:

$$E[\Pi_{\mathrm{m}}] = w\sqrt{a}\left(E[\tilde{\alpha}\tilde{k}_{\mathrm{r}}] - \Psi(w+m)\right) - ta, \tag{20}$$

with Ψ being defined identical to Eq. (14). Inserting m and a from Eqs. (17) and (18) into $E[\Pi_{\mathrm{m}}]$ yields:

$$E[\Pi_{\mathrm{m}}] = \frac{\left(E[\tilde{\alpha}\tilde{k}_{\mathrm{r}}] - \Psi w\right)^3 \left(4\Psi w - 3\Psi wt - E[\tilde{\alpha}\tilde{k}_{\mathrm{r}}]t\right)}{64\Psi^2(1-t)^2}. \tag{21}$$

Similar to the retailer's problem, one has to set the partial first order derivatives to zero. If we first consider the manufacturer's participation rate t, we get:

$$\frac{\partial E[\Pi_{\mathrm{m}}]}{\partial t} = \frac{\left(E[\tilde{\alpha}\tilde{k}_{\mathrm{r}}] - \Psi w\right)^3 \left[\left(-3\Psi w - E[\tilde{\alpha}\tilde{k}_{\mathrm{r}}]\right)(1-t) + 8\Psi w - 6\Psi wt - 2E[\tilde{\alpha}\tilde{k}_{\mathrm{r}}]t\right]}{64\Psi^2(1-t)^3}. \tag{22}$$

From $\partial E[\Pi_{\mathrm{m}}]/\partial t = 0$ one can derive:

$$t(w) = \frac{-E[\tilde{\alpha}\tilde{k}_{\mathrm{r}}] + 5\Psi w}{E[\tilde{\alpha}\tilde{k}_{\mathrm{r}}] + 3\Psi w}. \tag{23}$$

Please note that this expression can take negative values for $w < E[\tilde{\alpha}\tilde{k}_{\mathrm{r}}]/5\Psi$, which would violate the domain of definition given in Sect. 3.1. Therefore, it is necessary to check if the obtained solution for w complies with the condition $w > E[\tilde{\alpha}\tilde{k}_{\mathrm{r}}]/5\Psi$; otherwise, we have to set $t = 0$. Setting the partial first order derivative with respect to w,

$$\begin{aligned} \frac{\partial E[\Pi_{\mathrm{m}}]}{\partial w} = & \frac{\left(E[\tilde{\alpha}\tilde{k}_{\mathrm{r}}] - \Psi w\right)^2}{64\Psi^2(1-t)^2} \\ & \cdot \left[-3\Psi\left(4\Psi w - 3\Psi wt - E[\tilde{\alpha}\tilde{k}_{\mathrm{r}}]t\right) + \left(E[\tilde{\alpha}\tilde{k}_{\mathrm{r}}] - \Psi w\right)(4\Psi - 3\Psi t)\right], \end{aligned} \tag{24}$$

Table 3 Manufacturer Stackelberg equilibrium

	Margins	Advertising	Profits
Retailer	$m = \frac{E[\tilde{\alpha}\tilde{k}_r]}{3\Psi}$	$a = \frac{E^4[\tilde{\alpha}\tilde{k}_r]}{144\Psi^2}$	$\Pi_r = \frac{E^4[\tilde{\alpha}\tilde{k}_r]}{216\Psi^2}$
Manufacturer	$w = \frac{E[\tilde{\alpha}\tilde{k}_r]}{3\Psi}$	$t = \frac{1}{3}$	$\Pi_m = \frac{E^4[\tilde{\alpha}\tilde{k}_r]}{144\Psi^2}$
With $\Psi = \frac{1}{2}\int_0^1 \left(\tilde{\beta}^L_\varphi \tilde{k}^U_{r\varphi} + \tilde{\beta}^U_\varphi \tilde{k}^L_{r\varphi}\right) d\varphi$			

to zero yields an expression for w, which solely depends on participation rate t:

$$w(t) = \frac{E[\tilde{\alpha}\tilde{k}_r]}{\Psi(4-3t)}. \tag{25}$$

We can now solve the system of equations given by Eqs. (17), (18), (23), and (25) in order to obtain closed-form solutions of the Manufacturer Stackelberg equilibrium. The results as well as the corresponding profits are given in Table 3. It is easy to see that the calculated wholesale price $w = E[\tilde{\alpha}\tilde{k}_r]/3\Psi$ always complies with the condition which follows from Eq. (25). Hence, the participation rate $t = 1/3$, which results independent of model parameters, is feasible.

4 Numerical Studies

This section provides numerical examples of the previously obtained results (see Table 3). As described above, one advantage of fuzzy set theory is the ability to include the experience of decision makers, which is mostly verbalized by linguistic expressions like 'customers are *very sensitive*, *sensitive*, or *less sensitive* to changes in prices', which are rather vague than clearly assignable to a single (crisp) value. Therefore, we use triangular fuzzy variables of the form $\zeta = (x, y, z)$, which do not only describe one single number, but rather a range of possible values.

Hence, the first step is to determine appropriate triangular fuzzy variables, which correctly represent the decision makers' experience and estimation. One possible way can be found in Cheng (2004), who proposes a group opinion aggregation model based on a grading process. However, for the sake of simplicity, we arbitrarily choose triangular fuzzy variables for the parameters $\tilde{\alpha}$, $\tilde{\beta}$, and $\tilde{k}_r$ in this paper, which can be found in Table 4.

Let us now assume a medium base demand $\tilde{\alpha}$ (about 20), a sensitive price sensitivity $\tilde{\beta}$ (about 1.25), and a low advertising effectiveness $\tilde{k}_r$ (about 2). By means of Eq. (3), we can calculate the φ-pessimistic and φ-optimistic values:

Table 4 Allocation of linguistic expressions to triangular fuzzy variables

	Linguistic expression	Triangular fuzzy variable
Base demand $\tilde{\alpha}$	Low (about 10)	(5, 10, 15)
	Medium (about 20)	(15, 20, 25)
	High (about 30)	(25, 30, 35)
Price sensitivity $\tilde{\beta}$	Very sensitive (about 1.75)	(1.5, 1.75, 2)
	Sensitive (about 1.25)	(1, 1.25, 1.5)
	Less sensitive (about 0.75)	(0.5, 0.75, 1)
Advertising effectiveness $\tilde{k}_r$	Low (about 0.2)	(0.1, 0.2, 0.3)
	Medium (about 0.3)	(0.2, 0.3, 0.4)
	High (about 0.4)	(0.3, 0.4, 0.5)

$\tilde{\alpha}_{\varphi}^{L} = 15 + 5\varphi$	$\tilde{\beta}_{\varphi}^{L} = 1 + 0.25\varphi$	$\tilde{k}_{r\varphi}^{L} = 0.1 + 0.1\varphi$
$\tilde{\alpha}_{\varphi}^{U} = 25 - 5\varphi$	$\tilde{\beta}_{\varphi}^{U} = 1.5 - 0.25\varphi$	$\tilde{k}_{r\varphi}^{U} = 0.3 - 0.1\varphi.$

These values are inserted into Eq. (2) in order to determine $E[\tilde{\alpha}\tilde{k}_r]$,

$$\begin{aligned} E[\tilde{\alpha}\tilde{k}_r] &= \frac{1}{2}\int_0^1 \left(\tilde{\alpha}_{\varphi}^{L}\tilde{k}_{r\varphi}^{L} + \tilde{\alpha}_{\varphi}^{U}\tilde{k}_{r\varphi}^{U}\right) \mathrm{d}\varphi \\ &= \frac{1}{2}\int_0^1 [(15+5\varphi)(1+\varphi) + (25-5\varphi)(3-\varphi)]\, \mathrm{d}\varphi \\ &= 5\int_0^1 \left(\varphi^2 - 2\varphi + 9\right) \mathrm{d}\varphi = 41.67. \end{aligned}$$

Analogously, we can calculate $\Psi = 0.24$.

The resulting prices, advertising expenditures, and expected profits of manufacturer and retailer in a Manufacturer Stackelberg equilibrium, which derive from inserting $E[\tilde{\alpha}\tilde{k}_r]$ and Ψ into the expressions given in Table 3, are listed in Table 5, together with the results of the crisp case. Here, we can see that both players set the same margins m and w. However, the manufacturer can realize a higher profit than his retailer, which can be explained by the participation rate t = 1/3: The whole supply chain invests a = 35.84 into advertising (fuzzy case), whereof the manufacturer bears one-third, while two-thirds remain in the retailers responsibility. Even if this is only one certain set of parameters, these findings can be generalized to

Table 5 Numerical example with medium $\tilde{\alpha}$, sensitive $\tilde{\beta}$, and low $\tilde{k}_r$ (see Table 4)

	m^*	w^*	a^*	t^*	$E[\Pi_r]$	$E[\Pi_m]$
Fuzzy parameters	5.75	5.75	35.84	0.33	23.89	35.84
Crisp parameters	5.33	5.33	28.44	0.33	18.96	28.44

Table 6 Variation of fuzziness of $\tilde{\alpha}$, with sensitive $\tilde{\beta}$ and low $\tilde{k}_r$ (see Table 4)

$\tilde{\alpha}$	m^*	w^*	a^*	t^*	$E[\Pi_r]$	$E[\Pi_m]$
(10, 20, 30)	5.98	5.98	41.93	0.33	27.95	41.93
(12.5, 20, 27.5)	5.86	5.86	38.79	0.33	25.86	38.79
(15, 20, 25)	5.75	5.75	35.84	0.33	23.89	35.84
(17.5, 20, 22.5)	5.63	5.63	33.06	0.33	22.04	33.06
(20, 20, 20)	5.33	5.33	28.44	0.33	18.96	28.44

some extent, as it is visible from Table 3: Retailer's and manufacturer's margin are always identical ($m = w$) according to this model, and also the inequality $E[\Pi_m] > E[\Pi_r]$ holds for any parameters. Furthermore, the participation rate $t = 1/3$ is constant, as it does not depend on any parameter of the model.

Therefore, we turn our attention to the comparison of fuzzy and crisp case. Here, we can see that, besides the constant participation rate t, each variable assumes higher values, and that both players can expect higher profits under a fuzzy customer demand. The variation of the fuzziness of the market base $\tilde{\alpha}$ in Table 6 shows similar results. The higher the fuzziness of the market base, the higher the players set margins and advertising expenditures, which lead to higher expected profits. This is consistent with previous research on pricing models without advertising (see, e.g., Zhao et al. 2012b).

5 Conclusion

In this article, we analyzed a single-manufacturer single-retailer supply chain with fuzzy consumer demand, which is sensitive to prices and advertising. In order to increase the retailer's advertising expenditures, the manufacturer has the possibility to participate in his retailer's advertising costs by means of a vertical cooperative advertising program. To the best of our knowledge, this is the first application of fuzzy set theory to a cooperative advertising model. In contrast to deterministic approaches, which require detailed information about customer behavior and market characteristics, we are able to include experience of decision makers into our model, as fuzzy set theory allows us to transform linguistic expressions (e.g., *high* or *low* base demand), into triangular fuzzy variables. Through our numerical examples, we furthermore derive that a higher fuzziness of parameters, i.e., a bigger range of values the parameter may take, leads to higher expected profits, while the participation rate should be constantly set to one-third, independent of the market demand parameters.

However, this is only a first approach of applying fuzzy set theory to cooperative advertising in a supply chain and, therefore, underlies certain limitations: First, in order to reduce mathematical complexity, we had not only to restrict the price demand function to a linear shape instead of the more general form previously published; furthermore, we were only able to consider advertising of the retailer, while it is common in research to integrate also the manufacturer's decision on advertising into analysis. Besides this, future research should also consider different membership functions of fuzzy variables instead of the triangular one.

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Future Transport Volume and Demographic Change—An Intermodal GAMS Approach

Sascha Bioly and Matthias Klumpp

Abstract Prognosis of future transport volumes and modal split scenarios are a research field with major implications in transport policy and business practice alike. Therefore major decision frameworks as e.g. infrastructure investments or policy concepts as for example the EU commission white book are based on expectations regarding transport volume developments. But these calculations are mainly based on transport demand and only in very limited approaches on transport supply, assuming that in the very competitive transport markets there will always be capacity for supply adjustments to demand changes. Expected demographic changes in European countries as for example Germany will probably render this paradigm invalid—as already today i.e. truck drivers are sought but not readily found. Therefore this contribution outlines a first quantitative approach in transport simulation including demographic change restrictions e.g. regarding the number of available truck drivers. Implications on the modal split are tested and reported with a cost-minimizing GAMS model in order to explore expected implications on transport markets.

1 Introduction

Expected demographic change effects will impact the future number of employees in transportation and logistics as well as in other business sectors. Predictions about sector-specific effects diverge widely in many areas, but obviously future experts

S. Bioly (✉) · M. Klumpp
Institute for Logistics and Service Management (ild),
FOM University of Applied Sciences, Leimkugelstraße 6,
45141 Essen, Germany
e-mail: sascha.bioly@fom-ild.de

M. Klumpp
e-mail: matthias.klumpp@fom-ild.de

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and managers are missing and the logistics industry will be affected in a crucial way. Logistics service providers complain that it is very difficult to recruit suitable truck drivers already today. In this segment rather low wages are paid and under these circumstances this article examines the impact of future driver shortages on transportation service prices. It has to be assumed that the lack of drivers due to demographic changes significantly increases the price for transport services by road. At least a greater wage increase can be expected compared to other transport modes such as rail or shipping. This increase will have affect on the use of different transport modes, the modal split.

Therefore, the research objective (in the current research projects WiWeLo and DO.WERT) is to develop a *quantitative system-level model* that takes into account different price scenarios for drivers and that will reflect the feasible transport performance by road as well as other transport modes. By the expected road transport price increase redistribution effects to other modes of transport will be considered.

Due to the problem of system optimization a modeling from operations research is used: General Algebraic Modeling System (GAMS) is a modeling system for mathematical programming and optimization. The traffic capacity to meet future demand and an allocation under current conditions are assumed. Then a minimization of costs is implemented to identify optimal system solution levels. The maximum available number of workers limits the future feasible transport volume and there is a correlation between the number of drivers and transport capacity. In another study it has been found that (ceteris paribus) the contingent of drivers will not be sufficient to handle the entire transport demand. By gradually increasing the levels of drivers' wages and thus the maximum transport capacity, the respective minimum-cost transport mix will be calculated. Initially, the model is developed based on estimated data in order to develop and test model functionality.

The explanatory power increases in a second future step, when valid data could be used for modeling. With these findings, strategic decisions can be better supported. If a prognosis can be delivered regarding road transport price increases, decisions regarding transport service supply and allocation can be optimized and possible other transport alternatives can be considered. Two pieces of information are combined: On the one hand the situation of the drivers' labor market is becoming increasingly difficult for companies due to demographic change and nevertheless on the other hand transport volumes will continue to grow in the future —leaving logistics systems in a possible strategic misfit to be explored further.

The article proposes first a detailed *literature review* regarding demographic change, relevant prognosis studies and the impact for logistics and transport processes and markets in Sect. 2. The following Sect. 3 provides the detailed demographic changes and implications especially for the transport mode road. Section 4 describes the *GAMS modeling* regarding subsequent wage and price changes due to demographic developments and therefore expected differences in future modal split scenarios. Finally, Sect. 5 outlines an *outlook* regarding logistics research in the light of demographic changes ahead.

2 Literature Review

The Demographic Change has a big influence on the future performance of the German Logistic Sector. The generally demographic change is shown by statistics of the Statistisches (2009). This statistic illustrates that the German population is basically shrinking and the average age increases with the years. The Statistisches Bundesamt predicts e.g. a reduction of the German population from now just over 80 million in 2013 to 65–70 million in 2060 and an increase of the share of people who are 65 years and older from 20 % in 2008 to 34 % in 2060.

This development seems to be faster for the age distribution in the *logistics sector*, at least this is what the newest statistics of the Institut für Arbeitsmarkt- und Berufsforschung (2011) tell: It shows the development for people working as truck drivers, e.g. the number of people in an age of 50 and older, increasing from 25.4 % in 2001 to 39.1 % in 2011—with a simultaneous decrease of people below 35 years of age from 25.6 % in 2001 to 16.4 % in 2011. The negative aspects of this demographic development for the logistic sector are e.g. outlined in Beutler et al. (2007)—and have to be seen in the difficult context of increasing management knowledge and competence requirements in logistics (cp. e.g. Klumpp et al. 2013a, b).

On the other hand, the outlined developments in future transport volumes are pointing in the other directions: At least for Germany the transport volume prognosis has been adjusted several times, latest in 2012 after the economic downturn and recovery between 2008 and 2012. Different scenarios are assuming different paths, e.g. depending on the assumption of linear of volatile developments of future transport volumes—but still all of them are pointing upwards as depicted in Fig. 1 (Klumpp et al. 2012).

Due to demographic change in Germany a shortage of professionals is discussed for quite some time. For the German logistics industry, the auditing organization DEKRA provides concrete numbers: In 10 years 150,000 truck drivers are missing. During this period, nearly 30 % of today's driving personnel will reach retirement age and retire from professional life. These data bases on external studies and own DEKRA calculations from 2012. Since the organization is one of the leading training providers in the area transportation and is responsible, among other things, for training the truck drivers, these numbers appear to be resilient. In addition, these statements reflect the expectations of the study 'ZF Zukunftsstudie Fernfahrer' (ZF 2012) (future study truckers). 3,000 new professional drivers are trained per year and up to 12,000 men and women go through an accelerated qualification. Just to keep up the current numbers, about 25,000 new drivers are needed annually. Additional demand due to increasing demand for transportation services is not taken into account. Subsequently, the driver will be understood as operating provider of logistics services.

But especially in the commercial sector significant operational shortfalls can already be observed today. According to the Rhineland (2012) there already a significant shortage of truck drivers and the recruitment of suitable staff is always difficult. This is evidenced by the representative statements of TÜV study 'who

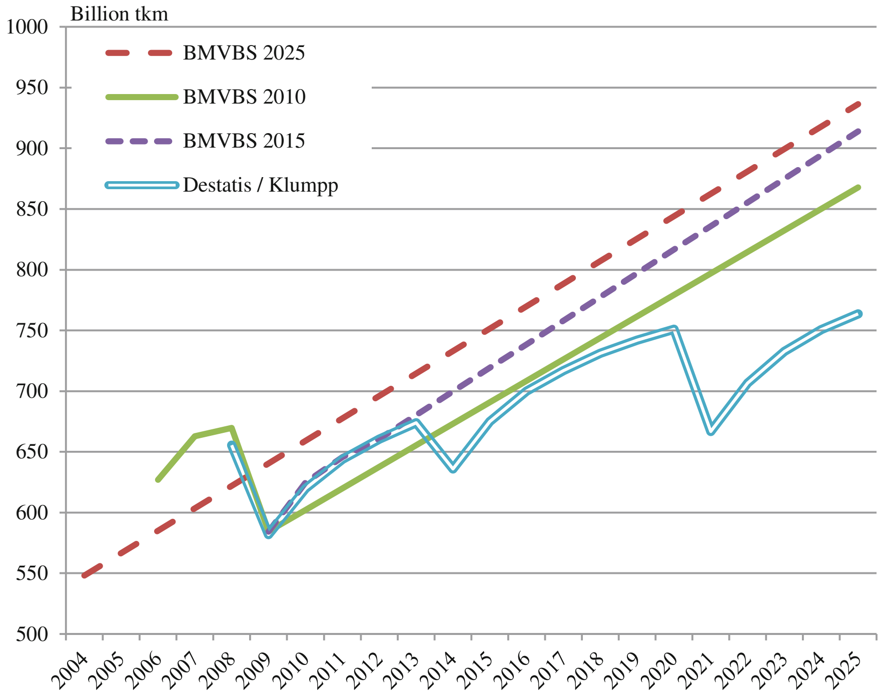

Fig. 1 Transport volume prognosis models until 2025

drive the trucks of tomorrow—young and shortage of drivers in the Federal Republic of Germany', in the nation-wide carriers were asked about. Thus 84 % of the companies surveyed confirmed that there is a noticeable shortage of qualified professional drivers since recent years. Besides the change in the population structure is cited as a reason for that the reasons for this are many:

- Employment as a professional driver is associated with high physical and psychic stress. High demands and ever-increasing pressure to perform make the profession for potential employees and from the perspective of young people uninteresting.
- The earnings are considered to be too low compared to the work to be performed. According to the above study industries where comparable performance at higher rates can be achieved there.
- By Roth et al. (2004) study by the Federal Institute for Occupational Safety and Health in 2004, according to nearly 50 % of truck drivers make regular overtime, with the remaining workforce is just under 20 %.
- Working long hours can influence health. So many professional drivers (20 %) feel a general fatigue, as opposed to 8 % for other people at work on average.
- Kroll et al. (2011) say that the activity in the transport sector is very often perceived and described as highly stressful.

- The German Federal Armed Forces train only very few drivers since some years and so per year 15,000 license holders are missing.
- The profession has a bad image to the public generally.

The Federal Office for Transport (BAG) also provides in its market monitoring detailed requirements for the technical understanding and numerous personal properties (Bundesamt für Güterverkehr 2012a). This limits over and above the pool of candidates for logistics companies. In figures, around one third of respondents blame the unattractive working conditions for a shortage of drivers. The license costs and the poor image of the profession are each called to 18 %, the abolition of the armed forces as a way to obtain a driving license is led into the field by 8 %. Under the possibility of multiple responses has over 70 % of respondents called the low attractiveness of the profession, to low payment (66 %), poor working conditions (59 %) and 55 %insufficient qualifications or unsuitable candidates (TÜV Rhineland 2012).

3 Modeling Data

The fact is that after the decline due to the economic crisis of 2008/09 the number of employed drivers in Germany has increased again in 2010 and 2011. In 2011 there were according to the BAG approximately 805,000 professional drivers (Bundesamt für Güterverkehr 2012a) (Table 1).

As can be seen from the table, the average age of professional drivers has increased in recent years. Comparing the absolute numbers from 2001 with those of 2011, as the number of drivers has increased by 1.3 %, the proportion of workers aged 50 years and older has increased by almost 56 % during the same observation period. According to the BAG approximately 315,000 professional drivers from the labor market will retire in the next 15 years, at the same time no corresponding number of young drivers move up (Bundesamt für Güterverkehr 2012b). The Institute for Labor Market and Employment Research of the Federal Employment Agency assumes for the next 10 years, the same image: approximately 200,000

Table 1 Age distribution for truck drivers between 2001 and 2011

Year	2001	2003	2005	2007	2009	2010	2011
Number of employees*	794,795	764,923	743,011	777,058	773,059	785,788	805,228
Portfolio development index (2001 = 100)	100	96.2	93.5	97.8	97.3	98.9	101.3
Under 25 years (%)	3.7	3.0	2.5	2.5	2.4	2.5	2.4
25 to under 35 years (%)	21.9	18.9	16.7	15.3	14.5	14.4	14.0
35 to under 50 years (%)	49.0	50.5	51.2	50.2	47.4	46.0	44.5
50 years and older (%)	25.4	27.5	29.6	32.1	35.6	37.2	39.1

*Subject to social insurance contribution truck drivers will be retiring from the profession, so that each year about 20,000 are missing (Binder 2012).

Putting the described development among drivers in relation to the forecasts of future needs, according to their figures the traffic performance from 2010 to 2050 will increase in road freight transport by almost 80 %, it is apparent that the transport capacity ceteris paribus can not be provided (Progtrans 2007). Assuming a relationship of number of drivers and potential transport capacity, a limitation of the realizable performance for road freight transport in the future.

The transport services by rail and inland water freight transport is limited due to the capacities of the infrastructure. Based on the presented forecasts is to be considered that the projected demand may exceed the supply of transport services. Putting the in 2011 realized traffic capacity of 460 billion ton-kilometer in road transport in relation to the nearly 800,000 drivers, taking into account the loss of 315,000 drivers (which is over 39 %), it can be questioned if the discussed infrastructure shortage is the main problem for road freight transportation in the future or the shortage of drivers will be the bottleneck in logistics. Assuming a uniform distribution of traffic performance on the driver, the remaining 485,000 drivers (c.p.) are able to perform under 280 billion ton-kilometers per year in road haulage. Thus, the supply of transport is greatly reduced and the price of transportation services increases accordingly.

The question whether an increase in working hours can compensate for the decline in the labor supply, as denied by Wanger et al. (2013). Even with a drastic increase in the participation of women and older people as well as a huge increase in annual working hours the trend of shortage of staff in general is just short stopped. The figure above of 39 % less drivers differs from the generally expected performance. In different scenarios, the working volume potential (potential labor force × working hours) for 2025 and 2050 was determined: while for the year 2025 through various adjustments a working volume potential was calculated with 92–111 % in relation to 2008, these values decrease for 2050 to 72 up to 87 % (Wanger et al. 2013). Similar statements apply various independent institutes such as McKinsey (2012) and Prognos (2010), even a full employment from 2020 no longer compensate the negative-acting demographic factor (Hoch and Heupel 2013).

4 GAMS Model

With at the same time increasing demand and falling offer new incentives for drivers must be created. In addition to the working conditions, the earning opportunities are often mentioned. In the following model excess demand leads due to the retiring drivers over the next 20 years to shifting to other transportation modes and with an increase in driver pay an additional incentive is created to become a driver, which affects the price structure in road freight transportation. First, the annual fluctuation of drivers was calculated from the figures shown.

A uniform distribution within the cohort was assumed and the net annual outflows and inflows were calculated. Furthermore, it is assumed that approximately the number of dropouts and of side-step newcomers corresponds equally. To increase the explanatory power that can be validated in further studies and adjusted if necessary. Based on these extrapolated future driver numbers the limit has been calculated in ton-kilometers of road freight transport for the years 2015, 2020, 2025 and 2030.

GAMS Modell (2030)

```
sets
i modal capacity 2030 / road2011, train, ship,
road2015, road2020, road2025, road2030 /
j modal use 2030 / use / ;

parameters
a(i) capacity in mio. tkm
/ road2011 371000, train 230000, ship
191000, road2015 44000, road2020 42000,
road2025 39700, road2030 371000 /
b(j) demand
/ use 1000000 / ;

table d(i,j) co2 emissions in gr per tkm
                use
road2011        45.75
train           24
ship            28
road2015        45.75
road2020        45.75
road2025        45.75
road2030        45.75 ;

table e(i,j) costs per tkm
                use
road2011        0.0500
train           0.0550
ship            0.0350
road2015        0.0512
road2020        0.0554
road2025        0.0623
road2030        0.0721 ;

parameter c(i,j) co2 per mode ;
c(i,j) = d(i,j) ;

parameter f(i,j) costs per mode ;
f(i,j) = e(i,j) ;

variables
x(i,j) co2 emission per mode
y(i,j) costs per mode
w costs in total
z co2 in total ;
positive variable x
positive variable y ;

equations
co2total        co2 emission over all
coststot        costs in total
supply(i)       obtain limit per mode
demand(j)       demand of transport ;

co2total .. sum((i,j), c(i,j)*x(i,j)) =l=
9999999999 ;
supply(i).. sum(j, x(i,j)) =l= a(i) ;
demand(j).. sum(i, x(i,j)) =g= b(j) ;
*coststot .. sum((i,j), f(i,j)*x(i,j)) =l= 46500 ;
coststot .. z =e= sum((i,j), f(i,j)*x(i,j)) ;

model transport /all/ ;
solve transport using lp minimizing z ;
display x.l, x.m ;
```

The first model in 2015 shows already an excess demand for road freight transport. As a function of the height of this overhang of a wage increase is believed to enhance the attractiveness, due to which the limitation of the mode of transport can adjust upward. With further increasing demand for transport services and falling supply of excess demand is so great in 2020 that increases the price of road freight transport on the price for the use of train. From this point on the rail and inland waterways are used to capacity (infrastructure permitted) and any other requested transport can be settled only on the road, the price increases again. This trend continues in the years 2025 and 2030, continuing to intensify. It is assumed that logistics services are more expensive in the future; the associated decline in demand is not yet taken into account.

As economic growth in the Federal Republic is directly linked to logistics services and each percent growth in the industry over the last 40 years an average 2 %-increase in traffic performance induced, the upper limit of the traffic capacity limits maybe the opportunities for growth throughout the economy.

The demographic change will also change the other side of the logistics, the demand side. Not only for Germany, more or less strongly predicted shrinkage effect and the change in the age structure of the population have an impact on the logistics requirements of the future. Similarly, structural changes of the regions are taken into account. So-called urbanization and re-urbanization effects change the situation in addition (Klumpp et al. 2013c). That the logistic growth is dependent of economic growth, is indisputable. The Solow growth model is the basic model of the modern neoclassical growth theory and the negative impact of population growth has been considered until yet only a little (Christiaans 2013). The shrinkage changes the prospects for demand in some areas of supply. The infrastructure will require less capacity, for example. The reduction in demand will not affect all areas proportionately, since the various age groups have different demographic trends and have diverse needs. The traffic shareholding (in the sense of movement of persons) depends on age, the group of people traveling from the age of 61 years, according to the Mobility Panel 2005 less than younger people. It is expected that the use of transport infrastructure decreases by passenger and frees capacity for freight. In what sizes that will go by, is not yet assessed.

Estimates based on the experience of the Dutch large-scale test (scaled to the size of the Federal Republic of Germany) assume that in Germany, almost 20 % (about 14 million) of the 64 million annual trips by truck (only 40-ton) can be dropped through the use of EuroCombi. Sounds like a lot, but this relates only to the long distance traffics. EuroCombis cannot be used in last-mile runs.

5 Implications and Outlook

The following striking implications can be taken from this first draft transport volume simulation model (see especially Fig. 2):

- The transport mode *ship* can due to the sustainability advantages (low carbon dioxide emissions) as well as the restricted capacity be seen as a “basic capacity” supplier without major changes also in future transport scenarios for Germany.

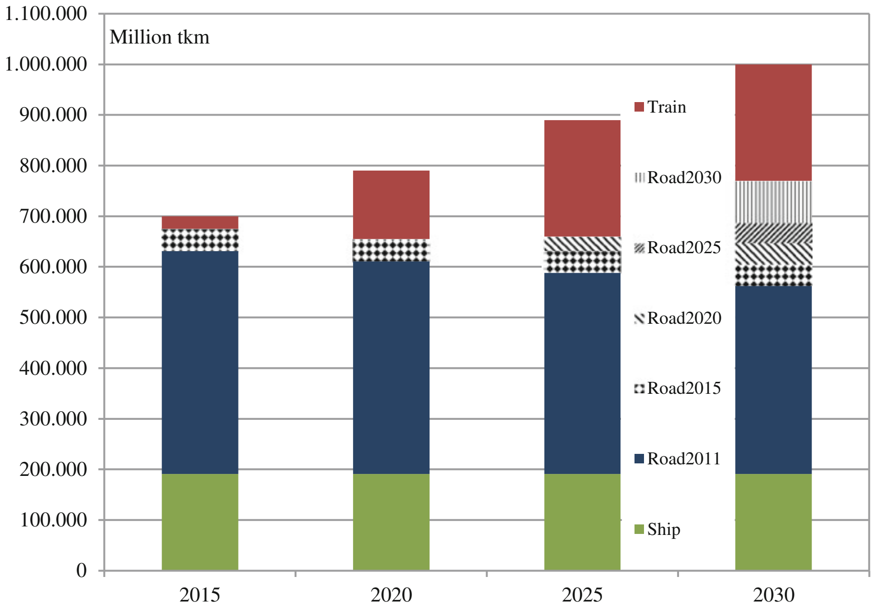

Fig. 2 Transport mode prognosis until 2030

- The transport mode *rail* is identified with this simulation model as a crucial factor for the increasing transport volume facing the sustainability as well as demographic challenges ahead: The model assumes a use of rail transports up to the total maximum capacity in increasing steps until 2030.
- Whereas the transport mode *road* may lose modal share as well as absolute transport volume due to increasing transport prices and wages of truck drivers due to increasing difficulties to employ ne drivers—the model assumes here that increasingly higher wages have to be offered to motivate these drivers (for new contracts only).
- Although the model is still missing the connection to existing real transport mode data (i.e. 2012), the direction of future changes are depicted very clearly: A *modal shift from road to rail* can be expected from demographic changes in combination with sustainability restrictions—which is in line with major policy expectations e.g. in the recent European Commission (2011) white paper on transport.

From these model implications several impacts for further research and also business practice can be derived:

- Employee and human resource management strategies are in dire need within the logistics and transport sector, to be jointly developed, applied and evaluated by research, politics and businesses within the sector.

- The combination of demographic and sustainability challenges may be in a complementary relation for the transport sector as both may lead to an increased use of the transport modes rail and ship—depending on system capacities and network structures in both cases.
- The expected modal shift is also expression of the implemented assumed wage and therefore transport cost increases in the road transport sector. This will have additional impacts for supply chains and transport networks.

With these results this quantitative approach regarding the implications of demographic change on the transport sector as well as the modal split has provided a first input into a discussion which will stay on for a long time, at least for one generation of researchers and managers.

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Operational Risk Response for Business Continuity in Logistics Agglomerations

Claudia Breuer, Hans-Dietrich Haasis and Guido Siestrup

Abstract Risks are part of every business operation and can never be avoided completely. To minimize the danger of corporate crisis, a conscientious and responsible approach to the handling of risks and the resulting impact on business is essential. Unforeseen events pose an especially great challenge for companies and require quick decision-making and immediate reactions. This paper presents a way of structuring decision problems as part of a concept for accelerated decision-making in the context of response to risk. The locus of our research is freight villages, which represent a typical example of logistics agglomerations, and the focus of our research are their business processes, which mainly consist of storage, transport and handling of freight.

1 Introduction

Due to the rapid changes within the business environment that require a steady reduction of reaction times, companies are experiencing a growing vulnerability towards the occurrence of risks. The increased integration of companies in

C. Breuer (✉)
Faculty of Business Information Systems, Hochschule Furtwangen University,
Robert-Gerwig-Platz 1, 78120 Furtwangen, Germany
e-mail: brc@hs-furtwangen.de

H.-D. Haasis
Institute of Shipping Economics and Logistics (ISL), Faculty 7, University Bremen,
Wilhelm-Herbst-Street 12, 28359 Bremen, Germany
e-mail: haasis@uni-bremen.de

G. Siestrup
Institute of Applied Research, Hochschule Furtwangen University,
Robert-Gerwig-Platz 1, 78120 Furtwangen, Germany
e-mail: sig@hs-furtwangen.de

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interlinked supply chains and the associated cross-company planning, synchronization and control of business processes further amplify the risk potential. This is emphasized by the fact that it often does not require a catastrophic event to cause major disruptions for companies: even relatively small and localized problems within the supply chain can create a corporate crisis (Waters 2011). Especially unforeseen risks pose a great challenge for the supply chain and require particularly quick decisions and reactions in the event of their occurrence (Waters 2011; Engel 2009). Adopting supply chain risk management can increase the quality of decisions (Schneck 2010). Supply chain risk management is characterized by an attentive and systematic handling of potential risks as well as a comprehensive assessment of risk impact (Schawel and Billing 2012).

A thorough evaluation of the situation at hand is often not possible because of the necessity for quick reactions to damaging events. Mesarović et al. (1970) refer to this as the fundamental dilemma of decision-making: "on the one hand there is a need to act without delay, while on the other, there is an equally great need to understand the situation better". A preventive decision strategy aimed at coping with damaging events can mitigate this dilemma.

In spite of an identified need for quick reactions to damaging events, it is remarkable that little attention is paid in the literature to the handling of risk impacts, with most measures that are discussed being in the context of risk avoidance and risk reduction (Wagner and Bode 2007).

In light of these facts, the main object of our research is developing a model that allows quick, appropriate and systematic decisions to manage risks and their impacts after the occurrence of a damaging event.

The focus of this paper lies on the structuring of decision problems as one important part of decision support. The theoretical approach is based in decision theory and risk management. After the occurrence of a damaging event all business processes should be focused on business continuity management thus focusing all attention on rapid resumption of business activity and maintaining the flow of goods.

The concept is based on the processes of warehousing, transportation and cargo handling within large logistics agglomerations. Freight villages are used as an example as they typify such agglomerations. Each freight village represents a pivotal logistics node within a larger network of logistics nodes, which provide important services for the supply of goods (Nobel 2004).

In the following section, we provide the theoretical basis of our research. Section 3 firstly introduces freight villages as subject of investigation and then presents the first steps of the conceptual design of a decision support model base on decision trees to manage damaging events. These trees enable a decision-maker to break down a problem into decision situations and they help to provide measures and suggested activities for different situations. The paper closes with a short discussion and considers further steps for research in this field of inquiry.

2 Decision-Making Within the Scope of Risk Response

Background knowledge of decision-making is given by decision theory, for which reason we will first discuss the basic principles of decision theory in Sect. 2.1. Specifically, we will focus on the term decision support and the process of decision-making. Owing to our attention to risk, some principles of risk management are explained in Sect. 2.2. Apart from risk management, several other concepts provide a possible basis for strategies for the mitigation of risk after the occurrence of a damaging event. These include crisis management and business continuity management. We differentiate between these concepts and provide a definition of the term "risk response", and our understanding of this term in the context of this paper.

2.1 Principles of Decision Theory

Decision theory draws on different scientific disciplines such as psychology, philosophy, political science, business science, sociology, game theory and engineering science (Jungermann et al. 2005) and addresses the decision behaviour of individuals and groups (Laux et al. 2012). Two different styles of decision theory can be used to perform a theoretical and practical analysis of decision behaviour: prescriptive and descriptive decision theory (e.g. Grünig and Kühn 2013; Domschke and Scholl 2005; Eisenführ and Weber 2010). Descriptive decision theory focuses on the description of real human decision behaviour (Domschke and Scholl 2005). It allows an analysis of how specific decisions are made and what caused the decision to be made in a certain way. Hypotheses gained through empirical evidence lead to insight regarding the real life decision-making process and can be used to ascertain authoritative forecasts of expected future decisions (c.f. Laux et al. 2012; Saliger 2003). In contrast, prescriptive decision theory indicates how a decision will be chosen under the assumption that there is a rational choice to be made between multiple decision possibilities (Laux et al. 2012; Domschke and Scholl 2005). Prescriptive decision theory offers a set of rules and procedures for breaking down information in a structured fashion and processing this information in such a way that the decision-maker is supported in making difficult and complex decisions (Jungermann et al. 2005; Eisenführ and Weber 2010). A situation in which a decision is to be made is considered to be increasingly complex for a larger number of influences impacting the result and the more targets there are to be accounted for. Furthermore a very large or an unusually small number of decision options can increase the difficulty of making a decision (Eisenführ and Weber 2010).

Our research aims to offer an approach to decision support in the context of risk management after the occurrence of a damaging event with a view to accelerating the decision-making process. The aim is not to describe real human behaviour but to break down the underlying problems in a structured fashion and process the available information. Thus this paper may be ascribed to the field of prescriptive decision theory.

Generally speaking, decision-making support is defined as taking measures to improve the efficiency of a decision (Pfohl 1977). We refer to improved decision-making efficiency as the improvement of the quality of decisions as well as a reduced effort in making a decision (Lassmann 2006). In decision theory, a decision is generally defined as the selection of one specific action from a set of multiple possible actions (Laux et al. 2012). Taking this into account, we consider a decision to be a reaction to a specific situation based on processed information, and as an event that separates the state of a system from the next consecutive state (Pfohl 1977). A decision is triggered when an aberration between the current actual state and the target state of a system is recognized (Grünig and Kühn 2013; Rennemann 2007; Pfohl 1977). A decision-making problem is defined as the difficulty that occurs when the discrepancy between target and actual system states can be reduced by multiple decision alternatives (Grünig and Kühn 2013). The basic structure of a decision-making problem can be described by the available decision-making alternatives, the state of the surrounding environment, and consequences of the decision as well as the objectives and preferences of the decision-maker (Eisenführ and Weber 2010). Action alternatives are referred to as decision-variables, action-variables or action-parameters and may consist of multiple individual actions. The state of the surrounding environment lies outside the decision-makers scope of influence and is either known to the decision-maker with certainty or is afflicted with uncertainty. Decisions under uncertainty can be further separated into decisions under risk and decisions under ambiguity (c.f. Camerer and Weber 1992). Consequences arise through the combination of a specific action alternative and the occurrence of a specific state within the surrounding environment. The decision field consists of the action alternatives, states of nature and consequences (Laux et al. 2012). Objectives and preferences represent the attitude of a decision-maker towards action alternatives and their consequences and are expressed by the decision rule (Laux et al. 2012; Eisenführ and Weber 2010). These elements and their relationships to each other are formally represented by a decision model, which is used to support the decision-making process. The decision-making process can be divided into several stages, the first of which is the initial recognition of the decision problem (c.f. Laux et al. 2012; Lassmann 2006; Heinen 1992; Pfohl 1977). Although there are numerous suggested approaches for systematically dividing the decision-making process into separate stages, they can all be traced back to the same basic pattern (Pfohl 1977) and describe the process of decision-making as a process of conscious information collection, information processing and information transfer (Heinen 1992). All stages of the decision-making process require partial decisions to be made that will have a considerable impact on the outcome of the overall decision-making process (Heinen 1992). On the whole, this stage based model should be considered as a methodological tool for decision-making. It provides an overview of the required activities that usually do not have to be performed in a strict sequence (Laux et al. 2012; Pfohl 1977). This paper is based on the decision-making process that is described in the following section.

As a basic principle, the process consists of the stages “will-formation” and “decision implementation” (Heinen 1992). According to Simon (1960) the will-formation stage consists of the three phases “intelligence”, “design” and “choice”. The intelligence phase begins with the recognition of a change in the environment, which calls for action. Once a problem that requires further action has been recognized, the design phase consisting of the three activities of inventing, developing and finally analyzing the possible courses of action begins (Simon 1960). In this phase, the identification and the correlation of the elements of the decision field and the decision rule, as described in the last preceding paragraph, take place. The will-formation stage is completed once a course of action that was designed within the design phase has been chosen, thus concluding the choice phase and resulting in a final decision. The decision implementation stage is characterized by the realization phase and the control phase (Heinen 1992). In the realization phase, the decisions made within the choice phase are applied to the decision situation and, accordingly, to the actual problem. Any deviation between the desired and the actually accomplished results is monitored during the control phase (Lassmann 2006). The information gathered during the control phase may necessitate follow-up activities, which lead to a requirement for new decisions, and this hence returns the decision-making process to the intelligence phase (Heinen 1991). The overall context of these terms and concepts is illustrated in Fig. 1.

This paper mainly focuses on the will-formation process and within that process specifically on the design phase. The conceptual design of a decision support model takes place within this phase, and, in this paper, only one conceptual aspect of our decision support model is presented, namely structuring a decision situation with decision trees.

2.2 Risk Response

If a risk situation occurs, difficult and long decision-making processes may not be possible in reasonable time. However, for an informed decision, the single phases of the decision-making process which have to be undertaken can be accelerated. To enable an immediate response to the occurrence of a risk, decisions must be made nearly instantly. An awareness of possible risks and their impacts can lead to a faster reaction in the case of a damaging event. Furthermore it reduces the risk of long business continuity interruptions. The examination of risks before they occur can be carried out in the context of risk management. According to Waters (2011), risk management is a systematic process that aims at the identification, analysis and response to risks throughout an organization.

In this paper, only the part of risk response within the risk management process is given consideration. Alternative strategies can be pursued related to risk response. A multitude of different definitions and terms for such response strategies are defined in the literature. Hopp et al. (2012) differentiate between the two risk response strategies of detection and speed, which are executed after the occurrence of a disruption. Related to supply chains, Ritchie and Brindley (2009) identify four risk response strategies as being: insurance; risk sharing; information exchange and

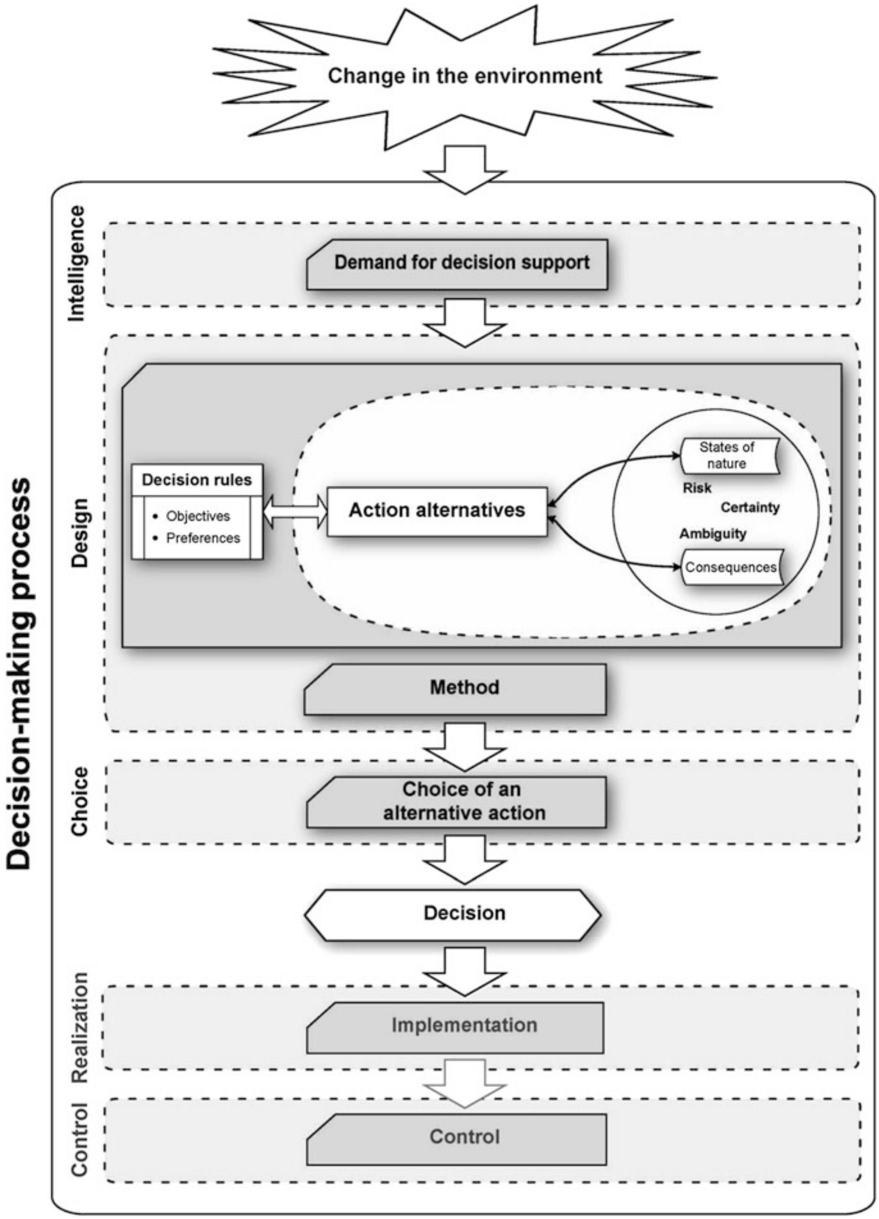

Fig. 1 Decision theory context

relationship development. Waters (2011) proposes a classification into eight risk response types, which cover a wide range of opinions, from ignorance of risks through to complete re-location to another environment. Sudy et al. (2013) propose four risk response strategies and categorize them into avoidance, reduction, transfer and acceptance of risks. According to this definition, the risk reduction strategy comprises measures for reducing risk impact.

Further concepts that deal with the response to risk events are crisis management and business continuity management (c.f. Waters 2011; Tandler and Eßig 2011). Crisis management is closely coupled with risk management and comprises the basic prevention, cognition, diagnosis and elimination of corporate crises (Schawel and Billing 2012). Besides coping with severe damaging events, the focus of crisis management lies in coping with operational misperformances (Brühwiler 2011). Business continuity management is focused on business processes and deals with the quick resumption of business performance (Brühwiler 2011). Crisis management and business continuity management can both be seen as components of risk management (c.f. Waters 2011; Brühwiler 2011).

In this paper, we follow the definition of Hopp et al. (2012) and take the term risk response to mean the reactions to coping with the negative impacts of damaging events that have occurred.

Based on Ross (2011), the central tasks in the risk response process are developing and evaluating alternative courses of action, determining appropriate courses of action and implementing risk responses according to the selected courses of action. These tasks are consistent with those described in the decision-making process in Sect. 2.1. For this reason, risk response itself can be seen as a decision-making process.

So, it can be seen that the development of alternative courses of action is a basic element of our conceptual design. We now turn to applying the approach to freight villages, the subject of investigation.

3 Conceptual Design of a Decision Tree for Risk Response

This section shows how the relevant elements of a decision can be structured to break down a decision problem. Section 3.1 deals with explaining the characteristics of freight villages. The characteristics of the decision elements and their detection in case of a damaging event needing a quick reaction are presented in Sect. 3.2. In Sect. 3.3, the use of decision trees is justified as well as their application for structuring decision situations in freight villages.

3.1 Freight Villages

Freight villages are a special type of logistics agglomeration. They primarily function as an interface between local and long-distance traffic (Welp 2010). A further function of freight villages consists in forming efficient, multimodal transportation chains. Hence, a freight village combines at least two modes of transport, usually road and rail, but sometimes also waterborne and air transport. To fulfill this purpose, a terminal of intermodal transport is located in a freight village (Rall 2008).

Multiple transport and logistics companies are co-located within a freight village. They include, for instance, forwarding agencies, logistics service providers, logistics intensive traders and industrial companies, as well as different transport carriers, all of which retain their legal and financial autonomy (Rall 2008; Kessler et al. 2009). These companies act within numerous connected supply chains and are concentrated within a relatively small area enabling the use of the same modes of transport and technical infrastructure (Wildebrand et al. 2011).

The interests of all participants are coordinated by a central business and development company, which mainly plans, establishes and continually helps the freight village to evolve. The operational business of the village remains, however, with the independent companies located on site (Rall 2008).

Freight villages make a major contribution towards securing the flow of goods at the regional, national and international level (Wildebrand et al. 2011). If a damaging event occurs in such a freight village, the freight village logistics processes of storage, transport and handling of cargo can be interrupted, and a number of business partners, supply chains and the regional as well as the national economy may be affected (Breuer et al. 2012).

In Germany, there is currently a network of thirty-five freight villages. The logistics processes of two of these freight villages were analyzed as part of the study reported here. The processes identified in these villages form the basis for the consideration of possible impacts and consequences resulting from damaging events. Particularly damaging events are likely to result from damage to the infrastructure in freight villages such as the terminals for intermodal transport and road and rail connections.

In the next section, the different decision elements are explained. Consideration is given to failure within the terminal of intermodal transport as an example of a possible damaging event within a freight village.

3.2 Detection of Decision Elements

A detailed knowledge of the decision situation is important to facilitate a comprehensive assessment of the appropriate measures, which will in turn enable an adequate reaction to the resulting negative impacts of a damaging event (Putz-Osterloh 1992). Decision support grows in importance as the complexity of a situation increases (Eisenführ and Weber 2010). According to Luhmann (2009), a situation's complexity grows in relation to the number of possible courses of action, the heterogeneity of the options, or an increase of interdependencies between them. If a damaging event arises, the best option for accelerated decision-making, and choice of the best possible risk response measure, may be arrived at by having already created a structured decision situation that reduces the situation's complexity. The first step in structuring the decision situation lies in examining the elements of a decision problem, already identified in Sect. 2.1: the courses of action, the states of nature, consequences as well as the objectives and preferences (Laux et al. 2012).

The *objective* to be pursued is maintaining the flow of goods. Resulting from this objective are the secondary targets of prompt resumption of business performance and quick recovery of business processes. This means, that in case of a damaging event, the *preferences* to be pursued with regard to the objective are the delivery rate, which should be as high as possible, and the avoidance of bottlenecks. Hence, the crucial logistics processes in freight villages of storage, transport and handling of cargo are at the centre of our attention.

In general, *courses of action* can be seen as a combination of a variety of risk response measures, which depend on the particular situation (Ross 2011). If a damaging event occurs in the terminal of intermodal transport within a freight village, in principle the possible courses of action are: reacting to the event, suspending a decision on action to a later date, or deliberate forbearance of the event. As a course of action to such a damaging event, in general the possible alternatives consist of either rerouting goods or carrying on delivering goods to the affected terminal. The goods that continue to be delivered can either be stored temporarily or turned immediately over to further onward transport. This means that directly after a damaging event there are four possible actions as follows: to do nothing, to reroute goods to another destination, to deliver goods to temporary storage, or to deliver goods and immediately forward them.

Not all courses of action will make sense and this will depend on further limitations imposed by the damaging event such as the scale of the damaging event, the type of infrastructure affected, and the importance of the affected goods. For example, either road, or rail, or both could be affected, and cranes or other equipment for loading and unloading may or may not be affected. It is likely that in most instances when a damaging event occurs, it will be necessary to undertake certain actions which will in themselves make it either necessary or unnecessary to undertake other actions. It is always necessary to understand the overall objectives and ensure that no actions are taken which might impede others actions which need to be taken in order to properly fulfil these objectives.

After a damaging event, there is usually uncertainty about the possible future *states of nature*. Basically, either a decline, an improvement or a perpetuation of the situation is possible. Different scenarios may arise through an association between different influences, for example a declining situation combined with high importance of the affected goods. A set of outcomes, n, with m possible states leads to m^n scenarios. Therefore, the relevant states of nature have to be identified in the context of the objectives being pursued (Eisenführ and Weber 2010).

Consequences represent realizations of objectives (Jungermann et al. 2005), and they result from the combination of states of nature which have occurred with one or more courses of action. Depending on the individual combinations, the following consequences may appear: the impacts of a damaging event are exacerbated, attenuated, absorbed or completely eliminated.

The structuring of the problem can be done by graphical means (Eisenführ and Weber 2010). Thus, in the next section different graphical means of representation are presented.

3.3 Structuring Decision Situations

For the structuring of decision situations, decision matrices, decision trees and influence diagrams can be used (Eisenführ and Weber 2010).

Decision matrices are tables which include the alternative states of nature as columns and alternative courses of action as lines. The cells represent the individual, evaluated consequences (Jungermann et al. 2005). The advantage of decision matrices is their clarity of representation, and they are also extendable. Conversely, a multilevel representation is not possible and as a result of this, decision trees are better. Decision trees can also be used for modelling and structuring of decision problems and are specifically aimed at the graphical representation of decision rules (Drews and Hillebrand 2007). They force a decision-maker to clearly and precisely formulate the objectives, the alternative actions, the states of nature and the consequences in a dendritic hierarchical structure (Eisenführ and Weber 2010). The disadvantage here is, that decision trees are unclear for complex situations in which the problem could be avoided by the aggregation of action alternatives (Recke 2005).

Influence diagrams are clearer than decision trees, but detailed information is missing (Recke 2005). This is because in influence diagrams, alternative courses of action, states of nature and consequences are only included as quantities (Eisenführ and Weber 2010).

Thus, decision trees are particularly suited for decision problems that are characterized by consequences that have a temporal dimension to them, or by a sequence of actions and consequences (Jungermann et al. 2005). For the depiction of the decision elements, three kinds of nodes and two kinds of branches are used (Middleton 2007). Decision nodes are depicted as a square and represent a possible decision situation (Laux et al. 2012). Event nodes, or chance nodes, are symbolized by a circle and characterize the occurrence of possible events (Jungermann et al. 2005). Each consequence represents a combination of certain decisions and states of nature. They are called terminal nodes and are represented by triangles (Middleton 2007). The branches emanating from a decision node symbolize all possible actions available at that point. Branches coming from a chance node symbolize the possible outcomes of an event that may occur at that point. By traversing the tree, decision rules can be established from the combination of certain decisions, states of nature and the connections between them. Subsequently, anticipated developments can be illustrated through decision trees, projecting as far into the future as desired (Jungermann et al. 2005). A sequence of conditional decisions is referred to as a decision strategy and includes multi-decision levels (Eisenführ and Weber 2010). Multi-decision levels make a contribution to an improved decision-making process

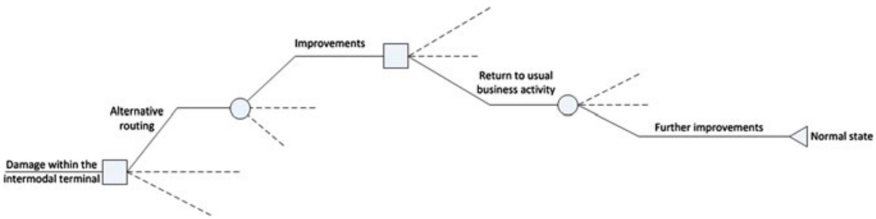

Fig. 2 Example of a decision tree

by showing intertemporal interdependencies of different actions and lead to an improvement of the information level over time. Future actions should be determined in accordance with the present natural state and consideration of all available relevant information (Laux et al. 2012). However, it should be noted that the decision about how many levels to adopt and the decision about further search for alternative actions will precede the actual decision (Eisenführ and Weber 2010).

Altogether, decision trees provide a useful framework and methodology for analyzing decision problems and for identifying a decision strategy as a sequence of decisions and states of nature. This supports particularly quick and appropriate understanding of a decision situation. Depending on the respective developments of the states of nature, the chosen measures can be incrementally adapted and enhanced through further measures.

Referring to a damaging event within a freight village, the specified decision elements in Sect. 3.2 can be combined in a decision tree as depicted in Fig. 2. In the illustrated decision tree, the decision strategy consists of the courses of action "alternative routing" and "return to usual business activity", which leads to a return to the normal state as the state of nature are continuously improves.

For each possible risk, a decision tree will be created which will include elements referring to a particular damaging event.

4 Further Steps and Conclusion

The purpose of our research is the support of decision-making in freight villages in the case of occurrence of unforeseen risks. Rapid reaction to such events is necessary in order to achieve a high level of business continuity and ensure the continued flow of goods.

Decision trees provide a useful framework for analyzing decision problems and for identifying risk response measures as a sequence of decisions. Hence, our focus lies on the conceptual design of a decision tree as a first methodological step for decision support in freight villages. The single elements of decision situations as well as the combination of these elements in a decision tree have been demonstrated in the context of freight villages.

To further develop the decision trees, the optimal number of decision levels must be determined and appropriate points of time must be selected at which the implemented response measures are to be reviewed. Furthermore decisions must be made in light of possible further exacerbating conditions.

In a next step, a simulation model will be developed which includes the organizational and operational structure of a freight village. The conceptual decision trees developed as part of the work reported in this paper will be implemented in this simulation model. It will thereby be possible to evaluate the different reactions to damaging events as well as the combination of different courses of action and states of nature. Interdependencies between different risks and domino effects may also be identified and considered in the simulation.

The aim of the simulation model will be the assessment of these strategies by simulation experiments.

The results of the modelled decision strategies will be incorporated into interactive standard operating procedures which can be used by a responsible person in a freight village. That person will be guided to appropriate course of action and so will be able to accelerate the necessary decision-making processes by following a path of yes/no questions about the damaging event that has occurred.

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Application and Evaluation of Multi-criteria Clustering Algorithms for Customer-Oriented Supply Chain Segmentation

Sebastian Terlunen, Guilherme Barreto and Bernd Hellingrath

Abstract Due to an ever increasing complexity, modern supply chains have to make use of Decision Support Systems to focus on the one hand on cost savings and on the other hand on a high customer orientation. This is especially difficult due to different service and costs expectations that have to be taken into account jointly to fulfill the customer expectations more precisely. While the need for a differentiated service fulfillment is generally acknowledged, little research exists to date addressing how an organization can identify different economical and logistical viable groups of a customer base for different logistical problem statements. Therefore, this paper seeks to enhance the knowledge in this area by the application and evaluation of a relative new data clustering algorithm based on Self Organizing Maps and comparing it to a standard data clustering algorithm based on the K-Means algorithm in the context of the research domain of supply chain segmentation.

Keywords Customer-oriented supply chain segmentation · Clustering methods · K-Means · Self organizing maps · Decision support systems

S. Terlunen (✉) · B. Hellingrath
Information Systems and Supply Chain Management, Westfälische Wilhelms-Universität Münster, 48149 Münster, Germany
e-mail: sebastian.terlunen@wi.uni-muenster.de

B. Hellingrath
e-mail: bernd.hellingrath@wi.uni-muenster.de

G. Barreto
Department of Teleinformatics Engineering Avenue Mister Hull, S/N—Campus of Pici, Center of Technology, CP 6005, Federal University of Ceará, Fortaleza, CE 60455-760, Brazil
e-mail: guilherme@deti.ufc.br

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1 Rationale for Customer-Oriented Supply Chain Segmentation

Today's supply chains compete in an increasingly complex, dynamic and uncertain business environment. Research and practitioners have broadly agreed that supply chains are faced with two conflicting goals, namely operational and market goals. To meet the former ones, savings in production, storage and distribution costs in terms of economic efficiency, profitability and cost effectiveness are highly desirable. To meet the latter ones, an increased degree of product individualization and individualized service fulfillment have to be offered to the customer. As a consequence, supply chains can consist of forecast-driven and customer order-driven related activities. Forecast-driven activities allow for realization of economies of scale and lot-size optimized value creation processes. Whereas, by customer order-driven activities storage and capital commitment costs can be kept at a low level and furthermore flexibility in terms of delivery lead time, production volume and product-specifications can be achieved. A supply chain can either completely consists of forecast-driven or order-driven activities, or combine both, dividing the supply chain vertically (Klaas and Delfmann 2002).

Besides, increased customer expectations, e.g. the demand for more product customization and features, for more responsive logistical services, and higher product availability, require a higher customer orientation. It is widely acknowledged and emphasized by practitioners as well as by academics that it is not appropriate anymore to apply the traditional and generic "one size fits all" approach, i.e. offering one logistical service level to the whole customer base. This approach will result in customer groups who are either being over-served or under-served (Butner 2010; PricewaterhouseCoopers 2012). Based on the idea that customers demonstrate heterogeneous demand and diversified needs with regard to product and logistical characteristics, a supply chain can be segmented horizontally, too. This may result in parallel processes serving specific customers or, if it is not economically viable, to provide customers in prioritized order fulfillment in case of bottlenecks of a shared resource (Delfmann 1995).

As a consequence, decision makers have to be empowered by approaches identifying different ecological and logistical viable groups of a customer base initially. Afterwards, based on the different customer groups, the decision makers have to decide at first how the supply chain should be segmented horizontally, i.e. should different customer groups be supplied by different parallel processes or even by different parallel sub-supply chains. In a second step they have to decide how the supply chain should be segmented vertically, i.e. which processes have to be organized forecast-driven and which process have to be organized order-driven (Godsell et al. 2011). For identifying different customer groups most of the supply chain segmentation approaches make use of only a small number of variables (Griffiths et al. 2000) and using rather generic guidelines instead of more sophisticated approaches (Collin et al. 2009; Jüttner et al. 2010). Besides, some approaches make use of explicit knowledge based methods. Hereby, classification rules are set up by decision makers in charge based on domain knowledge in advance, e.g. customer with a contribution margin of 5 % in comparison to the overall contribution margin belong to a premium customer segment. Apart from the fact that these approaches need specific domain knowledge, the main drawback can be seen that classification rules have to be predefined and may not be able to identify some customer groups, which are more homogenous in behavior. In general, it can be stated, that a relatively low accuracy in forecasting of cluster membership leads to a high portion of unintended members of each cluster. Misplacements result in ineffective measures that are designed to achieve an appropriate customer orientation. The problem, the identification of different ecological and logistical viable groups of customers, can be described mathematically and data clustering algorithms of the research domain of data mining can therefore be applied.

In this paper we apply and evaluate two data clustering algorithms, which do not limit the amount of used clustering variables and allow for detecting customer groups without predefined rules. We compare one relative new clustering algorithm based on a variation of an Artificial Neural Networks, called Self Organizing Maps (SOM) and a well-known clustering algorithm, the K-Means algorithm. The two data clustering approaches are exemplarily evaluated in a practical scenario by means of a data set from consumer packaged goods industry. We show that the application of two clustering approaches in combination with evaluation indexes measuring the resulting cohesion and separation ensure valid customer segments for which a customer-oriented supply chain segmentation is valuable. Hereby, we have implemented a full cycle required for clustering analysis: (1) Problem definition and variable selection, (2) Algorithm implementation, (3) Automatic cluster validation by suitable indexes, (4) Cluster validation by business knowledge.

The remainder of the paper is organized as followed: Sect. 2 covers the description of materials and methods, i.e. the argument-based choice of logistical and economic variables, of the chosen clustering algorithms and validity indexes. In Sect. 3 the application and the evaluation results are presented. Furthermore, we give recommendations of actions how supply chain segmentation can be conducted based on different customer groups, which have to be identified beforehand. The paper concludes with comments on the managerial implications and limitations, and a conclusion and an outlook. It has to be stressed, that this paper can be seen as a first step for achieving the research goal of customer oriented supply chain segmentation. The benefits of a customer-oriented supply chain segmentation and especially the proposed recommendations of actions have to be investigated more deeply, e.g. by means of evaluation methods like simulation.

2 Theoretical Basics

2.1 *Identification of Clustering Variables—A Literature Review*

For identifying possible variables for clustering, a structured literature review was conducted in consideration of the proposed literature search process by Vom Brocke et al. (2009). We investigated scientific contributions in journal papers in the research field of supply chain management, logistics, production and operation management from 1990 until today. We focused on scientific contributions that were at least ranked above the ABS level 4 proposed by Academic Journal Quality Guide 4 (Harvey et al. 2010) or at least above the JOURQUAL 2.1 level C proposed by Verband der Hochschullehrer für Betriebswirtschaft e.V. (Hennig-Thurau et al. 2004). Due to space limitations in this paper we only show in the following a rough overview of the conducted literature review. Besides, we only present quantitative variables and do not present qualitative variables like demanded degree of innovation speed or demanded degree of individualization due to the fact, that these variables cannot be directly used for the clustering algorithms.

The literature review has been conducted on scientific databases “Emerald Homepage”, “SciVerse ScienceDirect”, “WileyHomepage” and “Business Source Premier” by means of keyword search, keyword refinement, as well as forward and backward search techniques. Since the problem context of customer-oriented supply chain segmentation involves multitude of aspects from different research domains we make use of keywords originate from different research contexts. The resulting 21 keywords can be categorized into the following research aspects: “Supply Chain Design”, “Push-/Pull Systems”, “Customer order decoupling point positioning”, “Build-to-order/Build-to-stock supply chains”, “Postponement”, “Mass Customization”, “Lean-/Agile supply chains”, “Customer oriented/Demand oriented supply chains” and “Hybrid supply chains”.

The review resulted in the identification of 21 papers which on the one hand provide a literature review themselves and on the other hand concrete solution approaches to supply chain segmentation or related problems. In Table 1 the proposed clustering variables and their number of naming are presented. It can be concluded that economic variables like turnover, supply chain costs, variables for describing the demand pattern of the customers, like demand variability and demand predictability as well as variables describing the demanded logistics service level are considered as crucial.

2.2 *Applied Clustering Algorithms and Validation Indexes*

We make use of the K-Means algorithm as a benchmark because it is well known on one hand and one the other hand it generates relatively acceptable clustering

Table 1 Quantitative variables for identifying different customer proposed by scientific contributions

Clustering variables	Accepted delivery time	Delivery precision	Turnover	Demand volume	Demand predictability	Demand volatility	Production costs	Transportation costs	Inventory costs
Number of naming	16	4	1	10	8	15	6	4	4

results (Chaturvedi et al. 1997; Jain 2010). K-Means needs a fixed value of K in advance before performing clustering. Due to the fact, that one usually does not know the appropriate number of clusters, it is a common approach to conduct a clustering algorithm several times with different values of K. For determining the optimal value of K in each clustering step, we make use of the silhouette coefficient (Kaufman and Rousseeuw 2005; Adam et al. 2004). To guarantee that a good cluster solution will be found, we make use of the "Forgy Approach", where randomly multiple initializations of the algorithms are tested (in our case 50 initializations), and the most frequent solution is kept (Peña et al. 1999).

Apart from statistical clustering algorithms, starting in the early 2000s, a great deal of interest and effort has been directed towards using Artificial Neural Networks (ANN) for clustering in the research area of customer segmentation (Chattopadhyay et al. 2012). Among the different approaches in the context of using ANN, Self Organizing Maps (SOM) is the most used clustering algorithm in the research context of customer segmentation (Hong and Kim 2012). Although there are some comparing test studies (SOM against K-Means) a conclusions seem to be ambivalent which clustering algorithm outperforms the other. Some authors suggest that SOM outperforms or performs equal than the K-Means clustering algorithm (Kuo et al. 2006), while other authors conclude the opposite (Openshaw and Openshaw 1997). Nevertheless it is general stated that SOM are a robust alternative to traditional statistical clustering approaches like the K-Means (Chattopadhyay et al. 2012).

Formally, the SOM consists of a regular, usually two-dimensional lattice A of M neurons. The map $i^*(x_j)$: $X \rightarrow A$ is defined by weight vectors $W = \{w_1, \ldots, w_M\}, w_i \in \mathbb{R}^{p+q}$, and their corresponding coordinates $r_i \in \mathbb{R}^2$ in the lattice A. A data item x_j is mapped to the best matching unit c_k with the smallest distance between w_i and x_j defined by

$$c_k = \arg\min_i \|x_j - w_i\|. \quad (1)$$

The weights of the neurons are adapted iteratively in two steps. In the first step c_k is calculated for all x_j according to Eq. (1). To ensure that each neuron with its corresponding weight represents similar data items as its neighbors, the corresponding weights are not only adapted according to the best matching neuron c_k (first step) but also according to the weights of neurons in the neighborhood (second step). The neighborhood relationship between two neurons is defined by a Gaussian-like function $h_{ij} = \exp(-\frac{d_{ij}^2}{2r_t^2})$, where d_{ij} denotes the Euclidian distance between two neurons on the map, and r_t denotes the neighborhood radius which is set to decrease with each iteration t.

One general acknowledged advantage of applying the SOM approach is its ability of dimension reduction, while maintaining the original topological relations (Garson 1998). Therefore, the decision maker is enabled to visualize the relationships among inputs by means of a U-matrix, representing the position of the

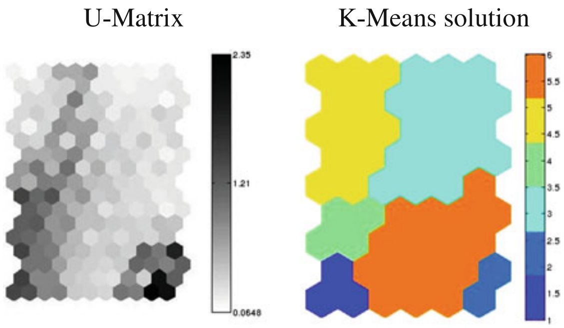

Fig. 1 U-matrix and resulting K-Means solutions (6 clusters, 10 × 10 neurons of the lattice)

resulting neurons after having conducted the two steps described in above. Figure 1 depicts an example of a resulting U-matrix after conducting the SOM training phase for the given data set in a gray scale. The whiter the region, the closer are the prototypes representing more closely data points. It can be concluded that the neurons cannot be assigned visually very easily.

To overcome this problem we make use the K-Means clustering algorithm following the procedure introduced by Vesanto and Alhoniemi (2000). The procedure is the same as performing the K-Means clustering directly on the data set. The only difference is that the r-th cluster of SOM neurons is comprised of weight vectors w_i that are mapped onto the centroids p_r of the K-Means algorithm.

For comparing the quality of the clustering results we make use of cluster validity indexes. Ideally, validity indexes should take care of the cohesion and separation aspects of partitioning. In our study we follow the survey of Milligan and Cooper who proposed the following index $J(k) = \frac{B(k)}{W(k)}$ where B(k) and W(k) denote the between and within cluster sums of squares of the partition respectively. Besides, we make use of the sum of square index to compute explicitly the cohesion of the clusters of the best partition result of the both clustering approach.

3 Applying Multi-criteria Clustering Approaches for Customer-Oriented Supply Chain Segmentation

3.1 Real-World Application and Selected Variables

For evaluating our theoretical findings regarding the relevant variables and the two clustering algorithms presented in a practical context, we conduct a case study on an enterprise from the consumer packaged goods industry. In general, the business environment of this industry is characterized by high competitive environment and demand fluctuations that are hard to predict (Adexa 2013). As a consequence, supply chains from this industry have to apply measures for cost reduction on the one hand and efforts for a higher customer orientation on the other hand, which may result in new unique selling propositions.

The enterprise of interest is a producer of premium table-top products and packaging solutions for take-away food. The company has about 2,000 employees in 17 countries. Its brand is sold in over 40 markets and holds a number one position in Central and Northern Europe. Customers are as well retailer as professionals. The retailers are grocery stores, supermarkets, specialty retailers, and interior design stores. The professionals are hotels, restaurants, and catering companies. The product portfolio ranges from candles, table coverings, plates and serving items to cups and glasses, cutlery, and party accessories.

Besides, one of the most important business objectives of the enterprise is to serve customer orders at a high delivery precision, which is regarded as one of the most important unique selling proposition. Due to that, 88 % of the products are driven by forecasts and only 12 % by customer order. As a consequence, the storage costs contribute a relative high share to the total logistics cost. The decision makers in charge stated in interviews that one of their new strategic goals is to apply customer-oriented supply chain segmentation. They expect among others advantages to reduce the overall costs and therefore to increase the annual revenue. Besides, it is assumed that a higher customer orientation can be achieved, e.g. by more tailored logistic services for the different needs of the customers.

As a proof-of-concept we apply our analysis to the product with the highest amount of customers (1,701), having highly various demand patterns and generating one of the highest total revenue among other products of the company. In consideration of the findings in Sect. 2.1 we make use of five clustering variables. Each value of the variables is calculated for each customer and is normalized for our analysis, as recommended in most of scientific literature in the research area of data clustering (e.g. Backhaus 2008; Wedel and Kamakura 2000).

The “accepted delivery time” of each customer is the first variable, which directly defines the maximum range of the order driven area. The “annual revenue per customer” is the second variable resulting from the operational costs and the turnover of every customer per year. Hereby, the costs of supply chain operations are composed of costs for storage (interest and stocking), production, procurement and transportation.

For measuring the offered logistics service level we make use of the “delivery reliability” for each customer. For the company of interest achieving a delivery reliability of at least 90 % is one of the most important business objectives. The variable relates the total amount of goods delivered in time to the total amount of goods ordered by one customer. This variable is a valuable source of information for identifying customer groups, which do not experience the intended minimal delivery reliability. Measures like a larger forecast-driven part of the supply chain, a higher safety stock level or a dedicated value chain processes could improve the delivery reliability and finally increase the customer satisfaction.

For describing the volatility and the predictability of the customer demand we make use of two variables. The volatility is described by the variables “variation coefficient of orders” and predictability is described by the “mean absolute percentage error”. The former variable is calculated by the standard deviation of the demand in relation to the average demand of the customer during the planning horizon. Customer with a more constant variation coefficient of orders allow for measures like broaden the order-driven area of a supply chain or decreasing the safety stock level. Instead of this, customers who have a higher variation coefficient of orders need a larger forecast-driven area or higher safety stock levels to avoid stock-outs that are more likely in this case. The latter variable is calculated by the mean of the absolute percentage errors between the real demand and the forecasted demand of a customer. Customers with a more predictable demand allow for measure like broaden the order-driven areas of the supply chain and to minimize safety stock levels. In contrast to this, customers which demand is more unpredictable need broader forecast-driven areas of a supply chain and higher safety stock levels.

3.2 Statistical Analysis of the Resulting Clusters

The results of our analysis for the real world data set are presented in Table 2 by the mean values of the observation variables of each cluster. Analyzing the overall values it can be concluded that the typical customer has a short accepted delivery time, a varying order pattern and is served with very high delivery reliability, which is one of the most important strategic goals of the company.

Comparing the size of the resulting clusters it can be concluded that majority of the customer base is represented by cluster C_4^K and C_5^K of the K-Means clustering algorithm and by clusters $C_{4,5,6}^{S/K}$ of the SOM/K-Means clustering algorithm. One advantage of the SOM/K-Means clustering algorithm can be seen here. With the help of the combined clustering algorithm the biggest part of the customer base can be separated more precisely. The remaining clusters of both clustering algorithms are smaller, but nevertheless important. In comparison to the overall mean values these clusters contain customers generating a very high revenue ($C_2^K, C_2^{S/K}$), having a low delivery reliability ($C_3^K, C_3^{S/K}$) or having a very long accepted delivery time ($C_1^K, C_1^{S/K}$). Here, the results of the combined clustering algorithm are preferable again, as the clusters contain more customers. Therefore, measures for customer-oriented supply chain segmentation can be applied more coherent concerning to the needs of the respective customer group on one hand and on the other hand the measures are more efficient.

3.3 Recommendations of Actions for a Customer-Oriented Supply Chain Segmentation

Each generated cluster represents a customer group, which is worthy of further investigation in order to analyze, how the supply chain has to be segmented to fit the needs of these different groups. The following recommendations of actions can

Table 2 Mean values of the variables, overall, per clusters

Cluster	Annual revenue (Euros)	Accepted delivery time (days)	Delivery reliability (percentage)	Variation coefficient of orders	Mean absolute percentage error	Segment size (# of cust.)
	Overall mean values					
	1,439.95	4.2	99.15	2.23	17.06	
	K-Mean results (mean values per cluster, per variable): SSE: 1.65; J: 8.48					
C_1^K	1,879.1	16.89	99.69	2.06	15.2	67
C_2^K	5,0449.81	6.15	97.06	0.65	4.4	9
C_3^K	2,103.75	5.45	55.64	2.00	14.4	23
C_4^K	248.14	3.44	99.98	3.14	25.0	801
C_5^K	2,025.28	3.85	99.54	1.35	10.1	801
	SOM/K-Means results (mean values per cluster, per variable): SSE: 1.67; J: 15.05					
$C_1^{S/K}$	1,874.51	14.47	99.73	1.65	12.0	75
$C_2^{S/K}$	3,3914.74	4.59	98.67	0.79	5.6	66
$C_3^{S/K}$	1,768.12	4.84	65.61	1.79	8.0	35
$C_4^{S/K}$	223.09	3.78	99.97	3.44	27.2	587
$C_5^{S/K}$	1,532.29	3.78	99.76	1.18	8.9	513
$C_6^{S/K}$	496.63	3.36	100	2.17	16	425

be set up for the clustering results of the SOM/K-Means approach. As described in Sect. 3.1, the product of the investigated customer base is produced by means of a purely forecast-driven supply chain. Especially the customer group ($C_1^{S/K}$) seems to be appropriate for vertical supply chain segmentation, i.e. a broaden order-driven part of the supply chain. These customer groups generate higher revenue, have lower demand variations, normal demand predictability, and do accept longer delivery times in comparison the overall mean values.

The customers represented by the cluster $C_2^{S/K}$ are the most valuable ones with the highest revenue per customer. Besides, these customers have a quite constant demand pattern, very good demand predictability, and do have an average requested delivery time. However, the delivery precision for this group of customers is worse than the overall delivery precision. Setting up a dedicated value chain process or at least a prioritized order fulfillment for this group is recommended (horizontal supply chain segmentation). It is likely that this will result in an increase of the overall revenue of the supply chain.

Customer group $C_3^{S/K}$ is confronted with the worst delivery precision although the variation in their demand pattern and their demand predictability is even lower as the overall average. In comparison to overall average customer revenue, this customer group is slightly more profitable. In consequence, an improvement of the logistical service for this group, e.g. realized by means of prioritized order fulfillment or higher safety stock levels. Dedicated value chain processes for this customer group are not recommended because of the only slightly more profitability.

Customer group ($C_4^{S/K}$) followed by the customer group ($C_6^{S/K}$) generates the lowest revenue and has one of the shortest accepted delivery time and has the highest variation in demand. However, these customers experience one of the highest delivery precision. In case of restricted resources, orders from this customer group shall be fulfilled with lower priority. Furthermore, a decrease in delivery precision up to the intended lowest delivery precision rate of 90 %, e.g. by means of a broader build-to-order driven part of the supply chain or by means of a lower safety stock level will lead to a higher revenue of the company.

Customer group $C_5^{S/K}$ are comparable to the customer group $C_4^{S/K}$ and $C_6^{S/K}$. The main difference is that these customers have a more stable and predictable demand pattern and a higher contribution to the overall revenue of the supply chain. Therefore, the current customer-orientation for this customer group seems to be appropriate.

4 Conclusion and Outlook

The concept presented in this paper is a first step towards customer-oriented supply chain segmentation. We have shown how multi-criteria data clustering algorithms can be used for finding homogenous customer groups with similar logistical and economical characteristics. Besides, we have proposed measures for setting up customer-oriented supply chain segmentation. Decision makers in charge can build up on this approach to align their value chain processes to an adequate customer-orientation.

Summarized, the presented proof-of-concept of applying and evaluating multi-criteria clustering algorithms enables decision makers to identify economical and logistical viable customer groups and measures which can be used to determine customer-oriented supply chain segmentation. The result will be an increase of customer-orientation on the one hand and a decrease of supply chain costs on the other hand.

Therefore, two clustering approaches are compared. By now these approaches were applied by means of their basic algorithms without taking optimized versions into account, like presented by De Smet and Montano Guzmán (2004) or by Van Hulle (2011). An extensive investigation of the optimized algorithms as well as a comparison of further clustering methods regarding their applicability is needed. Besides, a resulting supply chain segmentation based on these findings has to be performed. Afterwards, the overall economical and logistical effects of this segmentation have to be evaluated in comparison to established methods, using evaluation methods like simulation. Hereby, we expect to make profound conclusions that more precise customer-oriented supply chain segmentation results in cost savings as well as in a higher customer satisfaction.

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Order Promising—A Robust Customer-Oriented Approach

Ralf Gössinger and Sonja Kalkowski

Abstract Increasing production requirements have strengthened the academic interest for planning approaches that generate reliable delivery promises. An extended batch capable-to-promise approach is presented in this paper which includes preventive and reactive measures to increase planning robustness. We extend existing approaches by considering both, proposals for delivery dates that deviate from the original order specifications and customers' reactions to these modifications, in the model. To verify the impacts of the extended planning approach it is numerically analyzed on the basis of real-world data of a manufacturer of customized leisure products.

1 Introduction

In the literature different capable-to-promise approaches are suggested to generate relevant information for reaching agreements on delivery dates with customers. Usually a production-oriented perspective is chosen, while customers' reactions on suggested delivery dates and their adherence are often ignored. Paying attention to these two aspects more reliable statements about feasible delivery dates already can be given in the contract award process. Furthermore, deviations from promised delivery dates can yet be minimized in the order fulfillment process. As a result a higher customer satisfaction and loyalty is attainable in the long run. Therefore, the aim of this paper is to extend an existing capable-to-promise approach (Chen et al. 2002) in such a way that it allows for meeting promised delivery dates and quantities to the greatest possible extent even though uncertain environmental situations (e.g. order situation) might occur.

R. Gössinger (✉) · S. Kalkowski
Production Management and Logistics, Martin-Schmeißer-Weg 12, 44227 Dortmund, Germany
e-mail: Ralf.Goessinger@tu-dortmund.de

S. Kalkowski
e-mail: Sonja.Kalkowski@tu-dortmund.de

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Criterion	Characteristic value				
Trigger of the planning process	incoming order (Real time)		defined time interval (Batch)		
Objective	economic		technical		
	profit max.	cost min.	max. order acceptance	min. due date deviation	max. workload
Order rejection	not considered		considered		
Deviation from order conditions	not considered		considered		
Adaptation (ad.) measures	no ad.	time ad.	intensity ad.	quantity ad.	quality ad.
Capacity policy	global		nested		

Fig. 1 CTP classification and profile of the proposed approach

Capable-to-promise (CTP) approaches generalize available-to-promise (ATP) approaches that determine whether customer orders can be fulfilled, at which delivery date and in what quantity. In particular the generalization consists in the integration of additional information about capacities and intermediate product inventories in multi-stage production systems (Pibernik 2005). The existing CTP approaches can be classified according to the criteria and characteristic values represented in Fig. 1.

The characteristic values of the approach to be discussed in this paper are marked in grey. Existing approaches with similar intentions can be characterized as shown in Fig. 2.

The overview reveals that none of the existing approaches completely fits with the characteristics of the approach to be analyzed. Thus the considerations underlying the individual characteristics have to be explicated.

To model the two options of possible customer reactions on deviating delivery date proposals (placement or refusal of orders) Pibernik and Yadav (2008) integrate an order placement possibility that decreases with increasing deviation from the delivery date (reaction function) and analyze the impacts of different types of

Authors \ Criteria	Batch/ Real time	Objective	Order rejection	Deviation/ adaptation	Nested capacity
Che Han/Halim (2011)	B	cost min.	x	x	-
Chen et al. (2002)	B	profit max.	x	-	x
Gao et al. (2012)	B	profit max.	x	-	x
Halim/Muthusamy (2012)	B	cost min.	x	x	-
Jeong et al. (2002)	R	cost min.	x	x	-
Jung (2012)	B	cost min.	-	x	-
Lečić-Cvetković et al. (2010)	R	max. order acceptance	x	x	-
Pibernik (2005)	R	max. order acceptance	x	x	-
	B	profit max.	x	-	-
Pibernik/Yadav (2008)	R	max. order acceptance	x	-	x
Robinson/Carlson (2007)	R	cost min.	x	-	-
Zhao et al. (2005)	B	cost min.	-	x	-

Fig. 2 Relevant approaches

reaction functions. In the present paper their idea is adopted, but information about customers' reactions is integrated in the planning process itself.

Additionally, different adaptation measures are analyzed with regard to their impacts on robustness. To extend the degrees of freedom in planning and to gain a lower sensitivity towards changes of the order situation the option of partial deliveries (Pibernik 2005), where delivery dates are met for sub-quantities, will be considered. The second measure integrated in the planning approach, is the idea of a nested policy of capacity utilization (Jacob 1971; Harris and Pinder 1995). Access to a certain amount of capacity or inventory is only given to exceptionally profitable orders. If such orders are not present in the relevant planning situation, this reservation can be used for yet unknown future profitable orders. In summary, planning robustness is to be achieved by the following features:

- Consideration of customers‘ reactions on delivery date proposals that deviate from delivery dates requested by the customers.
- Integration of measures to adapt to changing order situations.

For this purpose a two-stage CTP-approach is derived based on the capable-to-promise approach proposed by Chen et al. (2002) (Sect. 2.1). At the first stage the decision about order acceptance or preliminary rejection of the orders is made. At the second stage alternative delivery date suggestions are generated for preliminarily rejected orders. Implications of this approach on the reliability of the delivery dates are analyzed numerically in Sect. 3 by means of the AIMMS environment using real-world data of a manufacturer of customized products. Finally in Sect. 4 we summarize the main results of the paper and give an outlook on our future research in this field.

2 Planning Approach

2.1 Basic Model

Starting point of our considerations are successively arriving orders with a specified desired delivery time interval $[t_i^F, t_i^S]$ and a quantity q_i of a product with a unit price p_i. The quantities $b_{i.r}$ of material $r\,(r = 1, \ldots, R)$ required to produce one unit of order i, the associated material costs k_r^R and inventory holding costs $k_r^{L.R}$and $k_i^{L.EP}$ for materials and finished products, given per quantity and time unit, are known. Additionally, information about the replenishment times and quantities of material stock $a_{r.t}^R$, the lead time deferrals ω_1 and ω_2 for products made in-house $(r = 1, \ldots, r_{k-1})$ respectively externally $(r = r_k, \ldots, R)$ procured materials $(\omega_2 < \omega_1)$ is available. Furthermore, the capacity requirements κ_i per unit of a finished product, the capacity C of the production system and the quantity and order independent transport costs k^T are known.

A rolling horizon with discrete time intervals and a length of T periods is the underlying planning procedure. At the beginning of the current planning period t_a orders are scheduled that arrived in between the periods $t_a - \tau$ and $t_a - 1$ (batch interval). The next planning run takes place at the beginning of planning period $t_a + \tau$ for orders that arrived in between the periods t_a and $t_a + \tau - 1$. Therewith in each planning run the planning horizon shifts by τ periods. Since the order fulfillment process covers multiple periods, the following order sets are to be distinguished at the beginning of the current planning period t_a:

- A: Set of orders that arrived in between the periods $t_a - \tau$ and $t_a - 1$.
- $\hat{A}$: Set of orders that were accepted before period t_a but are not completely fulfilled yet.
- $\underline{A}$: Set of orders that were rejected or completely fulfilled before period t_a.

In the basic model order- and resource-related *decisions* have to be made. With regard to orders it has to be determined whether to accept ($Z_i = 1$) or to reject ($Z_i = 0$) a present order that has not been considered up to period t_a. In case of order acceptance a delivery date $T_{i.t}$ is specified as well as the quantities $M_{i.t}$ to be delivered to the customer in period t. Decisions on *resources* are related to input quantities $Q^R_{i.r.t}$ of individual material types, production quantities $P_{i.t}$ of finished products and inventories $B^R_{r.t}$, $B^{EP}_{i.t}$ of materials and finished products. The *decision field* is restricted by the order specifications of the customers, the production conditions and logical requirements of the rolling horizon. *Customer-related* constraints are:

- The delivery quantity $M_{i.t}$ equals the ordered quantity q_i.
- The delivery date $T_{i.t}$ fits the desired delivery time interval $[t^F_i, t^S_i]$.

The following constraints are determined by the *production system*:

- The production capacity C cannot be exceeded by the capacity demand κ_i induced by the production of finished products $P_{i.t}$ required to fulfill the order.
- The quantities of the finished products $P_{i.t}$ to be produced determine the material consumption $Q^R_{i.r.t}$ in the preceeding periods according to the production coefficients $b_{i.r}$ and the lead time deferrals ω_1 and ω_2.
- The inventories $B^R_{r.t}$, $B^{EP}_{i.t}$ for material and finished products result from incoming quantities $a^R_{r.t}$ respectively $P_{i.t}$ and outgoing quantities $Q^R_{i.r.t}$ respectively $M_{i.t}$.
- In order to avoid a higher production quantity as needed for delivery, an empty stock of finished products at the end of the planning horizon is postulated.

Because of the rolling horizon, at the current planning period orders may exist that were accepted in previous planning periods but are not completed yet. Therefore inventories, production quantities, promised delivery dates and quantities from the previous planning run need to be considered as parameters of the current planning run.

In accordance with the operative character of the planning problem to decide about order acceptance and delivery dates, the usual objective of profit maximization is pursued. Thereby, the revenue is a positive component, while material, inventory holding and transportation costs are negative components. Several approaches suggested in literature (e.g. Che Han and Halim 2011; Chen et al. 2002; Halim and Muthusamy 2012; Pibernik 2005; Robinson and Carlson 2007) take penalty costs for order rejection into account. These penalty costs are opportunity costs resulting from future lost sales due to former order rejections which were induced by decisions at the tactical level (capacity planning, customer acquisition). Due to this indirect relation penalty costs for order rejection are not considered in the proposed approach. On the other hand order rejection at the first stage of the planning approach is only of preliminary nature, since the attempt to accept these orders with deviating conditions is made at the second planning stage.

The resulting linear mixed-integer problem can be formulated as follows:

$$\max \sum_{t=t_a}^{T} \left(\sum_{i \in A \cup \hat{A}} \left(M_{i.t} \cdot p_i - k_i^{L.EP} \cdot B_{i.t}^{EP} - k^T \cdot T_{i.t} - \sum_{r=1}^{R} \left(k_r^R \cdot Q_{i.r.t}^R \right) \right) - \sum_{r=1}^{R} \left(k_r^{L.R} \cdot B_{r.t}^R \right) \right) \tag{1}$$

subject to

- Customer-related constraints

$$M_{i.t} = q_i \cdot T_{i.t} \quad \forall t_a \le t \le T \,,\; i \in A \tag{2}$$

$$\sum_{t=t_i^F}^{t_i^S} M_{i.t} = q_i \cdot Z_i \quad \forall i \in A \tag{3}$$

$$\sum_{t=t_i^F}^{t_i^S} T_{i.t} = Z_i \quad \forall i \in A \tag{4}$$

$$\sum_{t=t_a}^{T} T_{i.t} = Z_i \quad \forall i \in A \tag{5}$$

- Production-related constraints

$$\sum_{i \in A \cup \hat{A}} P_{i.t} \cdot \kappa_i \le C \quad \forall t_a \le t \le T \tag{6}$$

$$b_{i.r} \cdot P_{i.t+\omega_1} = Q_{i.r.t}^R \quad \forall i \in A \cup \hat{A},\; r = 1, \ldots, r_k - 1,\; t_a \le t \le T \tag{7}$$

$$b_{i.r} \cdot P_{i.t+\omega_2} = Q^R_{i.r.t} \quad \forall i \in A \cup \hat{A},\ r = r_k, \ldots, R,\ t_a \leq t \leq T \tag{8}$$

$$B^R_{r.t-1} + a^R_{r.t-1} - \sum_{i \in A \cup \hat{A}} Q^R_{i.r.t} = B^R_{r.t} \quad \forall r,\ t_a \leq t \leq T \tag{9}$$

$$B^{EP}_{i.t-1} + P_{i.t} - M_{i.t} = B^{EP}_{i.t} \quad \forall i \in A \cup \hat{A},\ t_a \leq t \leq T \tag{10}$$

- Logical requirements

$$M_{i.t} = \hat{M}_{i.t} \quad \forall i \in \hat{A},\ t_a \leq t \leq T \tag{11}$$

$$T_{i.t} = \hat{T}_{i.t} \quad \forall i \in \hat{A},\ t_a \leq t \leq T \tag{12}$$

$$B^R_{r.t_a-1} = \hat{B}^R_{r.t_a-1} \quad \forall r \tag{13}$$

$$B^{EP}_{i.t_a-1} = \hat{B}^{EP}_{i.t_a-1} \quad \forall i \in \hat{A} \tag{14}$$

$$B^{EP}_{i.t_a-1} = 0 \quad \forall i \in A \tag{15}$$

$$B^{EP}_{i.T} = 0 \quad \forall i \in A \cup \hat{A} \tag{16}$$

$$P_{i.t} = 0 \quad \forall i \in A, t_a \leq t \leq t_a + (\omega_1 - 1) \tag{17}$$

$$P_{i.t} = \hat{P}_{i.t} \quad \forall i \in \hat{A}, t_a \leq t \leq t_a + (\omega_1 - 1) \tag{18}$$

- Domain of decision variables

$$Z_i \in \{0, 1\} \quad \forall i \tag{19}$$

$$M_{i.t}, P_{i.t}, B^{EP}_{i.t} \geq 0 \quad \forall i, t \tag{20}$$

$$B^R_{r.t} \geq 0 \quad \forall r, t \tag{21}$$

$$T_{i.t} \in \{0, 1\} \quad \forall i, t \tag{22}$$

$$Q^R_{i.r.t} \geq 0 \quad \forall i, r, t \tag{23}$$

2.2 Consideration of Adjustment Measures

One essential result revealed through the application of the basic model is the information about the orders to be accepted, their corresponding delivery dates as well as the orders to be preliminarily rejected. Reasons for order rejection can be order conditions that cannot be handled technically (e.g. desired delivery is before the earliest possible completion date) and/or that are economically not favourable (e.g. the order competes for scarce resources with more or less profitable orders that were already bindingly accepted). In the context of economically disadvantageous order conditions the producer can reduce the probability of occurrence (prevention) or adapt to these situations (reaction). Both opportunities aim at making robust delivery date decisions. The nested policy of capacity utilization and partial deliveries are considered as preventive measures that generalize the basic model. These measures enlarge the number of planning options in such a way that some of the otherwise appearing resource conflicts can be avoided. In contrast to these preventive measures the opportunity to adapt the desired delivery dates is considered as a reactive measure at the succeeding planning stage. At this second stage alternative delivery date proposals are generated for preliminarily rejected orders and customers decide on the acceptability of these suggestions.

Preventive measures: In the simplest form of a nested policy of capacity utilization the total capacity is splitted up into standard and premium capacity, and a cost premium for accessing premium capacity is introduced (Jacob 1971). As a result, premium capacity can only be used by more profitable orders. If these orders do not exist yet, it is reserved for profitable orders arriving in future. Implications for planning are on the one hand that the decision maker has ex ante to specify two additional parameters: the share of premium capacity ε and the costs k^P for utilizing premium capacity. On the other hand the basic model has to be extended by additional decisions, constraints and objective components. Additional decisions arise in the context of utilized units of standard $P^S_{i.t}$ and premium $P^P_{i.t}$ capacity. Therefore it is necessary to reformulate capacity constraint (6) for both capacity types (6a, 6b) and to ensure that the sum of capacity units used by an order equals its capacity requirements (6c). Finally the objective function (1) must be extended by the component of premium costs (1′). Formally these modifications can be formulated as follows:

$$\max \sum_{t=t_a}^{T} \left(\sum_{i \in A \cup \hat{A}} \left(M_{i.t} \cdot p_i - k_i^{L.EP} \cdot B_{i.t}^{EP} - k^T \cdot T_{i.t} - \sum_{r=1}^{R} \left(k_r^R \cdot Q_{i.r.t}^R \right) - k^P \cdot P_{i.t}^P \cdot \kappa_i \right) - \sum_{r=1}^{R} \left(k_r^{L.R} \cdot B_{r.t}^R \right) \right) \tag{1′}$$

$$\sum_{i \in A \cup \hat{A}} P_{i.t}^P \cdot \kappa_i \leq \varepsilon \cdot C \quad \forall t_a \leq t \leq T \tag{6a}$$

$$\sum_{i \in A \cup \hat{A}} P_{i.t}^S \cdot \kappa_i \leq (1 - \varepsilon) \cdot C \quad \forall t_a \leq t \leq T \tag{6b}$$

$$P_{i.t}^P + P_{i.t}^S = P_{i.t} \quad \forall t_a \leq t \leq T,\ i \in A \cup \hat{A} \tag{6c}$$

Additional degrees of freedom result, if the desired order quantities are fulfilled by multiple deliveries. Pibernik's approach (Pibernik 2005) to allow two partial deliveries, is going to be extended to the allowance of n deliveries with a defined minimum quantity of q_i^{TL}. Partial deliveries are possible for a relation of $q_i^{TL} \leq q_i/2$ between order size q_i and minimum quantity q_i^{TL}, while the customer can avoid partial deliveries by specifications in the range of $q_i/2 < q_i^{TL} \leq q_i$. Although there is no need for extending the basic model with regard to decisions and constraints partial deliveries imply slight modifications of constraints:

- Individual partial deliveries contain at least the minimum quantity specified by the customer and
- delivery dates may not lie outside the desired time interval.

Formally the following changes are relevant:

$$M_{i.t} \leq q_i \cdot T_{i.t} \quad \forall t_a \leq t \leq T, i \in A \tag{2a}$$

$$M_{i.t} \geq q_i^{TL} \cdot T_{i.t} \quad \forall t_a \leq t \leq T, i \in A \tag{2b}$$

$$\sum_{t=t_i^F}^{t_i^S} M_{i.t} = q_i \cdot Z_i \quad \forall i \in A \tag{3a}$$

$$\sum_{t=t_a}^{T} M_{i.t} = q_i \cdot Z_i \quad \forall i \in A \tag{3b}$$

$$\sum_{t=t_i^F}^{t_i^S} T_{i.t} \geq Z_i \quad \forall i \in A \tag{4a}$$

$$\sum_{t=t_i^F}^{t_i^S} T_{i.t} \leq \left\lceil \frac{q_i}{q_i^{TL}} \right\rceil \cdot Z_i \quad \forall i \in A \tag{4b}$$

$$\sum_{t=t_a}^{T} T_{i.t} \leq \left\lceil \frac{q_i}{q_i^{TL}} \right\rceil \cdot Z_i \quad \forall i \in A \tag{5'}$$

Adaptation of delivery dates as a reactive measure: For preliminarily rejected orders the second planning stage tries to find out which delivery dates outside the given delivery time interval can be met. The adjusted delivery dates are proposed to the customers and they decide themselves about whether to accept or reject the order. So the final order acceptance decisions are made by the customers. In this case a detailed distinction within order set $\underline{A}$ is necessary at the beginning of planning period t_a:

- $\tilde{A}$: Set of orders that were finally rejected or completely fulfilled before period t_a.
- $\bar{A}$: Set of orders that were preliminarily rejected before period t_a.

It is assumed that the producer has collected empirical data concerning customers' reactions on modified order conditions during past order negotiations. Furthermore, a function of acceptance probabilities depending on the extent of deviation from the given delivery time interval can be derived on the basis of this data by means of statistical tools. This reaction function $\beta_i(V_i)$ describes a non-increasing acceptance in case of increasing deviation (delay) V_i of the delivery date from the upper limit t_i^S of the delivery time interval. It is modelled as a discrete distribution with L levels and maximum/minimum acceptance $\beta_i^{\max}$, $\beta_i^{\min}$ at the first/last level:

$$\beta_i(V_i) = \begin{cases} \beta_i^{\max} & : V_i \leq \Delta_l^{\max}; l = 1 \\ \beta_{i.l} & : \Delta_{l-1}^{\max} < V_i \leq \Delta_l^{\max}; l = 2, \ldots, L-1 \\ \beta_i^{\min} & : \Delta_{l-1}^{\max} < V_i; l = L \end{cases} \quad \forall i \in \bar{A}$$

with $0 < \Delta_{l-1}^{\max} < \Delta_l^{\max}$, $0 < \beta_{i.l} \leq \beta_{i.l+1} \leq 1$ and $V_i = \max\limits_{t \in [t_a;T]} \{T_{i.t} \cdot t\} - t_i^S$

Since the final decision of order acceptance under modified conditions is made by the customer *order-related decisions* in the basic model reduce to decisions concerning delivery dates and quantities of preliminarily rejected orders ($\bar{A}$). The *resource-related decisions* in the basic model (input quantities, production quantities, inventories) still have to be made for order sets $\hat{A}$ and $\bar{A}$. With regard to the decision field those *customer-related decisions* are omitted that were linked with the order acceptance decision and the adherence of the delivery time interval (3a, 4b). An additional easing of constraints arises because of the facts that

- the order acceptance by the producer is given ($Z_i = 1 \;\; \forall i \in A$, in constraints 3b and 5′) and
- the delivery is permitted in the interval in between the earliest delivery date specified by the customer and the end of the planning horizon (4a′).

Under the assumption of a robustness oriented planning behavior the impact of scheduling preliminarily rejected orders on capacity and material requirements are considered in such a way that all adjusted delivery dates can be met even though all corresponding customers agree with these dates (no overbooking). Therefore it is not necessary to modify the constraints of the production system and the rolling horizon approach.

Two implications for the *objective function* result from the new planning situation. On the one hand the omission of the order acceptance decision induces the irrelevance of success components that are solely affected by this decision. On the other hand customers' reactions to modified order conditions are uncertain. Thus, the objective function includes an additional uncertain component for orders with proposed deviating delivery dates ($\bar{A}$). This component captures delivery date dependent expected values of revenues as well as inventory holding, material requirements, transportation and premium costs. In case of already confirmed orders

$\hat{A}$ delivery dates respective quantities and material requirements are specified. But the contingent scheduling of preliminarily rejected orders may reveal that modified dates or quantities of the finished products manufacturing, the storage of materials and finished products as well as a modified utilization of premium capacity induce lower costs. In comparison to the basic model a reduced deterministic (certain) component is therefore relevant in the objective function. The allocation of material inventory holding costs to both components cannot be made according to the principle of causation, since the material inventory is affected by the interaction of consumed materials of both order sets ($\bar{A}$ and $\hat{A}$). For estimating the expected inventory holding costs, the stock is hence considered in equivalence to the proportion of material requirements in both components. Formally these circumstances can be formulated as follows:

$$\max \sum_{t=t_a}^{T} \left(\sum_{i \in \hat{A}} \left(-k_i^{L.EP} \cdot B_{i.t}^{EP} - k^P \cdot \mathrm{P}_{i.t}^{\mathrm{P}} \cdot \kappa_i - \sum_{r=1}^{R} k_r^{L.R} \cdot B_{i.r.t} \right) \right.$$
$$+ \sum_{i \in \bar{A}} \beta_i(V_i) \cdot \left(M_{i.t} \cdot p_i - k_i^{L.EP} \cdot B_{i.t}^{EP} - k^T \cdot T_{i.t} - k^P \cdot P_{i.t}^P \cdot \kappa_i \right. \tag{1''}$$
$$\left. \left. - \sum_{r=1}^{R} \left(k_r^R \cdot Q_{i.r.t}^R + k_r^{L.R} \cdot B_{i.r.t} \right) \right) \right)$$

with

$$B_{i.r.t} = \begin{cases} \frac{q_i \cdot b_{i.r}}{\sum\limits_{i' \in \hat{A} \cup \bar{A}} q_{i'} \cdot b_{i'.r}} : & \sum\limits_{i' \in \hat{A} \cup \bar{A}} q_{i'} \cdot b_{i'.r} > 0 \\ 0 : & \text{otherwise} \end{cases} \quad \forall i \in \bar{A} \cup \hat{A}, r, t$$

$$\sum_{t=t_i^F}^{T} T_{i.t} \geq 1 \quad \forall i \in \bar{A} \tag{4a'}$$

Because of the dependency of the acceptance probability and the delivery dates being planned as well as their multiplicative linkage in the objective function a nonlinear mixed-integer programming model results.

3 Numerical Analysis

3.1 Test Configuration

Within the numerical analysis the suitability of the proposed two-stage planning approach is analyzed based on real-world data of a manufacturer of customized leisure products. For this purpose plans with regard to order acceptance and

Partial deliveries (PD)		Capacity Nesting (CN)		Adaptation of delivery dates
Description	**Value of** q_i^{TL}	**Description**	**Value of** (ε, k^P)	
No PD (N)	q_i	No CN (N)	(0, 0)	No adaptation (N)
Average number of PD (PD1)	$min\{q_i, 3\}$	Low level of CN (CN1)	(1/3, 2900)	Adaptation (L)
Maximum number of PD (PD2)	1	High level of CN (CN2)	(2/3, 3500)	

Fig. 3 Tested parameter constellations

termination of order quantities to be delivered are generated on the basis of order and resource data in a rolling horizon approach. The different model formulations are tested for varying simulated developments of reality in order to discuss the following questions:

- How do preventive and reactive measures affect the reliability of delivery dates?
- To which extent does the second planning stage influence the solution quality of the planning approach?

Starting point of the tests was a preliminary assessment of a planning horizon which is suitable according to the criteria solution time and profit. The planning horizons to be studied resulted from the latest delivery date accepted plus a share of the estimated maximum time necessary to complete all orders to be planned. For the present data constellation best results were obtained for a share of 10 %.

In order to analyze impacts of preventive and reactive measures on planning robustness, the following parameter constellations are combined in the planning approach and tested for 5 order scenarios (Fig. 3).

Real *order data* (scenario 1) from a period of 3 months was taken as the basis of the tests as well as realistically generated order data (scenario 2 to 5). The generated order data is a realization of random variables with regard to intermediate arrival times and order quantities that follow a normal distribution according to the parameters (expected value, standard deviation) revealed by the real data. A uniform two-week delivery time interval that starts with the period of the order receipt was assumed to be relevant for all orders. Furthermore, the reaction function has been empirical-qualitatively (expert survey) estimated:

$$\beta_i(V_i) = \begin{cases} 0 & : V_i \leq 0 \\ 0.6 & : 0 < V_i \leq 10 \\ 0.2 & : 10 < V_i \leq 25 \\ 1 \cdot 10^{-10} & : V_i > 25 \end{cases}$$

Within the planning process this function is applied and after a planning run the customer decision is simulated as a random variable with a probability value according to this function. Real data of the 7 best-selling product configurations was taken as a basis for *production-related data* (Fig. 4).

Materials (A-parts)	Capacity	Prices/Costs (in €)
$R = 56,\ r_k = 45$	$C = 3$	$k^T = 59,\ p_i \in (2599, 5750),\ k_r^R \in (6.71, 125.21)$
$\omega_1 = 3,\ \omega_2 = 2$	$\kappa_i = 1$	$k_i^{L.EP},\ k_r^{L.R}$: 0.25% of invested capital per piece

Fig. 4 Production-related data

Planning is done on a daily basis at the beginning of each week with a rolling horizon and an underlying batch interval of 5 days. The planning model was implemented in the AIMMS 3.13 environment. Plans at the first level (order acceptance, delivery dates and quantities for accepted orders) are exact solutions of the linear mixed-integer model determined by the solver CPLEX 12.5. In order to generate plans at the second level (delivery date and quantity suggestions for preliminarily rejected orders) locally optimal solutions are created with the "AIMMS Outer Approximation Algorithm", because of the nonlinearity of the mixed-integer model (Roelofs and Bisschop 2013). To avoid inacceptable computation times the maximum computation time permitted was set on 100 s per iteration and the amount of iterations was limited to 15.

Following Kimms (1998) a measure for planning robustness is considered to judge the reliability of delivery dates. In the discussed planning problem, robustness will be the higher the less production decisions $P_{i.t}$ have to be revised because of changing information between the planning runs. Then the robustness measure refers to

- those customer orders, that are planned to be processed in consecutive planning runs (set A^P) and
- overlapping time periods (set T^P) in consecutive planning runs $l-1$ and l:

$$T^P = \left\{\min\left(t_a^{(l-1)}; t_a^{(l)}\right), \ldots, \min\left(T^{(l-1)}; T^{(l)}\right)\right\}$$

For a normalized robustness index the cumulative changes in production quantities in between planning run $l-1$ and l are set in relation to the cumulated production quantities in planning run $l-1$. Additionally the weighting function ζ_t takes into account that - from an economic point of view - plan modifications in the distant future are less important than those that lie close to the current planning period. The lower the index $\varphi^{(l)}$ is, the higher is the robustness between the planning runs $l-1$ and l. For the robustness of the whole planning the worst value indicated in all planning runs is considered:

$$\varphi = \max_l\left(\varphi^{(l)}\right) \text{ with } \varphi^{(l)} = \frac{\sum_{i\in A^P}\sum_{t\in T^P}\zeta_t \cdot \left|P_{i.t}^{(l)} - P_{i.t}^{(l-1)}\right|}{\max\left\{\sum_{i\in A^P}\sum_{t\in T^P}\zeta_t \cdot P_{i.t}^{(l-1)}; 1\right\}} \quad \forall l > 1 \text{ and}$$

$$\zeta_t = \frac{1}{t - \min\left(t_a^{(l-1)}; t_a^{(l)}\right) + 1} \quad \forall \min\left(t_a^{(l-1)}; t_a^{(l)}\right) \le t \le \min\left(T^{(l-1)}; T^{(l)}\right)$$

3.2 Test Results

To point out the impacts of the second planning stage onto solution quality, the average values of computation times and profits achieved at the first and at both planning stages are compared. With regard to computation times it becomes obvious that although the nonlinear problem at the second stage (deviating delivery date suggestions) induces a higher computational effort (maximum time: 500 s) than the linear problem (order acceptance according to desired delivery dates) at the first stage (maximum time: 0.3 s), all computation times lie within an acceptable range. In order to ensure comparable profits, the generated profits (see Fig. 5) were adjusted by the access costs on premium capacity. The observation of these profits reveals that alternative delivery date suggestions considering customers' reactions are always economically advantageous. Regarding partial deliveries and nested policy of capacity utilization a heterogeneous picture emerges. In the majority of investigated parameter constellations profits can be increased by partial deliveries, whereas the nested policy mainly reduces profits. Therefore it can reasonably be assumed that the economic benefits of these measures are dependent on the fit between the chosen parameter values and the order situation.

Concerning the reliability of promised/suggested delivery dates it has to be pointed out that all planned delivery dates and quantities are met, because of the underlying certain resource and capacity availability. Although unexpected capacity or resource shortages were so far not directly taken into account, statements about the degree of reliability can be derived by consideration of the robustness measure and the average capacity utilization per period. As the one- and two-stage planning approaches achieve robustness values significantly below 0.5 (see Fig. 6), only few adaptions of production decisions caused by varying order situations are necessary. Production decisions are more robust, if only the first planning stage with partial deliveries is applied. The nested policy as well as the suggestion of modified delivery dates reduces planning robustness.

On the other hand these measures provide flexibility to react to modified order situations by causing a low average level of capacity utilization (see Fig. 7). In the first case premium capacity leads to the opportunity to revise production decisions in favour of accepting additional orders. The consideration of orders with modified

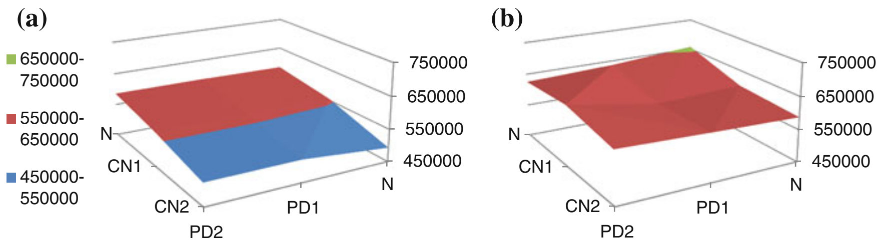

Fig. 5 Generated profits (**a** one-stage and **b** two-stage planning approach)

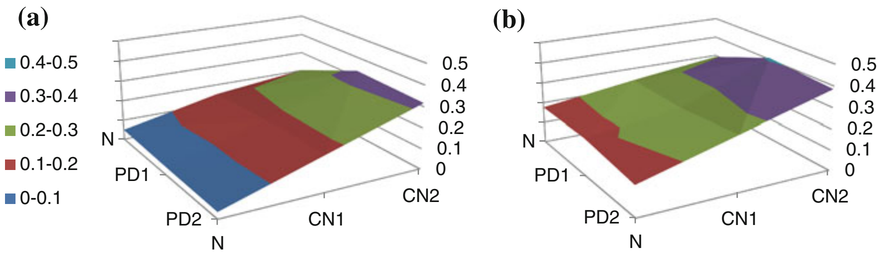

Fig. 6 Robustness index (**a** one-stage and **b** two-stage planning approach)

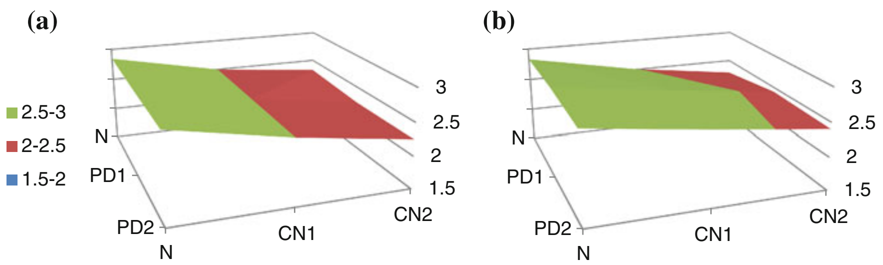

Fig. 7 Capacity utilization (**a** one-stage and **b** two-stage planning approach)

delivery dates in the latter case induces the uncertainty that customers do not accept deviating conditions and cancel the orders. With the released capacity it is possible to assign more advantageous production dates to accepted orders or to accept additional orders without endangering previously promised delivery dates.

4 Conclusions

In the present paper an extended capable-to-promise approach was developed and analyzed with the intention not only to generate high profits through order acceptance, but also to promise reliable delivery dates. The extensions refer to a nested policy of capacity utilization and partial deliveries as preventive measures and to the suggestion of modified delivery dates as a reactive measure. During the planning of modified delivery dates customers' reactions were considered with the help of an acceptance probability in dependency of the deviation from the originally desired delivery date. This approach can be seen as a significant extension of planning approaches proposed in the literature.

Using real-world data of a manufacturer of customized leisure products and several deduced test cases the solution quality and computational effort as well as impacts of the preventive and reactive measures on delivery reliability were numerically analyzed. It became apparent that

- all promised delivery dates could be met,
- suggesting modified delivery dates is economically advantageous and the benefit of the two other measures is dependent on the parameter choices,
- the computation time is acceptable and dependent on the application of the particular measures,
- partial deliveries directly increase planning robustness and
- the nested policy of capacity utilization and the suggestion of alternative delivery dates are additional options that can be used when deviating production situations occur.

Since material and capacity availabilities were assumed to be certain in the tests, the gained statements need to be verified in further analyses while considering stochastic influences. Furthermore, statements about optimal parameter choices for the different measures need to be generated in this context.

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The Cost and Service Impact of Different Organizational Forms of the Distribution Planning Process—Linking the Tactical and Operational Perspective in Furniture Distribution

Thomas Bousonville and Désirée Schmitt

Abstract The distribution of furniture is subject to a variety of practical constraints. The different skill profiles of the driving crew, the consideration of a heterogeneous fleet and more classifies the decision problem as a rich vehicle routing problem. The objective of this contribution is not to provide new solution methods on the operational level, but rather to investigate the surrounding planning process in which the vehicle routing decision is embedded and which can have a more or less constraining impact on the problems to be solved operationally. We consider different variants of the order fulfillment process and, based on data from a real life case, compare the resulting operational solutions, which are generated using a software package for vehicle routing. Conclusions regarding the trade-off between customer service and cost savings are drawn.

1 Introduction

Furniture retailing relies on various distribution channels. IKEA, for instance, builds its business model on huge outlets, where customers not only choose the furniture, but also transport it home themselves. Traditional retailers also use this system for products like simple storage racks, lightening equipment or household accessories. However, higher value articles like kitchens, sofas, tables and chairs for living and dining rooms are usually too bulky to be carried home by the consumer himself.

For those products, physical distribution is an important part of the added value of the retailer. As this type of furniture mostly has to be assembled at the site of the

T. Bousonville (✉)
Institut für Supply Chain and Operations Management, Hochschule für Technik und Wirtschaft des Saarlandes—University of Applied Sciences, Waldhausweg 14, 66123 Saarbrücken, Germany
e-mail: thomas.bousonville@htw-saarland.de

D. Schmitt
Möbel Martin Koordination, Kurt-Schumacher-Straße 24, 66130 Saarbrücken, Germany
e-mail: desiree.schmitt@moebel-martin.de

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customer, the drivers possess specialized skills and earn an adequate salary, which represents an important cost factor. Additionally, after years of market consolidation the bigger retailers organize the distribution of the furniture often from a central warehouse. As a consequence, the mean distance to the customer tends to increase as well as the size of the vehicle fleet.

Computer supported planning tools can offer help in these more and more complex planning contexts. In an extensive study, Drexl (2012) identified 50 vendors of commercial vehicle routing software (CVRS) in Germany and compared the theoretical state of the art with achievements in practical applications. One of the conclusions is that CVRS today provide support for a wide range of problem settings. While CVRS is above all used to generate better vehicle schedules and to reduce operational cost, cost is not the only objective that matters. The same furniture can be bought at competing retailers, often at comparable prices. Thus, customer service is an important way to differentiate.

The service offered to the customer is at least partially depending on the way the distribution process is organized: to which extent can we integrate customer preferences about the time of delivery during the day, how long is the mean delivery lead time, etc. are questions that are strongly linked to the design of the distribution process. But this design also leaves the planner of the operational vehicle schedule with a planning situation in which, important constraints (becoming cost drivers) for the final schedule are already fixed.

Therefore, the purpose of this study is to assess different forms of organizing the distribution planning process regarding their impact on service and cost. Methodologically we describe different process variants and, using data from a real life case, derive the corresponding input data sets for the vehicle routing step. The results obtained by using a commercial vehicle routing system are then compared with respect to induced cost.

The structure of the paper is as follows. Section 2 relates the research question to existing work. In the sequel, Sect. 3 embeds the process design decision in the context of hierarchical planning in transportation, describes the reference process, and details possible alternative variants. Section 4 presents the original transactional data (customer orders) on which our study is based. Furthermore, it shows how the same data is transformed into input data for the commercial vehicle routing software and the way this software has been used to solve the created instances. This is followed by a quantitative and qualitative assessment of the proposed variants for the planning process. Section 5 concludes the paper.

2 Related Work

Optimizing the cost linked to the delivery of a given set of customer orders with a given vehicle fleet is one of the best studied logistics problems in scientific literature. Starting with the ground laying work of Danzig and Ramser (1959), through the development of construction heuristics (e.g. Clarke and Wright 1964; Solomon 1987 and many others), the combination with local search and metaheuristics (for an overview see Bräysy and Gendreau 2005a, b) until the last advances using so called matheuristics (for a survey see Doerner and Schmid 2010), more and more sophisticated and powerful methods have been proposed.

The type of vehicle routing problems solved by the developed approaches are in practical contexts determined by the result of preceding (embracing) tactical decisions that have been adopted in accordance with an industry and company specific context. An example of a tactical decision is the determination of the size and mix of the vehicle fleet. Another one is the decision on the design of the planning process: e.g. the distribution of tasks between customer service department and the dispatchers and the organization of the communication between the company and the customer.

Assessing the impact of different process configurations on the achievable quality of vehicle schedules is the focus of this paper. To our knowledge, attempts to formalize this question are rare. In an empirical study Wendt et al. (2006) describe different possible planning scenarios without comparing them on a given benchmark data set. For an application in food-home-delivery Kunze (2006) describes different possible configurations of the planning process. The applicability of those configurations is assessed against the customer preferences and computational tests are performed for two selected process configurations. The findings on selected benchmark problems from the Solomon data set exhibit the dependency of the number of tours and tour length on the width of the time windows. Our approach is similar to the one of Kunze (2006), but differs as it refers to furniture distribution and because computational experiences are obtained on real life data and by using a different optimization method.

3 The Planning Process

3.1 Process Design as a Tactical Decision

Some decision situations in companies occur repetitively with a fixed frequency, e.g. every day or every month. These decisions are usually called operational. A typical example is the planning of the production master schedule or planning the vehicle routing schedule for a given day.

Other decisions are only taken occasionally and are organized in a project oriented manner. They are called strategic or tactical decisions. Note that operational decisions usually are short or mid-term (Fleischmann et al. 2005), while tactical and strategic decisions are mid-term or long-term respectively.

Strategic decisions in distribution include e.g. the location of distribution centers, the creation of new distribution channels or setting the company policy regarding the trade-off between customer service and cost (Vastag 2008). Typical tactical decisions concern the size and composition of the vehicle fleet (Golden et al. 1984;

Hoff et al. 2010; Subramanian et al. 2012) as well as the allocation of customer districts to warehouses.

In contrast to these decisions, the reorganization of the planning processes might look less tangible. It is nevertheless the result of a preceding system analysis, a comparison and assessment of different process variants followed by the implementation of the chosen option. This is how Schneeweiss (1992) characterizes general planning and decision making. We therefore consider the reorganization of the planning processes as a tactical decision.

3.2 Outline of the Sales and Distribution Process

Hertel et al. (2011) list the typical process elements of the order fulfillment process in retailing, but they also state that the sequence and concrete subset of these process elements vary depending on the retail channel, the industry and company specific requirements.

The overview of the order fulfillment process in furniture sales presented in Fig. 1 is derived from the company that provided the case for this study. According to an interview with a senior logistics responsible this is widespread practice in the furniture industry. Hence, the following analysis as well as the proposed process alternatives and their assessment provide transferable insights to companies operating in a similar scheme.

The process is composed by eight main elements, numbered from 1 to 8. If we associate a time stamp t_i with the execution of process element i, the total cycle time for the order fulfillment process is $t_8 - t_1$.

Without being exhaustive, the single process elements will be described regarding some particular features, which are important for better understanding of what follows. In process step 1, the sales person will communicate an estimated delivery week to the customer. This estimation is based on information on the standard delivery time of the respective supplier ($t_3 - t_2$) plus the time for the subsequent distribution planning and delivery process ($t_8 - t_3$). The estimates reflect mean values and of course the real times are stochastic at time t_1.

The time lap between process element 1 and 2 varies depending on the complexity of the sold article and subsequent order checking. Depending on the reliability of the supplier, step 3 could be anticipated and the process would then

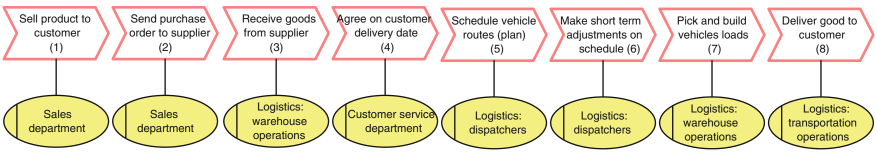

Fig. 1 Outline of the order fulfillment process

continue at step 4 without waiting for the completion of step 3. In order to implement this improvement, a systematic supplier evaluation is a prerequisite.

The critical parts of the process chain for the purpose of this study are steps 4 and 5. After making sure that the ordered goods have arrived at time t_3, the customer service calls the customer in order to agree on a delivery date. This works as follows.

The customer service has access to the number of orders that are already assigned to a given day in the future (called a "pool"). Additionally, each order has a property that estimates its service time at the customer. Therefore, the customer service can see the estimated total workload for each day in the future. When calling a customer, the customer service will propose the earliest date on which there is still free capacity. If the customer does not accept this date, an alternative date in the future will be suggested. Although customers are not encouraged to articulate preferred or hard time windows these wishes will eventually be accepted in an effort to offer a good customer service.

Once there is no available capacity left, the customer service will close the pool and hand it over to the planning department for determining a vehicle schedule (step 5). It is important to mention that the capacity of the pool is never consumed up to 100 % (during step 4), in order to leave some slack for the succeeding planning step. This step is done in a semi-automated way, combining the experience of the planner and a CVRS called PlanTour (PASS 2013). After having allocated and routed the orders coming from the pool (step 5a in Fig. 2), the planner will fill up the remaining slack in the route with suitable customer orders (that have not yet been treated by the customer service) or waiting repair orders (step 5b). Doing so, the planner has to interact with the concerned customers. This is a time consuming task.

As the plan has been established with some lead time, changes will have occurred until the day of delivery (cancelation by customers, illness of drivers etc.). Therefore, a final adjustment of the schedule is performed in step 6, usually the day before the delivery. This is also an opportunity to inform the customer about the expected arrival time (if resources allow). Assessing required load capacities during the planning phase can be difficult, because of the non-standard shape of the transported goods. It is nonetheless important for a smooth execution of the physical load building (step 7). If in exceptional cases the load does not fit into the truck, a feedback loop to step 6 may be necessary. The whole process ends with the delivery to the customer. For the sake of simplicity, absence of the customer, customer complaints and repair will not be considered here. It would not change the findings of the study, anyhow.

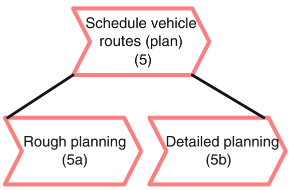

Fig. 2 Decomposition of the planning phase into two stages

As a consequence of the described process design, the vehicle routing problem to be solved in step 5 involves customer orders with a fixed delivery day, possibly having a time window. We will call this scenario DAY_TW (fixed day and time windows).

3.3 Alternative Designs for the Distribution Process

In this section two alternative process designs will be discussed. The first scenario is inspired by the result of a customer survey conducted by Möbel Martin in 2011. The findings of that survey were that customers usually press for time windows not because this is the only time they are available during the day, but rather to have an idea when to be at home. This is logical, because otherwise they are forced to stay at home all day.

Hence, in the first alternative scenario customers will not be called successively in order to fill up the pool capacity in step 4. Instead, the pool will be filled with customer orders ready to be delivered that day. Before interacting with the customers, scheduling and routing the orders (step 5) take place. This allows estimating the time when the vehicle will pass at each scheduled stop, information that can then be communicated to the customer. This time window is not constraining because it is derived from a prior optimization step.

For those customers who will not accept this proposition, a new day will be suggested as in the base scenario. Emerging gaps have to be filled in the same way as in the first scenario (step 5b). To sum up, the proposed approach compared to the initial process removes the time windows from the customer orders. We call this scenario DAY_WO_TW (fixed day without time windows).

In the second alternative scenario customer orders for a whole week (or a couple of days) are accumulated. Then vehicle scheduling takes place. Based on the established schedule customers are called and delivery date plus delivery time are agreed upon. Again, for those that cannot accept the proposition, a later date is arranged. Those deliveries will then be considered as fixed orders in the next planning period (week). This scenario will be named WEEK_WO_TW (week without time windows). Note that the number of orders to reschedule and the way of filling the created gaps are independent from the three proposed scenarios.

4 A Cost and Service Assessment of the Different Variants

The different process variants described in the previous section will be tested using historic data from a real life case. After presenting the data set in Sect. 4.1, the experimental design and computational results will be presented in Sect. 4.2. We conclude this section with a comparison of the variants with respect to customer service.

4.1 The Data Set for the Case Study

Möbel Martin is the leading furniture retailer in south-west Germany, operating nine outlets totalizing an exhibition space of roughly 160,000 m^2. The product assortment is composed by more than 62,000 different articles (Möbel Martin 2013). Besides smaller standard take-away furniture and household accessories, the two main product groups are "conventional furniture" (tables, sofas, chairs, carpets, etc.) and kitchens.

Conventional furniture and kitchens are delivered to the customers via central warehouses (depots) using a heterogeneous fleet of vehicles. Apart from the size of the used vehicles, the skills of the drivers, who often are carpenters, differ and there are compatibility constraints between orders and the qualification profile of the crew. As not all trucks are owned by the company, routes may end at other locations than the depot. There are reliable estimates of service times for most of the orders, but in reality deviations can occur. In the light of those non-exhaustive aspects, the planning problem is easily identified as a rich vehicle routing problem (Drexl 2012).

The data used for the following calculations concern deliveries from a single warehouse. Five days of historical data were used, each day having between 250 and 400 customer orders. 99.8 % of the orders were within 100 km distance from the depot. The time windows of the customer orders are distributed as given in Fig. 3 (by time window length).

It is important to note that only the 4 h time windows reflect original customer preferences. All other time windows have been added by the planning department after customer interaction during step 5b and after having previously established a, yet incomplete, schedule in step 5a. The names and description of the derived input data sets used for the CVRS in the next section are listed in Table 1.

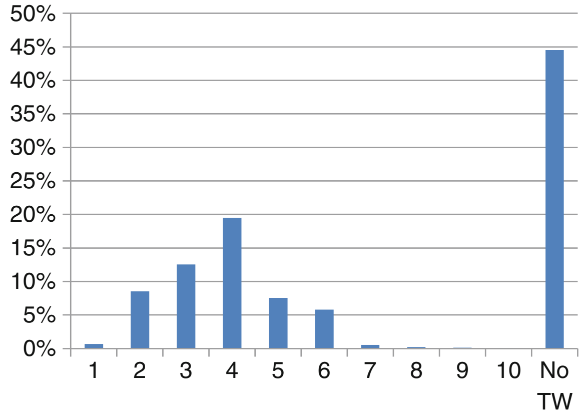

Fig. 3 Distribution of time windows (by time window length in hours)

Table 1 Data sets used for computational experiments

DAY_TW_ALL	These data sets include all time windows, even those that have been added by the planners in process Step 5b
DAY_WO_TW	These data sets refer to the first alternative planning scenario described in Sect. 3.3
WEEK_WO_TW	These data sets refer to the second alternative planning scenario described in Sect. 3.3

4.2 Computational Results

The instances defined in Table 1 were solved using a CVRS, capable of handling the constraints listed in the beginning of Sect. 4.1 (PASS 2013). As the software allows the selection of various start heuristics and further parameterization, intensive tests were necessary upfront to determine a suitable parameter set, which then was used throughout the experiments. For reasons of confidentiality, Table 2 only reports relative numbers about the improvements on the number of routes and total traveled distance. The three columns on the right report solutions that were generated with the CVRS without any manual post-optimization. All orders were scheduled and no violations of the constraints could be identified. The column "Basic computer support" contains the result of the manual planning process in place at the time of the study (it is based on the same data as DAY_TW_ALL, thus, it has to respect all time windows).

Taking the automated solution of the set DAY_TW_ALL as the reference solution, scenarios DAY_WO_TW as well as WEEK_WO_TW show an expected improvement compared to the more constrained data set. The improvement is less important when the time windows are removed from the daily data sets. This can be explained by the fact that only a minor share of the orders had restrictive time windows. The significant saving in the scenario WEEK_WO_TW highlights an

Table 2 Relative performance of the different process variants

	Basic computer support	DAY_TW_ALL	DAY_WO_TW	WEEK_WO_TW
Nb routes: relative improvement over DAY_TW_ALL (%)	−2.4	0.0	2.9	11.1
Travel distance: relative improvement over DAY_TW_ALL (%)	−16.8	0.0	3.0	19.9
Computational time (min)		60	60	390

important shortcoming of the "pool" planning concept, which allocates orders to days without trying to consolidate far away trips geographically over the week.

Interestingly, the solutions generated by the software outperformed the manually created ones. This is especially true for the traveled distance, which translates directly into a gain in variable cost.

4.3 Assessment of the Variants According to Customer Service

Important measures for customer service are: delivery lead time, on time delivery, time window flexibility (can the customer define the time window himself?), flexibility regarding the communication channel (email, phone …), quality of the interaction (mutual agreement on dates, instead of pure information per mail), delivery quality (are there reasons for customer complaints), friendliness and cooperativeness of the driver-carpenter team, and others. Table 3 lists only two measures that are directly influenced by the presented scenarios.

From the comparison it can be seen, that for instance, the communication of the estimated arrival time upon calling the customer is an improvement against the base situation. Therefore, a better cost position can be compatible with service improvements.

Table 3 Impact of the scenarios on customer service measures

	DAY_TW	DAY_WO_TW	WEEK_WO_TW
Communication of a delivery time estimate when the date is agreed	No	Yes	Yes
Customer can fix time windows	When buying the product and when being contacted for delivery	When buying the product; when being contacted for delivery, the TW can be rejected and another day would then be agreed	When buying the product; when being contacted for delivery, the TW can be rejected and another week would then be agreed
Delivery lead time (DLT)	–	DLT does not increase compared to DAY_TW	DLT would increase compared to DAY_TW, as one has to wait for consolidation of 1 week of orders

5 Conclusion

In this contribution a planning process for furniture distribution has been described. Two alternative ways of planning the distribution have been developed. The impact of the different process definitions on the resulting operational planning problems was described and quantified using examples from a real life case.

Although no general statement about expected savings can be made, the approach showed that the impact of process redesign decisions, understood as a tactical decision, can be quantified for a given context. In order to do so, a certain level of IT-competency and openness is required, e.g. the effort to implement a CVRS at least for a test phase seems to be a condition.

For further work it would be interesting to enlarge the test bed on which the results have been generated. Also, it would be worth to investigate the transferability of the approach to other industries, like parcel services.

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Development of a Reference Model for Spare Parts Logistics

Ann-Kristin Cordes and Bernd Hellingrath

Abstract Spare parts logistics deal with several challenges by provisioning the spare part to the end customer due to the sporadic characteristics of the demand. Thereby, the processes and information flows of several spare parts supply chain actors have to be coordinated. To provide a common understanding of all relevant processes and information flows in a spare parts supply chain we develop a reference model for spare parts logistics and identify the central elements. The processes and information flows described in this article cover the initiation of an order to the provisioning of a spare part. After the development, the reference model can form the basis for business process reengineering and investigation of the IT-support for spare parts logistics.

Keywords Spare parts logistics · Reference modeling · Supply chain planning

1 Introduction

The demand of spare parts occurs due to preventive maintenance or after a breakdown when a part of a technical system has to be replaced. When the required part cannot be replaced in time, delayed maintenance can result in declining profits and service perception, as well as a rise in costs (Espíndola et al. 2012). For guaranteeing efficient spare parts management (SPM) processes and the adequate usage of information systems, a model driven investigation of its logistics processes and information flows is necessary. The purpose of such an investigation is to represent the processes and information flows (Rosemann 2003). Based on this investigation, the improvement potentials concerning reengineering of the business

A.-K. Cordes (✉) · B. Hellingrath
Chair for Information Systems and SCM, WWU Münster, 48149 Münster, Germany
e-mail: ann-kristin.cordes@ercis.uni-muenster.de

B. Hellingrath
e-mail: bernd.hellingrath@ercis.uni-muenster.de

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process and the IT-support for spare parts planning can be deduced. The considered processes in spare parts logistics range from the initiation of an order to the provisioning of the required spare parts.

The special characteristics of processes in spare part logistics differ significantly from standard supply chain management (SCM) processes. Specifically, inventory management varies widely as spare parts have to be stored for a longer period of time sometimes exceeding the life cycle of the related product. Existing reference models for SCM like SCOR (Poluha 2008) can be applied to this area. But the respective reference model has to be extended by the special processes of spare parts logistics. As the development of a reference model for spare parts logistics has not yet been in the focus of research, this work aims at developing such a reference model by identifying the central elements for spare parts logistics, focusing on the machining industry. This reference model should provide a common understanding of the processes and structure of spare part logistics. Moreover, it should enable the precise definition functions of the processes as well as the visualization of information flows. Thereof, specific process models for use cases can be derived. Furthermore, it should support the identification of process reengineering and of IT-support for spare parts logistics. This is exemplified by our application of the reference model to a specific use case.

The main research questions of this work are what the central elements of a reference model for spare parts logistics are and how a reference model can be developed. To answer these questions, this work subsequently follows the first four steps of the design science approach as described in Peffers et al. (2007). Thus, the following article starts in Sect. 2 with the investigation of the characteristics of spare parts logistics, the literature review about reference models in this area as well as in production and logistics, and the justified selection of the reference modeling method. These aspects provide the foundation for identifying central elements of a reference model and for developing it. The development of the model in Sect. 3 is guided by the approach of Becker et al. (2002) on the one hand and on the other hand by the descriptions of spare parts logistics processes from literature. A use case within the machining industry forms the foundation for our application in Sect. 4. Based on the developed model, a structured description of spare parts logistics processes, are achieved. The developed model forms the foundation for describing feasible information system support. The paper concludes with a summary and final statements as well as an overall outlook into future work.

2 Theoretical Foundations

2.1 Characteristics of Spare Parts Logistics

Spare parts logistics is characterized according to Gopalakrishnan and Banerji (2002) in the following way. Companies, which offer spare parts have to deal with a high level of uncertainty due to the sporadic increasing demand through a breakdown.

This results in an unstable and fluctuating character of consumption. In consequence of these reasons and the extremely high variety of spare parts, the nature of storing and purchasing spare parts is accumulative. The tasks of spare parts logistics; are the provisioning of the required equipment and the ability to deploy the suitably qualified service personnel needed for the replacement, additionally guaranteeing the availability of the needed spare part in the adequate quantity, at the correct place and at the requested time. For providing these services to the end customer different areas of a spare parts supply chain are involved. These areas are; warehousing, procurement, production and transportation of the spare parts in addition to the service management, which is responsible for the spare parts' installation. Thus, the considered actors of a spare parts supply chain are; suppliers, manufacturers, maintenance service providers, logistics service providers and end customers (Biedermann 2008).

Spare parts and spare parts logistics have several specific characteristics. The relevant business divisions for SPM are; procurement, warehousing, production and transportation, as well as the planning of these divisions. Likewise, all divisions have to be considered that enable the listed spare parts business divisions. The provided services are; maintenance, repair, overhaul and/or dismantle of a technical system. Furthermore, the installation of the spare part can be supported by service personnel (manufacturers' personnel or service providers' personnel). Concerning the availability, the parts can be in stock, on safety stock or unavailable. If they are not available, two different procurement types exist (in-house production or external supplier). What is more, the procurement strategy differentiates in built-to-order and built-to-stock (Biedermann 2008).

2.2 *Reference Modeling in Spare Parts Logistics and Production and Logistics*

A reference model is defined as an information model, which describes and visualizes processes and information flows to achieve a general understanding of these processes and flows. This model should be transferable to other use cases (Becker et al. 2002). As already mentioned, a reference model for spare parts logistics is a promising approach that may contribute to a common understanding of the processes and structure of spare parts logistics (c.f. Sect. 2.1). But what are the relevant elements, processes and information for a suchlike reference model? There are a couple of reference models for spare parts logistics. As these do not cover all required processes, reference models of production and logistics are also taken into consideration. But can existing reference models, or at least parts of them, be used or transferred to spare parts logistics? Thus, the next logical step is a detailed look at the literature in order to identify existing models that deliberately focus on relevant processes. The foundation for the literature search process according to vom Brocke et al. (2009) were the definition of the main keywords (reference model, information model and process model) and the database (search engines: EBSCO, Web of Science, ScienceDirect, Base, Citeseer). These main keywords were combined with the keywords; *logistic*, *process*, *production*, *spare part*, *service*, *manufacturing*, and *supply chain* and a backward and forward search was carried out in the German and English language.

Hansmann (2003) has developed a reference and workflow model for the industrial order fulfillment considering the batch production. He uses the UML modeling language for the reference model. This model describes the processes of production planning and control in detail, focusing specifically on the order fulfillment. Therefore, it should be investigated whether there is a possibility to transfer these processes to the proposed reference model. For the automotive industry Klingelbiel (2009) has generated a reference model for built-to-order concepts in logistics networks. The model is illustrated with the UML modeling language in which inventory and production planning are analyzed in detail. The processes for built-to-order concepts focusing on inventory and production planning can therefore be a foundation for developing suchlike processes for spare parts logistics.

Some specific reference models related to after-sales-services show the limitation of only addressing a restricted section of the supply chain or a special task. Luczak and Stich (2004) have developed such a reference model concentrating on the machine industry, using the ARIS and event-driven process chain method for the description. This model aims at depicting how new service concepts of after-sales-services can be integrated into production planning and control. Out of this model, processes and information flows needed for production planning and control might be used for the proposed reference model as the service concepts of after-sales-services are related to spare parts logistics. In the model of Dangelmaier et al. (2004) the focus is put on the service and disposition task for service product design of after-sales-services within the automotive industry, using UML. Hence, this model deals with the processes of planning the required service personnel and equipment. The description of the processes and information flows will be partially used in the proposed model and will be subsequently applied to another industry. Gajewski (2004) has developed a reference model for describing business processes of after-sales-services within the telecommunication industry. He uses UML for modeling and emphasizes among other processes on staff planning being transferable to the reference model in topic.

2.3 Techniques for Reference Modeling

In literature different techniques for reference modeling are described, which aim at reusing a reference model. Configuration, instantiation, aggregation, specialization and analogy are the described techniques of construction according to vom Brocke (2003). Construction of an applied reference model to a specific use case, according to the *configuration* approach is carried out by selecting configurative parameters within the reference model. The *instantiation* of such a reference model is constructed by concretization of model aspects of the reference model which are formulated vaguely or generic, so that they have to be concretized. The main initiative of the *aggregation* technique is that the result reference model is designed by integrating one or more reference models. The *specialization* is based on changing and extending a reference model which is built in a generalized method. For the *analogy* technique it is assumed that the result reference model is related to the original reference model concerning an individual specific characteristic. In meaning, that the reference model can be reused regarding, for example, its structure or content for its application.

As the purpose of this work is to generate a reference model, which is configurable for a variety of spare parts logistics' applications by selection of several parameters, this work follows the configurative construction technique known as configurative reference modeling.

2.4 Application of Configurative Reference Modeling

Configurative reference modeling can be divided into 5 different phases (cf. Fig. 1). These phases can be seen as a guideline of how to generate a configurative reference model for spare parts logistics.

The first and the second phase are relevant for the preparation of the reference model design. In the first phase the objective has to be defined. This is derived from the highlighted area of activity and the perspective which needs to be observed for the chosen problem area. Afterwards, the modeling technique has to be specified. This means, that the framework and the configurative parameters as well as the

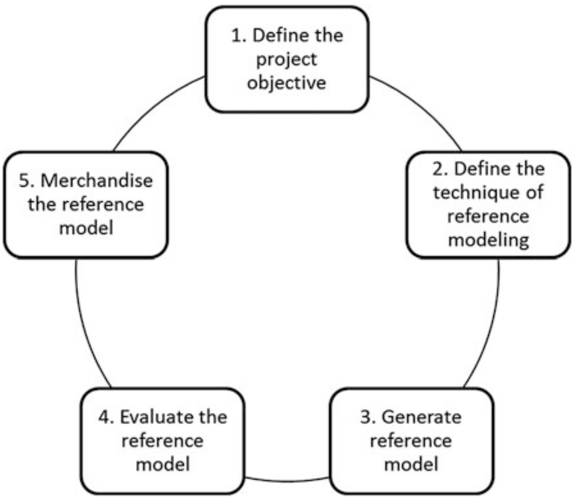

Fig. 1 Phases of the configurative reference modeling (Becker et al. 2002)

degree of abstraction are fixed. Subsequently, the reference model is generated based on these determined features in the third phase. In the fourth phase, the model is evaluated based on one or several real applications of the reference model so that for each case a result reference model is generated. Finally, in the fifth phase the reference model has to be merchandised (Becker et al. 2002).

3 Development of a Reference Model for Spare Parts Logistics

3.1 Purpose of the Reference Model

The areas taken into consideration of the spare parts supply chain and its divisions have to be defined before the reference model can be created. One of the purposes of the developed reference model is to visualize the processes and information flows of a spare parts supply chain. By investigating the processes, we are considering the perspective of the manufacturer of spare parts. In this context, we are using the SCOR model to plan, source, make, deliver, return and enable processes (Poluha 2008) in an adapted approach. For this reason, the notation for each process is extended by the acronym SPM. We have chosen the SCOR model as the foundation as we are able to consider all interfaces to the related spare parts supply chain actors. In addition, the intention of our reference model is that it should be applicable for all spare parts supply chain actors. Thus, the process types considered in the framework of the reference model (c.f. Fig. 2) are SPM Plan, SPM Source, SPM Deliver, SPM Make, SPM Return, SPM Enable.

The framework depicts an aggregated view of the reference model and enables a top-down procedure for the modeling. Thus, the area of activity comprises the processes and information flows from the initiation of an order to the provisioning of the required spare parts.

The further purpose of this reference model is to analyze the processes with regard to their reengineering and to investigate necessary IT-support for spare parts logistics. Therefore, we take into consideration the main processes and the detailed process steps. The detailed process steps portray the main processes and divide them into several sub-processes. Furthermore, we consider the information flow, the

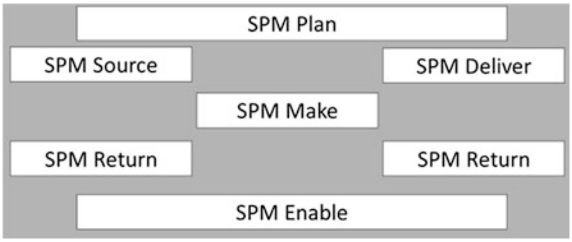

Fig. 2 Framework of the reference model

Table 1 Configurative parameters of the reference model

Attribute	Characteristics of attribute					
Process types	SPM Plan	SPM Source	SPM Make	SPM Deliver	SPM Return	SPM Enable
Location of maintenance	At manufacturer			At end customer		
Service	Maintenance	Repair		Overhaul	Dismantle	
Service personnel	Manufacturer's personnel			Service provider's personnel		
Carrier	Manufacturer		Logistics service provider		Self-pick-up	
Availability	On stock		Safety stock		Unavailable	
Procurement type	In-house production			External supplier		
Procurement strategy	Built-to-order			Built-to-stock		

data and the related functions including the IT-support. Being that the description of the major processes is adopted from SCOR, the detailed process steps are modeled in BPMN 2.0 as this modeling language can differentiate between the information and material flows and it is extensible by further symbols, for example, modeling IT-systems (Freund and Rücker 2012).

The level of the main processes provides a rough overview of all investigated processes and information flows. The purpose of this level is to delineate the considered processes and to allocate the responsible corporate division. The level of the detailed process steps gives an operative view on the processes and information flows and visualizes the relations between processes. Similar detailed explanations build the foundation for the improvement of the process execution. Furthermore, the configurative parameters for the reference model have to be considered. The configuration of the model is dependent on the requirements of the respective use case for which the reference model should be applied. They are deduced based on the characteristics of spare parts logistics described in Sect. 2.1 and depicted in Table 1.

3.2 Generation of the Reference Model for Spare Parts Logistics

In this subsection, the identification and modeling of all relevant processes and configuration parameters is carried out and it is described how the reference model is developed. The first level is a detailed view of the framework of our developed reference model and depicts a rough overview of the main processes illustrated in Fig. 3.

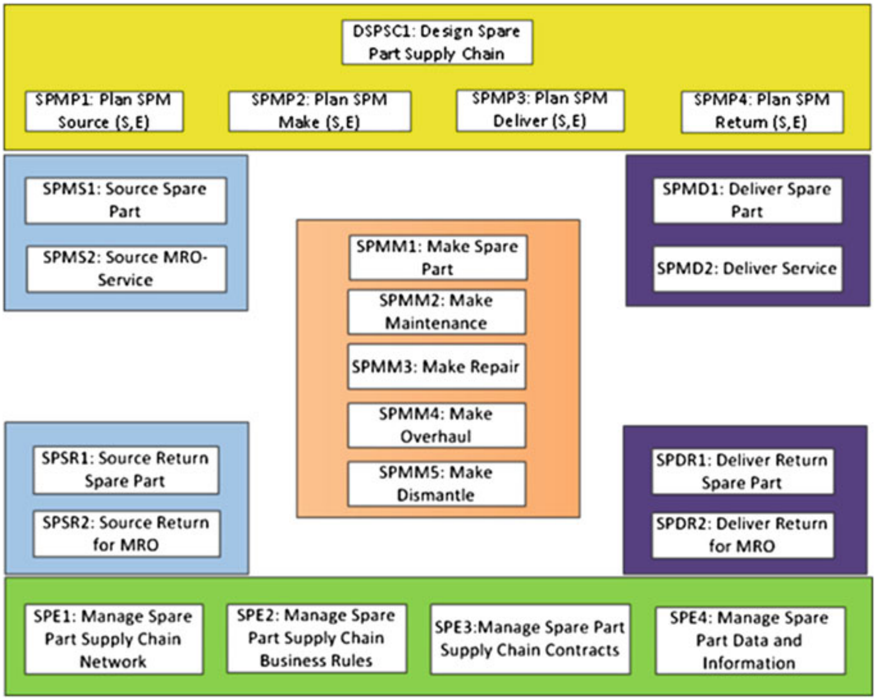

Fig. 3 Reference model for spare parts logistics on level 1

This level is created based on process descriptions explained in literature and the second level of the SCOR model (Poluha 2008; Biedermann 2008; Gopalakrishnan and Banerji 2002). The considered SPM Plan processes are those planning the source, make, deliver as well as return processes (SPMP1-4) plus the design of a spare parts supply chain (DSPSC1). The source processes are divided into two main processes (SPMS1-2). This division lies in the procurement of spare parts or of external MRO-services if they are a necessity. The make processes describe the production processes (SPMM1) and the different service processes (SPMM2-5). The transportation processes are illustrated by the two deliver processes (SPMD1-2). With these processes the transportation of the spare part and the delivery of a service might be modeled. Related to the source processes two respective source return processes are developed (SPSR1-2). The same applies to the delivery processes (SPDR1-2). The most relevant processes are the enable processes (SPE1-4) as these processes support all the other main processes.

In the second level the processes of the first level are visualized in a more detailed manner. This is shown exemplarily for the “order fulfillment”-process part of the “SPMS1: Source Spare Part”-process (c.f. Fig. 4). The detailed view is based on other existing reference models as described in Sect. 2.2. The foundation for the “order fulfillment”-process is the related section of the reference model of

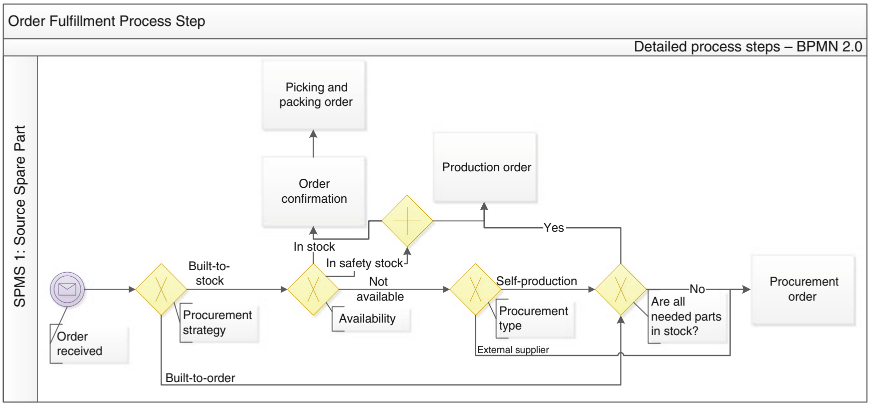

Fig. 4 Reference model for spare parts logistics on level 2: Order fulfillment process step

Hansmann (2003). The order fulfillment process can be transferred with only one extension. The configurative parameter of procurement type has to be integrated. This type needs to be observed in spare parts logistics because not every ordered part is produced by the manufacturer.

After receiving the order, the manufacturer has to identify, which procurement strategy is valid for the needed spare part (built-to-order or built-to-stock). In the case of a built-to-stock strategy, the next configurative parameter is the availability. If the spare part is in stock, the order is confirmed and a picking and packing order is initiated. In the case of available spare parts in safety stock the order is confirmed and a picking and packing order is initiated as well as a production order for refilling. No available spare parts in stock result in the next configurative parameter being the procurement strategy. In the case of an external supplier a procurement order is initiated. For self-production the next configurative parameter is the availability of all necessary parts. If all parts are available, a production order is initiated and if all parts are unavailable a respective procurement request is sent to the disposition department. In the case of a built-to-order procurement strategy, the next configurative parameter is the availability of all needed parts and afterwards the process continues as described above.

3.3 Investigation of Feasible Information System Support

In the following, the feasible information system support is analyzed exemplarily for the "order fulfillment" process step, particularly considering specific tasks for planning the logistics processes within spare parts management. Related to several sub-processes an information system support is attainable. If the spare parts are not available in stock a new calculation of the spare parts demand forecast might be

Table 2 Overview of IT-systems support possibilities

Process types	IT-Systems					
	ERP	APS	WMS	MES	TMS	CMMS
SPM Plan	x	x	x		x	x
SPM Source	x	x	x			x
SPM Make	x		x	x		x
SPM Deliver	x		x		x	
SPM Return	x		x		x	
SPM Enable	x					x

initiated via the utilized ERP-system. Standard ERP-systems use forecasting methods based on historical demand data. If the spare part was not requested over a long period of time the resulting forecast is exceptionally low. Due to the new occurring demand for this spare part it is necessary to recalculate the forecast resulting in a direct higher accuracy. After generating a new picking and packing order, staff planning might be carried out through an ERP or a MES. The same applies to the new initiated production order. This innovative production order implies changed production sequence. Moreover, the procurement order initiates a recalculation of future order quantities with the ERP or MES.

Besides the MES and the ERP, the functions of further IT-systems like APS, WMS, TMS and CMMS are investigated regarding the support possibilities for spare parts logistics processes. An overview about IT-systems which support different process types of our proposed framework is depicted in Table 2.

4 Application of the Reference Model

4.1 Process Description of the Application Case

The developed reference model is applied based on a real case of a global spare parts supply chain of an international machine manufacturer which develops and produces automation solutions for the oil industry. Moreover, the company acts as an MRO (maintenance, repair and overhaul) service provider for the produced equipment. Either the repair is done by company personnel or this task is delegated to a third party service provider. In this context, repairing means the manufacturer produces the original needed spare parts in case the parts are not in stock and assigns service personnel or a third party service provider to install these parts for the end customer.

Two different kinds of spare parts can be ordered—electronic and mechanical parts, however only the electronic parts are on inventory. For the mechanical parts a build-to-order (BTO) strategy is applied. If the broken electronic part is not in inventory, it is produced by adding it to the normal production schedule with high priority being delivered to the place of repair upon its production. The components for producing the spare parts are purchased from suppliers in Brazil, USA and China. Normally, all components are in inventory. But for some orders the procured components need to be produced by the respective supplier. After the provisioning of the spare parts, transport is organized depending on the size and the weight of the part. Small parts, which can be packed in normal parcels, are shipped via the Brazilian post. The transport of heavy spare parts is carried out by a logistic service provider. The means of transportation can be plane or truck.

4.2 *Procedure of Applying a Reference Model*

The procedure of generating a result reference model for the application case based on the developed reference model is described in the following. As in this article the configurative reference modeling technique is used, we demonstrate the application of the developed reference model to a use case. The first step is to select the configuration parameters out of the morphological box of Table 1. Based on the case description in Sect. 4.1 the configuration parameters for the application case are selected and seen in Table 3 (highlighted in grey).

These selected configurative parameters build the foundation for choosing the applied process steps of the reference model for generating the applied reference model depicted in Fig. 5.

Table 3 Configurative parameters of the application case

Attribute	Characteristics of attribute					
Process types	SPM Plan	SPM Source	SPM Make	SPM Deliver	SPM Return	SPM Enable
Location of maintenance	At manufacturer			At end customer		
Service	Maintenance	Repair	Overhaul	Dismantle		
Service personnel	Manufacturer's personnel			Service provider's personnel		
Carrier	Manufacturer	Logistics service provider	Self-pick-up			
Availability	On stock	Safety stock	Unavailable			
Procurement type	In-house production			External supplier		
Procurement strategy	Built-to-order			Built-to-stock		

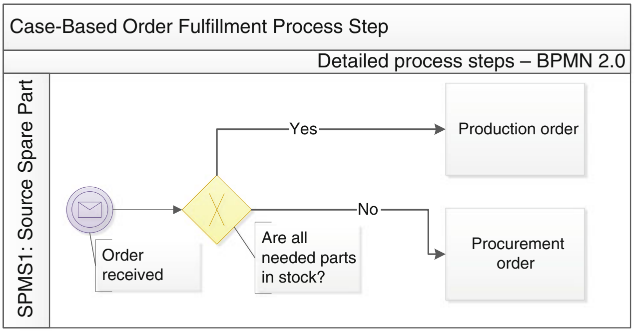

Fig. 5 Case-based result reference model for spare parts logistics on level 2

In the visualization of the second level of BPMN 2.0, several sub-processes are not considered due to the selected configuration parameters in the application case. However, this first evaluation of the developed reference model provides an indication that the developed reference model is applicable for this case scenario.

5 Conclusions

This article describes the development of a reference model for spare parts logistics. This reference model covers the processes from the initiation of an order to the provisioning of the required spare parts. The expected contribution of the results to theory lies in the structured understanding and description of the logistics processes and information flows of spare parts logistics within the machining industry. Furthermore, it is depicted how information systems can support the spare parts logistics processes.

As for the practical implications a company can benefit from the coherent perception of all processes by the staff members and the revised efficient processes through the adaptation of the company's processes utilizing the developed reference model. Based on the analysis regarding information systems support, recommendations for improving information systems utilization can be provided. To investigate the validity it has to be applied to further cases within the industry. Additionally, this work only takes into consideration processes within the machining industry, thus restricting the application area. Limitations concerning the chosen design science approach lie in the fact that so far only four steps of the approach are carried out by developing the reference model for spare parts logistics. Future research has to focus on improving the validity and extending the applicability to other industries as well as evaluating the design artifacts of the design science research approach.

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Orientation Towards IC-Technologies and Value Added Services at Logistics Service Providers

Helena Preiß, Marcel Papert, Christoph Klötzer and Alexander Pflaum

Abstract Value added services in combination with the utilization of innovative information and communication-technologies are a valuable source for differentiation of logistics service providers. To examine the orientation of logistics companies towards these aspects and to analyze their usage of formalized processes for the development of new services, a study among the German logistics industry was conducted. The study is based soundly in the theories of the Resource-based view, the Service-dominant logic and the concept of service engineering. With regard to the current market situation the main research results reveal a controversy: On the one hand, logistics service providers have realized the potential of both information and communication-technologies and value added services. On the other hand, they still lack formal development procedures. Closing this gap will be a challenging task for the management of the future.

1 Need for Value Added Services at Logistics Service Providers

The business environment for German logistics service providers (LSP) has become more competitive during the last decades (Klaus et al. 2011; Soinio et al. 2012; Wagner 2008; Wallenburg 2009) and shippers have become more demanding

H. Preiß · M. Papert · C. Klötzer (✉) · A. Pflaum
Chair for Supply Chain Management, University of Bamberg, 96052 Bamberg, Germany
e-mail: christoph.kloetzer@uni-bamberg.de

H. Preiß
e-mail: helena.preiss@uni-bamberg.de

M. Papert
e-mail: marcel.papert@uni-bamberg.de

A. Pflaum
e-mail: alexander.pflaum@uni-bamberg.de

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and request higher levels concerning quality and costs (Langley et al. 2005; Preiß and Weber 2012; Wilding and Juriado 2004). Furthermore, basic logistics services such as transportation and warehousing are perceived as exchangeable and the logistics market can be understood as a commodity market (Davis et al. 2008; Neubauer 2011). This leads to a further increase in competition as the price becomes the most important criterion for purchase decisions and innovations are quickly copied (Davis et al. 2008). In this sense, basic logistics services are standardized and substituted easily because customers are little loyal to a certain carrier (Christopher 2005; Wallenburg 2009). Facing these challenging circumstances, LSP are looking for resolutions to counteract this situation. One widely recognized option in literature is the differentiation through the offering of additional logistics services, so called value added services (VAS) (e.g. Christopher 2005; Liu and Lyons 2011; Wallenburg 2009).

VAS are defined as an enlargement of the basic logistics services which are offered to internal or external customers and which foster new revenue streams for the LSP (Berglund et al. 1999; Notteborn and Winkelmans 2001; Preiß and Weber 2012; Soinio et al. 2012). Next to revenue, they offer a couple of additional advantages: Increasing customer satisfaction, larger market shares and a higher customer loyalty (Grawe 2009; Busse 2010; Wagner and Busse 2008; Wallenburg 2009). There are different types of VAS and examples can be found at e.g. Grundey and Rimiene (2007) and van Hoek (2000). Especially the group of information- and communication (IC)-technology based VAS are promising concerning differentiation and revenue (Preiß and Weber 2012).

The need for differentiation and the positive impact of IC-technology based VAS are accepted both in theory and practice (e.g. Wallenburg 2009; Wong and Karia 2010). But how oriented are LSP towards IC-technologies and VAS and how does the status quo concerning the development of such innovative VAS look like? A comprehensive study among German LSP was conducted to answer this question. To present the findings, the remainder of this contribution is structured as followed: After the introduction, the theoretical background of the study is explained. In the third and fourth section, the applied research methodology and the achieved results are presented. The contribution ends with both theoretical and managerial implications as well as limitations concerning the research methodology.

2 Theoretical Background of the Conducted Study

In this section the theoretical background of the study is developed. For this case, three concepts are used: The Resource-based view of the firm and the Service-dominant logic as underlying theories and the principles of service engineering as guidelines for the successful development of services.

2.1 Resource-Based View of the Firm and Service-Dominant Logic as Theoretical Fundamentals

The first theoretical pillar associated with the underlying research is the Resource-based view of the firm (RBV). This theory is associated strongly with the concept of competitive advantage, which can be described as the distinction of a firm and its competitors from a customer's perspective which can be achieved through cost leadership, differentiation or focus (Porter 1985). The main target of the RBV is to create such a sustainable competitive advantage (Penrose 1959; Porter 1985; Wernerfelt 1984). The underlying ideas of the RBV can be ascribed to Penrose (1959), who already drew a strong linkage between a firm's resources and its profitability and growth. Following this understanding, the resources of a certain firm are the roots for sustained competitive advantage over its rivals (Grant 1991) and the RBV allows to identify such resources and capabilities (Wernerfelt 1984). A resource can therefore be seen as "anything which could be thought of as a strength or weakness of a given firm" (Wernerfelt 1984, p. 172) and can consist of physical, human and organizational aspects (Barney 1991). In order to do so, a given resource has to fulfill certain criteria in order to generate sustained competitive advantage (Barney 1991). Even though the RBV mainly refers to strategic aspects, this study also takes its increasing relevance within logistical research (Olavarietta and Ellinger 1997; Wong and Karia 2010) into account. According to the premises of the VRIN approach (Barney 1991), IC-technologies fail to fulfill some of these criteria. However, by serving as the basic for VAS, they become a source of differentiation and therefore for competitive advantage. By following this argumentation IC-technology based VAS are relevant resources within the RBV.

The second fundamental theory for this study is the Service-dominant logic (SDL). As many other relevant theories for logistics research (Defee et al. 2010), the SDL logic is rooted in marketing and was mainly developed and published by Vargo and Lusch (e.g. Vargo and Lusch 2004, 2008). SDL gains growing recognition in logistics and supply chain management research and is mainly used as a "theoretical lens" (Randall et al. 2010, p. 36) to explain and interpret scientific results (e.g. Fawcett and Waller 2012; Yazdanparasat et al. 2010). One of its objectives is the abundance of the dichotomy between physical goods and immaterial services (Vargo and Lusch 2004, 2008) and the integration of these two conflicting understandings into one overall logic. To do so, they introduced ten foundational premises (Vargo and Lusch 2008) while five of them build the second pillar of the theoretical framework for this study: (1) service is the fundamental basis of exchange; (2) goods are distribution mechanism for service provision; (3) operant resources are the fundamental source of competitive advantage; (4) the customer is always a co-creator of value; and (5) a service-centered view is inherently customer oriented and relational. The content of these five foundational premises are strongly linked to the focus of the conducted study. SDL changes the way we perceive services and LSP have to adapt this way of thinking to stay successful within competition. This assumption is also convergent with the RBV discussed above as SDL shifts the focus towards operant resources like the unique utilization of IC-technologies as a source of competitive advantages (Vargo and Lusch 2004).

2.2 Service Engineering and Innovations at LSP

The development of new services has been discussed in literature for over 20 years. While leading Anglo-American articles in this field were mainly published in the marketing profession under the key words of "new service development" and "new service design" (e.g. Cooper and Edgett 1999; Edvardsson and Olsson 1996), the German-speaking research community focuses on the term "service engineering" grounded in the areas of technology and innovation management (e.g. Aurich et al. 2010; Bullinger et al. 2003). The concept of service engineering will be the third theoretical pillar of this contribution. Service engineering as a scientific profession can be defined "[…] as a technical discipline concerned with the systematic development and design of services using suitable procedures, methods and tools." (Bullinger et al. 2003, p. 276). It mainly seeks to counteract the existing disadvantages of ad hoc, spontaneous and unstructured development projects because the list of advantages of a well-planed services development through service engineering is long (e.g. Aurich et al. 2010; Bullinger et al. 2003).

Despite the need for innovative VAS and the existence of corresponding concepts such as service engineering for the development of new service offerings, logistics research has not paid much attention to the topic of innovation yet. For example, Flint et al. (2005) conclude that "[…] logistics research has largely ignored the concept of innovation." (p. 113). And this observation has not altered over the last years (Busse 2010; Busse and Wallenburg 2011). Next to innovation, especially service development does not seem to be an issue for LSP. Wagner (2008) proved LSP as little innovative compared to companies of other sectors and identified a lack of innovation processes among the logistics industry. Wallenburg (2009) supports these results in his study as well and Busse (2010) revealed the little usage of R&D activities at LSP. Further empirical results on innovations and service development at LSP are missing revealing a scientific gap which has to be closed. To do so, a comprehensive study was conducted. Its content is closely related to the theories of RBV and SDL and it continues the research stream of innovations in the logistics industry. The main goal of the study was to examine the status quo concerning IC-technologies and VAS and their development at LSP. The methodology of the study is described in detail in the next section.

3 Research Methodology: Description of the Online Survey Among German LSP

In order to achieve the defined research goal, a comprehensive online survey among the German logistics industry between January and February 2013 was conducted. The focus on Germany is appropriate for two reasons: First, this market segment is the largest in Europe containing the highest sales and it is characterized by a strong segmentation (Klaus et al. 2011). Second, some of the most influencing articles on innovation management in logistics also use the German logistics industry as their sample. As we do so as well, we ensure comparability of our results.

The corresponding companies were identified by using WZ Codes (Destatis 2013) and the Hoppenstedt database. Additionally, selected LSP had to have ten or more employees to exclude micro-enterprises. Following these preconditions, 5,384 firms with their related contact information were identified. After the calculation of a random 90 %-sample out of these companies, 4,846 firms received an e-mail invitation to the online survey. For this purpose, a key informant approach (Daugherty et al. 2009) was applied whereby the relevant executives from the enterprises got the survey invitation. Our online survey was established with regard to the suggestions of Griffis et al. (2003), pretested with five logistics professionals and five logistics professors and all contacted companies got the offer for a summary report and non-financial prices to encourage responses (Dillman et al. 2009). Furthermore, two reminder e-mails were sent to increase the response rate. In total, 503 responses were received which results in a response rate of 10.4 %. With reference to Wagner and Kemmerling (2010), an acceptable response rate for logistics research was achieved.

In order to ensure reliability, both nonresponse bias and common method bias were evaluated. Item-nonresponse was covered by using a modified complete case analysis resulting in the elimination of questionnaires with less than 90 %-filled items. In total, 14 questionnaires had to be removed from the sample. Unit-nonresponse was addressed through an extrapolation based on a last respondent approach (Armstrong and Overton 1977). A symmetrical t-test for dependent samples with a 5 % significance level was used to test ten independent items answered by the first and the last 73 participants. As all pairs show $p > 0.05$, unit-nonresponse is not considered as a problem in this survey. A common method bias can arise from the key informant approach (Podsakoff and Organ 1986) and it "[…] refers to the degree to which correlations are altered (inflated) due to a methods effect." (Meade et al. 2007, p. 1). A common method bias can originate from the applied key informant approach. To assess its possible existence, the Harman's single factor test (Podsakoff et al. 2003) and the marker variable technique (Lindell and Whitney 2001; Podsakoff et al. 2003) were used. The results of both procedures indicated that common method bias is not an issue and that the achieved results are valid and reliable.

4 Research Results: LSP Are IC-Technologies and VAS Oriented—but They Lack Formal Structures

In this section, the results of the study are presented. Following the key informant approach, 78 % of the survey participants are members of the executive board belonging to the top management of the respective firm. The distribution of company sizes among the sample reflects the overall structure of the German logistics market (see Fig. 1): The main part of the participating LSP has 250 and less employees and can therefore be considered as small and medium sized enterprises. This observation leads to the conclusion that the achieved results can be considered as valid for the whole population.

A close look on the current and future IC-technology based VAS offered by the LSP (Preiß and Weber 2012) reveals two facts. First, especially tracking & tracing and information provision via the internet are widespread offerings among LSP. Second, only 47 of the companies do not plan to offer IC-technology based VAS in the future. The need for differentiation and the potential of innovative services seems to be widely recognized and accepted among LSP. Additionally, Fig. 2 shows, that currently 148 companies of the sample are not providing any of the listed VAS. By the time, IC-technology based VAS still offer the possibility of differentiation and can serve as a source for competitive advantages.

The study also shows the positive impact of VAS on the financial performance of the companies: 219 LSP would describe the profitability of their VAS as relatively positive compared to their competitors. If VAS are offered to the market, they are obviously accepted by the customers and ensure the overall financial success of the enterprise. Despite their positive profitability, the share of revenue generated by VAS is very diverse throughout the sample, see Fig. 3. This result can be interpreted differently. It indicates that LSP still focus on the traditional logistics services such as transportation and that VAS still play a minor role for these companies' overall turnover. Nevertheless, there are first pioneers among the sample earning more than 20 % of their revenue with VAS.

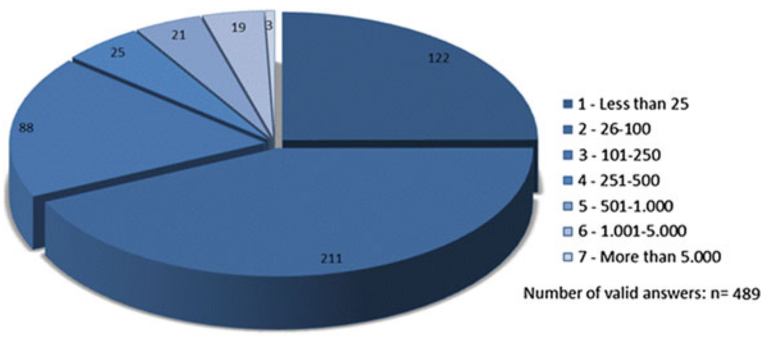

Fig. 1 Number of employees at the participating logistics service provider

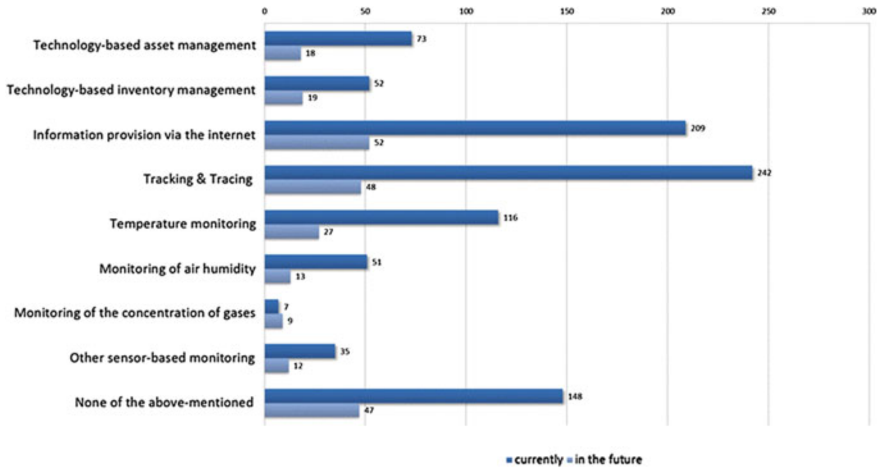

Fig. 2 Currently and future offerings of value added services

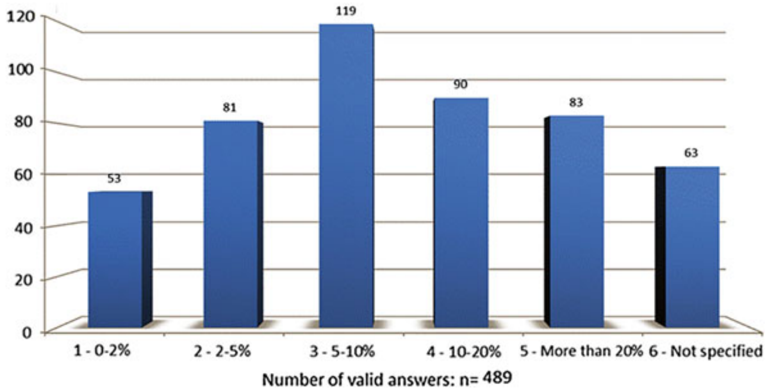

Fig. 3 Share of revenue earned through value added services

To answer the main research question of this contribution holistically, we also intend to shed a light on the underlying development processes for IC-technology based VAS established by LSP. To do so, one objective was to determine the awareness concerning the service engineering concept. With 13 % only a small number of the participants know this concept. In combination with the lack of a dedicated innovation strategy (51 % do not have any one and another 35 % only have a rudimental version) and missing formalized processes for the development of new service offerings (see Fig. 4), LSP can still be described as little innovative without a sufficient innovation management.

Although there is a lack of formal structures for a successful service development, VAS play an important role for LSP and the majority (46.1 %) regards VAS

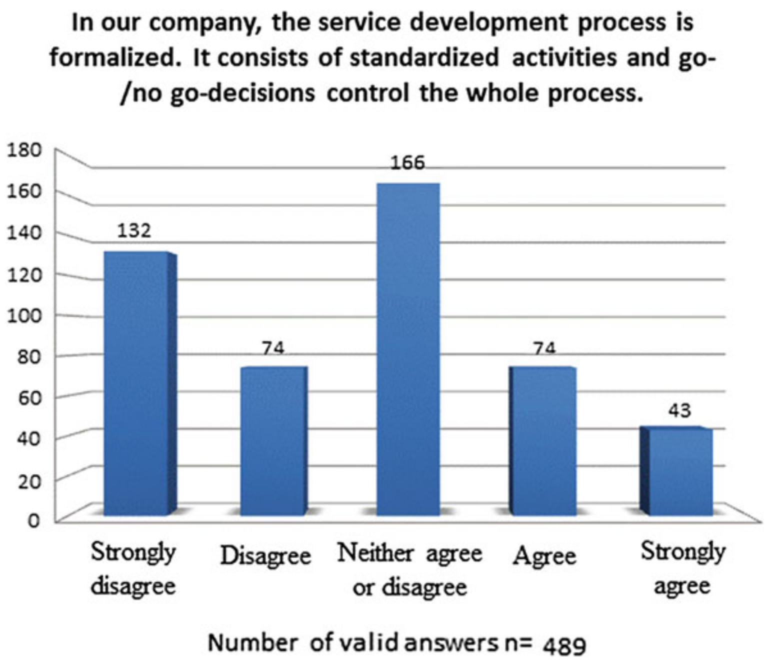

Fig. 4 Self-assessment of the process formalization concerning the development process for VAS

as an important part of their overall business strategy. This contrasts with the results of missing innovation strategies and little formalized development processes. Concerning the orientation towards IC-technologies, it can be noted that 314 enterprises follow the technological developments on the market. Additionally, the majority perceives IC-technologies as a source of differentiation (see Fig. 5).

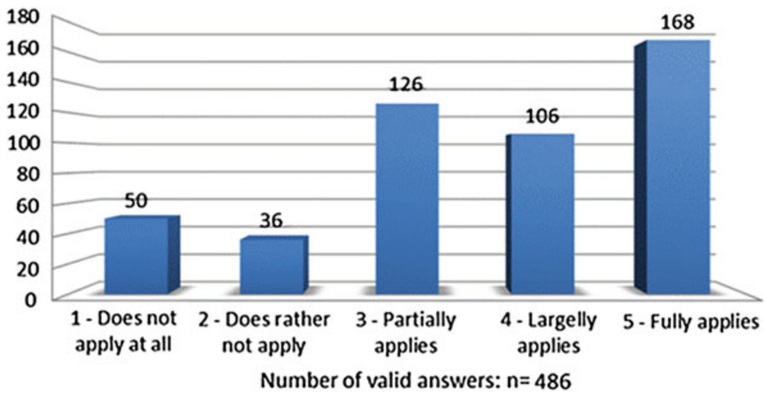

Fig. 5 Self-assessment of IC-technologies as a source of differentiation

5 Implications and Limitations

To sum it up, the conducted study and the presented descriptive results reveal a controversy: On the one hand, LSP would describe themselves as both IC-technology and VAS oriented and it can be concluded that the enterprises have realized the need for differentiation. On the other hand, it seems that they lack the formal and organizational premises for the development of IC-technology based VAS. LSP tend to miss defined processes for the structured development of VAS in the sense of a service engineering approach and they neglect the importance of an innovation strategy for the implementation of a companywide innovative mindset.

5.1 Theoretical and Managerial Implications

The theoretical implications of this work are twofold. First, it continues with the young and still underdeveloped research stream about innovation in the logistics industry. It provides a solid empirical foundation of primary data and helps to understand innovation and differentiation intensions of LSP. The results underline previous findings, for example of Wagner (2008) and Busse (2010), who identified logistics companies as lacking structures for the development of innovations. But the presented results also show some changes in the mindset of the top management. VAS and IC-technologies are perceived as valuable sources for differentiation and LSP start to reconsider their attitude towards innovative service offerings. The second theoretical implication concerns the used theoretical concepts. With SDL and service engineering two concepts form the basis for this research, which have not gained much attention among logistics and supply chain management research yet. Both rose in marketing and can offer useful insights related to service issues. From our point of view, a wider use of these two concepts improves the understanding of the dynamics of VAS and their potential for the success of LSP better and they deserve more attention from the scientific community.

The achieved results also lead to some managerial implications. Under the threatening market conditions, IC-technology based VAS promise a way for differentiation and solid turnover streams. They can build a counterbalance to the traditional logistics services which have turned out as commodities. Nevertheless, such types of service offers seem to be new to many LSP. To design them successfully, a functioning innovations management including defined development processes is needed. Consequently, top management should lay a special focus on this topic in the nearer future.

5.2 Limitations and Outlook

Limitations of the applied research methodology are mainly rooted in the focus of the study. The regional focus was laid on Germany and German LSP. Therefore, the results can only be generalized for this area. The participated companies reflect the German logistics market very well but the study misses some large companies. Only three participants have more than 5,000 employees. Including more big players of the logistics market might lead to a more sophisticated analysis of the current situation at LSP. The third limitation rises from the tight focus on IC-technology based VAS of this study. Next to them, there are many other VAS available to the customers, which have no or only little technological background. The last limitation is related to the presentation of the results. The descriptive data presented in this contribution does not provide any insight into the requirements of a successful VAS development nor does it prove the positive financial impact of such VAS.

Nevertheless, the limitations can be used as a valuable source for future research activities. It would be of scientific value to include more countries into the study, especially overseas or from the second and third world, and to compare the achieved results in the sense of a benchmark. Furthermore, the examination of the status quo concerning IC-technology and VAS orientation at different industry sectors and comparing them to the findings about the logistics sector might reveal some best practices and help to interpret the results in a different way. A third challenge for future research is the investigation of the underlying relationships between the different orientations, the degree of formal structures for the development of VAS and the overall financial performance of the LSP. Does a defined development process ensure a high quality of the final VAS? And do VAS really influence the financial performance positively? These and other questions have to be answered next.

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Toward Mobile Monitoring of Cargo Compartment Using 3D Sensors for Real-Time Routing

Hagen Borstell, Liu Cao, Saira Saleem Pathan, Olaf Poenicke and Klaus Richter

Abstract In this paper we present a system that monitors cargo compartments in transport vehicles in near real-time using RGB-D sensors (Asus Xtion Pro Live, Microsoft Kinect). The main component of this sensor system is a 3D analysis module that determines relevant logistical parameters of cargo compartment conditions such as free load meters, free cargo space and volume of cargo. Wireless GPRS technology transmits the results data to a central server along with GPS positioning. The latest information on a vehicle's location and its cargo compartment parameters are always available to dispatchers, thus enabling them to route vehicles flexibly based on incoming transportation orders. The mobile sensor system's easy and fast integration in the process make it extremely practicable. We also developed a calibration method based on simple planar markers.

1 Introduction

The quality and quantity of the global flow of freight the shipping industry has to handle is increasing as the time for shipments decreases. Modern information technologies allow customers to access a range of goods quickly and directly. Real-time fleet scheduling and routing are therefore essential requirements for the efficient transportation of goods to customers. Earlier approaches to fleet scheduling and routing (Bodin et al. 1983) are less than optimal because they use a previously established quantity of freight as the basis for calculation. The aforementioned approaches cannot be applied to combined pickup and delivery traffic as order cycles are growing shorter and the diversity of goods is increasing. They require methods of fleet scheduling and routing using real-time information (Yang et al. 1999). Such solutions rely on the existence of relevant real-time information on

H. Borstell (✉) · L. Cao · S.S. Pathan · O. Poenicke · K. Richter
Fraunhofer Institute for Factory Operation and Automation IFF,
Sandtorstrasse 22, 39106 Magdeburg, Germany
e-mail: hagen.borstell@iff.fraunhofer.de

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available cargo capacity. At present, real-time information for pickup and delivery traffic is only available during order processing. For reasons of cost, direct measurements of cargo are unavailable during loading. The inaccuracy of the underlying data eventually leads to uneconomic runs that fail to fully utilize cargo capacity. Another problem is that statistics on cargo capacity utilization only reference measurements of weight. These measurements indicate that average utilization rates are relatively low (Seidel et al. 2013). A technical solution that automatically measures the volume of cargo in a truck to systematically quantify cargo capacity utilization does not exist yet. Neugebauer et al. (2010) introduced a system and technique to directly measure the operating rate of transportation vehicles. It monitors the cargo compartments in transportation vehicles with ultrasonic sensors. Reflection and interference among the individual ultrasonic sensors can cause low resolution and strong noise, however. A further problem is the measurement's strong dependence on the cargo since potentially reflecting materials may be in it. The use of 3D image sensors can remedy these problems. In this paper, we propose a system for automatic real-time measurement of cargo compartments based on a particular type of 3D sensor, namely RGB-D sensors (Asus Xtion Pro Live, Microsoft Kinect). RGB-D sensors make it possible to take very close measurements and to detect small and slightly textured structures all over a large cargo compartment. Our proposed system is a refinement of an earlier prototype of ours (Voigt et al. 2011), which has been enhanced significantly, e.g. with an easy calibration procedure, real (metric) measurement based on point cloud processing and the option of configuring multiple sensors to monitor larger cargo compartments.

The paper is structured as follows. Section 2 presents the entire system. Section 3 describes the calibration method, Sect. 4 the analysis methods. Section 5 presents our evaluation concept. Section 6 is a short conclusion.

2 System Overview

The proposed approach to automatic cargo capacity monitoring consists of four components (Fig. 1). The RGB-D sensor module and the communication module are installed in a transport vehicle in an integrated unit termed a "mobile sensor unit". The localization server and web clients, used for operational support of the end user (e.g. the dispatcher), form the database unit.

The parameters of the cargo compartment are identified by the mobile sensor unit and transmitted to the localization server by mobile radio communication, i.e. GPRS. The localization server provides an information interface on loading status to web client applications used by dispatchers such as cargo monitoring systems. The cargo compartment parameters are: *loading volume*, *cargo space* and *load meters*. In combination with positioning data (GPS coordinates), they are important criteria for fleet management and vehicle routing. The parameter of *structural change* represents intolerable changes in the cargo's structure while en route, and

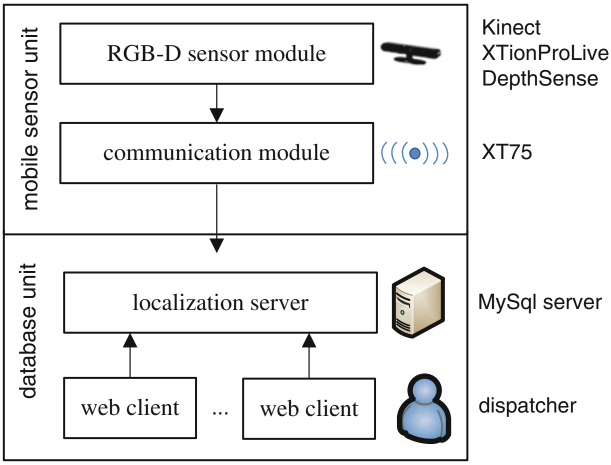


Fig. 1 Components of the complete system

thus facilitates the securing of cargo. The *occupancy* matrix is a compact 3D model reconstruction of loaded cargo that enables a dispatcher to monitor it manually. In addition, a color image containing the state of the cargo compartment is transmitted to the localization server for general process documentation.

Based on information generated by the proposed system, the dispatcher can identify vehicles with available cargo capacity matching the requirements of incoming transportation orders. The dispatcher can flexibly reroute vehicles based on their current location and remaining transport orders. This form of ad hoc logistics (Poenicke et al. 2010) holds potential to make shipping more cost effective and greener by facilitating greater utilization of cargo capacities.

3 Methods of Calibration

One main challenge to the practicability and acceptance of the mobile sensor system is finding a simple calibration method that untrained operators can use in the application domain. In this section, we explain the calibration method used in the proposed approach.

The calibration of imaging sensor systems is far more elaborate than the calibration of other sensor systems (e.g. ultrasonic sensors) because a variety of parameters have to be determined (see Table 1).

The literature provides a variety of methods for, for instance, calibration of depth sensors (Yamazoe et al. 2012) or color image sensors (Zhang 2000) or full calibration of both depth and color sensors including co-registration of the sensors (Herrera et al. 2011; Khoshelham et al. 2012; Zhang and Zhang 2011; Mikhelson et al. 2013). These methods are too complex to be applied in the field by an

Table 1 Parameters necessary for sensor system calibration (organized in groups)

Category	Parameters	Available methods
Pre-field	*Depth sensor* Focal length, principle points, lens distortion coefficients, base Length, distance to the reference pattern	Zhang (2000)
		Herrera et al. (2011)
		Khoshelham et al. (2012)
		Yamazoe et al. (2012)
Pre-field	*Color sensor* Focal length, principle points, lens distortion coefficients	Zhang and Zhang (2011)
Pre-field	*Color onto depth* Rotation, translation (between sensors)	Mikhelson et al. (2013)
In field	*Cargo compartment* Rotation, translation, range	Proposed method

untrained operator. Nevertheless, the calibration parameters must be determined in advance by experts to achieve the accuracies specified in the publications cited. Alternatively, the default calibration parameters available from OpenNI library (OpenNI 2013) can be used. Since these parameters are not adapted for the special characteristics of the individual sensors, the accuracy is affected. Since the default calibration parameters seems to be fairly good (Herrera et al. 2011), though, we use it in our approach. Indeed, we intend to perform the process of pre-field calibration ourselves in future research for purposes of comparison.

Practically, the most critical part of calibration is the determination of the extrinsic calibration parameters related to the cargo compartment (rotation, translation, range) because this type of calibration must be performed directly in the application field by a user without any experience in computer vision. There are many established methods for determining extrinsic parameters, e.g. Nobuhara (2012) or Rodrigues et al. (2010). Such methods are inapplicable to our needs since they have a laboratory character and do not exploit the RGB-D sensor's properties, e.g. depth information. Our calibration method relies on the special property of the RGB-D sensors used, namely the availability of color image data, 3D point cloud data and validity data in registered form. This allows us to use simple black and white planar markers as local references for calibration. The planar markers placed in the cargo compartment by the user represent the origin, the x-axis and the z-direction of the cargo compartment coordinate system (Fig. 2).

We use an adaptation of a marker recognition algorithm (Fiala 2004) to find the center points $\boldsymbol{c}_1^i$, $\boldsymbol{c}_2^i$ and $\boldsymbol{c}_3^i$ of the markers in the color image $\boldsymbol{I}_t$ (Fig. 3).

Since the color image is registered to the point cloud by means of pre-field calibration, we have direct access to the 3D position of the center points $\boldsymbol{c}_1^s$,$\boldsymbol{c}_2^s$ and $\boldsymbol{c}_3^s$ in sensor coordinates. We could establish a common least squares problem, for which the user would have to measure the cargo compartment coordinates of the three planar markers $\boldsymbol{c}_1^w$, $\boldsymbol{c}_2^w$ and $\boldsymbol{c}_3^w$. Instead, we use a different approach in which the user only has to determine the location of the origin marker in the cargo compartment. We do this as follows:

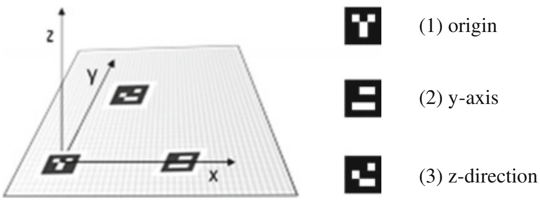


Fig. 2 Definition of the cargo compartment coordinate system with the aid of 2D markers: *1* defines the origin, *2* defines the x-axis in conjunction with marker 2, and *3* defines the z-direction in conjunction with markers 1 and 2

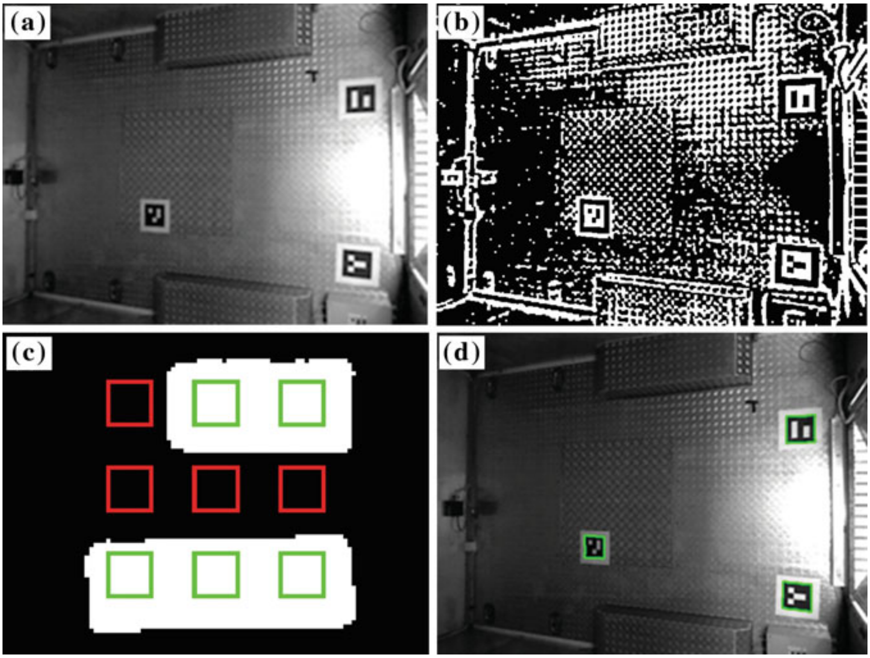


Fig. 3 Pipeline of marker recognition algorithm: **a** original image, **b** binarized image, **c** code reading and **d** result

- Find a rotation that determines the z-component $\boldsymbol{e}_z^w$ of the base vector $\boldsymbol{e}^w$ of the cargo compartment coordinate system. (We applying the Rodrigues' formula.)
- Find the remaining "2D-rotation" that determines the x- and y-components $(\boldsymbol{e}_x^w, \boldsymbol{e}_y^w)$ of the base vector $\boldsymbol{e}^w$ of the cargo compartment coordinate system.

We apply the Rodrigues' formula to determine the z-component,

$$\boldsymbol{R}_1 = \cos\alpha \cdot \boldsymbol{I} + (1 - \cos\alpha) \cdot \boldsymbol{r}\boldsymbol{r}^T + \sin\alpha \cdot \begin{bmatrix} 0 & -r_z & r_y \\ r_z & 0 & -r_x \\ r_y & r_x & 0 \end{bmatrix} \tag{1}$$

where

$\boldsymbol{R}_1$	rotation matrix
$\boldsymbol{I}$	identity matrix
α	magnitude of the rotation
$\boldsymbol{r} = \begin{pmatrix} r_x & r_y & r_z \end{pmatrix}^T$	rotation vector

When the Rodrigues' formula is applies, the unknown parameters α and $\boldsymbol{r}$ that determine $\boldsymbol{e}_z^w$ have to be calculated

$$\alpha = \cos^{-1}\left(\frac{\boldsymbol{n}^s}{\|\boldsymbol{n}^s\|} \times \boldsymbol{e}_z^w\right) \tag{2}$$

$$\boldsymbol{r} = \alpha \cdot \left(\frac{\boldsymbol{n}^s}{\|\boldsymbol{n}^s\|} \times \boldsymbol{e}_z^w\right) \tag{3}$$

We calculate the normal vector $\boldsymbol{n}^s$ thusly:

$$\boldsymbol{n}^s = \left(\boldsymbol{c}_2^s - \boldsymbol{c}_1^s\right) \times \left(\boldsymbol{c}_3^s - \boldsymbol{c}_1^s\right) \tag{4}$$

As mentioned before, the calculated rotation matrix $\boldsymbol{R}_1$ only links the sensor coordinate system to the component $\boldsymbol{e}_z^w$. The base vector's components $\boldsymbol{e}_x^w$, $\boldsymbol{e}_y^w$ are unassigned but are interrelated by $\boldsymbol{e}_z^w = \boldsymbol{e}_x^w \times \boldsymbol{e}_y^w$. This means, we only have to calculate a rotation matrix $R_2 \in \mathbb{R}^{3\times3}$ that determines $\boldsymbol{e}_x^w$ or $\boldsymbol{e}_y^w$. We generate $\boldsymbol{R}_2$ as the rotation matrix representing the rotation angle γ between $\boldsymbol{e}_x^w$ and position $\boldsymbol{R}_1\boldsymbol{c}_2^s$ of the rotated marker 2:

$$\gamma = \cos^{-1}\left(\left(\boldsymbol{e}_x^w \cdot \boldsymbol{R}_1\boldsymbol{c}_2^s\right)/\left\|\boldsymbol{R}_1\boldsymbol{c}_2^s\right\|\right) \tag{5}$$

The calibration procedure leads to a transformation formula and, thus, to a point cloud $\boldsymbol{P}_t^w$ in the cargo compartment coordinates:

$$\boldsymbol{p}_{i,t}^w = \boldsymbol{R}_2\boldsymbol{R}_1\left(\boldsymbol{p}_{i,t}^s - \boldsymbol{c}_1^w\right) \tag{6}$$

where

$\boldsymbol{p}_{i,t}^w$	ith point of point cloud $\boldsymbol{P}_t^w$ at time index t
$\boldsymbol{p}_{i,t}^s$	ith point of point cloud $\boldsymbol{P}_t^s$ at time index t
$\boldsymbol{R}_1$	rotation matrix that determines $\boldsymbol{e}_z^w$

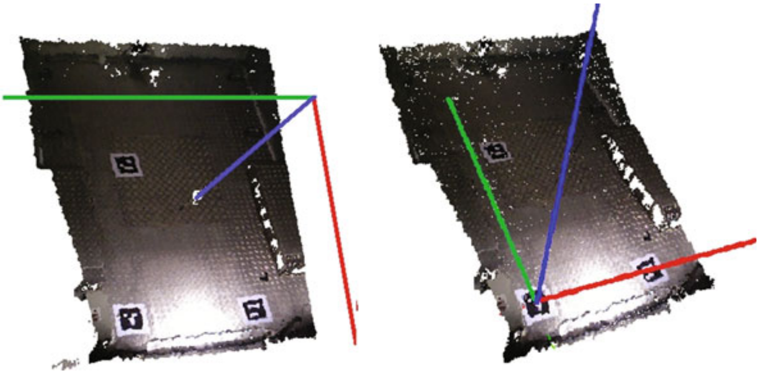


Fig. 4 Transformation from sensor to cargo compartment coordinate system. The colors indicate the x-axis (*red*), y-axis (*green*) and z-axis (*blue*)

$\boldsymbol{R}_2$ rotation matrix that determines $\boldsymbol{e}_x^w$ and $\boldsymbol{e}_y^w$

$\boldsymbol{c}_1^w$ translation vector (position of the origin marker)

Figure 4 presents the result of a transformation from the sensor coordinate system to the cargo compartment coordinate system using formula (6).

4 Methods of Analysis

The logistical parameters *loading volume*, *cargo space*, *load meters* and *structural change* are determined on the basis of the reconstructed 3D cargo compartment, which we obtain by applying formula (6) to the measured point cloud data. The distinctive feature of the analysis module's analyses are its conversion of point clouds (big data) into easily manageable, scalar or vector values (with the form of $func : \mathbb{R}^{3\times m\times n} \to \mathbb{R}^k$), which can be transmitted easily by GPRS. We combine them into a 3D analysis module and integrate it in a modular system concept (Fig. 5). The need for such a modular software concept has been made manifest by different requirements in different projects of ours, e.g. hardware independence, independence of communication interfaces and independent development of analysis and reconstruction methods. The most important advantage is that the methods of analysis can be applied directly to merged point ($\boldsymbol{P}_t^w = \boldsymbol{P}_{t,sensor\,1}^w \cup \boldsymbol{P}_{t,sensor\,2}^w$), thus allowing multi-view configurations that monitor larger cargo compartments to be built upon this concept.

The idea behind the methods of analysis is to project the point cloud $\boldsymbol{P}_t^w$ onto an equidistant grid $\boldsymbol{G}_t \in \mathbb{R}^{\tilde{m}\times\tilde{n}}$ and thus allow the use of fast 2D image processing methods. We define a $\tilde{m} \times \tilde{n}$ grid that lies in the xy-plane of the cargo compartment coordinate system with an offset $\boldsymbol{O} = (x_0, y_0)$ and the grid spacing parameters of

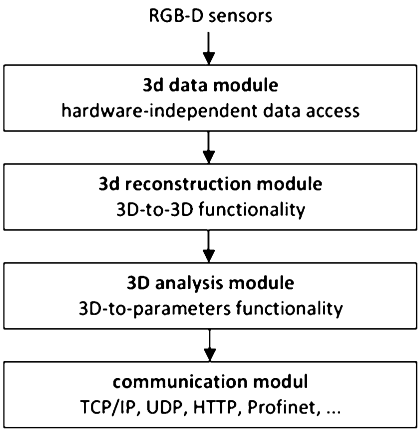


Fig. 5 Modular diagram of the proposed approach

Δx, Δy. We determine the points from $\boldsymbol{P}_t^w$ that are included in each grid area and assign a mean z value to g_{ij}. After projection, we can use a simple difference-image technique to calculate the difference at time t as follows:

$$\boldsymbol{D}_t = \boldsymbol{G}_t - \boldsymbol{G}_{t=0} \tag{7}$$

where

$\boldsymbol{D}_t \in \mathbb{R}^{\tilde{m}\times\tilde{n}}$ difference matrix at time index t

$\boldsymbol{G}_t \in \mathbb{R}^{\tilde{m}\times\tilde{n}}$ equidistant grid at time index t

$\boldsymbol{G}_{t=0} \in \mathbb{R}^{\tilde{m}\times\tilde{n}}$ equidistant grid at calibration time

We determine the occupied volume from $\boldsymbol{D}_t$ by simple integration:

$$V_t = \Delta x \cdot \Delta y \cdot \sum_{i=0}^{\tilde{m}} \sum_{j=0}^{\tilde{n}} d_{ij} \tag{8}$$

where

d_{ij} matrix elements of $\boldsymbol{D}_t$

Δx length of grid element in x-direction

Δy length of grid element in y-direction

We determine the occupied area A_t by applying a threshold function $f : \boldsymbol{D}_t \in \mathbb{R}^{\tilde{m}\times\tilde{n}} \rightarrow \boldsymbol{A}_t \in \mathbb{R}^{\tilde{m}\times\tilde{n}}$ followed by a simple integration:

$$a_{ij} = f\left(d_{ij}\right) = \begin{cases} 0, & d_{ij} < h \\ 1, & else \end{cases} \tag{9}$$

$$A_t = \Delta x \cdot \Delta y \cdot \sum_{i=0}^{\tilde{m}} \sum_{j=0}^{\tilde{n}} a_{ij} \tag{10}$$

where

d_{ij} matrix elements of $\boldsymbol{D_t}$

a_{ij} matrix elements of $\boldsymbol{A_t}$

h height threshold

$\boldsymbol{D}_t$ and $\boldsymbol{A}_t$ are two variants of the occupancy matrix, which is sent to the database as a control parameter for manual routing. Although $\boldsymbol{A}_t$ contains less information than $\boldsymbol{D}_t$, it also contains a significantly smaller quantity of data. This is relevant since we transmit the data by a mobile communication network.

We determine the load meter by first defining a vector $\boldsymbol{b} = (b_0, \ldots, b_{m-1})$ with $b_i = \sum_{j=0}^{n} a_{ij}$ representing the row occupancy of $\boldsymbol{A}_t$. This yields the following for one load meter L_t:

$$L_t = \Delta y \cdot \max(i|b_i > 0) \tag{11}$$

Finally, the structural change parameter c is specified by:

$$c = f(\boldsymbol{D_t}) = \begin{cases} 0, & (\max(\boldsymbol{D_t}) < d_{\max}) \\ 1, & else \end{cases} \tag{12}$$

where

$d_{\max}$ maximum tolerable difference

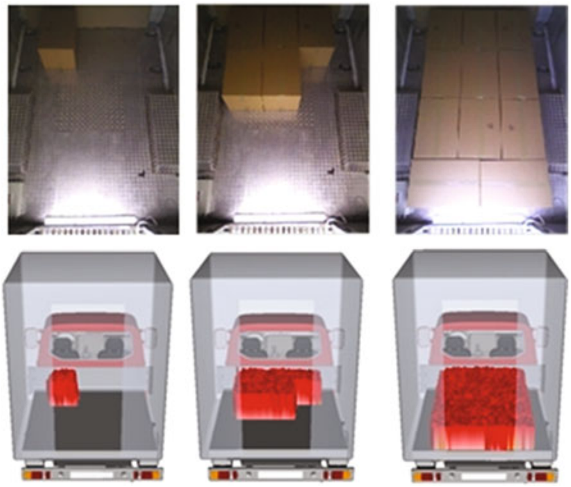
5 Evaluation Concept

The proposed approach is currently being tested using a dual evaluation strategy. First, we are evaluating the methods based on standard loading of a cargo compartment in a laboratory setting. Second, we are using the data acquired from the mobile sensor unit, i.e. color images, occupancy matrix, etc., to verify the results of analysis from the application field manually. This rigorous evaluation is necessary because a variety of complex loading structures appear in practice, which cannot be simulated in the laboratory (Fig. 6, top). We have a research prototype in operation in a logistics partner's vehicle and, thus, access to a constant stream of real data, which we use for manual evaluation (Fig. 6, bottom).

In parallel, we are currently performing the evaluation in a laboratory using standard bodies and standard loading of a cargo compartment. We have equipped our own test vehicle with the sensor system and have defined standard bodies,

Fig. 6 Complex loading structures: (*left*) three of many possible loading structures, (*right*) real evaluation example

Fig. 7 (*Top*) Standard bodies and standard loading for evaluation, (*bottom*) loading structure reconstructed with the aid of the occupancy matrix



which mainly differ in size and shape. Figure 7 pictures an example of standard loading of a cargo compartment with standard bodies. We expect our future research to deliver concrete findings on both evaluation strategies.

6 Conclusions

We have presented a system for cargo compartment monitoring using low cost RGB-D sensors, which reconstructs and analyze the cargo compartment. Based on the depth data, we determine several parameters that help a dispatcher to identify vehicles with available cargo capacity matching the requirements of incoming transportation orders. We have presented a calibration method, practicability and user friendliness being emphases of the related research and development. Our calibration method employs 2D-markers and renders the manual calibration step dispensable. The initial results of the evaluation have been very promising when tested under laboratory and real conditions. In particular, the parameters of cargo space and load meter are measured very robustly. At present, the system has some limitations, however, such as the low robustness of the parameter of cargo volume because of obscured areas in space.

In our future work, we will be focusing on two tasks. First, we will finish our work on our dual evaluation concept in order to clearly define the system's advantages and limits. Second, we will address the commercialization of the system developed. These findings will give rise to modified technical requirements such as the development of a fully integrated ARM embedded system based on our prototype mobile unit with an interface to trucks' onboard computers.

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RFID in Retail Supply Chains: Current Developments and Future Potential

Helen Rogers, Talat Abd El Hakam, Evi Hartmann and Marina Gebhard

Abstract This paper presents a study that investigates the implementation of RFID projects in German and Swiss retail supply chains from a qualitative perspective. The semi-structured interviews with experts from companies in the retail supply chain sector enabled us to gain insights into the problems RFID implementations have to face, as well as the benefits associated with them. In conjunction with a literature review, this allows us to identify the future challenges and potential of RFID applications in the retail industry.

1 Introduction

Due to the growing complexity of global supply chains and ever increasing competition, the pressure on companies to reduce costs, improve process efficiency and increase supply chain flexibility in order to stay successful is rising. This is especially true in the retail industry, where challenges also arise through the huge growth of discount formats and changing customer needs. One way to meet with these challenges is process innovations, such as Radio Frequency Identification (RFID), which promises to improve the efficiency of the processes and thus help to save costs and increase revenues. Although the technology already dates back to the 1950s and became a major issue in the retail industry in 2003 when Wal-Mart

H. Rogers · T.A.E. Hakam (✉) · E. Hartmann · M. Gebhard
Lehrstuhl für Betriebswirtschaftslehre, Insbesondere Supply Chain Management,
Lange Gasse 20, 90403 Nuremberg, Germany
e-mail: talat.hakam@wiso.uni-erlangen.de

H. Rogers
e-mail: helen.rogers@wiso.uni-erlangen.de

E. Hartmann
e-mail: evi.hartmann@wiso.uni-erlangen.de

M. Gebhard
e-mail: marina.gebhard@wiso.uni-erlangen.de

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issued the well-known RFID mandate to its suppliers (Roberts 2006; Collins 2003), implementation of comprehensive RFID systems is still scarce. Although the technology initially promised to revolutionize retail supply chains, to date the applications have not lived up to expectations.

Due to new developments, the industry currently is in a second phase of 'RFID hype'. This time, however, the focus is not on the tagging of pallets and cartons with RFID transponders for improved tracking but instead tagging at the individual product level in selected commodity groups. Many companies, especially in the textile industry, now seek to exploit the benefits of the automatic identification and data capture across the entire supply chain (Gilmore 2011). This is further promoted by the declining costs of RFID technology and the potential benefits, e.g. increased inventory accuracy at all stages, reduction of manual work and a higher product availability at all times (Howells 2011).

Nevertheless, the huge investments required for RFID projects, as well as lack of standardization and unresolved issues surrounding data protection still pose substantial challenges. Thus, the aim of our research is to investigate what the critical success factors for RFID applications are and what challenges still need to be overcome for a wider diffusion of RFID technology and hence future applications. Specifically, what are the current developments in the retail industry and where does the future potential for a widespread use of RFID applications in retail supply chains lie? Furthermore, how can value be added for the customers and the benefits shared by all partners?

By investigating the implementation of RFID projects in German and Swiss retail supply chains from a qualitative perspective and conducting semi-structured interviews with experts from companies in the retail supply chain sector we gained insights into these questions. Furthermore, we conducted a literature review to substantiate our findings.

2 Existing RFID Literature

The importance of RFID technology for supply chain management increases with the complexity of the supply chain and the demands on the efficiency of the processes. Current object identification techniques (mostly involving bar codes), require a large number of manual operations, which brings with it a relatively high error rate. With RFID systems, these processes can be automated (and hence accelerated) and made more resilient in order to meet today's challenges in supply chain management (Kärkkäinen and Holmström 2002).

Logistics processes in particular can be made more transparent and traceable as the location of objects can be mapped in real time and the identification automated (Thiesse and Condea 2009). This leads to an improvement in the information basis (McCrea 2005; Tajima 2007), as errors in the identification of objects will be reduced and also recognized at an earlier stage (McFarlane and Sheffi 2003; Hartley 2004; Lapide 2004). The improved real-time visibility of product flows also has the potential to reduce the bullwhip effect and, thus, allow for further reduction of safety stock levels (Bottani et al. 2010). These opportunities bring many advantages. For example, they foster a demand-driven production, lower inventories, higher product availability and avoidance of out-of-stock situations, improved theft protection, better utilization of transport and permanent inventory controls (Kärkkäinen and Holmström 2002; Prater et al. 2005; Andraski and Margulis 2012; Blecker and Huang 2008; Schuermann and Wiechert 2007; Hertel et al. 2011; Kinkel and Maloca 2009; Jones and Chung 2008; Bayraktar et al. 2011; Li et al. 2011; Tellkamp and Haller, 2005; Pezoldt and Gebert 2011). Based on a review of RFID literature, Sarac et al. (2010) report five main advantages of RFID technology in supply chains in the following fields: product and processes traceability and visibility, process efficiency and speed, information accuracy, reduced inventory losses, improved management through real-time information. The stages of a typical retail supply chain therefore offer many possible fields of application in which RFID technology can be used to improve the flow of goods and information across the entire supply chain (Blecker and Huang 2008; Salditt 2008).

Owing to possibilities such as these, the RFID technology offers supply chain partners a wider range of benefits than the barcode (Tajima 2007). Nevertheless, the maximum benefit can only be achieved in a networked system linking the whole supply chain. Therefore, the integration of partners and systems is crucial (Hellbach et al. 2007). A prerequisite for this is the adaptation of the existing systems and processes to meet the requirements of the technology (Pezoldt and Gebert 2011). Without this, it is impossible to create an integrated supply chain, that enables all involved companies to reduce their costs and inventory and at the same time ensure the availability of goods (Bhattacharya et al. 2007).

Although the implementation of RFID technology offers great potential, some significant challenges remain, preventing wider application. These include, but are not limited to, investment cost and precise ROI calculation, integration of RFID systems into existing systems, lack of standardization, concerns about data privacy, effective handling of data generated by RFID technology, uncertainty about benefits, lack of willingness of supply chain partners to cooperate, inaccurate data reading, especially in environments with metal or liquid objects, staff training (Jones et al. 2005; Wu et al. 2006; Chang et al. 2008).

More recently, several empirical studies of RFID adoption were published by Vijayaraman and Osyk (2006), Lee and Shim (2007), Leimeister et al. (2007), Chang et al. (2008), Goswami et al. (2008), Sharma et al. (2008), Shih et al. (2008), Strueker and Gille (2008), Madlberger (2009), Tsai et al. (2010), Thiesse et al. (2011)—who also provided a detailed overview of survey-based research on RFID adoption.

For comprehensive reviews of RFID literature, readers should refer to Chao et al. (2007), who explored technology trends and forecasts by using a historical review and bibliometric analysis; Ngai et al. (2008), who reviewed RFID literature published between 1991 and 2005; and Sarac et al. (2010) who analyzed existing literature on the impact of RFID on supply chain management published until 2009.

Table 1 Characterization of experts' companies

	Expert/Co. 1	Expert/Co. 2	Expert/Co. 3
Type of company	Vertically integrated clothing manufacturer	Logistics service provider	Vertically integrated retailer
Sales/no. of employees	702.7 Mio. €/3.260	1,008.5 Mio. €/15.500	24,858.8 Mio.CHF/86.393
Level of tagging	Item level	Means of transport level	Package level
Type of system	Open	Closed	Closed
State of application	Operational	Operational	Roll-out

3 Research Approach

In order to analyze the current state of RFID implementations, as well as identify critical success factors, future trends and existing challenges, we conducted interviews with managers from German and Swiss retail companies. The interviews followed a semi-structured interview guide to ensure all relevant topics were included, while still giving the experts space to go into more detail where appropriate. In the interviews RFID projects' goals, challenges and successes were described and also a general assessment of the technology and its possibilities and problems were given. Our objective was to determine which of the many possibilities of the technology are actually relevant for companies and what future potential for RFID applications exists (Table 1).

The interviews were then analyzed according to topic units, so that general and differing insights from the specific interviews can be compared against each other. Through the commonly shared institutional organizational context of the experts, the comparability of the interview texts is ensured. Additionally, comparability is ensured by using a common interview guide (Bogner et al. 2009). In our qualitative content analysis, we first built up a closed category system (as shown in the appendix), allocated the text into units of analysis, searched the text for relevance and finally assigned the information to the categories (i.e. coding) (Burger 2011). Alongside the interviews we carried out desk-based research and analyzed the available material on RFID implementation projects such as Gerry Weber, REWE, etc.

4 Findings

The fieldwork and a literature review enabled us to gain insights into some of the problems RFID implementation projects still have to face, as well as the benefits associated with them.

4.1 Cost Effectiveness and ROI

According to our experts, major obstacles are the still very high investment costs. Calculating the cost effectiveness presents companies with problems, as it is difficult to clearly assess the monetary value of process enhancements. However, the experts estimate that an ROI can be achieved within two years of the RFID implementation. Vertically integrated companies are often faced with an even shorter payback period. In some companies, the investment in RFID is also perceived as a strategic investment and implemented, even without detailed knowledge of payback periods. However, depending on the project status a real impact in controlling can be observed. Nevertheless, our findings show that RFID can help to increase the efficiency and improve the quality of the logistics processes. However, due to the small diffusion of the technology many possibilities remain underutilized (Table 2).

4.2 Technical Challenges and Maturity of Available RFID-Systems

Our experts agree that the technical level is sufficient for most current applications, at least in the textile industry. However, they consider that problems remain in other industries, especially in the food industry where metals and fluids are handled. Furthermore, technical challenges arise through the integration of RFID components into existing logistics systems. The problems the companies have to face lie in the fact that the logistics systems often are tailor-made solutions and thus the integration of RFID must be worked out individually. Another major task that must be taken seriously is employee training. In order to realize the technology's maximum potential, employees need to understand the technology and that the benefits can only be gained if the "new" processes are properly performed (Table 3).

4.3 Privacy Concerns and Other Impediments to Widespread Dissemination of RFID Technology

The widespread dissemination of the RFID-technology is currently no longer prevented owing to technical reasons, but more for economic reasons. These are mainly a lack of standardization, as well as missing concepts concerning the cost and benefit sharing between supply chain partners. Our experts reported that many RFID-related benefits are located downstream at the retailer while the upstream supplier/manufacturer incurs most RFID-related costs. This is especially relevant for companies that are not vertically integrated. These issues may be resolved by surplus sharing contracts (Chan et al. 2012) or cost sharing ratios (Demiralp et al. 2012),

Table 2 Experts comments on the cost effectiveness

	Expert/Co. 1	Expert/Co. 2	Expert/Co. 3
Scope, applications and objectives	Acceleration of incoming/outgoing goods through automated identification of individual components	Localization and identification of logistical objects in a high-bay warehouse	Temperature monitoring of the goods
	Acceleration of the goods receiving processes in stores		Enhance transparency of processes and process safety
	Implementing retail security systems		Improvement of site management and management of the operating times of the trucks with real-time RFID data
	Replacing annual inventory with weekly inventories and enhancing accuracy of inventory management		Identification of reusable containers
Cost effectiveness	Productivity in a completely RFID-converted logistics facility increased by 27 %	Difficult to measure/not measurable	The investment in RFID is seen as a strategic investment in the future competitiveness
	Reduction of incorrect deliveries to customers by 80 %		Many use-cases will arise only after the introduction of the technology
	Increased sales figures due to quicker goods receipt in the stores and so more consulting time for customers, as well as the increased availability of goods through improved inventory control		

however, to date, academic literature on this issue is still relatively scarce. The privacy policy plays a major role in industries where end-customers get in contact with the RFID-systems. Customers need to be informed about data handling, to allay their doubts. Furthermore, it would be helpful if a way could be found to allow the usage of RFID-tags after the payment process and still guarantee privacy. However, the legal basis in this context is still vague and needs further development (Table 4).

Table 3 Experts comments on technical risks and the maturity of available RFID-systems

	Expert/Co. 1	Expert/Co. 2	Expert/Co. 3
Maturity of RFID systems available on the market	Very good in the textile industry but other industries could be problematic (metallic objects, etc.)	–	Good or good enough, although a bulk reading rate of 100 % is not possible, this is not problematic as long as the logic of the whole process is mapped (package-level tagging)
Implementation challenges	Integration of RFID components into existing logistics systems	Integration of RFID components into existing logistics systems	Bulk/batch capturing
	Employee training		Capturing of packages containing fluids or metallic objects

Table 4 Experts comments on privacy concerns and other impediments to dissemination

	Expert/Co. 1	Expert/Co. 2	Expert/Co. 3
Impediments to technology dissemination	Benefit-sharing in supply chains is still an open issue	Costs and cost effectiveness is still a major problem (due to size of logistics real estate many RFID antennas are needed)	Standardization is still a problem, so that every partner in the supply chain uses the same technology
	In Europe the brand manufacturers who seek the use of RFID must convince retailers		
Privacy policy	Data protection is of utmost importance, due to use of an open RFID-system with end-customer contacts	In closed systems, data privacy aspects are of minor importance	–

4.4 Future Trends

In the textile industry, item-level tagging is currently in progress in terms of reliability, uses and dissemination. In combination with the declining cost of RFID tags this will lead to an increasing diffusion of the technology in the retail industry, as this also enables higher inventory accuracy, increased transparency and improved product availability. Therefore, most leading retail companies offering clothing or shoes, are likely to use RFID for item-level tagging in the next 3–5 years (Gorshe et al. 2012). The experts assume the same development for industries with similar characteristics as the textile industry. The greater the variety of the individual goods in color, size or style, the higher is the optimization potential that can be achieved through RFID, e.g. through higher inventory accuracy. In addition, the product should have a relatively high price and high profit margins so that the payback period is shorter. The product categories believed to be the next on the RFID list are clothing accessories, footwear, consumer electronics or computer and jewelry (Roberti 2011). Furthermore, perfume, alcoholic beverages and medicines also offer great potential for the use of RFID, as anti-counterfeiting and product security are gaining in importance.

5 Success Factors for RFID Implementation

Based on the insights gained in the interviews with industry experts, we have identified eight critical success factors for implementation of RFID technology that are relevant to achieve the full benefits of the technology.

Analysis of the company, the supply chain and the supply chain partners: The first step to a successful implementation is a thorough analysis of the whole company, the supply chain and the supply chain partners. Are the products offered suitable for an integration of RFID or are technical problems to be expected, e.g. low read-rates because of metallic objects or liquids? What is the position in the supply chain? Are the partners willing to also participate in the technology?

Definition of the objectives to be achieved with RFID: Before RFID can be integrated into the business processes and the supply chain, clarity regarding the objectives must exist. It must be clear in which application areas the technology should be implemented, e.g. manufacturing, logistics, warehouses or retail stores, and which improvements are expected. Furthermore, a decision needs to be made as to which product categories should be tagged and on which level, e.g. item or container.

Ensuring support from top management and employees: Gaining support from top management, as well as from the employees is crucial for success. Only if there is enough support available from the management, will it be possible to rethink the existing processes and structures, and adapt them to the new requirements. Furthermore, if employees are not convinced and don't understand the advantages of the new technology, it is likely that the benefits will not be achieved (Fig. 1).

Selection of the required system infrastructure and software/hardware vendors: Experienced system providers are able to identify challenges and to give advice in the implementation of the technology. Often, companies that seek to integrate RFID, have limited experience with the technology and thus are not in a position to anticipate problems.

Open communication and cooperation with the supply chain partners: Information sharing with the supply chain partners is a further consideration. A prerequisite for this is open communication and cooperation with the value chain partners. It is important to clearly communicate the planned introduction of RFID and to develop a common course of action. Equally, the desired goals of each company must be agreed upon. This may also lead to benefits along the whole supply chain that have not yet been considered.

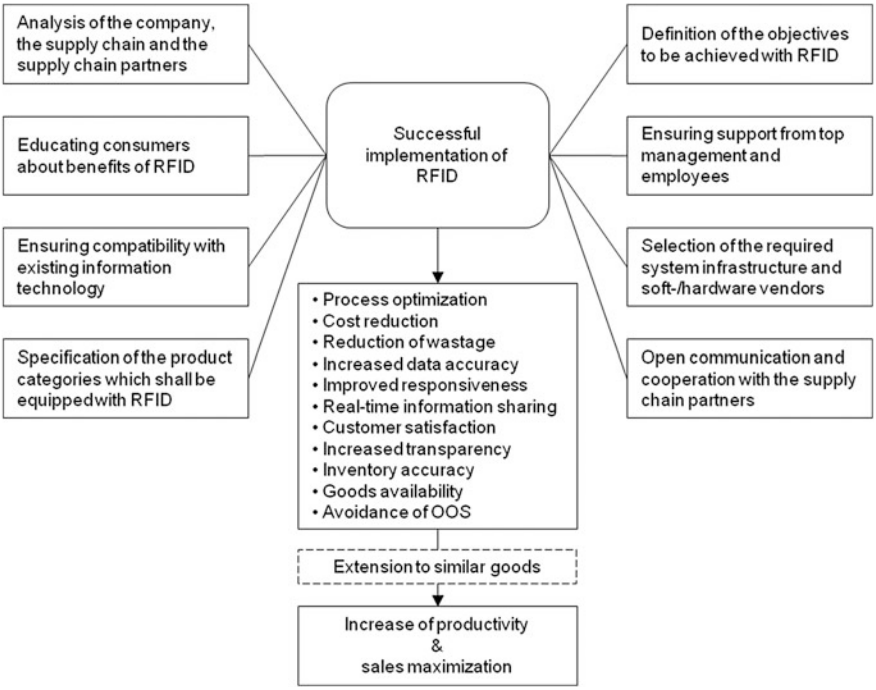

Fig. 1 Critical success factors for the implementation of RFID

Ensuring compatibility with existing information technology: Compatibility with existing IT systems is a key success factor. It is necessary to create interfaces that allow a smooth exchange of information with partners if possible.

Specification of the product categories to be equipped with RFID and extension to similar goods: Provided that the implementation of RFID in selected product groups is successful and appropriate knowledge is established, the expansion can be targeted to other similar products. In this way, the company can avoid already-known problems or solve them in a better way as the necessary infrastructure, regarding readers or tags, already exists.

Educating consumers about the benefits of RFID: To use RFID successfully on the item level, the advantages of the technology must be made clear to consumers and concerns on their part must be eliminated. In particular, data privacy concerns of consumers have to be taken very seriously. Only then will customers continue to buy the products when the companies reveal how they handle the data. Alongside regulatory compliance, an open dialogue with consumers is necessary to create trust.

In summary, we conclude that RFID technology offers the potential to further increase the efficiency and effectiveness of the supply chain processes. It assists with rapid customer need identification and response, enhances customer service and thus strengthens customer loyalty. Nevertheless, in most cases it is not possible to realize all benefits equally. This is also dependent on the situation prior to introduction, intended objectives, scope of RFID deployment and collaboration with the supply chain partners. However, if a company considers the above-mentioned critical success factors in the implementation process, the likelihood of a successful introduction will be significantly increased. Even so, it is likely that the benefits will not be achieved immediately, so, a long term perspective is important (i.e. they do not give up at the first sign of difficulties).

6 Conclusion

A number of pilot projects of RFID implementation have been carried out in retail supply chains. Owing to implementation-based issues, many RFID projects performed rather poorly and were discontinued. However, the picture has since changed as many retail companies have recognized the enormous potential it offers when integrated into existing systems infrastructure along the entire supply chain. Companies that implemented RFID applications also gained associated benefits spread along the supply chain. In order to analyze the current state of RFID implementations, we conducted interviews with managers from companies in the retail industry. In conjunction with a literature review, we identified critical success factors for RFID implementations, as well as future trends and existing challenges. As with other interview-based research, our results must be treated with caution, as they are likely to suffer from response bias. Therefore, we recommend further and above all larger scale studies be carried out to strengthen these initial findings.

Appendix

The closed-category system consisted of three categories, two of which have sub-categories:

C1: Introduction of experts and companies
C2: Presentation of the RFID projects

- C2.1 Scope, applications and objectives
- C2.2 Implemented technology
- C2.3 Technical challenges
- C2.4 Cost effectiveness

C3: General RFID Topics

- C3.1 Visionary RFID applications
- C3.2 Maturity of RFID systems on the market
- C3.3 Impediments to technology dissemination
- C3.4 Future trends/industries for RFID implementation
- C3.5 RFID and environmental protection
- C3.6 RFID and data privacy/privacy policy

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Impacts of the Locks Enlargement on the Access to the Panama Canal on Maritime Container Transport in the Central American Region

Joachim R. Daduna and Melina Hanisch

Abstract The Panama Canal is of great importance in international maritime freight transport. With the completion of the locks currently being constructed this importance will increase significantly more as the locks are designed to serve the Post-Panama Class vessels. This will thus lead to changes of worldwide shipping routes due to the fact that completely new and more (cost) efficient connections in transcontinental maritime freight transport will be feasible. This especially affects the Caribbean region so that logistical structures have to be adapted appropriately. In this paper the routes that are likely to change are presented and then a multi-level (and functionally differentiated) harbor network will be outlined. The objective is to establish sustainable shipping routes leading through the Caribbean to ensure an efficient supply of goods in the region in the long-term.

1 Maritime Freight Transport in the Central American Region

Maritime freight transport has always been of vital importance for the Central American region and this will also be the case in the future. Especially for the Caribbean Islands it is the basis for economic linkages with the adjacent mainland and also with international markets. Based on these structures the future economic development is inextricably tied to the performance of one single transportation mode.

Even though currently main shipping routes (see Fig. 1) lead through the Caribbean due to the Panama Canal as one of the two sea routes between the Atlantic and the Pacific, sufficient interconnections in maritime freight transport are missing in parts of this region. Because mobility and traffic infrastructure,

J.R. Daduna (✉) · M. Hanisch
Berlin School of Economics and Law, Badensche Str. 52, 10825 Berlin, Germany
e-mail: daduna@hwr-berlin.de

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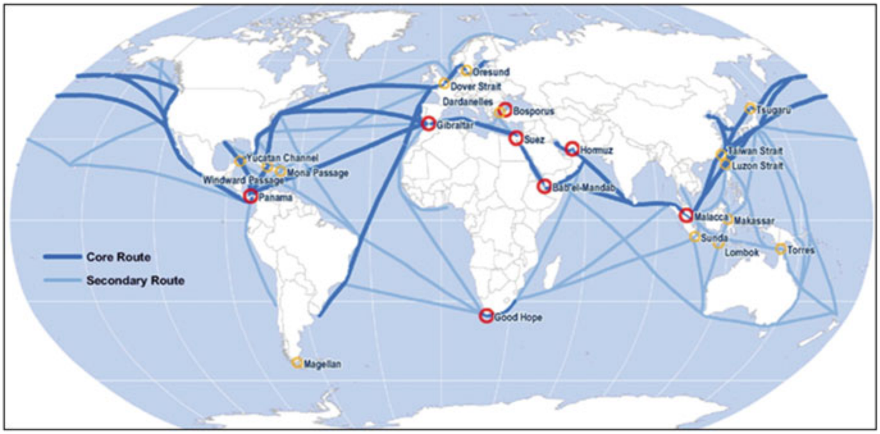

Fig. 1 Basic structure of worldwide shipping routes

respectively, are of great importance to ensure the economic development (see e.g. Gonzalez et al. 2008; Meersman and van de Voorde 2013) and also to promote regional integration, appropriate measures must be taken within the next few years. One important aspect is the shortening of the existing shipping routes through the construction of new canals and the elimination of bottlenecks through adjustments of infrastructure.

Their implementation should be made in conjunction with the structural changes resulting from the enlargement of the lock systems at the canal entrances, since in 2014 a completely different situation in maritime transport will arise worldwide and especially in the Caribbean region (see e.g. Salin 2010; Shi and Voß 2011; Ungo and Sabonge 2012). Up until now the vessel sizes were limited to the *Panamax Class* (L: 294.13 m/W: 32.31 m/D: 11.30/5,000 TEU), in the future however, sizes of the *New Panamax Class* (L: 366.00 m/W: 49.00 m/D: 15.20/12,000 TEU) will be possible (see Fig. 2). Since the technical infrastructure in the *seaport container terminals* (SCT) will be adjusted in accordance with the emerging needs, only some ports will be able to handle New Panamax Class vessels. This is why the enlargement of the lock system will have an impact on the structures in (international and national) *trade lanes* (see e.g. Knight 2008; Rodrigue 2010; Fan et al. 2009, 2012; Pinnock and Ajagunna 2012b).

The changes in the main shipping routes do not only have impacts on the economy but also on the ecology. However, these impacts differ significantly (see e.g. Corbett et al. 2012; de Marucci 2012) depending to a large extend on the *relations* and the *means of transport* looked at. Strong impacts result due to the enhanced connections in transit traffic which connect the harbors of the North American East and West Coast. Similar situations emerge for the relations between the Asian markets and the East Coast as well as for the relations between European markets and the West Coast (see e.g. Pinnock and Ajagunna 2012a, b). For the

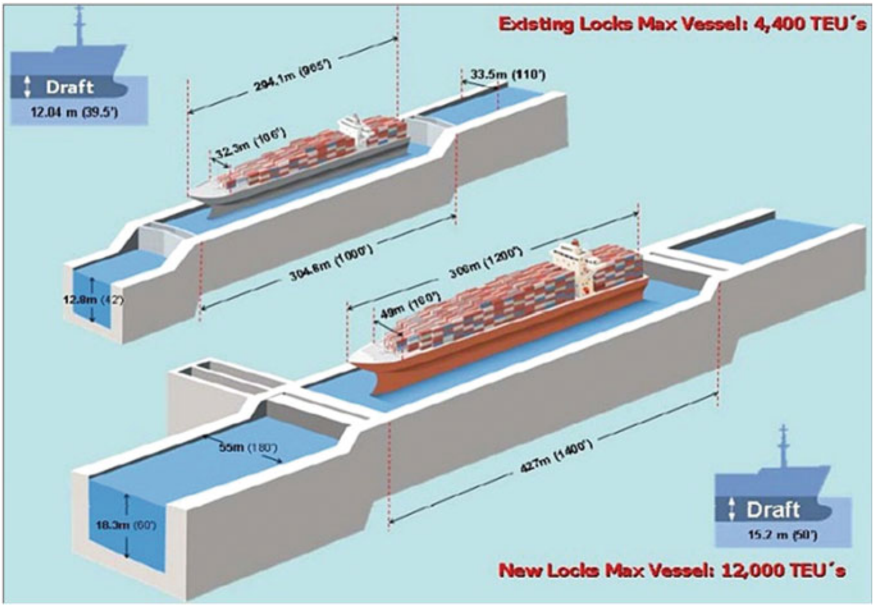

Fig. 2 The current and new Panama Canal locks

Central American region and the Caribbean the resulting effects are only partly measurable due to non-congruent objective structures (e.g. costs, time, and sustainability). A reliable statement can therefore only be made on the basis of case-specific structures.

But not only shipping route structures will change making use of New Panamax vessels. Also the number of ports of call will increase due to economic reasons. This results in an increasing competition between the harbors in the Caribbean region which are suitable for acting as a central hub with international linkages due to their geographic location but regardless of their current state of development. In conjunction with the use of New Panamax Class vessels on the main routes, changes in the fleet structure become necessary in order to provide appropriate services that are in line with the harbor structures. In this context *short sea shipping* (SSS) will increasingly gain in importance (see e.g. Baird 2007; Ng 2009; Paixão Casaca and Marlow 2009; Styhre 2009; Medda and Trujillo 2010; Daduna 2013), whereby feeder transport as well as the expansion of regional infrastructure development (see e.g. Sánchez and Wilmsmeier 2005; Paixão Casaca and Marlow 2009) become necessary.

In this paper we start with a rough estimate of the (geographic) regions for the positioning of possible hubs. Afterwards existing and planned SCT will be analyzed and evaluated. Based on the results, possible network structures will be designed and their advantages with respect to the development of an economically and also ecologically reasonable sea freight transport system will be presented. At the end of the paper we give an outlook for long-term developments, especially with regard to a comprehensive and efficient logistical development.

2 Potential Locations of Central Hubs

When taking the current route structures which exist in international maritime transport at present as a basis (see e.g. Rodrigue et al. 2009: 133), the transit function of the Caribbean region becomes evident. The central point here is the Panama Canal (see Fig. 3) which allows a better connection (and therefore more competition) in freight transport between the American East and West coast (see e.g. Fan et al. 2009, 2012). Moreover it facilitates the access of the Pacific region and the East Asia region to the Atlantic region respectively.

Due to these far reaching structural changes and in conjunction with the use of New Panamax Class container vessels, new routes in maritime freight transport, and especially in container transport, in Central America and the Caribbean arise

Fig. 3 The Panama Canal (geographical overview)

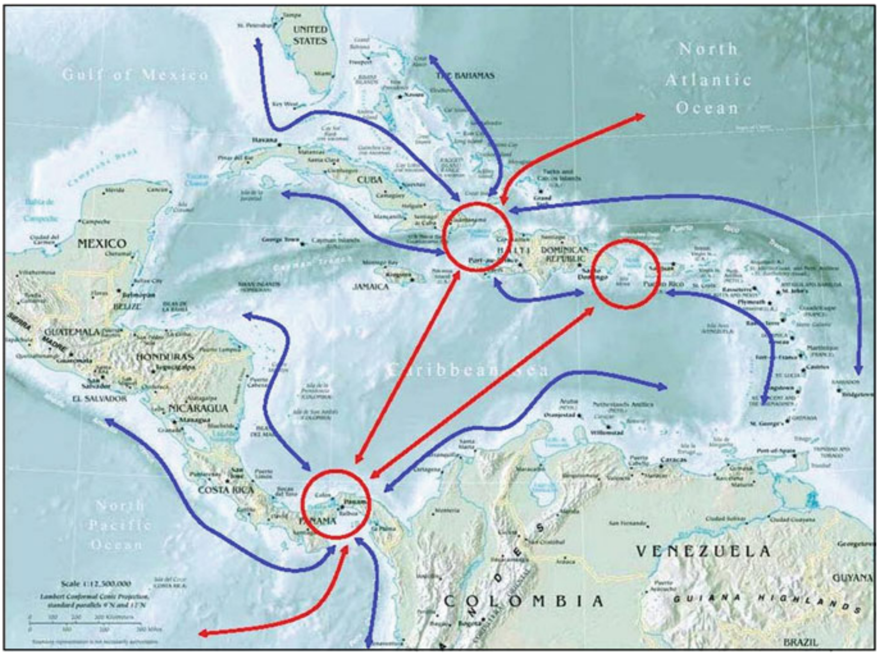

Fig. 4 Shipping routes in the Central American and Caribbean region

(see Fig. 4). Moreover, trunk connections with accordant volume potentials will evolve which are parts of a *round-the-world-service* (see Rodrigue and Notteboom 2013). In accordance with that, the east-west moving container flows will inevitably be concentrated on very few central hubs since with the increasing vessel sizes it is economically not reasonable to serve a higher number of harbors (see e.g. Müller and Schönknecht 2005). On the basis of these few hubs, appropriate feeder structures have to be developed in order to guarantee a connection of the harbors in the Caribbean, in the Gulf of Mexico as well as along the coasts of North-, Central-, and South America (see e.g. Pinnock and Ajagunna 2012a).

In view of the change of shipping routes that is to be expected three geographical regions can be identified which are suitable for the establishment of a central hub. In the Panama Canal region this would be *Balbao* on the southern side of the Panama Canal and *Colón* on the northern side. These two locations do not have a lot of competition today due to lacking alternatives.

However, with the planned expansion of a SCT in *Moin* (Costa Rica) by APM Terminals Management B.V. a relevant competitor for *Colón* would emerge. In order to prevent the possible economic loss due to this kind of development, it is planned to extend both locations (*Colón* and *Balboa*) to international industry and logistics centers, like with the *Panama Pacifico Industrial and Logistics Park* project in the area of the *Miraflores locks* (see e.g. Sheffi 2013). With these kinds of measures, which are also gaining importance in ports on a global scale (see e.g. Nam and Song 2012), the strong dependence on revenues generated from the canal fees should be reduced and the economic growth (see e.g. Pagano et al. 2012) should be stimulated. This dependence is clearly demonstrated by (Sheffi 2012: 68) who talks about the Panama Canal as a *toll road* between the Pacific and the Atlantic Ocean.

On the northern side of the Caribbean (to the Atlantic) two competing regions exist, the passage between the islands of *Cuba* and *Hispaniola* (*Windward Passage*) on the one hand and the passage between *Hispaniola* und *Puerto Rico* (*Mona Passage*) on the other hand.

Kingston (Jamaica) and *Port-au-Prince* (Haiti) are the two relevant harbors for the Windward Passage area. The inclusion of the Cuban deep sea harbor *Mariel* (in the west of Havana), which is discussed over and over again, does not make sense as it is located too far west of the major routes. The same situation also applies for the harbor of Havana where also the extension of the navigable channel for larger vessels is not possible. A suitable site because of its geographic location would be *Guantanamo Bay* in the east of Cuba which is out of question given the current political structures. So Cuba, as the biggest island state in the Caribbean, will not be able to play a larger role in the long run as under the given circumstances no relevant harbor location will be available as subject of further discussions.

In the area of the Mona Passage the harbor of *Caucedo* (Dominican Republic) is relevant as well as the harbors of *San Juan* und *Ponce* (Puerto Rico). Caucedo is a very new port that has been growing rapidly since its opening in 2003 to substitute the Rio Haina SCT in a long-term view. This was necessary since this SCT, in contrast to Caucedo SCT, cannot be expanded further due to a lack of space. Here in 2010, more than one million *Twenty Feet Equivalent Units* (TEU) were being handled. Since the current capacity is 1.25 million TEU the port is already approaching its maximum capacity of the first two construction stages. The two ports of Puerto Rico, San Juan and Ponce, belong to the biggest harbors of the region. However, one can observe a contrary development of the two. While San Juan has been in the centre of attention in the past years, since 2010 a clear decline in container throughput of 25 % becomes obvious. At the same time the importance of Ponce increases since the government is planning to establish an international SCT there to operate the emerging container flow that is going to be expected in 2014. Other harbors in the region are not suitable either because of their geographic location outside the main routes, like e.g. *Freeport* (The Bahamas) and *Port of Spain* (Trinidad and Tobago) or because of the current size and lacking development potentials, as e.g. *Rio Haina* (Dominican Republic) as well as the (smaller) harbors of the *Lesser Antilles* and the *Netherlands Antilles*.

An overview of the harbors discussed beforehand (and data to the countries concerned) can be found in Table 1 (see e.g. UNCTAD 2011, 2012; World Bank 2012a; TI 2010, 2012) and Table 2. (see e.g. Containerisation International 2012; Pinnock and Ajagunna 2012a).

Table 1 Structural data (countries)

Country	Panama	Jamaica	Haiti	Dominican Republic	Puerto Rico
Area (km^2)	75.52	10.83	27.56	48.32	8.87
Population (2011)[1]	3.33	2.90	9.80	10.10	3.71
GDP (US$) (2010/2012)[2]	7,539/9,444	4,942/5,657	0,665/0,820	5,227/5,805	25,863/n.a.
CPI (2010/2012)[3]	36 (73)/38 (83)	33 (87)/38 (83)	22 (146)/19 (165)	30 (101)/32 (118)	58 (33)/63 (33)
LPI (2010/2012)[4]	3.02/2.93	2.53/2.42	2.59/2.03	2.82/2.70	n.a.
LSCI (2010/2012)[5]	41.09/42.38	33.09/21.57	7.58/5,08	22.25/23.72	10.65/13.67

[1] In million habitants
[2] Gross domestic product (GDP) per capita (current prices/$US)
[3] *Corruption perceptions index* (CPI)
[4] *Logistics performance index* (LPI)
[5] *Liner shipping connectivity index* (LSCI)

Table 2 Structural data (harbors)

Harbors	Balboa	Colón	Kings-ton	Port-au-Prince	Cau-cedo	San Juan	Ponce
Terminals	1	3 (4)	3	1	1	1	1
Mio. TEU 2009/2010/2011	2,012/2,759/3,232	2,211/2,811/3,372	1,782/1,892/1,757	n.a.	0,906/1,005/n.a.	2,007/1,525/1,485	n.a.
Quay length (m)	2,270	980	2,310	450	1,220	n.a.	n.a.
Depth (m) (planned)	>15	14	11–13 (15)	8–10	13.5–15	12.5–13.7	>15
Number of cranes[1]	22 (4)	38 (8)	34 (14)	n.a.	6 (1)	n.a.	n.a.

[1] Number of quay cranes (number of Superpost-Panamax)

3 Hub Selection

Based on the data shown in Tables 1 and 2 the chosen possible hub ports need to be analyzed and evaluated. In addition to the technical data which describes the current performance, also the planned or partly executed expansion measures need to be included. Moreover, one has to consider the political and economic circumstances of the different countries. Major conclusions can be drawn by analyzing the values of the *Gross Domestic Product* (GDP) *per capita*, the *Corruption Perceptions Index* (CPI), the *Logistics Performance Index* (LPI) and the *Liner Shipping Connectivity Index* (LSCI).

- GDP per capita: This index represents the country's standard of living. The calculation is based on the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output divided by midyear population (see World Bank 2012b: 23).
- CPI: This index describes the perceived level of public sector corruption of the different countries (see Transparency International 2012). Values range from 0 (very corrupt) to 100 (very clean).
- LPI: The calculation of the logistics performance is based on research and the personal evaluations of involved freight forwarders (see Arvis et al. 2012: 7). The categories of evaluation are the efficiency of customs and border management clearance, the quality of trade and transport infrastructure, the ease of arranging competitively priced shipments, the competence and quality of logistics services, the ability to track and trace consignments, and the frequency with which shipments reach consignees within scheduled or expected delivery times. The LPI values range between 1 (very low) and 5 (very high).
- LSCI: The calculation of the LSCI is based on five components (see UNCTAD 2011: 90): the number of ships and their size (container carrying capacity), the number of shipping companies involved, the number of services provided, and the size of the largest vessels that provide services from and to each country's seaports.

After analyzing the indices shown in Table 1, the Port of Kingston has to be considered the best location for the route through the Windward Passage (see also McCalla 2008). Besides the current stage of development and the resulting performance, the intended enlargements are a major factor for this result (see Port Authority of Jamaica 2006). With regard to the current general conditions in Jamaica, one can observe evident deficits in the amount of GDP and the LPI. The CPI, however, has a value of 38 which means that Jamaica is on rank 83 in the world. In comparison with the countries included in this research, Jamaica's CPI is ranked in the middle. Clear locational advantages become obvious when looking at the LSCI which has the best value in the Caribbean region. Also the harbor data for Kingston Port in Table 2 shows an overall positive picture. Port-au-Prince currently is of little importance as harbor facilities were significantly destroyed during the earthquake of 2010 and still are not yet sufficiently rebuilt. In addition to that, the indices of Table 1 and the data in Table 2 are comparably poor for Haiti and also the Port-au-Prince harbor which leads to the conclusion that this location does not meet the necessary requirements of becoming a hub port.

In the region of the Mona Passage two ports, Caucedo and Ponce, will be in the foreground as new harbors with corresponding development potential. Nevertheless, differences concerning the general conditions can be observed. While the GDP and CPI are on a rather low level in the Dominican Republic, Puerto Rico has much higher values mainly due to the close connection to the *United States* (US). The LPI of the Dominican Republic is comparably low (for Puerto Rico no data is available) while the LSCI is significantly higher, especially compared to Puerto Rico. For San Juan it is expected (in contrast to Ponce and Caucedo) that its importance will decrease due to lacking enlargement possibilities, which is why this port will no longer be considered in this analysis.

Based on the emerging trends, Kingston seems to be the best suitable location for a central hub at the Atlantic coast region. Nevertheless, a second hub could make sense given an appropriate increase in demand. In this case, Caucedo would be more likely to emerge as the second hub, since Puerto Rico's general conditions are less favorable and their connection to the US may be perceived negatively.

4 Establishment of a Network Structures

Besides these decisions on where to locate central hubs, a hierarchically structured network of port locations has to be designed. With the help of this network a differentiated connection below the level of the central hub(s) is ensured (see Fig. 5). These are on the one hand regional SCTs and on the *local* level *Ro/Ro terminals* on the other hand. This results in the capacitive and technical design of the harbors which are appropriately adopted and which are aligned with the container throughput that is to be expected as well as the container vessels used. This is necessary to avoid possible bad investments in over-dimensioned port facilities and hence also avoid destructive competition which could arise owing to these circumstances.

Not only the level of port locations has to be defined, but the sites must be dimensioned with respect to the underlying problem of designing a hierarchically structured network. Besides this, ports on lower levels have to be assigned to the hubs or other main ports, which means that a *location allocation problem* has to be resolved.

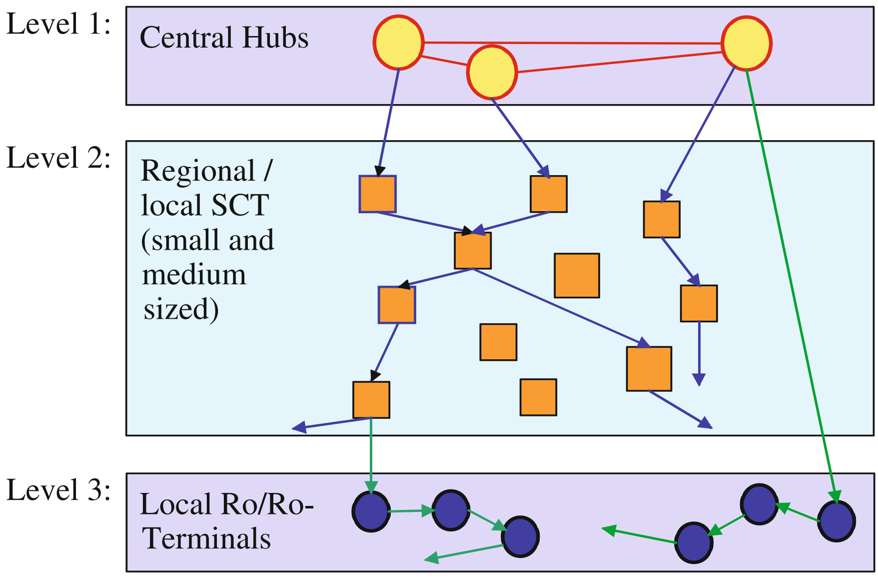

Fig. 5 Hierarchical network (basic structure)

At the same time *route structures* for a vertical and horizontal interconnection have to be taken into consideration (*location routing problems*) to be able to ensure a service of the harbors as efficient as possible. The overall objective needs to be the development of reliable service structures on the basis of shipping schedules in order to be able to guarantee a secure and sustainable supply of the small Caribbean islands as well.

The increased use of *multi-modal Ro/Ro transport*, together with the use of demand-based *Ro/Pax ferries* among other things, can be of substantial importance to provide a differentiated and cost-effective interconnection on the lowest level of the network structure. This relates especially to smaller harbors with Ro/Ro terminals on the local level, e.g. to serve the islands of the Lesser Antilles. As a result of the reduction of the requirements for technical equipment substantial savings in investments and operating costs can be achieved. The resulting efficiency advantages can then lead to lower harbor fees. Moreover, lay times in harbors will be reduced due to the simplification of loading and unloading processes. Consequently time savings can be achieved. Thanks to the shortening of vessel rotations also a reduction of the amount of vessels needed for the shipping services will be achieved.

On the basis of Ro/Ro oriented service structures passenger transport can be included which would increase the attractiveness and lead to additional revenues for the operators. At the same time, the connectivity between the islands will be improved and economically attractive travel alternatives for passengers (e.g. in comparison to air transport) can be offered with Ro/Pax ferries. Examples for the successful functioning of this kind of service structures exist among others in the Aegean. In addition to that, an improved connectivity between the islands can lead to an increased opening of the local markets, provided that trade is not being limited by protectionist measures.

5 Outlook

The *development* and especially the *implementation* of a hierarchically structured location network for maritime freight transport in the Central American regions and the Caribbean in particular has to be looked at from a long-term point of view. This concerns the provision of the investment funds for the infrastructure measures but also the procurement of suitable vessels. The matter of *national interests* is also of major importance where not only economic considerations are important but also prestige plays a role that should not be underestimated. In view of a sustainable and economic reasonable development of the traffic-related network in the Central American region new structures are mandatory even if these do not coincide with the national interests of the states affected.

In order to realize a hierarchically structured location network, the development of a *road map* is mandatory because of the expected duration and the diverging interests of the parties involved. Based on this road map a targeted and coordinated approach can then be achieved. This does not only include the enhancement and extension of the infrastructure but also the adaption of the legal regulations and organisational processes in cross-border transport to the changes in transport related requirements and procedures (see e.g. Wilmsmeier and Hoffmann 2008; Pinnock and Ajagunna 2012a).

The planned and still under discussion being infrastructure measures in this region do not lead to any fundamental changes of general conditions. An example would be the above mentioned extension of the SCT in Moin (Costa Rica). Like this only a new relevant competitor for the SCT in Colón will arise which will only have a small impact on the basic network structure.

The long-discussed construction of a *Nicaragua Canal* (see e.g. Ammen 1878; Maestro 2006) which has been decided upon in the summer of 2013 will impact the *competitive situation* significantly and permanently (see Fig. 6). However, the basic concept of creating a hierarchical structured location network will not be influenced by it.

Through the construction of another inter-oceanic connection between the Atlantic Ocean and Pacific Ocean new options arise, like for example the dimensioning of the canal locks to handle *Triple-E-class* container vessels (with more than 18,000 TEU) as well as e.g. *Ultra Large Crude Carriers* (ULCC). Such a new connection is from a geostrategic and economic-political point of view of special importance for the *Peoples Republic of China*. The long-term guarantee of energy and natural resources supply is the main focus here (see e.g. Wong and Yip 2013). From this point of view, the planned investments of the Chinese are understandable in order to achieve these goals. Therefore the construction of a Nicaragua Canal seems to be reasonable. Furthermore, some countries see the Nicaragua Canal as a measure to reduce the power-political influence of the United States on the most important traffic infrastructure in this region (see e.g. Maestro 2006) by implementing a competing route.

Although the political decision has been made it is unclear if and when the project will be realized. Whether the project will be economically viable in the long term is questionable. If no unique position can be generated, a competition with the

Fig. 6 Route options for a Nicaragua Canal

Panama Canal Authority will result which is unlikely to be won by the owners of a newly built Nicaragua Canal. The current and for the next years continuing monopolistic situation strengthens the *Panama Canal Authority* especially if it comes to a ruinous competition. In addition to that, one has to consider the repeatedly discussed long-term changes in international shipping routes. These changes result from the impacts of climate change and may lead to an increased use of Arctic routes in the next years. Depending on the harbor locations the use of Arctic routes can reduce the sea routes significantly (see e.g. Somanathan et al. 2009; Hong 2012). This is especially true for the Northwest Passage which can be used as an alternative route to connect the East Coast of North America with the West Coast and the East Asian region. With regard to the power-political interests of the Chinese government, this sea route can be of significant importance (see e.g. Li and Bertelsen 2013). Taking this into consideration, one has to question whether the construction of a Nicaragua Canal can be indeed economically and ecologically reasonable (also from the Chinese point of view). In order to come to a conclusion, further research is necessary since the use of the Arctic routes and its arising possibilities is being controversially discussed (see e.g. Lasserre and Pelletier 2011).

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Relevance of Efficient Hinterland Access for the Inter-Port Competitiveness of European Container Ports

Jan Ninnemann

Abstract Driven by globalization and increasing world trade volumes most European seaports have seen significant growth rates especially in container traffic over the period from 2000 to 2008. With regard to the future growth perspectives, most European container ports have carried out ambitious plans for the extension of container handling capacities. Due to the economic crisis in 2008 and the inherent stagnation of container volumes after the recovery 2010 the terminal landscape can be characterized by overcapacities. Further plans for the provision of additional container facilities such as in Wilhelmshaven (Jade-Weser-Port), Southern UK (London Gateway) and Rotterdam (Maasvlakte II) as well as the upgrade and optimization of existing handling facilities are supposed to intensify the inter-port competition in Northern Europe. Therefore, the hinterland access of the ports will gain importance as competitive element.

1 Introduction

Driven by globalization and increasing world trade volumes most European seaports have seen significant growth rates especially in container traffic over the period from 2000 to 2008. With regard to the future growth perspectives, most European container ports have carried out ambitious plans for the extension of container handling capacities. Due to the economic crisis in 2008 and the inherent stagnation of container volumes after the recovery 2010 the terminal landscape can be characterized by overcapacities. Further plans for the provision of additional container facilities such as in Wilhelmshaven (Jade-Weser-Port), Southern UK (London Gateway) and Rotterdam (Maasvlakte II) as well as the upgrade and optimization of existing handling facilities are supposed to intensify the inter-port

J. Ninnemann (✉)
Studiengangsleiter Logistics Management, Hamburg School of Business Administration (HSBA), Alter Wall 38, 20457 Hamburg, Germany
e-mail: jan.ninnemann@hsba.de

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competition in Northern Europe. Therefore, the hinterland access of the ports will gain importance as competitive element.

The current situation of many ports can be characterized by a high degree of infrastructure utilization with strong impacts on transport quality and competitive situation of the port. As investment plans in almost all major container ports mirror a strong lack of hinter-land orientation, accelerating bottlenecks and hinterland congestion in the context of an enhanced geographical market coverage makes hinterland accessibility increasingly important for the competitiveness of a seaport. Besides guaranteeing basic requirements of a competitive hinterland transport system ports are more and more forced to focus on an optimization of port accessible by fostering modal shifts to transport modes with vacant capacities, by optimizing operational procedures and by displacing downstream container activities to supplementary terminals. Capacity restraints and pending infrastructure upgrades in the main hinterland terminals emphasize the necessity of a synchronized hinterland concept.

The intended derivation of sound recommendations for an increasing inter-port competitiveness through the improvement of hinterland accessibility has to consider a general evaluation of competitive factors in inter-port competition in Europe and experiences in selected ports of the Hamburg-Antwerp range. The subsequent assessment of legislative, organizational and operational framework conditions in Hamburg as one of Europe's leading container ports shall give an idea about the complexity of an efficient hinterland concept facing co-operative aspects between the port, regional authorities, national authorities, national network operators, shipping lines and hinterland carriers.

2 Assessment of Competitive Factors

In addition to a variety of port-related issues, factors focusing on the hinterland perspective of seaports play an increasingly important role for the competitiveness of seaports. In a first definition, the seaport hinterland can be characterized as the upcountry territory limited by the origin or final destination of the goods handled in the port (Biebig et al. 1995, p. 290). A second definition by Lieb (1990) is based on the differentiation between the so called geographic and the economic hinterland. The geographic hinterland is determined by the temporal and spatial distance from any hinterland location to the port whilst transport costs as a function of distance, mode of transport, transit time and the transport volume demarcate the economic hinterland. Another definition by Bird (1971) considers the intensity of inter-port competition. The primary hinterland of a seaport can therefore be defined as region with no inter-port competition and strong focus on local volumes. The secondary hinterland compounds the area with an intense competition of different logistic chains.

Subsuming the previous definitions the hinterland can be described as dynamic figure that is substantially determined by

- load potential and economic development in the main hinterland markets,
- hinterland infrastructure and quality/performance of hinterland transport,
- transport costs.

The inter-port competition of European container ports is more and more affected by the infrastructural development and the efficiency of transport service providers. With a growing volume of transit cargo, this aspect becomes more important. From shipper perspective aspects like rapidity of transport, customer orientation, flexibility and reliability can be considered as key success factors for ports in inter-port competition (Gielessen 1998, S. 71). Highly frequented and reliable hinterland connections can thereby only be achieved by bundling hinterland services in few hub-ports. An efficient capacity allocation and utilization through matching volumes in im- and export flows is under economic and ecological view favourable. Especially for the development of marketable intermodal hinterland services, the bundling of cargo volumes enabling large economies of scale is of major importance.

Using the analytical approach of the conjoint analysis the relevance of hinterland-related factors for the inter-port competitiveness of a seaport can be evaluated. Taking the con-joint analysis as a model and technique used to assess the different weights individuals place on the variables presented to them in a given purchase situation, decision makers from terminal operators, shipping companies, logistics providers and regional authorities have been asked for their opinions. The selection of the participants turned out in close co-operation with shipping and transport associations to ensure a representative character of the analysis. Based on the instrument of individually composed profile cards the preferences of the participants with regard to eight port- and hinterland-related competitive factors were assessed.

Table 1 gives an overview showing the relative importance of eight selected competitive factors based on the aggregated utility weights.

The overall assessment of the mentioned factors confirms a dominant role of port infra- and superstructure (17.09 %) and maritime access conditions (15.98 %).

Table 1 Relative importance of selected competitive factors

	$I^{Terminal}$	$I^{Shipping}$	$I^{Logistics}$	$I^{Authorities}$	I^{Total}
Port infra- and superstructure	22.88	15.90	13.87	13.30	17.09
Terminal productivity	8.85	8.97	12.72	21.33	12.60
Intra-port competition	6.85	3.06	4.64	4.82	5.15
Existence of maritime cluster	6.22	10.15	6.75	6.68	7.12
Maritime access conditions	19.17	16.59	13.37	14.03	15.98
Load potential and economic development of hinterland	7.41	13.63	15.38	11.59	11.64
Quality of hinterland services	16.15	16.88	15.02	14.41	15.58
Transport costs	12.47	14.81	18.24	13.85	14.83

Source Own assessment

With percent-ages between 11.64 and 15.58, the hinterland-related factors also stand for a strong impact on the competitive situation of a seaport. Depending on the different participant group, the results show divergent estimations regarding the relative importance of the eight factors. As expected, terminal operators put a strong emphasis on the port infra- and superstructure (22.88 %). Due to their dependence on competitive hinterland connections, the quality of hinterland services stands with 16.15 % above the average. Same as terminal operators also shipping companies are highly interested in a good quality of hinterland services. Reasonably logistic providers show the highest affinity to hinterland-related factors. For them costs for hinterland transport play the most important role in inter-port competition. Surprisingly regional authorities consider terminal productivity as most important factor for the competitiveness of a seaport.

Subsuming the results of questioning it can be stated that the three hinterland-related factors stand for a cumulated relative importance of 42.05 %. The quantified relative importance of the hinterland issues indeed gives no evidence regarding the type and the quality of hinterland access and intermodal transport. The following qualitative approach carries out some general trends in European hinterland transport.

3 General Trends in Hinterland Transport in Hamburg-Antwerp-Range

The assessment of modal shares in hinterland transport for selected ports in the Ham-burg-Antwerp-Range mirrors a special relevance of different modes of transport for the examined ports (Table 2).

All port statistics (except for Bremerhaven) indicate a truck share of more than 50 % leading to more or less the same problems in all ports. Road congestion within the port area as well as on the main hinterland axis, limited terminal capacities to handle trucks especially in peak hours and delays due to administrative obstacles like long customs clearing processes have led to various initiatives for a modal shift to railways and waterways. Additionally the intensification of legal framework conditions for road transport (e.g. German road toll, adjustment of driving and resting times all over Europe) have set further incentives for modal shifts especially on the long haul.

Table 2 Modal share in selected seaports 2011 (intermodal transport in %)

	Road (%)	Rail (%)	Barge (%)
Antwerp	55	10	35
Bremerhaven	31	65	4
Hamburg	61	37	2
Rotterdam	60	9	31

Source Port statistics

Particularly the German ports Hamburg and Bremerhaven stand for a significant railway share considering the total hinterland volume. A superior connection to the European railway network, flourishing intramodal competition, high load potentials hinterland areas with excellent rail access and save transport conditions at moderate product-related costs can be named as key success factors for rail transportation to and from the German seaports (Aberle 2000, p. 508). The competitiveness of intermodal services in comparison to road haulage highly depends on the realization of disintegration on the long run levelling the additional costs of terminal feeding and double container handling (Boes 1999, p. 18). Coming from the non-liberalized market approach a minimum transport distance of 500 km is considered as necessary to reach the mentioned effects of disintegration (Ewers and Fonger 1993). Positive impacts on the operational side mainly resulting from a rising intramodal competition set the framework for productivity increases shortening the minimum transport distance for an efficient railway transport. Current logistics trends support the development of railway transportation through internationalization and cross-border transport on long-distances. The innovative potential of new market entrants arising from an increasing intramodal competition contributes to push back "historical" problems of cross-border railway transportation. Besides different technical standards (six major different electrification and 23 different control-command and signalling systems) inefficiencies of the incumbent national railway operators, the pending liberalization process in various countries and administrative obstacles at border stations still affect the European railway sector. Due to the fast growing container volumes railway transport experiences an increasing number of bottlenecks facing the port adjacent infrastructure as well as the main hinterland corridors and terminals. Long-winded approval procedures and a port-oriented subsidization of intermodal terminals have led to an imbalance between seaports and hinterland terminals.

Same as railway transport inland navigation is suffering from bottlenecks in the main European seaports as well. Port congestion can be considered as of high relevance for barge operators calling Rotterdam and Antwerp. Typical scenarios include unavailability of berths, impossibly small berth windows and containers left behind. Barge operators have also incurred extra costs by having to charter extra barges to fill the gaps caused by the delays. Additional effects like unstable water levels on the Rhine River and the in-creased efficiency of railway transport due to a rising intramodal competition have fostered the development of barge terminals to trimodal logistic centres offering a wide range of rail-related services as well. With the opening of the dedicated freight route Betuwelijn connecting Rotterdam with its German hinterland, the port of Rotterdam has taken another attempt to reach a wider spread of modal share.

The first overview reflecting some more general trends on the hinterland side indicates that almost all ports in the Hamburg-Antwerp range are affected by the impacts of in-creasing requirements from the market side. To understand the full complexity of a holistic hinterland approach the example of the port of Hamburg gives a more detailed analysis of key strategic factors for an efficient hinterland orientation of container ports.

4 Detailed Assessment of Hinterland Transport Conditions in Hamburg

With regard to the total traffic volume (container and bulk), railway transport stands for 30.2 % of all hinterland traffic, rising from 28.8 % in 2007. The container volume trans-ported by rail mounted from 780,000 TEU in 2000 to 1,970,000 TEU in 2012 (+8.0 % p. a.). Due to the way of calculating the modal share (with or without transshipment) this is equal to 22.1 % (based on total volume) or 37.1 % (based on hinterland traffic excluding transshipment). Considering the high proportion of local bound containers being distributed by truck the railway share rises to >60 % of goods to/from hinterland outside Hamburg metropolitan region and 70 % of all long-distance containers (over 150 km). Compared to the development in most competing ports in the range Hamburg's development prospects are divergent. An updated handling forecast from October 2010 predicts a cargo handling volume of 296 million tons in 2025, equal to an annual average growth rate of 6.4 %. Container handling will develop much more strongly than total cargo or bulk cargo in the port of Hamburg. Annual growth in container traffic will average 8.3 % up to 2025, by which time it will total 25.3 million TEU in the most likely base-case scenario. A more detailed assessment of the forecast figures shows that hinterland volumes will partly lose their dynamics—the hinterland share is supposed to decrease from 65 to 50 % under-lining the strong impact of transshipment volumes for the future port development. After the weak results in 2012 (downturn of container volumes by −1.7 %) a growing number of experts believes in a trend change towards a more stable market development without exceeding growth rates and an ongoing shift of market shares from Hamburg to Rotter-dam (Preuss 2013). The ongoing struggle concerning the planned adjustment of the River Elbe navigation channel and the ambitious expansion plans in Rotterdam have in-creased the pressure on Hamburg to defend its position as one of the leading container ports in Europe.

The provision of efficient hinterland services especially to Southern Germany and Eastern Europe can still be considered as the core competitive advantage of Hamburg. Following the expectations for an increase of railway share from now 37.1 % (based on hinterland traffic excluding transshipment) to 41 % this might lead to a container volume of 5.7 million TEU in 2025 to be handled by rail. Current predictions foresee that the number of freight trains with source/origin in the port will double from currently 200 freight trains per day to 400 by 2020.

To cope with the expected growth, port planning requires the substantial expansion of rail infrastructure facilities over the period to 2025. The Hamburg Port Railway as a service provider in accordance with railway legislation is responsible for the 386 km of railway tracks within the port area. The current port railway network implies various bottlenecks, which lead to restrictions and operational inefficiencies. Examples like the non-electrified single-track connection between Hamburg-Sued and Hohe Schaar, the single-track gateway for northbound traffic in interchange Veddel, the single-track link between eastern and western port areas via rail/road dual use bridge "Kattwykbruecke" and the equal level single track access to the national railway network in Hausbruch mirror the necessity of future infrastructure upgrades.

Considering the mentioned bottlenecks both the infrastructure facilities and operations of the port railway need to be optimised. This comprises in particular the expansion of existing railway yards and the construction of new track facilities as well as further operational improvements. The illustration shows the port railway and the planned measures (Fig. 1).

Operational inefficiencies predominantly affect a capable capacity allocation on the port rail network. The current infrastructure utilization of 90 % together with the forecasted increase of rail volumes and train movements accentuate the necessity to investigate managerial and organizational framework conditions in hinterland transport by rail. To en-sure the short- and mid-term continuance of competitive railway transport to/from the port of Hamburg, measures to improve the operational efficiency on the port rail network have to be undertaken. These measures cover aspects like

- the guarantee of non-discriminatory access to the port rail network,
- the contribution on an efficient slot management at the rail terminals to optimize capacity utilization,
- monetary incentives for optimized train utilization and wagon loads through the HPA charging regime,

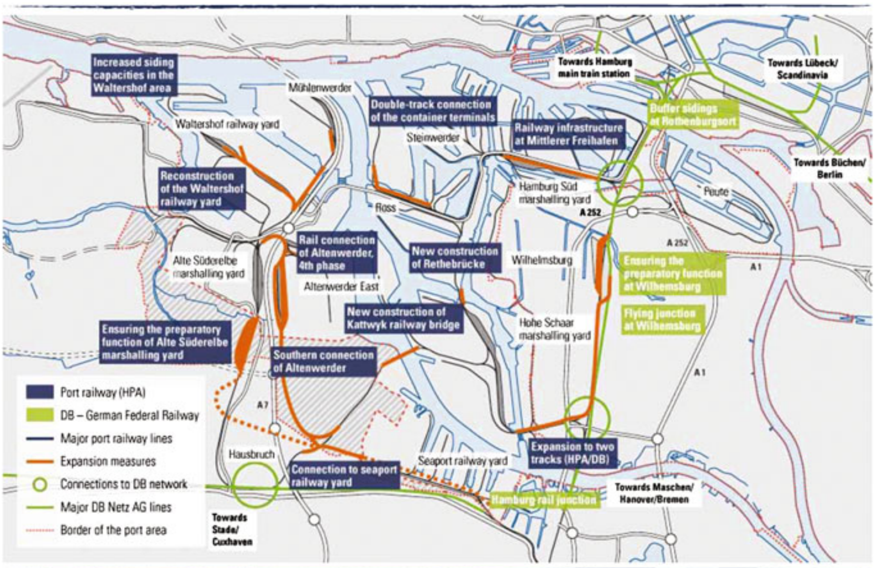

Fig. 1 Railway track network of the port railway and planned measures. *Source* Free and Hanseatic City of Hamburg—State Ministry of Economic Affairs, Transport and Innovation (2012), p. 51

- incentives to reduce dwell-times in container yards by bonus-malus-systems,
- incentives to avoid train formation on port rail network,
- the simplification of customs clearing processes,
- an extension of time-based port operations to avoid peak loads.

Assessing the framework conditions for truck transportation it is considerable that the port of Hamburg is known for its high share of local cargo. This means that more than one third of the goods arriving in the port of Hamburg have their destination within the Ham-burg metropolitan region (HHM 2012). Comparable to the situation on the rail side, road transport is affected by infrastructural and operational difficulties. Infrastructural bottlenecks can mainly be observed on the port route between Waltershof and eastern port areas as well as on the roads leading in and out of the Suederelbe area, to Finkenwerder and to the motorway A7. Traffic volumes causing congestions arise not only from container transport, but are also generated by port-related businesses and workplaces. The discussion on future infrastructure extensions is mainly driven by the planned motorway new construction of the section of the A 26 between the A 7 and the A 1. With 35.000 crossings per day (thereof 35 % trucks) and an expected growth of 118 % until 2015 (HPA 2010, p. 21) the Koehlbrandbruecke can be one of the main future bottlenecks. As necessary upgrades to improve the situation at the traffic junctions adjacent to Koehlbrandbruecke have yet not been undertaken the real capability of the bridge to handle the forecasted volumes can hardly be assessed. Even if traffic flow optimizations may lead to a sufficient capacity, questions regarding the future constructional resistance of the bridge foster plans for an additional Koehlbrand crossing.

Besides infrastructural projects terminal operators are heading for an optimization of terminal related activities to reduce truck-gate congestion. First experiments with extended gate opening hours (24/7) have been started with poor results. Main problems are the opening hours of inland distribution centres and downstream logistic providers who have not adapted to the extended opening hours of the terminals with the consequence of remaining peaks especially in the late afternoons. Other means like vehicle booking systems to smooth out the flow of truck arrivals throughout the day can contribute to an optimized hinterland transport on the road side.

With a 2 % share of total hinterland traffic inland navigation only plays a minor role in (container) hinterland transport (HHM 2012). Main reasons for this purpose can be seen in operational difficulties in navigating the waterway. Besides ice in winter and low water in summer constant dredging is necessary. Several parts of the river also still need to be cleared to open up the possibility for an efficient container transport by barge. The Elbe-Seitenkanal as major link to the German inland waterway network is highly affected by capacity restraints from the ship-lift in Scharnebeck. In addition to transport-related problems the terminal operational side can be considered as another obstacle for the development of significant barge volumes. The necessity to use cost intensive gantry cranes for the loading and unloading of barges leads to imbalances regarding the handling costs with major advantages for road or rail.

Growing transport volumes with origin in the port of Hamburg do not only affect transport capacities, they also cause problems arising from capacity restraints in the main hinterland terminals. Precise extension plans and terminal investments in the seaport contrast with difficult conditions for the terminal development along the main hinterland corridors. Unverified prospects regarding general hinterland strategies and future transport volumes of the big ocean carriers, the demand for investment capital together with difficult framework conditions for terminal subsidization (due to main focus on the subsidization seaport rail terminals) as well as long-winded approval procedures in the context of tightened environmental laws delay a need-driven capacity extension.

5 Conclusions and Recommendations

The preceding analysis has substantiated a considerable importance of a strong hinterland orientation for the competitive situation of a seaport. The evaluation of hinterland operations indicates that almost all ports in the Hamburg-Antwerp range are affected by bottlenecks in hinterland transportation. One of the key conclusions arising from the described complexity of hinterland processes is to understand container transport as one chain comprising quayside, terminals, port railways, hinterland railways and hinterland terminals. In the short- and mid-term perspective, the optimized utilization of existent infrastructure and transport systems is vital to face the upcoming challenges of the dynamic market development. Incentives to foster modal shifts by using all disposable capacities in barge- and railway-transportation can be considered as one of the main objectives to tap potentials on the carrier side. Additionally, prospectives arising from a liberalized railway sector should be considered. For a sustainable infrastructure allocation short-term measures optimizing the organizational framework for the infrastructure use as well as the establishment of incentives for traffic flow maximization have to be undertaken. Significant efficiency increases for all parties involved, can also be achieved by an advanced IT periphery. The possibility for a sophisticated container disposition along the total transport chain will lead to extensive improvements for terminal operators, carrier and infrastructure operators. As infrastructure upgrades usually require an advanced planning, bottlenecks need to be identified early; planning processes have to be initialized.

In the long term, rail infrastructure in the ports needs to be upgraded to create future capacities for the handling of the forecasted container volumes. The synchronization of port-rail related infrastructure projects and infrastructure and terminal capacity extensions on the main hinterland corridors can be considered as another important issue. Further-more rail hinterland concepts have to be carried out reflecting the different requirements of high-speed traffic and cargo transportation. Agreements on common technical standards have to be promoted, supporting the strength of railway transportation on the long run. The example of the Betuweroute, where the port of Rotterdam has taken a leading role in the development of additional hinterland infrastructure, demonstrates that a stronger engagement of seaports in the promotion and provision of port-related hinterland infrastructure becomes more and more important.

The further endorsement of inland navigation as mode of transport with environmental advantages and still remaining transport capacities has to be accompanied by future up-grades of canals and locks to reduce economic disadvantages of barge transportation in comparison to road and rail. From the dimension of transport policy, political efforts for equal framework conditions on the transport market have to be undertaken; incentives for modal shifts have to be supported.

Facing the situation in the hinterland terminals the materialization of information from ocean carriers and hinterland operators on future transport strategy, expected volumes and favourable relations are of high relevance for a sustainable capacity planning. Furthermore, an improved and transparent exchange of load specific data between shippers and terminals is important to increase operational performance along the whole transport chain. Thereby an increased schedule reliability of rail transport can contribute to avoid operational inefficiencies due to accounted buffer times and volumes within the container disposition. Requirements for the granting of subsidies need to be revised with respect to stronger hinterland orientation of terminal investments. As subsidization is limited to the promotion of handling activities, additional measures for the funding of container storage areas should be undertaken. Additionally, incentives for private investments in hinterland infrastructure should be fostered by simplifying the legislative framework conditions.

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Ocean Container Carrier Selection Processes

Interview Analysis from North-West Europe to Develop Set-up for Discrete Choice Studies

Sven Gailus and Carlos Jahn

Abstract Existing literature has covered carrier selection criteria in various surveys asking shippers to rate or rank selection criteria, but rarely modeled the final impact of criteria on the selection decision or even expected market shares of liner services. This paper examines the decision processes leading to a container liner service selection. Based on a series of qualitative interviews the paper maps the various paths that ocean container carrier decisions follow and illustrates the ocean carrier tender process in detail. From the process examination we develop implications for discrete choice experiments that could be used by researchers to develop choice modeling studies.

1 Introduction

Ocean container transportation has experienced tremendous growth over the last decades and is expected to grow further in the years to come. Although widely recognized as commoditized services there have been ongoing discussions among researchers and practitioners if container liner shipping was a purely price-driven industry or if certain quality of service indicators also play significant roles when shippers decide about container carriers. Especially with the background of globalization and the integration of supply chains, service parameters such as transit time, reliability, customer service, information services, or environmental aspects could be expected to rise in importance. Existing literature has covered carrier selection criteria in various surveys asking shippers to rate or rank selection criteria, but rarely modeled the final impact of criteria on the selection decision or even expected market shares of liner services.

S. Gailus · C. Jahn (✉)
Fraunhofer Center for Maritime Logistics and Services, Schwarzenbergstr. 95D, 21073 Hamburg, Germany
e-mail: carlos.jahn@cml.fraunhofer.de

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This paper covers some empirical pre-work towards the future development of a market share model using stated preference discrete choice methods. The primary research goal is to understand decision processes shippers follow when they select their ocean carriers in detail and to find anchor points and set-up for future discrete choice analysis.

2 Literature Review

2.1 Ocean Container Carrier Decision Process

The process of deciding for an ocean container carrier has not been widely discussed in the scientific literature. The most renowned study was probably carried out by Mary Brooks in: Brooks (1983, 1985b, 1990, 1995). She examines the application of the 'Buygrid Framework' on ocean container carrier selection. Brooks (1990) concludes that in the case of buying container liner services, decisions are largely similar for new task buys, modified rebuys or straight rebuys. She further concludes that the number of individuals involved, the information sources used, and the level of influence held by decision-makers were similar. She condenses to a 3 stage process model. *Stage 1* covers the recognition of the need for a carrier choice and distinguishes between shipper internal decisions or decisions made by an external agent (e.g. a freight forwarder). In *stage 2* the shipper develops a list of carriers. She filters this list based on availability of liner service(s) between origin and destination ports and other constraints [e.g. space availability, consignee requirements or company policies (Brooks 1983)]. The shippers' final carrier decision follows in *stage 3* by establishing a list of selection criteria and assessing carriers against them.

D'Este (1992) further specifies the selection process based on an example for Ro/Ro ferry choice in Australia. A first filter in D'Este's process model eliminates all shipping services from the set of options that cannot perform the required task (this is analogue to stage 2 in the Brooks' model). In the next step all feasible options are filtered that do not prove a minimum quality of service or maximum cost. According to D'Este (1992) in this stage shippers try to minimize the risk related to the transport decision. The process model then splits into a *many baskets branch* where shippers allocate a base level of volume to each feasible and satisfying shipping options and a *discretionary branch* where shippers further assess differences between carriers regarding a set of criteria and allocate transport volumes according to a resulting ranking of carriers. Mangan (2002) develops a similar process model for the port/ferry choice in Ireland. Additionally Meixell and Norbis (2008) provide an extensive overview of carrier and mode selection literature.

Both Brooks' and D'Este's studies present useful starting, but also offer room for further deep dives. Brooks for example does not specify the decision processes followed by external decision makers. Also the study does not distinguish between types of carrier decisions such as long-term contracts or spot market bookings. D'Este presents a more detailed process model, but uses a very specific sample.

2.2 Ocean Container Carrier Decision Criteria

Literature on ocean container carrier selection criteria is more extensively available than literature on the selection process. Most of the authors use stated preference techniques such as surveys with rating or ranking scales, some combine surveys and personal interviews. Again Brooks' longitudinal study of Canadian shippers over the years 1983, 1985a, 1990 and 1995 is probably the most prominent one. Latest results presented by Brooks (1995) are illustrated in Table 1.

The cost of service turns out as the most important decision criterion, closely followed by the problem solving capability of the carrier personnel. Also the availability of equipment, documentation accuracy, and on-time delivery are highly ranked. Surprisingly transit time seems to be of no high importance to shippers in this 1991 survey, despite transit time was rated higher earlier (Brooks 1985a).

A number of more recent publications again focus on the selection of ocean (container) carriers for different regions [e.g. Lu (2003), Thai (2008), and Kannan et al. (2011)]. In a parallel study we analyzed selection criteria in the existing literature in more detail (Gailus and Jahn 2013). We conclude from this extensive literature review that the freight rate seems to play the most important role in ocean carrier selection, but numerous studies prove that service factors such as transit time, transit time reliability, service frequency, equipment availability, customer service, or quality of documentation also influence shippers' decisions.

2.3 Choice Modeling of Ocean Container Carrier Selection

Only three publications could be identified that examine the ocean carrier selection with choice modeling methods. Tiwari et al. (2003) develop a combined port and carrier selection model using the discrete choice method on a sample of container

Table 1 Ocean container selection criteria importance identified by Brooks (1995)

Attributes	Europe [rank]	North America [rank]
Cost of service (freight rate)	1	1
Problem solving capability of carrier personnel	1	1
Availability of equipment	3	3
Accuracy of bill of lading production	n/a	4
Consistent timely pick-up and delivery	3	4
On-time pick-up and delivery	3	4
Quality of equipment	6	7
Timely arrival notices	n/a	7
Transit time	Not important	7

shippings in China. However their primary focus lies on port selection factors (number of port calls, TEU volumes, number of berths and cranes, water depth, number of liner services, capacity utilization and fees). They only test three crude, carrier-specific factors: nationality, total TEU handled and number of vessels. Furthermore they do not cover the freight rate in their study.

Nind et al. (2007) compare choice preferences of shippers from China and those from New Zealand in the trade between both markets. They conclude that shippers on both ends of this particular trade lane differ significantly. While for Chinese shippers the one dominant decision parameter is the freight rate, New Zealand shippers decide more differentiated by including parameters such as service frequency, particular port calls, and accuracy besides the freight rate. The authors only reveal a narrow excerpt of results and methodology. For example they leave out the full list of attributes examined; also they do not develop results into a market share model for container shipping lines.

In a third publication from Asia, Wen and Huang (2007) develop a discrete choice model for carrier selection in the trade between Taiwan and the USA. Modeling results indicate that freight rate, transit time and reliability influence Taiwanese shippers' decisions. Unfortunately results of these studies only provide indications for selected niches of the liner shipping market. They do not yet allow for derivation of a more general choice model, e.g. for market share modeling purposes.

3 Research Methodology

Semi-structured interviews are used to explore shippers' decision processes. Shippers were recruited from both major groups of shipping line customers: cargo owners and freight forwarders. We ensured to interview shippers of small, medium and large size (measured in annual transport volumes). To allow for a conclusive perspective also major shipping lines were interviewed.

An interview guide structured in four main sections was used. Sections cover: basic company information, end-to-end decision and booking processes and responsibilities, decision criteria, and configuration issues for choice experiments. Interviews were conducted in person and lasted between 1.5 and 2 h. This gave enough room for open-ended questions and explorative deep dives. A major portion of time was spent on process identification and understanding. Participants were asked to provide insights on their selection processes and criteria at least differentiated into two major paths: spot market bookings and contract bookings.

All decision processes that were identified during the interviews are mapped as paths in a single chart which we call the "Navigational Chart of Container Bookings". Paths always start with the cargo owner and end with the physical container carrier executing the transportation. Each path represents a structurally unique way a container booking (or a group of structurally identical bookings) follows until the physical carrier of the container(s) is determined. To generate paths booking processes identified in the interviews are clustered into groups of (almost) identical process steps, decision points and decision makers. Whenever one of the three dimensions varies a new path is opened up. Finally all paths are mapped in the chart including respective differentiating characteristics and decision points.

In a final step decision points along the paths mapped in the Navigational Chart are analyzed to identify possible anchor points for stated preference discrete choice experiments. This follows the idea that for each decision point mapped decision scenarios could be developed. These could be presented to a representative group of decision makers to collect stated preference choice data later.

Discrete choice models are defined by a certain experimental design. According to Hensher et al. (2005) important experimental design characteristics include: description of a choice situation, a set of choice alternatives distinguished by a number of attributes, a sample of decision makers, as well as a statistical design (which is not in the focus of this work). Hence this paper defines those experimental design characteristics for the decision points identified along the paths. To handle the high number of decision points identified, points are assigned to groups whenever experimental characteristics seem similar.

4 The Various Paths of Container Booking Decisions

4.1 Interview Sample from North-West Europe

Empirical results of this study are based on an interview sample of both container shippers and container liner carriers. Over a period of 3 months interviews with 19 container shippers and 6 container carriers were conducted. A total of 96 shippers and 20 carriers were contacted in a written form leading to a participation rate of 20 and 30 % respectively. Most of the shippers were of German origin, but most of them ship their containers over multiple North-Western-European ports or show global activity. Figure 1 shows selected demographic details.

Fig. 1 Selected interview partner demographics

Among the 19 shippers were 11 freight forwarders and 8 cargo owners. The interviewed companies vary in the size of their annual controlled container volumes from 800 TEU p.a. up to >300,000 TEU p.a. with the majority of shippers coming from medium container volume segments. Shippers interviewed furthermore cover all major industry segments with a slight focus on traditionally strong German segments such as automotive or industrial segments.

4.2 Navigational Chart of Different Container Booking Paths

Figure 2 shows 20 different paths each representing a unique class of ocean carrier selection process identified from the interviews. From a carrier's perspective each container booked on one of his vessels should have followed one of these paths. We identified three major dimensions, which drive differentiation of booking decision processes: *process ownership*, *existence of a core carrier program*, and *type of contract* between carriers and shippers. Two further dimensions were identified depending on process ownership: *risk exposure* (for freight forwarders) and *booking execution* (for cargo owners).

The first major dimension of differentiation is *process ownership*. The market splits into two major streams: cargo owners that select their ocean container carriers in-house and cargo owners that outsource the ocean carrier decision.

Existence of a core carrier program is the next dimension of differentiation. Core carrier programs are usually implemented by globally acting medium to large freight forwarders or large corporate cargo owners. In a core carrier program the shipper usually selects 5–10 ocean carriers as preferred carriers and allocates major volumes to those carriers. Core carriers are usually selected once a year, typically with regular (e.g. quarterly or monthly) review intervals. Core carrier selection takes place on the basis of shippers' strategic considerations, carriers' past operational performance, as well as contractual terms. In return for the core carrier status, carriers offer rate discounts, capacity reservations or financial kick-backs.

Contract bookings and *spot market bookings* are the major *types of contracts*, but differentiate further especially in a freight forwarder environment. *Contract or tender bookings* are characterized through a fixture of contractual terms, volume/capacity allocations and rates for a medium to long-term time frame. Interviews revealed contract periods between 3 and 24 months, while in the latter case a major rate review is performed after 1 year. Contract duration was in most cases 6 or 12 months. Tenders are usually issued by the cargo owners, but also freight forwarders tender with shipping lines, either for single large customers (so called *Named Accounts*) or groups of customers *Group or Basket Accounts*.

Spot market bookings are characterized through short-term and one-time shipping decisions. Volumes are often less projectable than in contract settings and carriers are assessed and compared for each single shipment. Spot market bookings usually contain 1–20 containers but could also reach small three digit numbers in extraordinary cases. Spot market business is also known as *Freight All Kind or FAK* business.

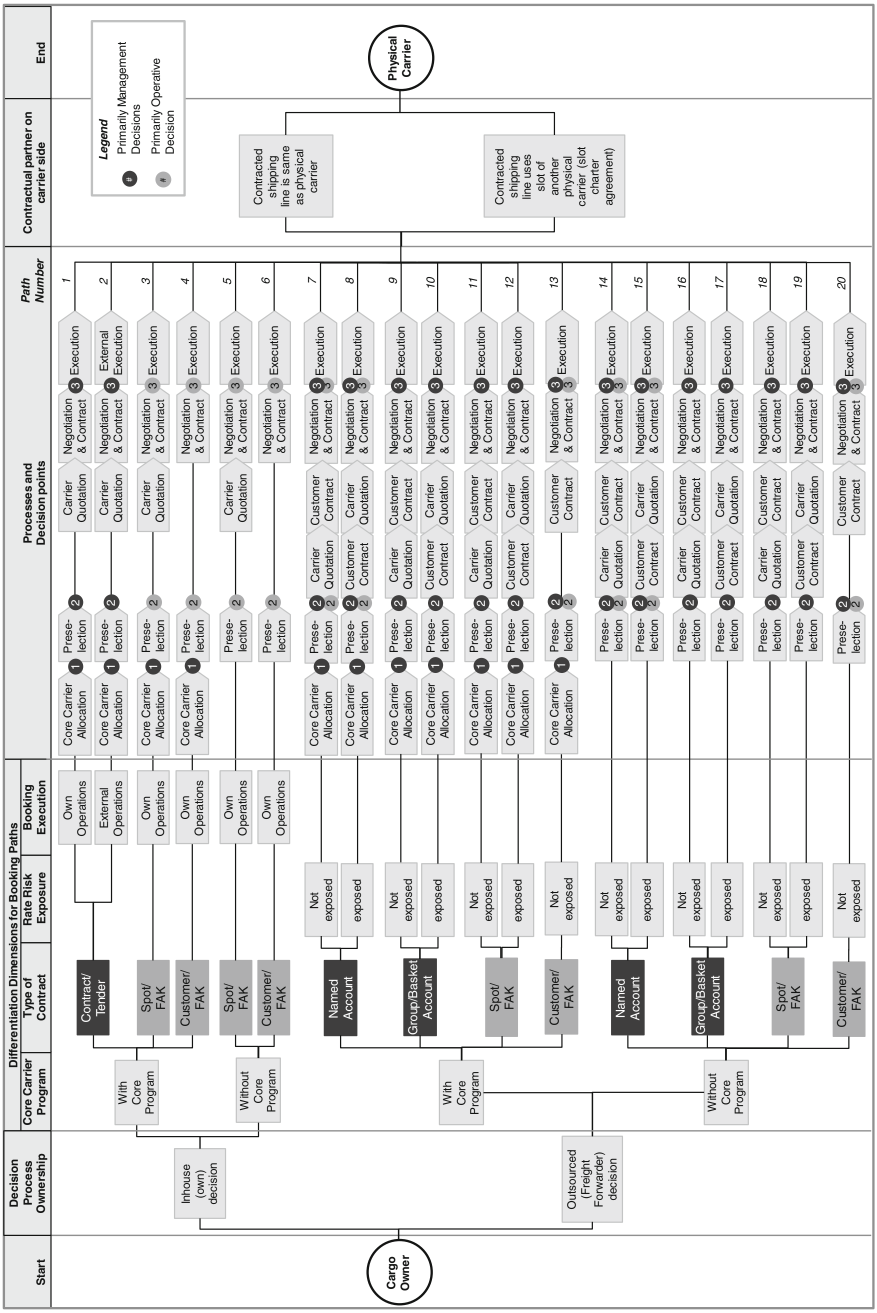

Fig. 2 Navigational chart of container bookings (own elaboration)

Carriers regularly issue FAK rates, which shippers could use to request spot bookings spontaneously. Often carriers group shippers and issue individual grades of FAK rates to those groups depending on the importance of customers (*Customer/FAK*). If no close relationship exists between shipper and carrier, regular *Spot/FAK* transactions are based on general FAK rates and terms of carriers.

In case of process ownership by cargo owners a process differentiation through the *booking execution* was observed. Bookings are either done in house (*own execution*) or outsourced (*external execution*) to booking agencies or logistics providers (e.g. freight forwarders). But only booking, documentation, and accounting processes are outsourced not the carrier decision itself. If process ownership lies with freight forwarders another dimension of differentiation was observed in terms of the *rate risk exposure* freight forwarders are willing to take. In one path freight *forwarders expose* themselves to own risk by first engaging in a contract with their customers at a specified rate (without yet having a carrier quote). Negotiation and allocation of volumes with carriers takes place in a second step. In the other stream freight forwarders do *not expose* themselves to that type of risk by first collecting quotations from their shippers and using them to calculate their own offers.

4.3 Container Carrier Selection Processes

From our interviews we developed process maps to understand in detail how decision processes work. We found that process maps for spot market decisions are reasonably well reflected by D'Este (1992). There are some deviations especially in terms of the process of rate request, negotiation and confirmation. Therefore in this paper we focus on the other major contract type the "Contract/Tender" process. This process is run by both cargo owners and freight forwarders (for named account or basket/group businesses). Figure 3 shows a detailed process map for an example contract/tender booking process from the start of the tender process until the first container booking in context of the contract. An in-depth version of the spot decision process is available from the authors upon request.

4.4 Decision Makers

For a further examination of the ocean container carrier choices it is important to understand who the relevant decision makers are. According to our interviews again a differentiation of the type of contract and between freight forwarders and cargo owners seems reasonable, as well as a differentiation of the shippers' size. Large cargo owners with regular tendering activity in most cases have a small dedicated team managing those *tenders* and the selection of core carriers. Teams are either lead by a corporate purchasing manager or corporate logistics manager supported

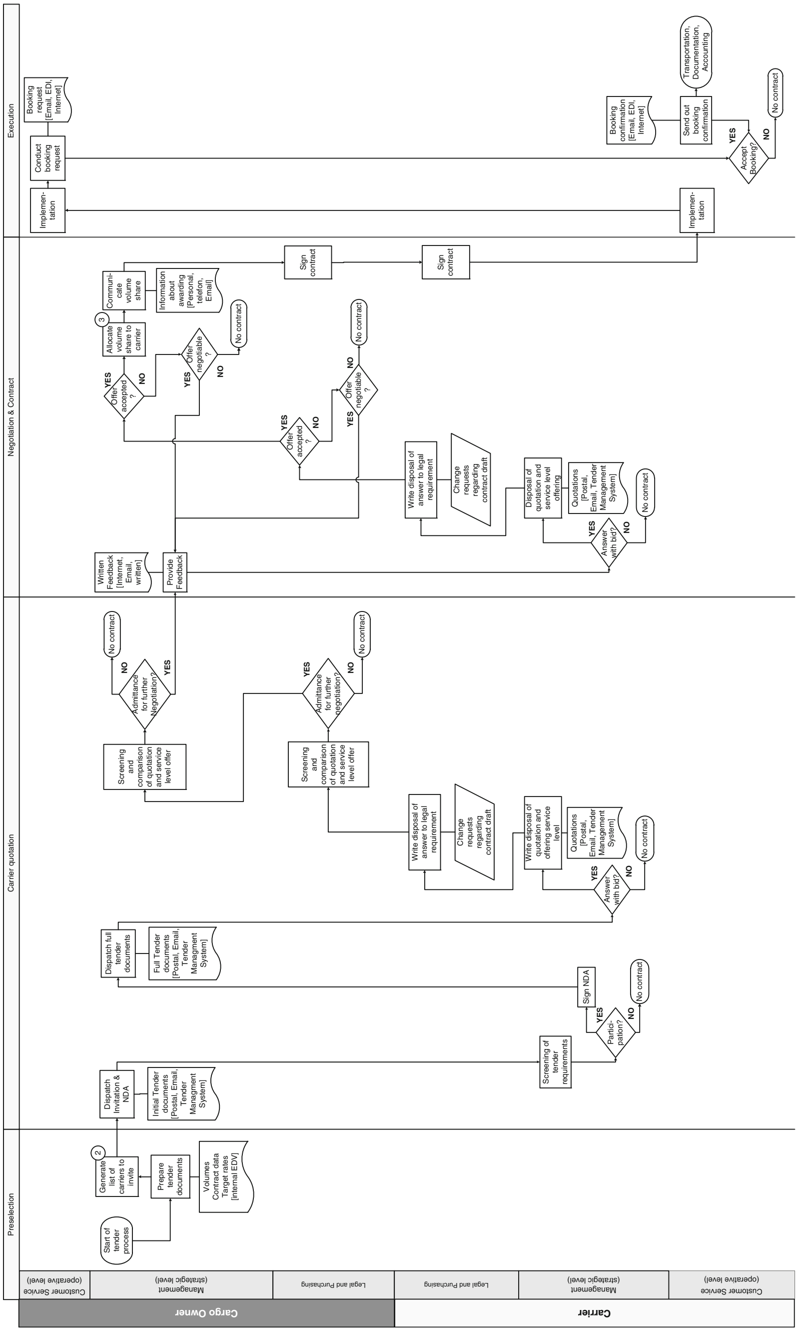

Fig. 3 Example contract/tender booking decision process (own elaboration)

by operative logistics and purchasing functions in international locations. Usually tender management teams are highly autonomous in managing the tender process and developing a proposal for the carrier selection. Responsibility for tendering activity in a freight forwarding environment is usually organized similar to the cargo owners. Most large freight forwarders have central tender management teams in their country/regional organizations, some additionally on a global level or even in the field sales organization. Small freight forwarders handle tenders either with a centrally responsible person or on business management level. Tender management teams are responsible for managing tenders regarding named account and group/basket account business.

In most cases those *spot market booking* decisions are made by operative staff. In case of cargo owners this is the local logistics responsible. In some cases operative functions in a purchasing organization get involved, especially in larger corporate settings or for larger container volumes. At freight forwarders spot bookings usually are placed by operative sales staff or booking desk clerks. Some decisions are influenced by middle management, e.g. in case of larger container volumes or towards the end of controlling periods when kick-back negotiations with carriers are coming up and volume thresholds should be reached. Occasionally freight forwarders also centralize spot market bookings. In these cases customer bookings are collected in the sales organization and queued in an internal system. A central booking team under supervision of a middle manager then places the bookings.

5 Implications for the Set-up of Discrete Choice Experiments

To develop choice models, researchers could use the Navigational Chart of decision processes to collect choice data and model the choices with statistical methods. Two major ways of choice data collection are available: *revealed preference* data (actual container bookings) or *stated preference* data (data containing virtual booking choices from experiments). We provide insights for the second approach.

As time and budget constraints place a burden on the number of choice situations that can be examined in a single study. Thus we argue for a re-combination of choice situations. From the interviews we believe that two major types of carrier selection decisions exist: *contract decisions* (representing paths 1–2, 10–13, and 17–20 in Fig. 2) and *spot decisions* (representing paths 3–9 and 14–16). The pooling of tender processes managed by either cargo owners themselves or freight forwarders seems reasonable, because in the majority of cases freight forwarders simply forward industry customers' requirements. Consequently the decision situation is structurally similar. "Group/Basket Accounts" could be combined with this class of decision situations, because freight forwarders create their own tender situations by combining groups of smaller customers and volumes into one basket of higher volumes. Furthermore all types of bookings combined under *contract*

Table 2 Proposal for discrete choice examinations of the ocean container carrier decision

Scenario type	Contract	Spot
Decision situation (in Nav. Chart)	3 (final decision)	3 (final decision)
Minimum information provided to participants	Trade lane, commodity, expected TEU volume, sending pattern	Trade lane, commodity, TEU volume, sending date, distance from seaport of loading
Target participants	**From cargo owners**: indirect purchasing managers, corporate logistics managers **From freight forwarders**: ocean freight procurement managers, tender management responsibles, general managers (of small forwarders)	**From cargo owners**: local logistics responsibles, export managers **From freight forwarders**: ocean freight procurement managers, regional sales management, sales and booking desk staff, central booking unit managers/staff
No. of alternatives	4–5	4–5
Labeled versus unlabeled alternatives	Unlabeled (labeled in case real booking alternatives are known incl. prices)	Unlabeled (labeled in case real booking alternatives are known incl. prices)
Relevant decision criteria to be examined (based on literature review and	Freight rate, transit time, reliability, service frequency, equipment availability, quality of documentation, customer orientation	Freight rate, transit time, reliability, service frequency, equipment availability, quality of documentation, customer orientation
No. of choice sets	Max. 25 (in total series)	Max. 25 (in total series)
Additional information needed for market segmentation	Industry, number of employees, annual container volume, job position of decision maker, main booking channels,…	Industry, number of employees, annual container volume, job position of decision maker, main booking channels,…

decisions are usually made by experienced middle-management. Pooling of spot decisions also seems feasible. Decision processes are very similar: logistics or purchasing staff at a cargo owner, or booking desk staff at a freight forwarder compare carrier offerings for a single transport job. Table 2 summarizes our proposed approach for discrete choice studies of ocean container carrier choice.

6 Conclusions

The selection of ocean container liner carriers is a more complex decision situation than expected from an outside perspective. From our interviews we were able to identify 20 different decision paths that container bookings could follow. One of the most influential decision processes, the contract/tender process has been documented in a detailed way and thereby made available to the scientific discussion. To further assess and quantify relevant carrier selection criteria we propose to conduct stated preference discrete choice experiments for two major scenarios: contract decisions and spot decisions. Data should be collected in a way that an examination of various market segments (e.g. different industries, commodities, trade lanes, etc.) would be possible. Our interview series suggests that also the relevance of selection criteria should to be assessed in a more differentiated way than most existing literature provides.

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Innovations for Accessing Rail Transport Networks

Hans G. Unseld and Herbert Kotzab

Abstract According to recent studies, the key obstacles for the low acceptance of rail transport by logistics service providers refer mainly to uneasy conditions for network access. These obstacles relate particularly to interface processes and physical movements. Hence, ground breaking supply chain specific business innovations including new solutions in rail logistics are required in order to win more users for a significant shift towards using rail for transport. This paper reports about a concept with which one can cope with the significant increase of seaport hinterland transport in Germany by using the rail. At present, German hinterland transports by rail are organized as direct transports between seaport terminals and more than 140 inland terminals. Their performances and expansion limitations are similar to any non-network transport service structure. For planning new infrastructures, a new innovative supply chain approach is suggested, incl. the development of an innovative regional rail distribution transport network with innovative access designs. This approach will support a significant shift to rail transport at short distances in hinterland regions.

1 Introduction and Purpose of the Paper

Shifting more freight in load units to rail is actually part of every strategy for reducing CO_2-Emissions. However, today's rail freight transport capacity and competitiveness is limited by traditional transport organisation structures, complex and costly freight consolidation methods and loading processes. This is mainly caused by an established loading technology once implemented for handling sea

H.G. Unseld (✉)
Lerchenfelder Str. 44/1, 1080 Vienna, Austria
e-mail: unseld@cargo.at

H. Kotzab
Bremen University, Wilhelm-Herbst-Str. 12, 28359 Bremen, Germany
e-mail: kotzab@uni-bremen.de

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containers between vessels and trucks in the late 60s of the previous century. Efforts in developing new transhipment systems did however not result in a competitive rail transport network structure; although this is the premise for a significant modal shift of Hinterland transport from road to rail.

The hypothesis of this paper calls for a new strategy based upon new technologies for automation of physical handling of load units, strategic innovations and rapid implementation. It also calls for focussed deployment activities to turn inventions into innovations in support of on-going shift-to-rail debates regarding zero-CO_2 freight transport by 2050. This bundle of actions is also needed for significantly improving the logistics and overall competition performance of rail transport.

Existing rail networks are traditionally an expression of strategic objectives set forth by actual societal conditions at that time and with first main lines dating back to the second half of the 19th century. According to Weidmann (2013), the existing rail way developed in a "40 years-rail-development-cycle"; the last "cycle" indicates rail transport as a modern, safe and competitive, technology adaptive and future oriented means of transport. This holds for passenger, however, not for rail freight transport. Rail freight transport is organised as A-B[1] transports involving many actors, complex consolidation processes and has missed for years growing transport market opportunities as a mass transport mode. Compared to truck transport, this is a lamented fact and no solution seems to emerge. For that reason, rail freight transport has to undergo significant changes in policies, strategies, environmental considerations and market turbulences for many years to come. When looking out for the next 40 years it becomes apparent, that new innovations, never addressed before are laying ahead of present engineers and business developers.

In a previous paper, Kotzab and Unseld (2012) explained the core philosophy of hinterland transport and innovation; in summary, a new paradigm for pushing any valuable handling resources to their limits is described, involving material flow process perspectives, rail logistic facilities' layouts and loading technologies. This paper takes a more general perspective and extends its focus to four new rail transport issues: 1. Competitiveness and Enabling Technologies, 2. Energy and Environment, 3. Intelligent Mobility, and 4. Networking Capabilities.

The remainder of the paper is as follows: After presenting the problem background, we define in Sect. 2 the major components of our concept. Section 3 provides more insight in the previously mentioned four new rail transport issues. The resulting business innovation options and real life examples are provided in Sect. 4. Section concludes the paper with an estimation of prime criterion for turning the vision into realities from both commercial and societal perspectives.

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[1] That means the rail transport between a loading point A and loading point B, both points being either terminals or other freight loading facilities.

2 Defining the Components

The following components are central for the presented argumentation[2]:

- Rail transport networks
- Road transport network
- Network interfaces
- Rail freight network transport
- Rail freight network actors
- Freight
- Network transport specification
- Rail Network Market Design

Rail transport networks are understood as the sum of all rail infra structure elements for carrying the freight specified within and beyond the region of scope. This includes rail tracks (with different parameters regarding axle load, train length, energy provision, train control system, junctions to external networks and utilities, noise emission factor) and further installations required for handling the train according to time table, environmental (i.e. noise) limits, sophisticated controls and external instructions. This applies for freight and mixed (freight/passenger) rail tracks.

Road transport network are defined as the sum of all road infrastructure elements which are assigned for freight transport within an beyond the region of scope, such as high ways, main roads and any further road side facilities required to perform the freight transport on long and short distance transport distances. This includes also passenger crossings [if needed for roads assigned for freight transport], noise emission protection facilities, and standard and advanced traffic management installations. In summary, it applies for any road assigned for trucks carrying freight.

The sum of any installations which supports the physical transfer and all movements of freight between networks, of which at least one is a rail network is defined as *network interfaces*. This includes two transfer modes (a) interfaces between rail and rail and (b) interfaces between rail and road, or rail and high way. Network interfaces may include further service functionalities at load units, like storage, sort, turn, scan and others of the sealed units.

We understand a *rail freight network transport* as physical movement and real time data control and transfer of any load unit according to a NTS (Network transport specification) between a network entrance and a network exit point, according to instructions received en route and irrespective of routes, network type, load, load units type, identity and interfaces.

The *rail freight network actors* are neutral transport service provider for providing services plus neutral interfaces serving transport and terminal operators.

[2] The presented definitions are based on the notions of Gudehus and Kotzab (2012), Hildebrand (2008), Bretzke (2008), Aberle (2009) and Ihde (2001).

With *freight* we define any load unit with standardized dimensions (length from 20 to 45 ft) and qualified for any type of goods (manufacturing goods, liquids, dangerous goods, any other goods which is filled in load units up to allowed limit in size and weight). This includes empty load units and excludes semi trailers.

The *network transport specification* defines all transport parameter to transport and move a dedicated physical load unit through a network within a specified time, handling procedure, price, SLA (service level agreement) and controlled by internal process control and external instructions when needed.

Finally, the *rail network market design* describes a new kind of approach in order to find a well-balanced economic validation for investments into long lasting sustainable transport networks with decent capabilities at optimal conditions for implementation and operation.

3 Setting the Scene for Rail Freight Transport in Networks

3.1 Why Change Is Required

A summary of the relevant literature for future freight transport service scenario 2050 in Germany was published by SRU (2012). The growth rates ranged from +58 to +102 % starting with 2005/2010 as reference. The report says that: "Sustainable economic activity requires that prosperity be decoupled from resource use by making fundamental innovations and appreciating of vital ecosystem services" (SRU 2012, 3).

The report also stimulates the debate about further economic growth: "… compliance with environmental limits does not necessarily mean the end of growth" (SRU 2012, 3)… continuing with a focus on rail:

> One indispensable factor for economic activities within environmental limits is an innovation strategy that goes hands in cloves with a transformation of major infrastructures and production systems. As a result of various market and government failures, however, market prices do not deliver the right signals. In line with their institutional responsibility (Article 20a of the German Basic Law, Article 191 of the Treaty on the functioning of the European Union), governmental institutions will have to take regulatory action to bring about a breakthrough in solutions for the future (SRU 2012, 3).

Based on this we suggest a radical innovation strategy for a new rail orientation in physical load handling and interface infrastructures within a European context and spatial development of freight villages and alike in regions with high industrial and consumer activities along main TEN-T network trunks. The horizon of 2050 as time line to achieve a zero-CO_2-emission transport seems appropriate for upgrading present infrastructures over the next 35 years to come.

3.2 Competitiveness and Enabling Technologies 2050

3.2.1 Competitiveness and Cost Efficiency in Transport Networks 2050

"In 2050 …rail should tackle any freight booming market, including the last mile challenge and develop research on new concepts, new business models and new marketing for this segment in order to reduce the required investment and find the best way to make attractive proposals on selected corridors…" (ERRAC 2012, 32). In other words, this shift in investment paradigm requires also a new way of *market design*. The components *sustainability* and *environment* must become an integral part of any return-on-investment, market and policy development.

Consequently, a radical next step has to be taken. Successful businesses in road freight network transport and high yield rail passenger networks tells by comparison, that even rail freight transport, designed for 2030 as direct train, single wagon load or as intermodal transport service is lacking in strict and full resource utilisation management.

This unresolved core problem requires indeed a strategic redesign of the train, load and freight consolidation process as interface part of an integrated complete physical transport supply chain: including existing main roads and their capabilities, existing (passenger plus freight) rail networks including signalling systems, auxiliary services and brown fields and merge them towards a true co-modal system.

We identify interfaces as the *missing link* and suggests rail freight transport networks as solution with rail, taking the lead transport mode for monetary reasons and the road transport mode takes second for flexibility reasons.

3.2.2 Enabling Technologies for Rail Freight Volumes 2030 and 2050

In 2012, rail transport activities in Germany accounted for 115 Btkm with a realistic growth prediction up to 231 Btkm for 2030 (Holzhey 2010). In the light of achieving a zero-CO_2-emission scenario in 2050, Holzhey et al. (2012) proved already the fundamental feasibility and ambition to handle up to 500 Btkm.

It is however obvious that this immense flow of freight on rail in particular is a challenge never addressed before. Rail infrastructure is much more complex and expensive to extend and adapt than road infrastructures because of stricter rules for safety and security.

This fact suggests developing first a strategy to extend rail logistics capabilities towards a commonly agreed long-term target and to adopt the road transport network accordingly.

That means that foremost "European rail products manufacturer have to be at the forefront of new technologies in 2050. They have to deliver the most advanced rolling stock and infrastructure technology for railway systems. Technology innovation will play a predominant role in enabling rail to become the most popular transport mode in Europe" (ERRAC 2011, 32).

The actual options for improving competitiveness and cost efficiency in rail transport within the next 10–20 years include longer trains, more automation in shunting and other operational processes, new designs of wagons, mixed train operations, extensive use of IT-systems for operations support (König and Hecht 2012). This is however not enough to achieve the 2050 targets.

We consequently suggest new *network interfaces* which take over the role as enabler of a seamless door-to-door transport between different rail and road transport networks. They primarily include new technologies for physical movement, candidly communicated and accepted noise reduction, sophisticated freight flow control means and challenging infrastructure ideas. Also new operation concepts and organisation innovations are included (see e.g. Kotzab and Unseld 2012). The concept of network interfaces will provide spatial planning with ideas for an all new societal accepted and sustainable rail-based co-modal transport (Adelsberger 2012).

3.3 Energy and Environment 2050

"Rail transport activities in 2050 are still the most energy efficient and environmentally friendly transport mode… Trains will be quiet and no vibration will be perceived around the railway infrastructure. In 2050, trains will run 24 h services in urban areas and near settlements without causing noise and vibration annoyance" (ERRAC 2011, 26). This will apply for passenger as well as for freight transport.

In Germany, the environmental impact of this strategy would allow to nearly achieve the ambiguous target of zero-CO_2-emission in 2050. According to Holzhey (2010) this can be accomplished with a main shift to rail (see Fig. 1) and additional initiatives in road transport. This result points towards rail freight as a likely capable solution for achieving one of the most ambiguous targets in transports without harming industrial and societal prosperity.

SRU (2012) further suggests three complementary strategies: (a) Increasing the efficiency and reducing the demand of road and rail transport, (b) Shift to rail by measures for increasing the freight flow capabilities of rail track and terminal infrastructure, and (c) Substitution of prime energy consumption by shift of road freight transport towards regenerative-electrified propulsion systems, with the project ENUBA 2 (2012) as one example.

The first and second strategies stretch the rail capabilities to their limits. The third strategy stimulates new challenges in road transport. This is why we suggest to primarily supporting the first and second strategy, following the third as back-up for last mile and urban applications.

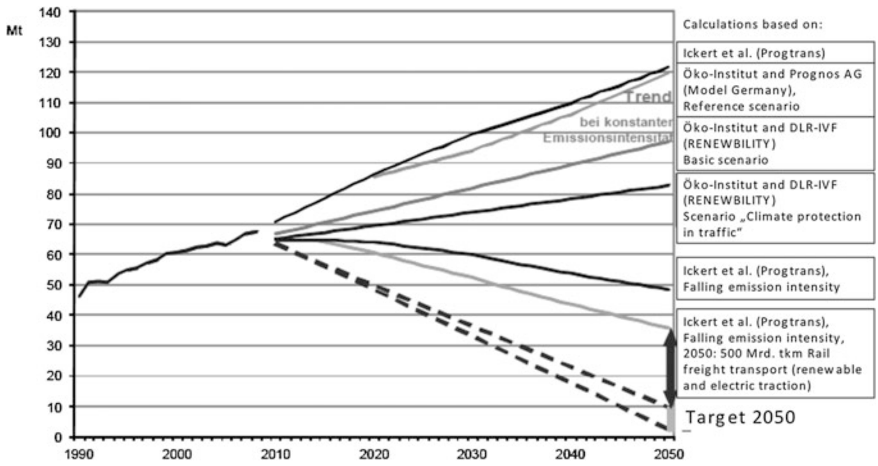

Fig. 1 CO_2-Emissions from freight transport and potentials for reductions. *Source* SRU/UG/2012, 150; see there for the indicated literature

3.4 Intelligent Mobility 2050

In 2050, ERRAC (2012, 29) expects the "establishment of (some dedicated) freight networks serving the economy with longer, heavier and faster trains increasingly undertaken by containerised freight trains … like passenger trains". One can expect that this type of rail transport network will feature significant technology, operational and organisation innovations, as discussed in Sect. 3.2. This will improve management techniques and result in higher reliability of trains schedules. Every customer will receive online accurate information about the train position throughout Europe. As a result, 50 % of road freight over 500 km will be transferred to rail without any negative consequences for competitiveness and service.

The described intelligent mobility stands for both modes road and rail and their mode complementary. When implementing these innovations, however, in today's business world, high technology and organisation hurdles exists for rail transport. In road transport many transport and logistic process relevant innovations are relatively simple to implement, since no interaction with safety related processes happens.

In rail transport, the segregation between safety regulations and logistics processes barely exist today. This is one of the main stumbling elements for system certification, flexibility and mode interaction. Therefore, one of the most prominent innovation jobs for the next decade has to address this and develop a strategy to segregate transport network assets for rail and road, and to re-integrate them in a common business framework, see Chap. 4.

3.5 Networking Capabilities 2050

For intermodal rail freight transport, no network structure exists at present. The implementation of this type of freight transport by using existing mixed (passengers and freight) rail infrastructure is very challenging. Thus we suggest to first focus on some basic elements.

An ideal rail transport network includes the following features: (a) means for running trains with low noise standard wagons between nodes at full track and train capacity (automatic load handling), (b) organisation for unrestricted rail liner transport services with high efficiency train operation and by different operators, (c) control mechanisms for control of load according to logistics and supply chain requirements in all modes, (d) remote accessible buffer capabilities for rail, (e) neutral treatment for road and rail from customer perspective, (f) unrestricted 24/7/365 h operation for rail and road, (g) low noise operation and full compliance with zero-CO_2-emission transport strategies, (h) new nodes and interfaces, fully compliant to rail and road environmental and safety regulations.

First experiences indicate that the German rail infrastructure—when re-organised as rail transport network—will basically be able to become a prominent contributor for a zero-CO_2-emission transport. According to SRU (2012), this would put a shift of the prognosis volume of 500 Btokm to rail by 2050 within reach.

3.6 Potentials for Shift from Road to Rail in Transport

In a recent study, Bohne (2012) discovered the access to transport networks, infrastructure and nodes as dominant priority for present actors in industry and public actors in transport, when asked for their future concerns in technology and infrastructure. This is another indication for the urgent need for practical solutions. It is also an indication that traditional forecast methods resulting in presently known scenarios do not represent the true need and potential in freight inter-modality.

The following strategic innovation hypotheses are suggested for estimating potentials for shifting freight from road to rail (in order of priority):

1. Provision of unrestricted 24/7/365 h access for unloading and loading trucks within minutes in Network interfaces as pre-booked operation.
2. The shift focuses on the growing market of freight with goods in NST/R 9 categories. This implies primarily freight transport by load units and trailer; for efficiency reasons, trailers are excluded from this hypothesis.
3. The number of train tracks should be recalculated with adjusted train performance data (selection): mixed time-tabling operation, trains run with 99 % utilisation for value-adding transport, 700–835–1.000 m train length depending on regional infrastructures, electric traction only.

4. Network interfaces (NI) will offer:
   (a) Provision of truck loading processes in advanced loading bay (ALB) in parking lots at motor ways for pre-booked consignments,
   (b) Provision of load units feeding into classical or new type of terminals supporting highly efficient train loading operation,
   (c) Provision of transport between ALB, rail terminal and buffer,
   (d) Provision of e-freight for clients, real time rail operation IT services for high efficiency rail operations and for local networks.
5. Network interfaces should handle between 20.000 and 500.000 load units p.a. with basically identical ALB and logistics supra structure. Facilities for handling load units within NI are scalable according to the capacity needed. Approximately 500 NI should be erected in "shifting regions" within next 40 years complementary to existing terminals in Germany.
6. Cost for handling load units in NI equals 10 km of load unit transport.
7. Policy support is needed, i.e. for freight handling and subsidy legislation.

The core idea of these hypotheses is to respect truck transport as back bone of transport, and to enable an easy shift towards rail transport networks in a secure and neutral way without considering safety-related complexities of rail transport.

4 Network Interfaces (Present Concept)

Network interfaces are infrastructure elements for interconnecting the physical flows between land transport infrastructures for rail and road transport. The basic concept was presented by Kotzab and Unseld (2012).

Recent developments include studies on ballast less tracks for vibration attenuation, upgrading the rail loading facilities, certification process of the protected drive way and sophisticated versions of remote operated facilities for loading tracks at motorway stations. The actual design of network interfaces consists of three parts (see Fig. 2).

The design comprises of the two loading facilities for road and rail and the driveway in between; the distance between depends on the existing location of railway freight service facilities, like terminals or shunting yards and the location of new or existing motorway facilities.

The rail loading zone is the core piece with new type of ballast less tracks for significant noise attenuation and for precision reasons. Both, the rail and the road loading facilities are currently in process of design completion and patent registration; details will be revealed in a later paper.

However, three features are important for further planning of this type of facilities: the facilities class, function and interaction. The definition of them is driven by the complexity of the undisputable requirements of rail operations, the

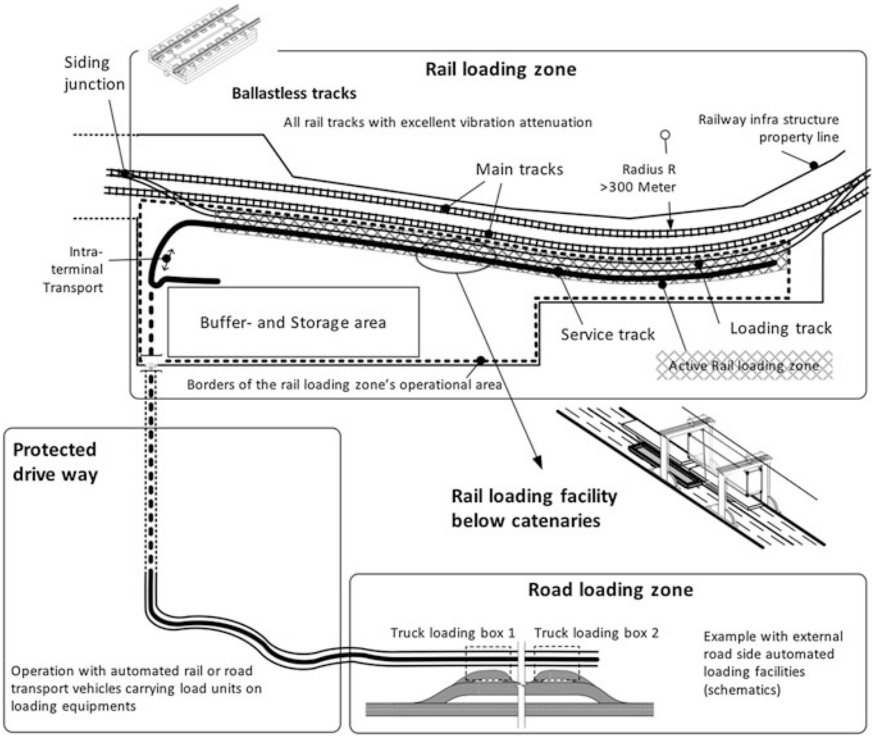

Fig. 2 Network interface configuration

need for automation of logistics processes and the nature of human centred truck operations.

These features are classified in three classes (see also Table 1):

- Asset Class 1: Logistics supra structures within rail infrastructure. This describes standardised modifications of existing infrastructures and sidings to enable automatic operation processes in rail freight transport off main tracks. They are

Table 1 Network interfaces' asset functions and interactions

Asset class	Asset group	Asset functions and interaction		
		Security related	Safety related	Operation related
Class 1	Supra structure	Self sustainable	Very limited interaction	No interaction
Class 2	Handling facilities	Limited interaction	Self sustainable	Limited interaction
Class 3	Consumer type of facilities	Very limited interaction	Limited interaction	Self sustainable and based on operation critical inputs

long term investments, marking "maximum design capacities" and form the basis on which Class 2 facilities operates.

- Asset Class 2: Facilities for physical handling and movement of load units off rail and according to logistics rules. This describes new and off-rail techniques for automation and control thereof under safe logistics management conditions. The standardised facilities are easily duplicated and performance is scalable.
- Asset Class 3: IT and Communication equipment. The path of development is driven by public consumer demands and unmatched by any other technologies in logistics. It is therefore mandatory to give IT a clear role, which does not interact with safety operations at rail, or with security driven operations in the logistics work flow. This type of equipment interacts only on public standard protocols.

The design of the network interfaces respects this classification as base line for the system design and system communication, i.e. integrating Class 1 assets into rail related TSI's. This classification also defines the base line for commercial calculation and business planning.

5 Real Life Examples

The examples in Figs. 3 and 4 demonstrate the flexibility of network interfaces in real life applications. Each case includes an infrastructure analysis, study of alternative designs and estimation of investment as well as rail operations and material flow concepts and operations costs.

The example in Fig. 3 shows a rail loading zone as part of a previous shunting yard interconnecting two main rail lines between Seaports and Hinterland terminals.

They are both fed by four regional terminals T1–T4 (three of them with road connection), each of them with own dedicated Hinterland services. The business case calculated a handling capacity with 40 bypassing trains per day on both main lines with an average throughput of >20 LU per train per time-table halt of <60 min

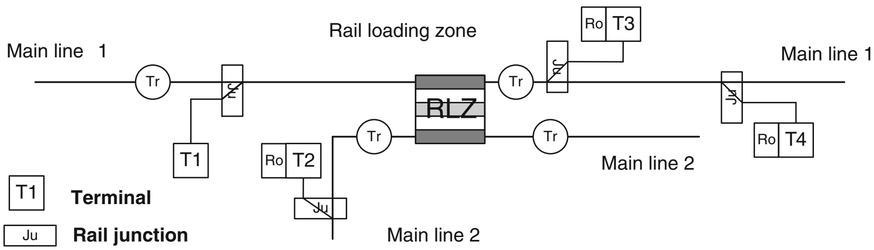

Fig. 3 Network interface, consisting of shunting yard as RLZ for virtual regional network

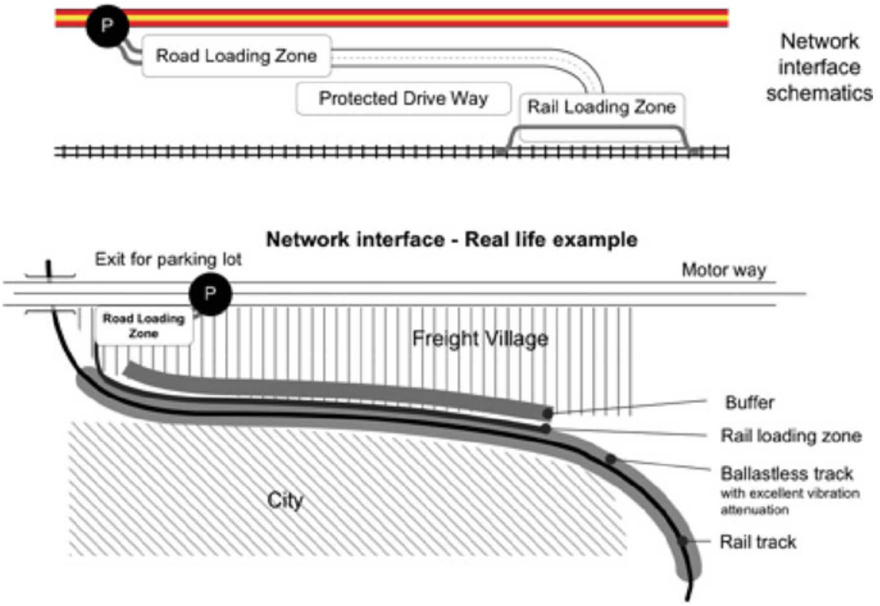

Fig. 4 New network interface close to motorway

and a buffer capacity of 400 TEU. Inter terminal service to be done by regional providers.

Figure 4 describes the latest development that contributes to innovative rail systems within tight urban restrictions. By that, it addresses a scalable solution to meet changing logistics conditions and challenges over time as well as high performance and environmental objectives.

The network interface schematics indicate the interconnection of a parking lot at the motorway with a loading facility within the railway infrastructure. The real life example shows how the new elements are implemented in a given narrow area along side the rail infrastructure. All handling activities are planned for automatic operation and transport is done with specific automated guided vehicles.

6 Conclusions

This paper presented some key elements for long term innovation strategies are presented for achieving a zero-CO_2-emission target by 2050 in Germany. The time span for full implementation could last for the next "40 years-rail-development-cycle" and will bring about a freight transport system in a true European dimension and with world class performance.

The investments estimated over the next 40 years are estimated to below 300 Million Euros per year for creating a sustainable network with some hundreds of Network interfaces at motor way and rail ways in Germany and in support of competitive multimodal operation costs.

The density and type of rail transport network described implies and enables the creation of regional distribution networks as virtual networks with organisation and service innovations associated with.

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Cloud-Based eBusiness Standardization in the Maritime Supply Chain

Hans-Dietrich Haasis, Thomas Landwehr, Guido Kille and Michael Obsadny

Abstract Currently the logistics related business processes are arranged error-prone and inefficient because of media disruptions at interfaces between the SC actors. A central goal is to largely exclude existing media disruptions through the implementation of a mediator. The presented work-in-progress article discusses the research project SMART SC—eBusiness Standardization in the maritime Supply Chain (SMART SC is funded by the Federal Ministry of Economics and Technology within the framework of the initiative eStandards. The research project has a large application-oriented focus with the goal of improving the efficiency of cross-company data communications in the maritime supply chain with respect to the road-related container traffic. The research project is running since 01.04.2012 and has a duration of three years. The first milestone was achieved in April 2013. The research project is a collaborative project between the partners a.i.o. IT for Logistics GmbH, dbh Logistics IT AG, i2dm consulting & development GmbH, Institute of Shipping Economics and Logistics (Project co-ordinator) and JadeWeserPort Zone Logistics GmbH & Co. KG.), which focuses on the sustainable improvement of inter-company communication structures in the port-related supply chain to increase national competitiveness in the international freight transport through the cross-company use of eBusiness standards. Data, information and documents accompanying the physical flow of goods must be exchanged in the cloud efficiently and with a minimal error rate between the participating companies in the supply chain, which presents an increasingly challenge with growing international transport volumes. The aim of SMART SC is to increase the efficiency of existing

H.-D. Haasis (✉) · T. Landwehr · G. Kille · M. Obsadny
Institute of Shipping Economics and Logistics, Universitätsallee 11/13,
28359 Bremen, Germany
e-mail: haasis@uni-bremen.de

T. Landwehr
e-mail: landwehr@isl.org

G. Kille
e-mail: kille@isl.org

M. Obsadny
e-mail: obsadny@isl.org

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logistics processes along the entire container-related value chain in import and export to improve the performance of the physical processes (transport, handling, storage, etc.) through the harmonization of information, communication transaction means.

1 Introduction

The intermodal container transportation is characterized by a heterogeneous structure of the parties—both in terms of their role as well as in terms of their size and degree of innovation. Especially the field of trucking companies is dominated by small and medium-sized enterprises.

This heterogeneity is also reflected by the organization and structure of associations: Ports, shipping companies, freight forwarders, trucking companies, railway companies, etc. have respectively own national and/or regional organizations. A driving force towards standardization of processes is therefore—unlike in other industries—not given.

This situation leads to the fact that cross-company processes along the value chain cannot be perfectly matched. Exemplary current problems are the followings:

- *An inadequate coordination at the interface Terminal/Hinterland*: The trucks only log in partially at the seaport terminal. Congestion, capacity utilization of parking spaces or non-availability of fetched containers are not communicated. Unnecessary delays, avoidable empty runs and problems with driving and rest periods are the result. Because there is no contractual relationship between trucking companies and terminal operators, a realization can only take place via win-win approaches.
- *Inadequate coordination during import*: Terminal operators are not informed, by which transport mode the containers are further transported—existing potential for optimization of the terminal processes are not currently used.
- *Inadequate communication concerning variations in the transport process*: The availability of status messages is—if indeed—given only for those partners directly affected in the supply chain. In addition, following supply chain actors (SC actors) identify deviations from the plan process too late to develop efficient fallback solutions. If plans are not met, an update of the plans would have to take place between the partners. Problems would have to be identified earlier in order to avoid the dominating suboptimal ad hoc decisions.

By implementation of an eBusiness standardization in the maritime supply chain SMART SC designs an integrated solution for the settlement of cross-company electronic communication processes for all involved companies (freight forwarders, shippers, terminals, trucking companies, etc.) and administrative bodies (customs, port authorities, etc.) in the container-related supply chain (SC) in form of a mediator. The practical suitability is reflected on the basis of demonstrators.

The overall objective of the funded project "SMART SC" is to increase efficiency of all existing logistics processes along the entire container-related value chain in the import and export with particular emphasis on small and medium-sized enterprises (hereinafter referred to as "SMEs") and authorities to improve the performance of the physical processes (transport, handling, storage, etc.) through the harmonization of information, communication and transaction means.

For this purpose, a so-called SMART SC mediator is developed, which represents the core system in the research project. The objective of the SMART SC-mediator consists in enabling data communication processes of the container related supply chain via a central system, which should particularly benefit SMEs (forwarders and trucking company). The project serves as the basis for the proposed development to a real system.

Supporting the goal of a high acceptance of the SMART SC mediator for practitioners already from the outset, especially SMEs, the existing communication processes of in the supply chain involved enterprises and government organs were analyzed (customs, port authorities, etc.). Needs and requirements for a standardized, integrated eBusiness system based on a SMART SC mediator are identified in dialogue with associated industry partners.

The SMART SC mediator is supplied by order related planning data and real data. The planning data present target data, which are based on an individually planned transport process and are sent to the SMART SC mediator. These planning data include for example job-related data such as involved contractors, dates, quantities, transport and carrier information, information on dangerous goods, customs information, etc.

Real data present actual data, which are generated in the course of an already initiated transport process. They are generated in form of procedures like the scanning proceedings or in the future in eventual reading RFID tags at specific locations where a container handling takes place like loading, handling operations, scanning at the gate, customs stops, etc. In particular, the actual data couple order-related information with time and location information, where the location identifier is carried out by use of GPS coordinates, Cell-ID of mobile phones or postal address of real estate (e.g. scanning of the container at the shipper, handling operations, terminal, etc.).

A particular challenge represents the design, development and implementation of appropriate procedures and algorithms to match data of planned transport processes (target data of a planned transport process) with the real data (actual data after initiation of each transport process), the feedback and in case of deviations of actual data in the process plan to inform the one following in the supply chain involved company and/or management about this deviation. This problem underlines the high research character of the project.

Another challenge is to achieve a high acceptance in practice (see above). On the one hand a major challenge is represented in the evaluation and presentation of the efficiency of the action and its sustainable effects on freight transport systems in the immediate environment of the terminal and on the environment. On the other hand strategies for a comprehensive transfer concept have to be developed, to motivate especially SMEs, in addition to the presentation of the feasibility and cost-effectiveness, to actively participate in a data communication flow using SMART SC mediator achieving standardized, collaborative eBusiness strategy in the container related supply chain within Northwest Germany. Furthermore in the context of the project it is necessary to present the applicability of the measure to other port locations.

2 Background

Regarding the electronic communication between big-sized companies (e.g. between ship owners and terminal operators), such as for the transfer of stowage plans and loading respectively unloading lists, EDIFACT is used. In this case the Implementation Guides of the SMDG[1] has been established.

Each universal port provides a so-called Port Community System (in case of the ports of Bremen the Bremen port telematics (BHT) operated by the dbh Logistics IT AG), which links the involved companies and agencies for certain port-related processes. Some messages are mandatory, as for example the electronic transmission of export orders or dangerous goods declarations. Access to these systems is possible via (proprietary) interfaces or via the Internet. However, in this case the consideration of the entire chain is missing, but it is required as a basis for SMART SC.

Currently, the logistics related business processes are error-prone and inefficient due to media disruptions at interfaces between the SC actors. A central goal is to largely exclude existing media disruptions through the implementation of a mediator.

The BERLECON study "eBusiness Standards in Germany"[2] emphasizes the need for further harmonization of standard formats (Quantz and Wichmann 2003). Although with EDIFACT a basic eBusiness standard as a framework for data communication in the logistics industry is established, there are significant differences regarding the assortment of the data packets exchanged (implementation guide and semantic interpretation of content) between the SC actors. A comprehensive integrated eBusiness standard for cross-company communication in value chains does not exist yet.

The research project SMART SC aims a data transfer and communication harmonization of the existing EDI and XML standards along the entire container-related supply chain considering all involved SC actors. Therefore, in addition to

[1] SMDG is a non-profit foundation, run by and on behalf of companies and organizations working in the maritime industry, like container terminals, ocean carriers and related companies and organizations. SMDG develops and promotes UN/EDIFACT EDI-messages for the Maritime Industry and is an official Pan European User Group, recognized by the UN/EDIFACT Board.

[2] Further information at http://www.berlecon.de.

handling, transport and logistics stakeholders and regulatory agencies such as Customs and Port Authority in particular also shipper or receivers have to be involved.

3 Aims

The aim of SMART SC is to increase efficiency of existing logistics processes along the entire container-related value chain in the import and export to improve the performance of the physical processes (transport, handling, storage, etc.) through the harmonization of information, communication and transaction means.

The mediator developed in the framework of the project SMART SC will contain functions following the above objectives. In particular, the focus is to enable data communication of all participants in the container-related supply chain via a centralized system, which will particularly benefit SMEs (forwarders and trucking companies). The research project serves as the basis for the proposed development to a real system.

For the required data alignment between planning data (target data) and real data (actual data), a so-called SCEM module is created based on the theoretical foundation of supply chain event management and finds a practical use here.

In addition, interfaces to existing mobile components are produced, and new applications for smart phones and tablet PCs are created, by which carriers are supplied with order-related data from the SMART SC mediator on the one hand and can make entries on their own on the other hand.

The mobile components are to be used particularly with regard to the demonstrator Wilhelmshaven for future web applications with value added services, which for example are developed by the JWP logistics zone for the location Wilhelmshaven. Here, the application fields aiming at a truck supply control and additional value-added services within the Freight Village Wilhelmshaven. Another demonstrator for the Port of Bremerhaven is implemented by integrating associated partners.

Another success factor is the number of SMEs involved in this demonstration project. The factors listed here are analyzed and subject to ex ante/ex post comparison to concretize the potential for the solution.

The project aims examples for the region of North West Germany. An eBusiness standardization of message contents in a cross-company data communication in the container-related supply chain by implementing a SMART SC mediator SMEs, especially freight forwarders and carriers, will gain competitive advantages in the port hinterland transport settlement in the north-west German seaports, whereby sustainable jobs in the region can be secured. Thus, future investments by SMEs within the value chain for bilateral EDI interfaces (customer–supplier) with regard to the assortment of exchanged data packets sustainably ensured to other partners by standardization by means of the mediator and thus the competitiveness of companies in the port hinterland transportation of the Northwest German North sea ports, especially SMEs, can be sustainably ensured.

4 State of Science and Technology

From a scientific perspective the used approach is closely connected to the area of research in cloud computing. According to the NIST definition of cloud computing, the project SMART SC fulfils all essential characteristics of a cloud model like on-demand self-service, broad network access, resource pooling (Mell and Grance 2011).

The services offered are a combination of the service models Software-as-a-Service (SaaS) and Platform-as-a-Service (PaaS). The latter denotes a system environment in which own applications can be used (Schuldt et al. 2010). SMART SC provides the users a platform to communicate via a single interface with all their partners electronically by keeping their established interfaces. Concerning SaaS, one aim of the research project is the development of mobile applications for various mobile devices to enable a flexible use of the solution. With the focus on interacting partners along the entire container-related value chain in the import and export, the selected cloud infrastructure is only shared by several organizations and supports a specific community—community cloud (Mell and Grance 2011). Other deployment models are private, public or hybrid clouds (Baun et al. 2011).

The potential market for cloud computing solutions in the logistics environment is very large and demands innovative applications even in the intermodal supply chain area (Daniluk and Karakoyun 2010). Based on the tasks of the research project SMART SC it should be noted that until now it lacks one, the entire supply chain respectively all SC actors' comprehensive inter-company communication structure and consequently has no company-border use of eBusiness standards. The same applies to the integration of a SCEM module for the target-actual-comparison of planned and actual data in such a system, because a similar system does not exist yet.

Currently for Electronic communication between the major companies in the supply chain (e.g. between shipping companies and terminal operators) the international eBusiness standard EDIFACT is used as a framework for data communication. However, there exist significant differences regarding the assortment of exchanged data packets (Implementation Guide and semantic interpretation of content) between the SC actors. Coordination regarding the assortment of exchanged data packets are usually done on a bilateral level. A comprehensive, integrated eBusiness standard for cross-company communication in value chains is until now non-existent.

Currently the logistics related business processes are arranged error-prone and inefficient because of media disruptions at interfaces between the SC actors. Thus a central goal is to largely exclude existing media disruptions through the implementation of a mediator.

5 Concept

In accordance with the objectives SMART SC focuses in particular on SMEs like forwarders and trucking companies including governmental institutions such as customs and port authorities. Nevertheless, for completeness also non-SMEs, such as the container terminals, shipping and optionally exporters/importers have to be integrated in the overall approach. The ICT processes which accompany the upstream (import) and downstream (export) physical flow of goods are considered and not the commercial business processes connecting the above mentioned SC actors.

The success for the acceptance and implementation of standardized ICT processes in the container-related supply chain depends significantly on the willingness of users to participate in these processes. Therefore, the users are involved in the discussions concerning the planning conception right from the beginning. Furthermore, within the project a comprehensive communication, transfer and training concept is developed and should be implemented by corresponding measures such as two demonstrators towards the end achieving a very widespread impact and demonstrating the economic benefits for all in the supply chain involved companies. Achieved milestones should be published in form of status reports at regular intervals during the project period via a web page.

5.1 eBusiness Standards and Mediator

SMART SC aims to the standardization of contents of electronic messages in the container-related supply chain. The concept focuses on the following two target groups:

- New communication partners (especially SMEs): Standards provide them a tool to connect to the developing platform of the so-called mediator, in order to communicate via a single interface with all their partners electronically.
- Existing communication partners: They can keep their established interfaces and be linked to the internal standards of the mediator by means of a converter function. For this purpose, the above mentioned standardization of the contents is essential.

With this cloud-based approach, the chance of success integrating both target groups is significantly higher than estimated with a "forced usage" of the standards. Information and data islands can be eliminated by using cloud computing to share information and data over a (SMART SC-) mediator (Zhou and Lv 2011) (Fig. 1).

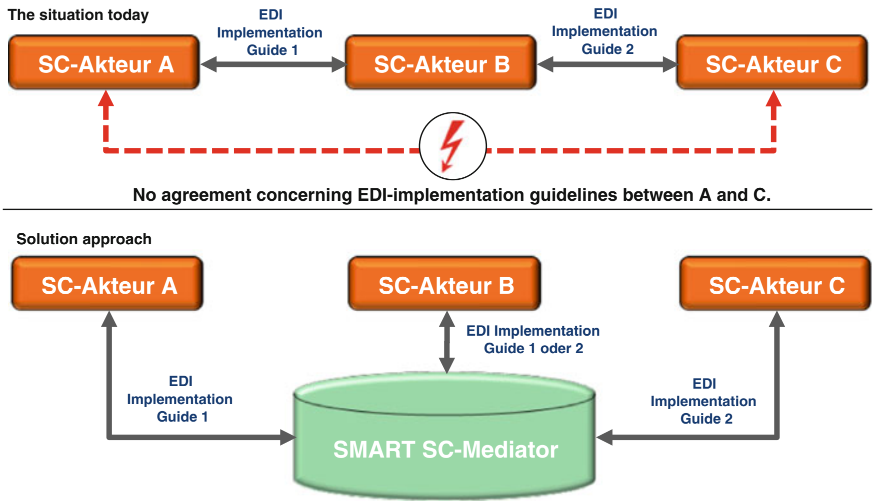

Fig. 1 Integration of business processes by standardization of communication processes in the supply chain by means of a mediator

5.2 SCEM Approach

Beyond the pure exchange of information the developing mediator based on the Supply Chain Event Management (SCEM) approach in conjunction with the developing SCEM module also allows an alignment between planned target-processes in the transport sector (planned data such as weekly plan, day schedule etc. of different SC actors) and transport-related actual data (temporal and local recording of the transport process and status information for a specific transport process). By the implementation of interfaces between the SC actors and the mediator a harmonized multilateral, cloud-based data transfer and alignment of the target and actual data will be provided.

5.3 Demonstrators

Next to the conception and design of the mediator verifying the objective of the project strives for the development and testing of two application-oriented demonstrators at the sites Wilhelmshaven and Bremerhaven, which are intended to illustrate the added value of improved data communication within the supply chain with respect to effects on the physical transport during the feed to the container terminals in Bremerhaven and Wilhelmshaven in real use. The experiences of the practical orientated demonstration projects should be made available for a broad public at regular intervals even during the project period and further on.

6 Methodology

6.1 Creation of a Questionnaire, Implementation and Evaluation of Interviews as Part of the Requirements Analysis

In 2010 the Institute of Shipping Economics and Logistics conducted a feasibility study "Development of a rough concept to increase the competitiveness of the ports of Bremen by optimizing information processes in the supply chain" (Haasis et al. 2010). The knowledge gained there was included in the request and actual analysis. As part of the request and analysis a differentiated qualitative company questionnaire was developed in 2012. The questionnaire is used for actual recording of today's data communication processes in companies, especially SMEs, and thus it serves as a guide for company interviews. In addition to the actual situation of sub-processes also the needs and requirements of the company to a future SMART SC mediator were collected by means of interviews. The evaluation of the survey confirmed the need for harmonization of data from a business perspective. Especially for SMEs this is an advantage, because the mediator represents a technical solution to be included in the data communication along the entire chain. Existing bilateral data harmonization between large companies can be extended economically to other actors, especially to SMEs with the help of the mediator. After the evaluation of the interviews a detailed illustration of the actual communication processes is created and the necessary requirements for a SMART SC mediator are defined. The representation of the actual processes and the requirements catalog serve as an agenda for the specification of a standardized eBusiness solution.

- Specification of the core system and the demonstrators in the framework of the overall specification of eBusiness standards and a demonstration platform
- Development of a SMART SC mediator and functional demonstrator
- Creation of interfaces to mobile devices and creation of mobile applications
- Web based value added services in hubs and Container terminals
- Economic Evaluation and sustainability of the action
- Development of a comprehensive transfer concept, representation of sustainability in relation to the region and Germany and elaboration of recommendations.

7 Prospects of Success

7.1 Economic Prospects of Success

Based on the perceptions gained from the funded project modern technical information services should be built up with the aim to improve inter-company communication within the port-related supply chain. These services are available for all actors from dbh Logistics IT AG connected sea ports (mainly Bremen/Bremerhaven and Wilhelmshaven) and lead to a competitive advantage for those ports as well as to the strengthening of maritime logistics clusters Northwest Germany.

These information services include for example IT applications for the optimization of the feed control in the container terminals and logistics zones in Wilhelmshaven and Bremerhaven, systems for geo-fencing, systems for an optimal tour planning (including dynamic plan-actual comparison with proactive problem detection) and IT management systems for government provide for the monitoring of container transportation.

With the integration of the expected results from the SMART SC operations in the logistics processes of the involved sea ports a greater involvement of SMEs in the planning and monitoring processes along the value chain is realized. Moreover, the obstacles integrating into existing chains and networks are significantly reduced. Through the optimization of planning processes along the supply chain results improved information flows to increase the reliability of planning processes and accelerate the quality improvement of the information base for importers and exporters.

The optimization of feed control to the container terminals and logistics zones in Wilhelmshaven and Bremerhaven should reduce bottlenecks at clearance of the loading and traffic carriers. Moreover, a prevention of congestion on the supply roads, provision of sufficient parking space and an intelligent traffic control relieving nearby populated and downtown areas are possible. The improvement of utilization of loading and traffic carriers and the reduction of empty runs contribute to the reduction of exhausted emissions.

Within the research project a knowledge advantage in the field of SCEM-research is ensured with the practical elaboration of the SCEM module and its testing and implementation on the basis of demonstrators.

Applicable solutions on pilot base by means of the SMART SC mediator for eBusiness standardization in maritime supply chains are a competition advantage both for the in the project involved partners and for the logistics region North West Germany. An efficient design of the port and logistics region North West Germany affects union interests because the German foreign trade significantly depends on the performance of the port locations.

The realization chances for the SMART SC mediator and the demonstrators are highly valued. The desired eBusiness standardization by means of the SMART SC mediator in the former collaborative project is a unique characteristic. A competition situation has not existed before. Therefore the height of innovation is assessed as very high.

7.2 Scientifical/Technical Prospects of Success

Within operative research of the optimization of supply chain processes the pursued cloud-based approach of eBusiness standardization in the container related maritime supply chain is regarded in this project as an innovative approach in scientific research and is a necessary technical platform (PaaS) for a future practical implementation of cross-company key figure systems in terms of Supply Chain Controlling.

The research and development relevant elements of the project on the one hand consist of the development of the SCEM module and of the core system (mediator) with converter function for such as different EDI-Implementation Guides and the connection to mobile devices. The conclusion of the relevant perceptions in this project about the technical communication is that modern technical information services can be developed. The technical extension and simplification of access opportunities lead to an increase in communication opportunities in the information network port telematics.

This research project primarily aims to develop eBusiness standardization by means of a SMART SC mediator on the standardization of cross-company communication processes. The system has demonstration character and should be certificated accordingly by standardization at the end of the project within the exploitation phase.

7.3 Scientifical/Economical Compatibility

This project has model character and can be applied on other port locations, freight villages and logistics agglomerations. With the modular design of the SMART SC mediator (core system) in combination with the SCEM module and mobile components that interact with each other by means of interfaces. A flexible system is created, which can be adapted to other port locations and logistics agglomerations. Especially the applicability of mobile applications on various mobile devices and established telematics systems enables flexible use of the solution for SMEs (trucking company) and thus increases the acceptance because already at the present time such devices are frequently used and the applications developed in the framework of the project support these devices.

Largely it should be noted that the developed SMART SC mediator in the collaborative project should be complemented in future projects by a decision module based on the target-actual data alignment of the SCEM module independently applies decisions at deviations of the real data from the target process. Herein an approach using software agent technology would be feasible. Furthermore, the overall system can be further complemented by a control module, which plans new reactive transport processes (decision module) for planned transport processes that are no longer depreciated because of delays, incomplete documents, etc., and controls (control module) and informs the actors involved in the supply chain by timely information transfer (transfer).

7.4 *Specific Exploitation Steps After Project Completion*

The demonstrators to be realized in SMART SC are continued to operate after the end of the project and will be further developed into independent IT products. These can be complemented by additional modules (SaaS) in a following development phase that allows for example to generate alternative processes at deviations from the planned transport process from the system and submit this information to each affected SC actor by implementing a decision support module as well as a supply chain control module. Through the generally applicable approach, the transferability of the mediator to ports and other chains in Germany and other European countries is desired. Furthermore, the knowledge about the eBusiness processes and standards is absorbed in advisory, training and educational offerings of the project partners, so that also in this point the sustainability of the results is given.

Up to 6 months after the project it is aimed to implement comprehensive transfer measures of research and development results by performing and presenting the demonstrators at exhibitions. After one year after the end of the project it is aimed to perform first implementation measures in live operations with partners. In addition, it is contemplated to evaluate the status of the real operation two years after the project completion.

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A Comparison of the Productivity of Single Manning and Multi Manning for Road Transportation Tasks

Heiko W. Kopfer and Udo Buscher

Abstract In all member countries of the European Union, legislation on driving and working hours of persons engaged in road transportation are prescribed by legal acts whose rules are to some extend different in case that a vehicle is manned by one single driver (single manning) or in case that the vehicle is manned by a team of two drivers (double manning). In this paper, we analyze the productivity of the two alternative operating modes (single and multi manning). The body of legislation for driving and working times is presented and a cost function for driver and vehicle deployment is proposed. Within a quantitative analysis, the costs for fulfilling a given transportation task are determined in dependence of the choice of the applied operating mode. The productivity of both operating modes is evaluated and contrasted by considering the total costs of transportation fulfillment. Thereby, it is possible to identify characteristics of transportation tasks which should advantageously be executed by single manning and characteristics of those tasks which are preferentially suitable for double manning.

1 Introduction

A good deal of all research related to the operational planning of road transportation is focusing on vehicle routing and scheduling problems with an objective function which mostly strives for travel distance minimization or transportation cost minimization. Recently, there has been published some research on vehicle routing and

H.W. Kopfer (✉)
Department of Mechanical Engineering, Institute of Engineering Design, University of Siegen, Paul-Bonatz-Straße 9-11, 57076 Siegen, Germany
e-mail: heiko.kopfer@uni-siegen.de

U. Buscher
Industrial Management, Business Management, Faculty of Economics, Technical University of Dresden, Helmholtzstraße 10, 01069 Dresden, Germany
e-mail: udo.buscher@tu-dresden.de

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scheduling problems including statutory regulations for driving and working times of drivers engaged in road transportation. In the existing literature, these regulations are considered mostly for the situation (e.g. Derigs et al. 2011; Kok et al. 2010; Kopfer and Meyer 2010; Meyer 2011) that a vehicle is staffed by one single driver (single manning) and rarely for the situation (e.g. Goel and Kok 2012) that the vehicle is staffed by two drivers (double manning). Goel (2007) considers a case study with mixed operating modes for a small routing problem with three orders and two vehicles. In this case study, it is fixed in advance that one vehicle is single manned and the second vehicle is manned by two drivers. Altogether, the decision whether to assign a single driver or a driver team to a deployed vehicle is considered in literature, if at all, irrespectively of vehicle routing and scheduling. Furthermore, there is even no work known in literature which is contrasting both operating modes (single manning and multi manning). In more detail (to the best of the authors' knowledge), there is no work in literature comparing the productivity of single manning and multi manning under the consideration of the statutory regulations for breaks, driving times, rest periods and working times. The goal of this paper is to investigate the question whether a given transportation task (i.e. a task comprising driving, loading, unloading and waiting) should be better executed by single manning or by double manning. At first, the regulations for driving and working hours are presented. Then, a cost function for vehicle deployment in dependence of the chosen operating mode is proposed. Based on the official regulations and the proposed cost function the productivity of the two alternative operating modes are evaluated and opposed to each other.

2 Overview on EU Regulations for the Limitation of Driving and Working Hours

The European social legislation for drivers in road transportation mainly comprises two legal acts (Meyer et al. 2011). The first one, Regulation (EC) No 561/2006 published in European Union (2002), lays down rules on drivers' driving hours. The second one, Directive 2002/15/EC published in European Union (1985), restricts working hours of persons engaged in road transportation. EC Regulation No 561/2006 comprises three different time horizons for driving activities: single driving periods, daily driving times and weekly driving times. Figure 1 illustrates the relationship between these different time horizons. On each time horizon, the set of relevant rules can be split into standard rules and additional rules allowing some exemption. Since additional driving time allowed by exemptions has to be compensated for most exceptional rules, our analysis of the productivity of operating modes is confined to the standard rules only.

According to Regulation (EC) No 561/2006 the driving time in each single driving period is restricted to maximum 4.5 h. Drivers have to take a break of at least 45 min at the end of each driving period. A driving period ends, if and only if a break of sufficient length has been taken.

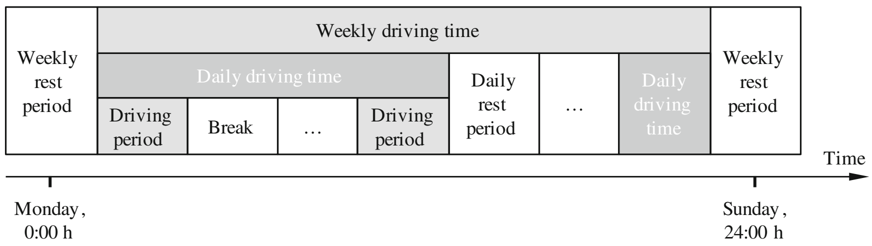

Fig. 1 Relation of the different time horizons (Kopfer et al. 2007)

The daily driving time is restricted to 9 h. Daily driving times are defined as the accumulated driving time between two daily or between a daily and a weekly rest period, respectively. A daily driving time ends if and only if a daily rest period is taken or a weekly rest period starts. A daily rest period is defined as a period of at least 11 h in which a driver may freely dispose of his time. Within each period of 24 h after the end of a daily rest period or weekly rest period a driver shall have taken a new daily rest period (24-hour-rule).

The weekly driving time is defined as the sum of all driving time during a calendar week, i.e. between Monday, 0:00 a.m. and Sunday, 12:00 p.m. The weekly driving time is limited to 45 h. A weekly rest period is a recreation period in which a driver may freely dispose on his time. The length of a weekly rest period is at least 45 h. Daily rest periods and weekly rest periods may be taken in a vehicle, as long as the vehicle has suitable sleeping facilities for each driver and the vehicle is stationary. A weekly rest period shall start no later than at the end of six 24-hour periods (144-hour-rule) from the end of the previous weekly rest period.

According to European Union (2002), ‘Multi manning’ means the situation where, during each period of driving between any two consecutive daily rest periods, or between a daily rest period and a weekly rest period, there are at least two drivers in the vehicle to do the driving. The above mentioned regulations for driving periods, daily driving times and weekly driving times are generally binding independently whether single or multi manning is applied. But, by way of derogation, there is a 30-hour-rule replacing the 24-hour-rule for rest periods in case of multi manning. Within 30 h of the end of a daily or weekly rest period, a driver engaged in multi manning must have taken a new daily rest period of at least 9 h (instead of 11 h for single manning).

EC Regulation No 561/2006 refers to driving times. As driving times are considered to be working times, they are also affected by Directive 2002/15/EC described in European Union (2002) and by its implementation into national laws in the member states of the European Union. In Germany this directive is implemented by the “Arbeitszeitgesetz” (ArbZG 2013). The relevant legal acts regulate daily and weekly working times as well as mandatory breaks. In Directive 2002/15/EC, the working time is defined as the time devoted to all road transport activities, i.e. driving time, time for loading and unloading, for assisting passengers while boarding and disembarking from the vehicle, time spent for cleaning and technical maintenance, and the time a driver has to wait in any situation with the end of the waiting time not being foreseeable. The directive postulates that workers have to take a break at least after a working time with 6 h duration. The total duration of rest periods countable as break according to Directive 2002/15/EC must equal at least last 30 min. If the working time exceeds 9 h, the total break time per shift has to amount to at least 45 min. A shift-time should not extend 10 h. Consequently, a break which meets the requirements of EC Regulation No 561/2006 also satisfies Directive 2002/15/EC. But in case that a driver has to spend working time which is not counted as driving time, the limitations on working times specified by Directive 2002/15/EC instead of the limitations on driving times may become restrictive. Furthermore, the Directive 2002/15/EC restricts the maximum weekly working time to 48 h per week.

3 Driving Times and Driving Efficiency for Single Manning and Double Manning

Whether a given transportation task can be executed by a driver team or must be necessarily executed by a single driver depends on some prerequisites, in particular with respect to the availability of drivers, the social structure within the driver crew and the availability of the vehicle equipment required for double manning. Contrariwise, in some situations there may be conditions requiring double manning because of security and safety aspects. Additionally, double manning might become advantageous or even necessary due to complicated and complex loading and unloading activities. In this paper, we assume that all prerequisites for single manning as well as for double manning are fulfilled; i.e. all tasks can alternatively be executed by single manning or double manning. Our analysis considering the productivity of single and double manning is based on the consideration of the operation time needed for the execution of transportation tasks and refers to the comparison of the related costs. That is why our analysis is helpful for typical situations of crew management when drivers (and vehicles) have to be assigned to long-haul trips.

Driving hours and rest periods for single manning and multi manning are regulated in a different way with respect to two specific prescriptions. The first difference refers to 30-hour-rule, in particular to the time lag between two daily rest periods and the required duration of daily rest periods. In case of single manning a daily rest period of at least 11 h has to be taken every 24 h (24-hour rule). In case of multi manning a daily rest period of at least 9 h has to be taken every 30 h (30-hour-rule). It is important to notice that in any case the vehicle must be stationary during the whole rest period; i.e. it is not allowed for multi manning that one driver is driving while other drivers are taking their daily or weekly rest period. The second difference between the two operating modes refers to the breaks between single driving periods. In case of single manning, a 45-minute-break is required after 4.5 h of accumulated driving. In case of multi manning, drivers are allowed to take their break while the vehicle is moving; i.e. one driver is driving while other accompanying drivers are taking their break. Consequently, it is possible to schedule the breaks of a driver team in a way that 45-minute-breaks will never cause a stop of the vehicle.

The total lapse of time T which is at least needed for driving h hours without violating the statutory regulations is denoted by the clock time min $ct_s(h)$ for single manning and min $ct_d(h)$ for double manning. The driving efficiency f is defined as the quotient of the time a driver is driving and the total time he is staying on board of the vehicle; i.e. $f = h/(\min ct_s(h))$ for single manning and $f = h/(2 \cdot \min ct_d(h))$ for double manning. The maximum driving efficiency which is reachable at the utmost within a considered time horizon $T = [0, t(h)]$ is denoted by $\max f_s(h)$ respectively $\max f_d(h)$.

In case of single manning, a schedule with maximal efficiency can be generated by combining two adjacent driving periods to a driving block which is split by a 45-minute-break. Such a block has to be followed by a daily rest with 11 h duration. Consequently, a driving block and its subsequent daily rest constitute a daily block of at least 20.75 h. Such daily blocks for single manning are iterated five times. The concatenation of five daily blocks is denoted as compact driving scenario. At the end of a compact driving scenario, the maximum limit for weekly driving hours is reached. This limit requires a weekly rest of 45 h duration. After the weekly rest, another compact driving scenario is implemented followed by a new weekly rest. According to this iterative strategy for building schedules, the clock time needed for driving h hours includes a break of 0.75 h for each totally completed driving period of 4.5 h (i.e. the clock time is augmented by $0.75 \cdot \lfloor h/4.5 \rfloor$ due to the mandatory breaks between two adjacent driving periods). Because of the compulsory daily rests, the clock time is increasing another 11 h for every 9 h of driving. Consequently, the clock time has to be increased by 10.25 h for every entire driving block of 9 h driving, in case that we add 0.75 h at the end of every driving period. Finally, the clock time has to be increased by a duration of 45 h for a weekly rest period (respectively 34 h in case that we increase the clock time by 11 h at the end of each driving block) whenever a driving time of 45 h has accumulated since the last weekly rest period. Hence, the clock time $\min ct_s(h)$ can be calculated as $\min ct_s(h) = h + 0.75 \cdot \lfloor h/4.5 \rfloor + 10.25 \cdot \lfloor h/9 \rfloor + 34 \cdot \lfloor h/45 \rfloor$. Since there is a new daily rest for each daily block (i.e. after 20.75 h) and since there is a new weekly rest for every five daily blocks (i.e. at least after 103.75 h), this strategy automatically complies with the 24-hour-rule for single manning and the 144-hour-rule. For short horizons T, the driving efficiency is very high while it is decreasing when the length of the horizon is increasing. In case of $h \leq 4.5$ the efficiency $\max f_s(h) = 1.0$ and in case of $4.5 < h \leq 9$ it is $\max f_s(h) = 92\,\%$. After the first daily rest, this value goes down to 43 %. At the end of the first compact driving scenario $\max f_s(h) = 49\,\%$. The efficiency is going up at the beginning of driving periods and it is going down at the beginning of rest periods. For increasing h, the function $\max f_s(h)$ it is approximating a lower bound given by $(1/(1 + 0.75/4.5 + 10.25/9 + 34/45)) = 1/3.06 \approx 32.7\,\%$. This bound cannot be reached since concatenating daily driving blocks can only be continued while the limit for the weekly driving time is not exceeded. Due to this limitation, given by the bi-weekly limit of 90 h, the driving efficiency reachable by single manning over a longer time span is limited to $45/168 = 26.8\,\%$.

In case of double manning, a strategy for building a compact driving scenario is based on 18-hour-blocks consisting of four driving periods with permanent driving. Such blocks can be implemented by rotational driving of two drivers with each driver contributing 9 h of driving. Subsequently, a rest period of 9 h has to be taken. The vehicle is not allowed to move during this rest period. Each 18-hour-block and its subsequent daily rest constitute a daily block of 27 h. Such daily blocks for double manning can be repeated until a weekly rest of 45 h duration is required. Then, a new compact driving scenario can follow until the next weekly rest is necessitated, and so on. According to this iterative strategy for double manning, the clock time is increasing by a rest period of 9 h for every totally completed 18-hour-block of accumulated driving. Additionally, the clock time proceeds by another 45 h (respectively 36 h in case that 9 h are added at the end of each 18-hour-block) during the mandatory weekly rest periods. Therefore the clock time can be calculated as $\min ct_d(h) = h + 9 \cdot \lfloor h/18 \rfloor + 36 \cdot \lfloor h/90 \rfloor$. In analogy to single manning, the 30-hour-rule and the 144-hour-rule are automatically fulfilled by this strategy since a daily rest period will occur every 27 h and a weekly rest period will start 135 h later than the end of the last weekly rest period. During the first 18 h the driving efficiency amounts to 50 %. After 27 h (i.e. after the first daily rest) the efficiency is 33 %. In the long run (i.e. for $h \to \infty$), $\max f_d(h)$ goes down to $1/(2 \cdot (1 + 9/18 + 36/90)) = 26.3\,\%$. Additionally to this bound, the long-term driving efficiency for double manning is restricted by the upper limit of 90 h weekly driving time. In contrast to single manning, this limit is never restrictive since $26.3\,\% < 90/(2 \cdot 168)\,\%$.

Figure 2 illustrates the compact driving scenarios for single and double manning. It shows the functions $\max d_s$ (single manning) and $\max d_d$ (double manning) representing the maximal reachable accumulated driving time h over the total lapse of time T which is needed by drivers for transportation activities including driving, mandatory breaks and rest periods. The functions $\max d_s$ respectively $\max d_d$ are the inverse functions of $\min ct_s$ respectively $\min ct_d$.

The compact scenarios represent very tight schedules which are based on the following extreme assumptions:

(a) A driver will start and go on driving whenever it is allowed by EC Regulation;
(b) There are no waiting times which might potentially occur due to customer time windows and there are no service times at customer locations;
(c) Driving is allowed each day, i.e. weekend lorry bans are not considered.

An increase of the working time above 10 h per day will be avoided if the driver starts his driving block in a time window between 12.00 a.m. and 15.15 p.m. So the compact scenario complies with the conditions for the working time limitation according to Directive 2002/15/EC and the German Arbeitszeitgesetz. But considering several consecutive weeks of single manning, the full compliance with

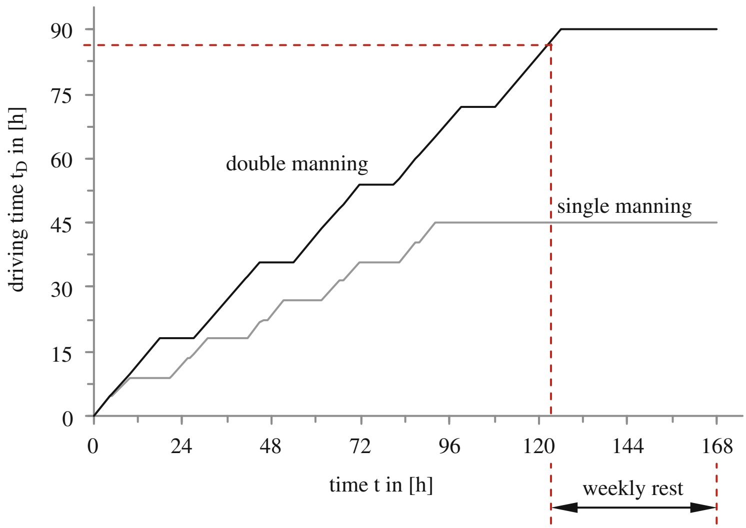

Fig. 2 Driving time of the compact scenarios for single and double manning

these restrictions will cause a slight decrease of the driving time efficiency of the compact scenario since driving time regulations allow an average efficiency of 45/137.75 (=32.67 %) per driving block while working time regulations restrict the efficiency to 48/168 (=28.57 %).

In order to analyze a second and more realistic scenario, we relax condition (a) by assuming normative driving and working conditions which usually are aspired by dispatchers in transportation companies. We presume that the weekly driving time is evenly spread over five working blocks summing up to the maximal allowed value for the weekly driving time and weekly working time. Consequently, 45 respectively 90 h of weekly driving time and 9 respectively 18 h for driving blocks are implemented for single manning respectively double manning. Relaxing condition (b) means that during the considered time horizon T waiting times and service operations might occur which have to be added to the elapsed time. The amount of waiting and service time is dependent on the type of transportation orders and the disposition of vehicles. This amount can vary a lot in dependence of the considered transportation scenario. In our scenario we assume (in accordance to the working time limitation for single manning) that the sum of waiting and service time amounts to 3 h for single manning and 6 h for double manning per week evenly spread over the working blocks. A relaxation of condition (c) which results in a typical situation for many carriers is to assume that all transportation will be done by five daily blocks within one calendar week.

In case of single manning, the above assumptions for the normative scenario imply an accumulated driving time of 9 h, two breaks of 0.75 h for two driving periods and a rest period of 13.5 (=24 − 9 − 1.5) hours for a single day. Consequently, the values for the total time needed for transportation fulfillment are:

$n - ct_s(h) = h + 0.75 \cdot \lfloor h/4.5 \rfloor + 13.5 \cdot \lfloor h/9 \rfloor + 48 \cdot \lfloor h/45 \rfloor$. For each daily cycle there are 9 h of driving and 15 complementary hours for replenishing a full day. The complement of 15 h is composed of two 45-minute-breaks, 0.6 h for waiting and service time, 11 h for a daily rest period and 3.4 h slack. Additionally, there is a time span of 48 h for completing an entire week (168 h). In case of double manning, we have to reserve 45 h for a mandatory weekly rest period, 36 h for four daily rest periods of 9 h duration, and 6 h for service and waiting time per week. Since we are considering a weekly schedule with 168 h duration, there is only a budget of 81 (=168 − 45 – 36 − 6) hours left for driving which is equally spread over five driving blocks with 16.2 h each. For each driving block we have to deposit a non-driving time of 10.2 h since we compute 9 h for a daily rest period and 1.2 (i.e. 6/5) hours for service and waiting time. For each weekly period we have to count 45 h (36 h in case that we deposit 9 h at the end of each driving block) after 81 h driving time. Consequently, $n - ct_d(h) = h + 10.2 \cdot \lfloor h/16.2 \rfloor + 36 \cdot \lfloor h/81 \rfloor$. The values of the functions $n - ct_s(h)$ and $n - ct_d(h)$ as well as the corresponding values for driving efficiency can easily by calculated, e.g. by spreadsheet software.

4 Comparison of the Fulfillment Costs for Single Manning and Double Manning

The main costs for transportation fulfillment are composed of the wages for drivers, the costs for the disposability and usage of vehicles, the costs for the consumed fuel and the road charge. We assume that the payment of drivers' wages is based on a day's rate. This is a reasonable assumption since, according to EC Regulation No 561/2006, drivers should not be paid, even in the form of a bonus or wage supplement, related to distances travelled and/or the amount of goods carried. For our cost determination we are considering vehicles which are heavy-duty trucks with 40 tons gross weight. In the EU, it is required for such vehicles that their drivers have a driver's license of class CE and, additionally, the drivers must have a certificate of competence allowing them to commercially drive vehicles of that size (BMJ 2011). Based on the judgment of practitioners, the monthly salary for drivers fulfilling the above conditions is assumed to be 2,700.00 € plus an employer's contribution of 20.85 %. For an average labor time of 21.6 days per month the day's rate for the driver amounts to 151 €. Concerning the type of vehicles, we come from a conventional combination of a tractor with semi-trailer. It is a widespread business practice for leasing companies that such vehicles are hired on a daily basis. The price for hiring a tractor on a daily basis is independent of the degree of deployment of the vehicle and in particular independent of the distance driven per day. That is why the daily leasing rate covers both, the fixed cost for the disposability and the variable costs for deploying the vehicle. The price is fluctuating and it ranges from 180.00 € per day to 245.00 € per day (Miet24.de-TGX 2012; Miet24.de-TGA440 2012) with an average value of 215.00 € per day plus VAT. The price for hiring a semi-trailer averagely amounts to 32.00 € per day plus VAT (Miet24.de-Stand-Sattel 2012; Miet24.de-Gard-Sattel 2012). Taken together, the price including VAT which has averagely been found out in the internet for leasing a tractor with semi-trailer sums up to 293.93 € per day. Furthermore, we assume a price of 1.40 € per liter diesel fuel and an average fuel consumption of 34 l per 100 km. This values result in a cost rate of 0.416 € per km. We assume the exclusive deployment of EURO V trucks with 5 axles. In Germany, the toll for such trucks amounts to 0.155 € per km (Maut-Tarife 2013). For long-haul trips it is reasonable that 80 % of the accomplished distances are driven on roads which are obliged to toll. This will result in a cost rate for the toll of 0.124 € per km. Summing up all considered costs, the deployment of a vehicle for one day and driving the vehicle d kilometers will cause costs according to the following function $c = 294 + 0.54 \cdot d$. The employment of a driver will account for 151 € per day.

Due to the above cost assumptions, the daily fixed costs add up to 445 € for a single manned vehicle and to 596 € for a double manned vehicle. Partially fractured days have to be fully paid since it is neither possible to get good tariffs for truck leasing on an hourly basis nor is it acceptable from a social point of view to reduce the driver's salary due to not fully occupied days. The additional costs for fuel and toll are identical for both, single and double manning. They account for 0.54 € per km. Since we are mainly considering the situation of long-haul trips on highways, we assume an average speed of 70 km per hour.

Now we can calculate the functions for the total costs of transportation ($norm - \cos t_s(h)$ respectively $norm - \cos t_d(h)$) in dependence of the elapsed time needed for fulfilling a given transportation task and the distance driven during transportation fulfillment. The elapsed time is given by $n - ct_s(h)$ and $n - ct_d(h)$, respectively. The distance can directly be computed since we know the duration of driving and the average speed. Just as in Sect. 3, we consider the situation of a single vehicle which is used for the execution of a transportation task. We contrast the situation of single manning with the situation of double manning for the normative scenario. Figure 3 shows the functions $norm - \cos t_s(d)$ for single manning and $norm - \cos t_d(d)$ for double manning for the total cost of transportation fulfillment in dependence of the total travel distance d.

Figure 3 demonstrates that it is most profitable to perform transportation tasks requiring less than 9 h driving by single manning. In case of normative conditions, tasks requiring between 9 and 16 h driving time are most profitably performed by double manning while single manning is most profitable for tasks between 16 and 18 h driving time. Double manning is more beneficial from 18.5 to 32 h. The total transportation costs of both operating modes are almost equal if the required driving time ranges between 32.5 and 36. For transportation tasks with more than 45 h driving under normative conditions, double manning is more cost efficient than single manning.

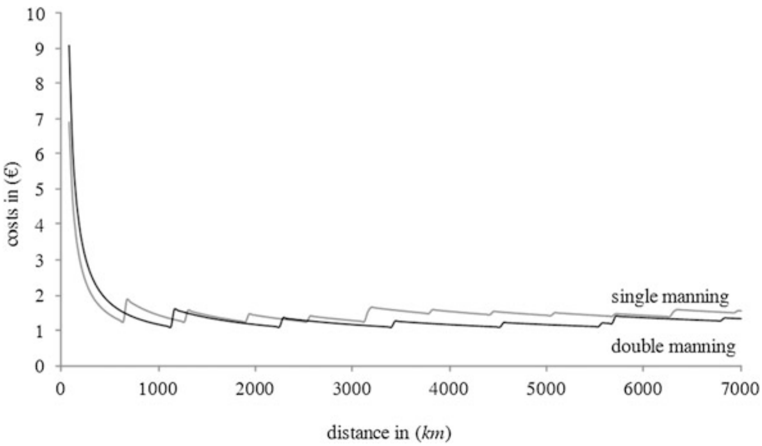

Fig. 3 Costs for the normative scenarios for single and double manning

5 Conclusions and Future Research

The decision whether single manning or double manning is more advantageous for the execution of a given transportation task depends on two factors: (1) the length of vehicle and driver deployment and (2) the driving profile. The length of deployment is specified by the driving hours needed for transportation fulfillment. The driving profile is characterized by the portions of driving, waiting, service, rest and idle time which are all together contributing to the total execution time. In order to analyze the characteristics of single manning and double manning, two particular profiles specified by a compact and normative scenario are considered. For these scenarios, the values for driving efficiency can be calculated in dependence of the length of deployment. Based on a proposed cost function the total costs for transportation have been determined for the normative scenario and have been compared for single manning and double manning. The results of this comparison, and particularly the proposed evaluation method, constitute a powerful support for inevitable decisions on the choice of appropriate operating modes for transportation fulfillment. In future research a sensitivity analysis will be performed in order to analyze the effect of varying values for essential variables (e.g. amount of waiting and service time, driver wages, fuel prize, fee for road charge, prize for vehicle leasing) on the outcome of the comparison.

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A Bicriteria Skill Vehicle Routing Problem with Time Windows and an Application to Pushback Operations at Airports

Silvia Schwarze and Stefan Voß

Abstract In the Skill Vehicle Routing Problem (Skill VRP), each vehicle is assigned a skill, representing its qualification. A vehicle is able to serve a node if its skill is sufficiently large regarding the skill requirement of the node. In this paper, we move the focus of the cost-oriented Skill VRP to time-related aspects. To that end, we add time window restrictions and, secondly, design an alternative, time-oriented, objective function. This problem extension is motivated by an application in the airport ground control where time issues play a major role. We present a mathematical model and carry out an extensive numerical study that includes load-balancing aspects as well as a multi-objective analysis.

1 Introduction

Consider a directed graph $G = (V, E)$ with nodes $i \in V$ and edges $(i,j) \in E$. Moreover, let node $0 \in V$ be the unique source node. The *Skill Vehicle Routing Problem* (*Skill VRP*) is a variant of the basic Vehicle Routing Problem (VRP), where each vehicle $t \in T$ has a certain skill level $\hat{s}_t \geq 0$ and each node $i \in V \setminus \{0\}$ requests a skill $s_i \geq 0$. A vehicle t is allowed to serve a node i if and only if $\hat{s}_t \geq s_i$ is satisfied. For each edge $(i,j) \in E$ we denote by $c_{ij}^t \geq 0$ the vehicle-dependent routing cost. Typically, $c_{ij}^t \geq c_{ij}^{\bar{t}}$ does hold for $t, \bar{t} \in T$ with $\hat{s}_t \geq \hat{s}_{\bar{t}}$ to reflect that a higher-skilled vehicle t is more expensive than a lower-skilled one. The objective of the Skill VRP is to minimize the total routing costs. There are no other restrictions like capacities or time windows given for the Skill VRP. Note that the Skill VRP is a variant of the *Site-Dependent VRP*; see, e.g., Cordeau and Laporte (2001).

S. Schwarze (✉) · S. Voß
Institute of Information Systems, University of Hamburg, Von-Melle-Park 5, 20146 Hamburg, Germany
e-mail: silvia.schwarze@uni-hamburg.de

S. Voß
e-mail: stefan.voss@uni-hamburg.de

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Applications of the Skill VRP are given, e.g., by service technician routing or assignment of health care personnel (Cappanera and Scutellà 2013). The qualifications of staff members, like education or experience, are indicated by skill values. Dependent on the particular requirements at the customer, for instance given by the complexity of a repair job, node skill requirements are defined. The Skill VRP has been introduced by Cappanera et al. (2011) who developed and compared different mathematical formulations. Later, Schwarze and Voß (2013) discussed load balancing and resource utilization aspects of the Skill VRP. Alternative approaches minimizing the maximum routing costs are proposed. Finally, Cappanera et al. (2013) extended the model by introducing skill sets. In this work, motivated by an application in the airline industry, we extend the Skill VRP by moving the focus to time-related issues. First, by adding time windows, we obtain the *Skill VRP with Time Windows* (*Skill VRP-TW*). Moreover, as an alternative for the cost-oriented objective, we introduce a new, time-oriented, objective function.

Part of the ground operations at an airport are *pushback operations*. During pushback, airplanes are moved backwards to leave the gate and to proceed to the taxiways. By technical reasons and to avoid accidents or damages to the terminal buildings it is not feasible for airplanes to move backwards using their own turbines. Instead, *tugs*, or, *pushback tractors*, take over the pushback operations. Assume that we have a fleet of tugs, where each tug has a certain skill. Moreover, we have a set of pushback operations to be carried out, each of them within a certain time window, given by the flight plan restrictions as well as the slot definition provided by control authorities. In addition, each pushback operation requires a minimum tug skill, depending on the size of the aircraft. The task is to assign tugs to pushback operations and to generate tours such that time windows as well as skill constraints are satisfied. This setting can be modeled as a Skill VRP-TW. As higher-skilled tugs create higher operational costs, a pure cost-oriented objective, namely *minimize total routing cost* is considered. However, in terms of obtaining a stable flight plan, *minimize the sum of completion times* plays an important role. Related research is presented by Khadilkar and Balakrishnan (2012) who discuss the option of delaying pushbacks to obtain positive effects on the congestion on taxiways. Atkin et al. (2013) discuss pushback activities within a broader context and include, e.g., variable take-off times and positions of aircrafts. However, the assignment of pushback vehicles is not addressed. Moreover, see, e.g., Andreatta et al. (2014) for airport ground operations in general.

In this paper, we develop a mathematical model for the Skill VRP-TW and apply it to the problem of assigning tours to pushback vehicles at airports. In a numerical study, we provide computational results regarding the two objective functions. The numerical study is twofold. First, in order to understand the effects of the objective functions on load balancing and resource utilization, we consider the two objectives separately and compare the corresponding results. Second, we carry out a simultaneous analysis for both objective functions by addressing multi-objective approaches. To detect parts of the Pareto front, we apply different multi-objective optimization techniques.

2 Preliminaries

In this section, we prepare definitions necessary for carrying out a multi-objective analysis, see Ehrgott (2005) for details. Let $p \geq 1$ be the number of considered objective functions. Consider the following problem

$$f(x) = \big(f_1(x), \ldots, f_p(x)\big) \rightarrow \text{Min} \quad \text{s.t.}\, x \in \mathcal{X} \tag{1}$$

with $\mathcal{X}$ being the set of feasible solutions. In order to solve (1) we define the notions of (weakly) efficient solutions. Let $y^1, y^2 \in \mathbb{R}^p$, then we denote $y^1 \leq y^2$ if for all $k = 1, \ldots, p$ we have that $y^1_k \leq y^2_k$ and $y^1 \neq y^2$ does hold. Moreover, we denote $y^1 < y^2$ if $y^1_k < y^2_k$ is satisfied for all $k = 1, \ldots, p$. Finally $y^1 \leqq y^2$ is denoted if $y^1_k \leq y^2_k$ does hold for all $k = 1, \ldots, p$. Consider two solutions x^1, $x^2 \in \mathcal{X}$. We say x^1 dominates x^2 if $f(x^1) \leq f(x^2)$. A feasible solution $\hat{x} \in \mathcal{X}$ is called *efficient* if there is no $x \in \mathcal{X}$ such that $f(x) \leq f(\hat{x})$ does hold, i.e., if there is no dominating solution. Analogously, $\hat{x} \in \mathcal{X}$ is called *weakly efficient* if there is no $x \in \mathcal{X}$ such that $f(x) < f(\hat{x})$ is satisfied. The *efficient set* (*weakly efficient set*) $\mathcal{X}_E$ $(\mathcal{X}_{wE})$ is the set of all efficient (weakly efficient) solutions $\hat{x} \in \mathcal{X}$. It holds that $\mathcal{X}_E \subseteq \mathcal{X}_{wE}$. Let $\mathcal{Y} = \{f(x) \in \mathbb{R}^p : x \in \mathcal{X}\}$ be the image of the set $\mathcal{X}$ with respect to a mapping by the objective functions. Then, the set $\mathcal{Y}_E = \{f(\hat{x}) \in \mathcal{Y} : \hat{x} \in \mathcal{X}_E\}$ in the criterion space relates to efficient solutions and is called the *Pareto front*. Within this work, we address four approaches to determine (weakly) efficient points. See Ehrgott (2005) for an overview on further methods.

In order to compare two solutions x^1 and x^2 under *lexicographic optimality*, the objective values $f_k(x^1)$ and $f_k(x^2)$ are analyzed separately for increasing $k = 1, 2, \ldots, p$. Let $k^* = \min\{k : f_k(x^1) \neq f_k(x^2)\}$ be the smallest k for that the objective function values f_k differ. Then we define $f(x^1) <_{\text{lex}} f(x^2)$ if $f_{k^*}(x^1) < f_{k^*}(x^2)$ is satisfied. A solution $\hat{x} \in \mathcal{X}$ is called *lexicographically optimal* if there is no $x \in \mathcal{X}$ such that $f(x) <_{\text{lex}} f(\hat{x})$ does hold. A lexicographically optimal solution $\hat{x}$ is efficient, i.e., we have $\hat{x} \in \mathcal{X}_E$ (Ehrgott 2005). Alternatively, scalarization techniques modify (1) such that $f(x)$ is replaced by a scalar. The ϵ-*constraint method* is such an approach where only a single objective $f_j(x)$, $j \in \{1, \ldots, p\}$ is minimized. For the objectives $k \neq j$, bounds $\epsilon_k \in \mathbb{R}$ are fixed and corresponding constraints are added to the problem. We obtain

$$\min f_j(x) \quad \text{s.t. } x \in \mathcal{X},\ f_k(x) \leq \epsilon_k \ \ \forall k \neq j. \tag{2}$$

Consider an arbitrary $j \in \{1, \ldots, p\}$ and let $\hat{x}$ be optimal for (2). Then we have $\hat{x} \in \mathcal{X}_{wE}$ (Ehrgott 2005). The *hybrid method* is another scalarization method, that guarantees even efficient solutions $\hat{x} \in \mathcal{X}_E$ by combining the ϵ-constraint method with the *weighted sum method*. The objective function of (2) is replaced by a weighted sum over all objectives. Let $\lambda_k > 0$ for all $k = 1, \ldots, p$. Then we have

$$\min \sum_{k=1}^{p} \lambda_k f_k(x) \quad \text{s.t. } x \in \mathcal{X}, \quad f_k(x) \le \epsilon_k \; \forall k = 1, \ldots, p. \tag{3}$$

Finally, the *compromise solution* is detected by considering

$$y_k^I = \min f_k(x) \quad \text{s.t. } \; x \in \mathcal{X} \tag{4}$$

for $k = 1, \ldots, p$. The point $y^I = (y_1^I, \ldots, y_p^I)$ is called the *ideal point* of (1). For any solution $x \in \mathcal{X}$ we have that $y^I \leqq f(x)$ is satisfied. However, the ideal point is not necessarily within $\mathcal{Y}$, e.g., if the objective functions are conflicting. The compromise solution minimizes the distance to the ideal point. If the l_∞-norm is addressed, the following problem has to be solved.

$$\min_{x \in \mathcal{X}} \max_{k=1,\ldots,p} (f_k(x) - y_k^I) \tag{5}$$

If $\hat{x}$ is an optimal solution for (5) then $\hat{x} \in \mathcal{X}_{wE}$ (Ehrgott 2005). Moreover, $\hat{x} \in \mathcal{X}_E$ holds if $\hat{x}$ is a unique solution of (5).

3 Skill Vehicle Routing Problem with Time Windows

We next present a mathematical programming formulation for the Skill VRP-TW as an extension of *StrongDistTechDis* (Cappanera et al. 2011). Let $\tau_i = \{t \in T : s_i \le \hat{s}_t\}$ be the set of feasible vehicles for node $i \in V \backslash \{0\}$. Furthermore, let $c_{ij}^t \ge 0$ be the time needed by t to traverse edge (i, j) and let $a_i, b_i \ge 0$ be lower and upper bounds of the time window for node i. Finally, let the operation time $o_i \ge 0$ be the time needed to carry out the service at i and M be a large number.

We have four classes of decision variables. First, for each $(i,j) \in E$ and each $t \in (\tau_i \cap \tau_j)$, let x_{ij}^t equal one, if (i, j) belongs to the tour of t and zero otherwise. Second, for each $(i,j) \in E$ with $j \ne 0$, for each $k \in V \backslash \{0\}$ and for each $t \in (\tau_i \cap \tau_j \cap \tau_k)$ variables y_{ij}^{kt} denote a flow from depot node 0 to node k that runs over (i, j) and is served by t. Third, for each node $k \in V \backslash \{0\}$ and each $t \in \tau_k$ we have variable $\bar{y}_k^t$ equal to one if k is served by t and $\bar{y}_k^t = 0$ otherwise. Finally, $w_k^t \ge 0$ denotes the time vehicle t starts the service at k. For the subsequent model, we assume that the graph $G = (V, E)$ is complete. The Skill VRP-TW is then given as

$$\min f_1(x, y, \bar{y}, w) = \sum_{(i,j) \in E} \sum_{t \in (\tau_i \cap \tau_j)} c_{ij}^t x_{ij}^t \tag{6}$$

$$\sum_{i \in V \backslash \{j\}} \sum_{t \in (\tau_i \cap \tau_j)} x_{ij}^t = 1 \quad \forall j \ne 0 \tag{7}$$

$$\sum_{i \in V \setminus \{j\}: t \in \tau_i} x_{ij}^t = \sum_{i \in V \setminus \{j\}: t \in \tau_i} x_{ji}^t \quad \forall j \neq 0;\ t \in \tau_j \tag{8}$$

$$\sum_{\substack{(i,j) \in E: \\ i \neq k, j \neq 0 \\ t \in (\tau_i \cap \tau_j)}} y_{ij}^{kt} - \sum_{\substack{(j,i) \in E: \\ i \neq 0, j \neq k \\ t \in (\tau_i \cap \tau_j)}} y_{ji}^{kt} = \begin{cases} \bar{y}_k^t & \text{if} \quad i = 0 \\ 0 & \text{if} \quad i \neq 0, k \\ -\bar{y}_k^t & \text{if} \quad i = k \end{cases} \quad \forall k \neq 0;\ t \in \tau_k \tag{9}$$

$$\sum_{t \in \tau_k} \bar{y}_k^t = 1 \quad \forall k \neq 0 \tag{10}$$

$$y_{ij}^{kt} \leq x_{ij}^t \quad \forall (i,j) \in E;\ k \neq 0, i;\ j \neq 0;\ t \in (\tau_\mathrm{i} \cap \tau_\mathrm{j} \cap \tau_\mathrm{k}) \tag{11}$$

$$w_i^t + o_i + c_{ij} - w_j^t \leq M\left(1 - x_{ij}^t\right) \quad \forall (i,j) \in E: j \neq 0;\ t \in (\tau_i \cap \tau_j) \tag{12}$$

$$a_k \bar{y}_k^t \leq w_k^t \leq b_k \bar{y}_k^t \quad \forall k \neq 0;\ t \in \tau_k \tag{13}$$

$$\sum_{j:(0,j) \in E, t \in \tau_j} x_{0j}^t \leq 1 \quad \forall t \tag{14}$$

$$x_{ij}^t \in \{0,1\} \quad \forall (i,j) \in E;\ t \in (\tau_i \cap \tau_j);\quad \bar{y}_k^t \in \{0,1\},\ w_k^t \geq 0 \quad \forall k \neq 0;\ t \in \tau_k \tag{15}$$

$$y_{ij}^{kt} \geq 0 \quad \forall (i,j) \in E: j \neq 0;\ k \neq 0, i;\ t \in (\tau_i \cap \tau_j \cap \tau_k) \tag{16}$$

The objective function (6) minimizes the total routing costs. Constraints (7)–(11) are given in StrongDistTechDis (Cappanera et al. 2011). In particular, (7) ensure that each node is visited by a suitable vehicle. Constraints (8) require that the vehicles travel on tours whereas (9) establish flow from depot node 0 to nodes k. Constraints (10) ensures the assignment of vehicles to customer nodes and (11) set up a link between the flow and the tours of the vehicles. Constraints (12)–(14) ensure feasibility regarding time windows. More specifically, (12) ensure the correct computation of the service starting times $\mathrm{w}_\mathrm{k}^\mathrm{t}$ whereas (13) support a correct implementation of the time windows. Finally, (14) make sure that each vehicle is allowed to carry out at most a single tour and prevents infeasible solutions where duplicates of one vehicle are running on different tours at the same time.

In order to move the focus from the pure-cost oriented approach, see (6), to a time-oriented aspect, we introduce a second objective function by considering a minimization of the sum of completion times. As the completion time for node k is given as $w_k^t + o_k$ if vehicle t serves node k, and as moreover, the operation times o_k are constant, we have the following objective function.

$$\min f_2(x, y, \bar{y}, w) = \sum_{k \neq 0;\, t \in \tau_k} w_k^t \tag{17}$$

As G is assumed to be complete, in an optimal solution a vehicle t will never visit a node i that is not served by t. Thus for each k, w_k^t is positive for at most one vehicle t. Thus, there is no need to include the variable $\bar{y}_k^t$ into (17).

4 Numerical Study

The numerical study consists of two main parts. First, in order to compare the two types of objective function we study their effect on load balancing and resource utilization. To that end, we consider the objectives separately and compute optimal solutions for the single-criteria cases. Secondly we undertake a joint analysis of both objective functions by applying multi-objective methods leading to a (partial) representation of the Pareto front. We designed test instances based on an airport with 17 gates and six tugs. The vehicles' skills are $\hat{s}_1 = \hat{s}_2 = 1$, $\hat{s}_3 = \hat{s}_4 = 2$, and $\hat{s}_5 = \hat{s}_6 = 3$. At each gate there is a single airplane that requests a pushback operation with a fixed skill requirement. We have three airplanes that require skill 1, seven airplanes requiring skill 2 and seven airplanes requiring skill 3. We designed ten test instances by choosing random time windows. For instances *inst_100_i* (*inst_300_i*), $i = 1, \ldots, 5$, the time windows start between time units 0 and 100 (0 and 300) and each time window has a constant length of 25 time units.

Recall that we denote by $f_1(x, y, \bar{y}, w)$ and $f_2(x, y, \bar{y}, w)$ the objective function values obtained by addressing (6) and (17) of the Skill VRP-TW, respectively. In order to keep the notation clear, for the subsequent analysis, we use x as argument for the objective functions. Table 1 consists of two main parts corresponding to (6) and (17). Columns $f_1(x^1)$ and $f_2(x^2)$ give the optimal objective function values, columns *LP* give the objective value of the respective LP-relaxation and columns *gap*(%) give the integrality gap in percent. Moreover, columns *T*(*s*) give the computational time in seconds, carried out on an Intel® Core™ i3-2100 CPU with 3.1 GHz and 4 GB RAM using IBM ILOG CPLEX 12.4. Columns $f_2(x^1)$ [in part Minimize $f_1(x)$] and $f_1(x^2)$ [in part Minimize $f_2(x)$] report the function values of the alternative (not minimized) objective. Columns $\Delta(\%)$ give the deviation of $f_2(x^1)$ from its optimal solution value $f_2(x^2)$ [similarly for $f_1(x^2)$ and $f_1(x^1)$].

Let x^1 and x^2 be optimal under $f_1(x)$ and $f_2(x)$, respectively. First, it can be observed from Table 1 that if the total routing costs $f_1(x)$ are minimized, then the summarized completion times $f_2(x^1)$ are at an average 11.9 % higher than regarding their optimal solution value $f_2(x^2)$. However, in the reverse case there is an increase of the total routing costs $f_1(x)$ average 95.9 % if one minimizes summarized completion times. That is, if we minimize the sum of completion times, we have to

Table 1 Single-criteria problems under objectives $f_1(x)$ and $f_2(x)$

Instance	Minimize $f_1(x)$ (6)						Minimize $f_2(x)$ (17)					
	$f_1(x^1)$	LP	Gap(%)	T(s)	$f_2(x^1)$	Δ(%)	$f_2(x^2)$	LP	Gap(%)	T(s)	$f_1(x^2)$	Δ(%)
inst_100_1	312	186	40.4	4,058	1,171	15.4	981	975	0.6	555	720	130.8
inst_100_2	318	186	41.5	1,839	1,166	24.0	906	875	3.3	2,474	622	95.6
inst_100_3	306	186	39.2	1,254	1,180	13.9	1,002	975	2.6	2,926	624	103.9
inst_100_4	288	186	35.4	4,126	1,007	16.0	834	800	3.9	28,271	634	120.1
inst_100_5	254	186	26.8	1,177	954	14.3	801	750	6.1	3,360	582	129.1
Average			36.7	2,491		16.7			3.3	7,517		115.9
inst_300_1	328	186	43.3	1,899	2,355	5.1	2,206	2,200	0.3	376	702	114.0
inst_300_2	338	186	45.0	1,495	3,034	7.9	2,779	2,775	0.1	396	600	77.5
inst_300_3	372	186	50.0	2,857	2,014	12.4	1,758	1,725	1.8	544	556	49.5
inst_300_4	382	186	51.3	1,616	2,929	7.4	2,692	2,675	0.6	1,365	650	70.2
inst_300_5	382	186	51.3	5,336	2,784	2.8	2,675	2,650	0.9	184	642	68.1
Average			48.2	2,640		7.1			0.7	573		75.9
Total aver.			42.4	2,566		11.9			2.0	4,045		95.9

Table 2 Load balancing and skill utilization under objective $f_1(x)$ and $f_2(x)$

Instance	Minimize (6)					Minimize (17)				
	#os	os(%)	# by veh.skill			#os	os(%)	# by veh.skill		
			1	2	3			1	2	3
inst_100_1	9	52.9	1	0	16	1	5.9	3	6	8
inst_100_2	9	52.9	1	0	16	3	17.6	3	4	10
inst_100_3	10	58.8	0	1	16	4	23.5	2	5	10
inst_100_4	9	52.9	1	0	16	2	11.8	3	5	9
inst_100_5	7	41.2	0	5	12	3	17.6	2	6	9
Average	8.8	51.8	0.6	1.2	15.2	2.6	15.3	2.6	5.2	9.2
inst_300_1	9	52.9	0	2	15	7	41.2	2	2	13
inst_300_2	3	17.6	2	5	10	6	35.3	2	2	13
inst_300_3	10	58.8	0	1	16	4	23.5	3	3	11
inst_300_4	8	47.1	2	0	15	4	23.5	2	5	10
inst_300_5	6	35.3	0	5	12	4	23.5	2	5	10
Average	7.2	42.4	0.8	2.6	13.6	5.0	29.4	2.2	3.4	11.4
Total aver.	8	47.1	0.7	1.9	14.4	3.8	22.4	2.4	4.3	10.3

accept a strong increase of total routing costs. Note that these results have to be considered with caution as, so far, we do not apply multi-objective techniques and the generated solutions might be not efficient. Our subsequent multi-objective study indeed reveals that, dominating solutions can be found, see Tables 3, 4, 5 and 6. Second, it turns out that the integrality gap is much smaller for objective $f_2(x)$. However, this does not always lead to shorter computational times. Especially for the instance set *inst_100_i* with tighter time frame, computational times are at an average higher if we address $f_2(x)$ [compared to $f_1(x)$].

Table 2 illustrates load balancing and resource utilization and contains two main parts regarding $f_1(x)$ and $f_2(x)$. A service at node i is *over-skilled* if $\hat{s}_t > s_i$ does hold for t. Columns *#os* (*os*(%)) give the over-skilled services in absolute numbers (percent). By tendency, high values in these columns indicate bad resource utilization. Columns *# by veh.skill* give the absolute value of services carried out by vehicles, summed by vehicles' skills. In terms of resource utilization, at an average one obtains better results (22.4 % over-skilled services) when minimizing the sum of completion times $f_2(x)$ compared to the minimization of total routing costs $f_1(x)$ (47.1 % over-skilled services). Also it turns out that the workload is better balanced for $f_2(x)$ as vehicles t with skill $\hat{s}_t = 3$ carry out average 10.3 services [14.4 for $f_1(x)$]. Generally, it can be noticed that both previously described effects are more evident if we only consider the instance set *inst_100_i*.

The multi-objective is carried out exemplarily for *inst_100_1* and *inst_300_1*. We start by a lexicographic analysis. The efficient solutions obtained provide ranges of objective function values that contain efficient solutions. In order to determine further efficient solutions we apply the hybrid method afterwards and generate weakly efficient solutions using the ε-constraint method. Finally, we compute a

Table 3 Lexicographic optimality

	inst_100_1		*inst_300_1*	
	$f_1 \to f_2$	$f_2 \to f_1$	$f_1 \to f_2$	$f_2 \to f_1$
$f_1(x)$	312	588	328	490
$f_2(x)$	1,067	981	2,230	2,206

compromise solution by using the ideal point as reference. To carry out the lexicographic analysis, we consider the two possible orders, namely $f_1 \to f_2$ and $f_2 \to f_1$. The results are presented in Table 3.

Table 3 gives two feasible and efficient alternatives for each instance. Moreover, we can immediately see that the corresponding solutions provided in Table 1 are not efficient. That is, the alternative objective found through the single-criteria approach can be improved, i.e., we have non-unique solutions in the single-criteria case. Thus it is advisable to implement multi-objective approaches to improve the overall situation. Moreover, from Table 3 we can directly yield the ideal points $y^{I100} = (312, 981)$ and $y^{I300} = (328, 2{,}206)$.

We use the ranges of objective function values given in Table 3 as input for the scalarization methods. We divide the range $981 \leq f_2(x) \leq 1067$ into ten equidistant intervals and use the interval-borders to assign eleven alternative values of ϵ_2, see Table 4. In order to set up a hybrid method, we fix the weights $\lambda_1 = \lambda_2 = 1$ and obtain the objective function "min $f_1(x) + f_2(x)$".

See Table 4 for the results of the hybrid method and the ϵ-constraint method, both using an additional constraint $f_2(x) \leq \epsilon_2$. Note that the ϵ-constraint method yields only weakly efficient solutions which, e.g., can be observed for interval 3. Analogously, the scalarization techniques can be carried out by bounding the objective $f_1(x)$. We give the results of the ϵ-constraint method in Table 5.

Finally, computing the compromise solution for *inst_100_1*, we obtain $f(x^{C100}) = (360, 1{,}029)$. Note that this solution is weakly efficient and already

Table 4 Instance *inst_100_1*: hybrid method and ϵ-constraint method with bound on $f_2(x)$

Interval	0	1	2	3	4	5	6	7	8	9	10
ϵ_2	981	989.6	998.2	1,006.8	1,015.4	1,024	1,032.6	1,041.2	1,049.8	1,058.4	1,067
$f_1(x^H)$	588	500	424	400	384	360	360	360	332	316	316
$f_2(x^H)$	981	989	998	1,004	1,009	1,024	1,024	1,024	1,048	1,053	1,053
$f_1(x^\epsilon)$	588	500	424	400	384	360	356	356	332	316	312
$f_2(x^\epsilon)$	981	989	998	1,006	1,015	1,024	1,032	1,041	1,049	1,055	1,067

Table 5 Instance *inst_100_1*: ϵ-constraint method with bound on $f_1(x)$

Interval	0	1	2	3	4	5	6	7	8	9	10
ϵ_1	312	339.6	367.2	394.8	422.4	450	477.6	505.2	532.8	560.4	588
$f_1(x^\epsilon)$	312	332	364	392	416	450	472	504	522	550	588
$f_2(x^\epsilon)$	1,067	1,048	1,023	1,007	1,002	998	992	989	987	983	981

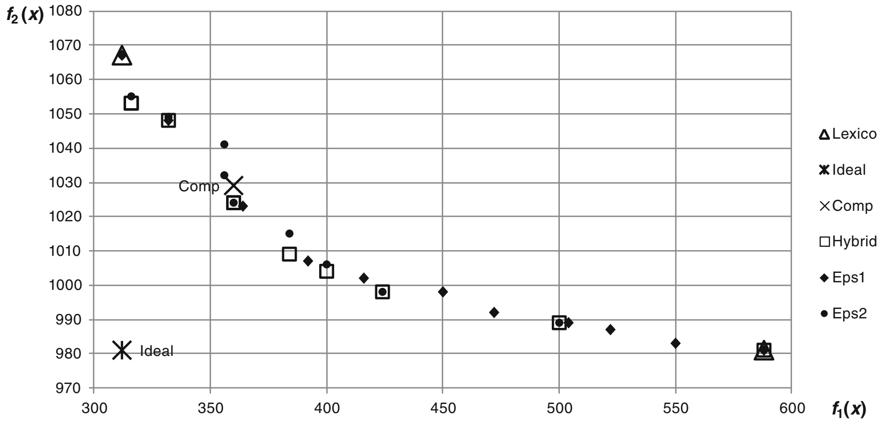

Fig. 1 Instance *inst_100_1*: representation of (weakly) efficient solutions in $\mathcal{Y}$

dominated by the solution given in Table 4, interval 5. Figure 1 illustrates the solutions in the criterion space. The points *Eps1* (*Eps2*) relate to the ϵ-constraint method if $f_1(x)$ ($f_2(x)$) is bounded by ϵ_1 (ϵ_2). It can be observed that the ϵ-constraint method yields solutions that are in some cases even efficient, namely if they equal a hybrid or a lexicographic solution. On the other hand, if the point lies on a horizontal or vertical line with other dominating points then it is obvious that such a solution cannot be efficient. As an example, see $f(x^1) = (450, 998)$ which is dominated by $f(x^2) = (424, 998)$. However, there are points like $f(x^3) = (472, 992)$, found using *Eps1*, for that no dominating solution has been detected yet. For those cases it is not clear whether this solution is efficient or only weakly efficient.

The analogous results for *inst_300_1* are given in Tables 6, 7, and Fig. 2. The respective compromise solution is $f(x^{C300}) = (340, 2{,}226)$ which is equal to a solution found using the hybrid approach, i.e., x^{C300} is proven to be efficient.

A comparison of Figs. 1 and 2 reveals that for *inst_100_1* we have nine points that are proven to relate to efficient solutions. That exceeds the value for *inst_300_1* where only five such points are found. For this instance, the hybrid method delivered many multiple solutions. Moreover, for *inst_300_1* more pairs of dominating solutions have been detected which gives an impression of the weakly efficient parts of $\mathcal{Y}$. These results emphasize the importance of multi-objective approaches that allow exploiting the potential of all objectives.

Table 6 Instance *inst_300_1:* hybrid method and ϵ-constraint method with bound on $f_2(x)$

Interval	0	1	2	3	4	5	6	7	8	9	10
ϵ_2	2,206	2,208.4	2,210.8	2,213.2	2,215.6	2,218	2,220.4	2,222.8	2,225.2	2,227.6	2,230
$f_1(x^H)$	490	490	490	392	392	372	372	372	372	340	328
$f_2(x^H)$	2,206	2,206	2,206	2,212	2,212	2,216	2,216	2,216	2,216	2,226	2,230
$f_1(x^\epsilon)$	490	490	486	392	392	372	372	372	372	340	328
$f_2(x^\epsilon)$	2,206	2,208	2,210	2,213	2,214	2,218	2,220	2,222	2,225	2,227	2,230

Table 7 Instance *inst_300_1*: ϵ-constraint method with bound on $f_1(x)$

Interval	0	1	2	3	4	5	6	7	8	9	10
ϵ_1	328	344.2	360.4	376.6	392.8	409	425.2	441.4	457.6	473.8	490
$f_1(x^\epsilon)$	328	340	352	372	392	396	420	432	432	420	490
$f_2(x^\epsilon)$	2,230	2,226	2,226	2,216	2,212	2,212	2,212	2,212	2,212	2,212	2,206

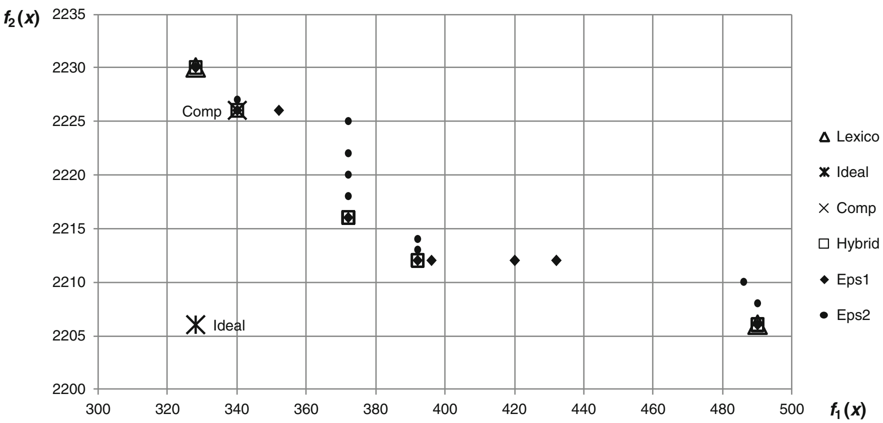

Fig. 2 Instance *inst_300_1*: representation of (weakly) efficient solutions in $\mathcal{Y}$

5 Conclusions

In this work, we extended the Skill VRP by adding time windows and a new objective function regarding completion times. We presented a mathematical model and described an application within airport ground handling. The numerical experiments included two instance classes with varying time frame. We studied single-objective problems and a multi-objective version and detected efficient solutions. It turned out that the time-related objective leads to reduced integrality gaps. However, this positive effect does not carry over to the computational times in general. Moreover, if a pure cost-oriented objective is addressed, the increase in the time-related objective (with respect to its optimal value) is smaller than the increase of the cost-oriented objective in the reverse case. In terms of load balancing and resource utilization, our numerical studies showed better results for the time-oriented objective. Finally, the multi-objective analysis reveals that we have to deal with many weakly efficient but not efficient solutions. This is an indicator that it is worthwhile to carry out a multi-objective approach in order to exploit the possibilities of the alternative objective. In order to approach larger problem instances, it will be recommended for future work to focus on heuristics for the Skill VRP-TW and for the general Skill VRP. Moreover, to extend the study on load balancing, a suitable objective, like “minimize maximal load” can be included into the analysis.

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Advantages of Decoupling Containers and Vehicles at Customer Locations

Sebastian Sterzik, Herbert Kopfer and Julia Funke

Abstract The option to leave containers at customer locations (decoupling) and pick them up later by any other vehicle is analyzed for hinterland transportation scenarios. Several test instances are considered in order to estimate the positive effect of decoupling containers and vehicles. The solutions of the proposed test instances are determined by a tabu search approach for hinterland container transportation which includes vehicle routing and scheduling and empty container repositioning simultaneously. The impact of the width of time windows on the frequency and profitability of decoupling containers is analyzed by considering data sets with tight and wide time windows. Additionally, solutions for the minimization of travel distances and the vehicles' total operating time are compared and opposed to solutions for cost minimization. The computational results show that the option of decoupling containers and vehicles leads to improved solutions regardless of the underlying objective function.

1 Introduction

Hinterland container transportation deals with the service of receivers or shippers with full and empty containers by trucking companies in seaport hinterland regions. Although hinterland container transportation problems include the field of vehicle routing and scheduling as well as empty container repositioning, solution methods in the literature mostly focus on just one of these two fields (see e.g. Braekers et al. 2011). As a consequence, the interdependency of vehicles as active transportation entities, which are able to move autonomously, and containers as passive transportation entities, which have to be moved by vehicles (Meisel and Kopfer 2014), is neglected and leads to suboptimal deployments of vehicles and containers.

S. Sterzik · H. Kopfer (✉) · J. Funke
Faculty 7, Business Studies & Economics, Chair of Logistics,
Wilhelm-Herbst-Str. 5, 28359 Bremen, Germany
e-mail: kopfer@uni-bremen.de

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The importance of this interdependency becomes obvious if the service of shipper or receiver customers is regarded. If customers have the possibility to pick up delivered containers from trucks by means of van carriers, reach stackers or lifting ramps, trucking companies can leave an empty/full container at a customer location until it is loaded/unloaded. In this case, trucks do not have to wait until containers are loaded/unloaded and can leave the customer locations for different tasks. The loaded or unloaded containers can be picked up later by any other vehicle. In the literature, the opportunity to leave a container at a customer location is usually neglected; i.e. vehicles and containers are coupled during the entire tour assigned to them and are decoupled only at terminals or depots. Hence, a certain container is moved by a certain vehicle from its source to its sink and cannot be left for a different vehicle. Obviously, neglecting the option of decoupling at customer locations results in decreasing flexibility and increasing expenses for the operating trucking companies.

In this contribution, we explicitly allow the decoupling of containers and vehicles at all customer locations and seek to analyze the benefits of the additional flexibility given by time windows of different size. Test instances with tight and wide customer time windows are solved in order to analyze the effects on the efficiency of transportation. For solving the presented test instances, a heuristic approach for hinterland container transportation is applied which includes vehicle routing and scheduling as well as empty container repositioning. By means of the computational experiments presented in this paper the benefit of being able to decouple containers and vehicles at customer locations is demonstrated. Solutions for the minimization of travel distances and the vehicles' total operating time are compared and opposed to solutions for cost minimization.

2 Problem Description

The proposed problem is based on the Multi-Company Inland Container Transportation problem (MCICT; Sterzik and Kopfer 2012) which defines a hinterland container transportation scenario where several trucking companies serve their customer bases. Thereby, the vehicles of a company start and end their routes at the company's depot. Adopting all main characteristics of the MCICT the following problem focuses on only one trucking company operating from several depots and is, therefore, defined as the One-Company Inland Container Transportation Problem (OCICT).

In a local region full and empty containers have to be moved between different locations by the operating trucking company. In detail, we consider a hinterland of at least two terminals, a number of customers and several depots. At every depot, a certain number of vehicles can be parked and, moreover, the depots are defined as repositories for a large number of empty containers. Regarding the terminals, not only seaports can be enclosed within the hinterland region. Further terminal types

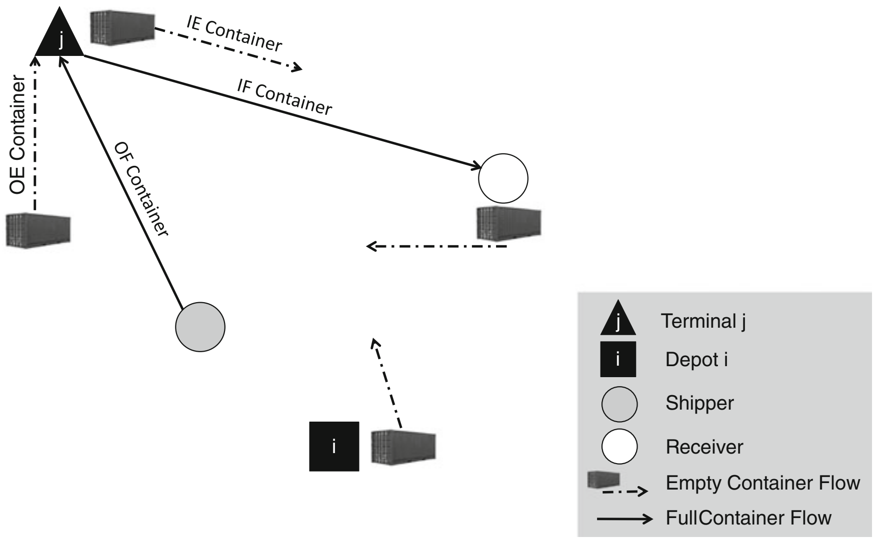

Fig. 1 Simplified OCICT with one terminal and one depot

can be provided by rail yards or river ports. A customer is considered a plant that receives or sends freight by containers.

As can be seen in Fig. 1 we distinguish four transportation request types: Inbound full (IF), inbound empty (IE), outbound full (OF) and outbound empty (OE). Incoming containers located at a terminal that need to be moved to their destinations in the hinterland are called inbound containers. Reversely, containers located in the hinterland that need to be delivered to a terminal are called outbound containers. The defined container terms derive from the well-known research field of inbound and outbound logistics (see e.g. Lai and Cheng 2009).

Two types of customers are considered. On the one hand, shippers offer freight which is to be transported to a foreign region via a terminal. The flow of a full container from a shipper to the terminal is defined as an OF request. As stated, this transportation request is defined as outbound full since a full container needs to be moved from the hinterland to the terminal. On the other hand, receivers require the transport of their goods from an outside region via the terminal. The full container which has to be transported from the terminal to a receiver is called an IF container. For both full transportation types, the pickup and delivery location are always given in advance. Obviously, these transportation tasks lead to an empty container positioning or repositioning problem. Firstly, before an OF task can be handled, a shipper requires an empty container to fill its freight into. The origin of this empty container must be determined during the solution process. Secondly, the receiver of an IF task obtains an empty container after the container is unloaded. The determination of the container's destination also requires a decision for allocating empty containers.

Due to the imbalance between import- and export-dominated areas, we also need to consider OE or IE containers which either have to be moved to a terminal or derive from it. The origin of an OE container within the hinterland (i.e. which container to take for the OE process) and vice versa the destination of an IE container is not given in advance and thus has to be determined during the solution process. Considering an import-dominated area, a surplus of empty containers is available in the hinterland related to this area. Therefore, these additional empty transportation resources must be moved to export-dominated regions as OE containers via the terminals. The possible origins of these containers are the locations at which empty containers accrue. Within the underlying setting these locations are the depot and the receiver locations after an IF container is unloaded. In an export-dominated area, a lack of empty transportation resources arises and leads to necessary transportations of empty containers from different regions via the terminals to the hinterland. Therefore, the trucking company needs to move empty containers from the terminals to locations at which empty containers are required. If there is no shipper which needs an empty container, there is the possibility to store the containers temporarily at a depot. The predefined pickup and delivery nodes of IF and OF transportation requests, as well as the repositioning problem for empty container movements can be seen in Tables 1 and 2. Due to the intransparency of local container flows in hinterland areas and global flows between hinterland areas, it is possible that there are OE containers as well as IE containers at the same time and for the same hinterland area.

To complete the problem description, it has to be noted that the trucking company considered in the OCICT serves its requests using a homogeneous fleet of vehicles. Since our analysis is restricted to 40-feet-containers, a vehicle can only move one container at a time. Each vehicle starts its route at the depot where it is parked and ends its route at that depot which minimizes the route length. While time windows at depots do not have to be considered, customer and terminal time windows have to be kept. Containers have to be made available at customer locations for predefined time-intervals. During these time-intervals the containers

Table 1 Predefined locations of full container movements

	IF	OF
Origin	Terminal	Shipper
Destination	Receiver	Terminal

Table 2 Repositioning problem of empty containers

			Empty container	
	IE	OE	For a shipper	From a receiver
Origin	Terminal	Receiver or depot	Receiver, terminal or depot	Receiver
Destination	Shipper or depot	Terminal	Shipper	Shipper, terminal or depot

can be loaded or unloaded by the customers. Since a truck needs not to stay at the customer location during its container's predefined time interval, it can perform some other transportation tasks before the container will be picked up. The flexibility of vehicle routing and scheduling is increased even further by the fact that it is not required that the delivery and the pickup of a certain container is performed by the same truck. The predefined time-interval for a container at a customer location is determined by two surrounding time windows at each customer location. During the first time window the full/empty container has to be delivered to the receiver/shipper location. After the container is unloaded/loaded, it can be picked up by any other vehicle during the second time window. Furthermore, a service time for the picking up/dropping off operation of a container is considered.

Three different objectives are applied in order to analyze the effects of decoupling containers and vehicles at customer locations. In detail, the objectives are the following:

1. Minimization of the vehicles' travel distances
2. Minimization of the vehicles' total operating time
3. Minimization of the vehicles' fixed and variable costs

3 Solution Procedure

The heuristics proposed in this paper deal with container movements being part of routes. Thereby, two basic types are distinguished: while the first type describes full container flows which always comprise an origin and a destination location (OF or IF transportation requests), the second basic transportation type describes empty container flows which require the allocation of empty containers and, thus, are only defined through one location (origin or destination location). The two types of container movements are illustrated in Tables 1 and 2.

The general outline of the solution methodology can be described as follows. For constructing an initial solution for the OCICT, a modified Clarke & Wright-savings algorithm (1964) is used. Subsequently, a tabu search heuristic is applied to generate a final solution. The solution procedure refers to the heuristics for the MCICT by Sterzik and Kopfer (2012).

3.1 Modified Clarke & Wright-Savings Algorithm

To adapt the algorithm of Clarke and Wright (1964) for the OCICT we additionally consider multiple depots and terminals, different customer types as well as time constraints. In detail, each container movement is initially assigned to its nearest depot. Subsequently, every container movement $r \in R$ is served by exactly one vehicle in a pendulum tour. For instance, an IF transportation request is served by exactly one vehicle. Afterwards, the construction of routes is handled as in the usual original Clarke & Wright-savings algorithm. i.e., for each combination of two container movements belonging to the same depot the savings are calculated. The container movements of each depot are then sorted in descending order of the savings. Beginning at the top of this list the routes are then merged into one. The established routes have to be feasible and must not delete/interfere with a previously defined connection between two container movements.

3.2 Tabu Search Heuristic

The tabu search heuristic (see e.g. Glover 1986 or Gendreau 2003) for the OCICT comprises an initial and a main phase. In the initial phase, the algorithm seeks to reduce the number of required vehicles at each considered depot to a certain amount *m*. Thereby, *m* is defined through the number of vehicles that are parked at a depot. The number of parked vehicles is the same at each considered depot in the OCICT. Every additional vehicle which exceeds *m* at a depot is penalized with the additional costs $cost_{pen}$. The summation of all penalty costs is determined through p(s). These penalty costs have to be added to the objective function f(s) where s describes the current solution. The initial phase ends if p(s) = 0. During the main phase enduring $iter_{\max}$ iterations the excess of the defined vehicle limit is forbidden. While the first phase is mainly characterized by the *Operator Selection* component which rapidly seeks to find a solution that does not include penalty costs, the second phase specially emphasizes the *Intensification Strategy*, as can be seen in the outline of Algorithm 3.1. Further general criteria that affect the search process of the tabu search heuristic are determined by the calculation of the objective functions, the tabu tenure and aspiration criteria, as well as the consideration of diversification elements.

Algorithm 3.1: Framework of the Tabu Search Heuristic

$\Theta \leftarrow$ number of tabu iterations;
Solution of Savings-Algorithm is used as s;
while p(s)>0 **do**
    Operator Selection is applied
end while
while $iter_1 < iter_1^{max}$ **do**
    Operator Selection is applied;
    Intensification Strategy is applied;
    $iter_1 = iter_1 + 1$
end while

3.2.1 Objective Functions

Three different objectives are applied for the tabu search heuristic. The first objective function refers to the minimization of the travel distances covered by all operating vehicles. The second objective function focuses on minimizing the total operating time of all vehicles. Beside the time needed for traveling (1 time unit = 1 distance unit) the service time as well as the waiting time at the locations are considered. While service time includes the dropping off and picking up of a container at a terminal or customer location the waiting time is defined as the time that a vehicle is idle at a location. Waiting time can for instance occur due to the early arrival of a vehicle before the beginning of a time window. In case that a vehicle stays at a customer location all the time between the first and the second customer time window, the waiting time also covers the loading or unloading process. A more detailed description of the calculation of this objective function can be found in Sterzik and Kopfer (2012). The third objective seeks to minimize the costs incurred by fulfilling all transportation requests. These costs comprise the expenses for the utilization of a vehicle per day (including costs for tire wear and oil change), the wages of the truck drivers per day as well as the costs for fuel and toll. It should be noted that the underlying test instances exactly characterize the transportation requests of one day (comprising 600 time units = 10 h). The tariffs for the costs illustrate practical expenses for trucking companies in Germany.

3.2.2 Tabu Tenure and Aspiration Criteria

The tabu list T is constituted as a deterministic list which records each container movement r that is removed from a route of vehicle k. After the removal, r is not allowed to be served by vehicle k for Θ iterations. Generally, a tabu status is overruled if the algorithm finds a solution which is better than any solution known so far.

3.2.3 Operator Selection

The neighborhood of a current solution s is composed of all solutions that can be reached by applying one of the local-search operators. Three types of move operators are used in the given tabu search approach:

- The *insertion operator* removes a randomly selected container movement $r*$ from its route and inserts it in another route or at another place in its current route
- The *cross operator* swaps a randomly selected container movement $r*$ from its route and exchanges it with container movement $r \in R \backslash \{r*\}$
- The *route reduction operator* tries to reduce the number of routes by inserting the elements of each short route into another route. Thereby, a short route is defined as a route which comprises less than y container movements with 2 and 3 as reasonable values for y. Obviously, the operator is very similar to the first operator since for each element of a short route the insertion operator is applied.

In each iteration, each operator is applied once. A special case marks the route reduction operator. In order to guarantee the efficiency of the heuristic, it is only used for a defined probability value α. After applying an operator, the best non-tabu solution of the discovered neighborhood becomes the new current solution s. After applying an operator, the tabu list T has to be updated.

3.2.4 Intensification and Diversification Strategies

The *usual* search process can be interrupted for an *intensification strategy*. The frequency of interruption depends on the probability value β and the quality of s, which is related to $(1+\gamma) * f(s^{best})$ where s^{best} determines the best known solution so far, and γ is a constant parameter in the interval [0,1]. If the *intensification strategy* is applied, s is modified |R| times where |R| defines the cardinality of R. By using each $r \in R$ once for the *cross* and *insertion operator*, respectively, both solutions are compared and the best solution according to the objective value is chosen. Based on this modified solution, the *operator selection* algorithm is applied for $iter_2^{\max}$ iterations.

Algorithm 3.2: Intensification Strategy

```
β ← probability value;
γ ← number in the interval [0,1];
if (Ξ < β) ∧ (f(s) < (1 + γ) * f(s^best)) then
        T={};
        Θ is updated;
        for r ∈ R do
                r is used for Cross Operator and leads to solution s*_CO;
                r is used for Insertion Operator and leads to solution s*_IO;
                if f(s*_CO) < f(s*_IO) then
                        s ← s*_CO;
                else
                        s ← s*_IO;
                end if
                while iter_2 < iter_2^max do
                        Operator Selection is applied;
                        iter_2 = iter_2 + 1;
                end while
        end for
        Θ is updated
end if
```

To diversify the search, a mechanism is implemented which penalizes any neighborhood solution $s^N \in N(s)$ where $N(s)$ defines the neighborhood of s. The penalty factor is, thereby, proportional to the additional frequency of its attributes and a scaling factor. In detail, q_{rk} describes the number of times container movement r has been added to the route of vehicle k during the search process. The intensity of the diversification process can be adjusted by parameter γ. Thus, unless $f(s^N) < f(s^{best})$ penalty term $\gamma * q_{rk}$ is added to the total solution costs $f(s^N)$. The illustrated diversification strategy is a modification of the mechanism used in Taillard (1993).

4 Computational Experiments

The proposed algorithm has proved its efficiency and effectiveness for small- and large-sized test instances for the MCICT in Sterzik and Kopfer (2012). Thereby, it is shown that small test instances with 12 transportation requests can be solved to optimality. Besides, for large-sized instances high-quality solutions can be determined within a reasonable amount of time. Since the OCICT is very similar to the MCICT only differing in the number of operating trucking companies, the solution procedure is well-suited for the OCICT.

For the computational experiments test instances of Sterzik and Kopfer (2012) are taken for the OCICT. Instead of five trucking companies only one company that is in charge of 75 transportation requests is considered in each test instance. In detail, the operating company serves 30 IF requests, 40 OF requests and five IE requests. In the underlying hinterland region three terminals and five depots of the operating company are considered. At each of these depots 15 trucks are initially parked.

We want to investigate the impact of the width of time windows at customer locations on the benefit of decoupling vehicles and containers. The consideration of tight time windows is stipulated by the fact that many customers only have restricted storage place for containers and, thus, delivered containers can only be left at a customer’s location for a short time span. Therefore, the first and second customer time windows are defined tightly and are fixed just before and immediately after the given service time windows for the containers. Wide time windows provide the opportunity for trucking companies to leave empty containers at customer places for a defined period before or after a container’s loading or unloading process is completed, respectively. For example, IF containers that are emptied at receiver locations are available after the service has finished and should be picked up before the end of the underlying time period. Empty containers for OF requests can be delivered from the beginning of the time period and should be delivered to the shipper before the service begins. For the consideration of tight and wide time windows ten data sets are defined. Each data set is solved in terms of the three proposed objective functions.

Table 3 Impact of time windows' size on the objectives

DS	Distance			Operating time			Costs		
	T-TW	W-TW	Ben	T-TW	W-TW	Ben	T-TW	W-TW	Ben
1	12,142	11,447	5.72	15,777	14,934	5.34	29,365	28,575	2.69
2	13,361	12,350	7.57	16,729	15,609	6.69	32,502	26,035	19.90
3	11,658	11,498	1.37	15,794	15,013	4.94	31,927	26,500	17.00
4	12,612	11,971	5.08	16,658	16,203	2.73	29,525	26,075	11.69
5	10,869	10,617	2.32	14,369	13,714	4.56	27,321	23,876	12.61
6	15,208	14,829	2.49	18,382	18,068	1.71	30,400	27,782	8.61
7	12,086	11,770	2.61	15,467	15,354	0.73	26,840	25,778	3.96
8	12,687	12,426	2.06	16,199	16,045	0.95	29,475	26,798	9.08
9	10,185	10,104	0.80	13,566	13,245	2.37	25,539	25,353	0.73
10	14,395	14,245	1.04	17,955	17,831	0.69	32,027	29,395	8.22
∅	12,520	12,126	3.15	16,090	15,602	3.03	29,492	26,617	9.75

DS data set, *T-TW* tight time window, *W-TW* wide time window, *Ben* benefit (in %)

Table 4 Vehicles waiting at customers' locations for the different objectives (in %)

Distance		Operating time		Costs	
Tight TW	Wide TW	Tight TW	Wide TW	Tight TW	Wide TW
79.14	62.00	29.43	26.57	58.86	33.86

The determined objective values for each data set are illustrated in Table 3. Besides, relative benefits that compare the values of the objective functions of data sets with tight and wide time windows are shown. In case of the minimization of the vehicles' travel distances the consideration of wide time windows leads to objective values that are on average 3 % below the corresponding values of tight time windows. A similar result has been determined for the minimization of the vehicles' total operating time. Remarkably, this benefit is much greater if the costs are minimized. In this case, the trucking company can save 10 % on average.

In general, the option to decouple vehicles and containers at customers' location is used remarkably often in order to generate good routes as can be seen in Table 4. The table illustrates the frequency of vehicles waiting at customer locations from the first to the second time window by means of average values for ten data sets. Especially if the vehicles' total operating time is minimized the computational experiments show that the increased flexibility is actually exploited in order to improve the objective values. In case of tight time windows, 71 % of the vehicles skip the inactive service time between the customers' time windows and leave the customer locations for different tasks. Surprisingly, even if the distances should be minimized 21 % of the vehicles skip the waiting time. This is surprising due to the fact that vehicles serving the customers' first time windows can also serve the customers' second time window without increasing the objective value. Considering the minimization of the costs incurred by serving the customers, 41 % of the

Table 5 Number of vehicles

Distance		Operating time		Costs	
Tight TW	Wide TW	Tight TW	Wide TW	Tight TW	Wide TW
55.3	50.2	54.2	51.6	50.6	42.8

vehicles skip the service time. Focusing on wide time windows, it can be seen that the increased flexibility provided by wide time windows is fully utilized for improving the objective values. According to the minimization of the vehicles' travel distances 22 % more vehicles skipped the waiting time in case of the consideration of wide time windows compared to the data sets with tight time windows. Especially if the total costs are minimized, this increasing flexibility is used since the rate of vehicles which skip the waiting time rises by 42 %. Consequently, the frequency of vehicles waiting at customer locations is strongly related to the relative benefits of objective values (see Table 3).

In Table 5 the average number of operating vehicles during ten test instances is illustrated. Compared to the minimization of the vehicles' travel distances or the minimization of the vehicles' total operating time much less vehicles are required to serve the transportation requests if the costs are minimized. Certainly, the reason is due to the definition of the objective function. While the minimization of travel distances and the minimization of the total operating time completely ignore the number of vehicles, an operating vehicle is associated with certain deployment costs if the costs should be minimized. However, for all three objectives the increasing flexibility of wide time windows to serve the customers leads to a decrease of used vehicles.

5 Conclusions

The frequency of making use of the option of decoupling vehicles and containers at customer locations as well as the effects of the width of time windows on the determined solutions have been analyzed. Thereby, several data sets for a comprehensive hinterland container transportation problem have been solved by means of a tabu search heuristic. The computational results show that the option of decoupling containers and vehicles leads to improved solutions for each objective function considered in this paper. Especially, if the vehicles' total operating time is minimized the possibility of vehicles to skip the waiting time at a customer's location is used to determine good objective values. The variation of the width of time windows directly impacts the operations for decoupling. Moreover, the possibility to leave a container for a long period at a customer's location favors the option of a trucking company to make use of decoupling vehicles and containers.

Due to practical relevancy, future research should focus on data sets which illustrate a hinterland more accurately. Since not all customers are in possessions of van carriers, reach stackers or lifting ramps, data sets should also include customers who do not have the possibility to pick up delivered containers from trucks. Moreover, different cost rates of vehicles and drivers should be investigated. Since this contribution is focusing on cost rates in Germany, an analysis on the sensitivity of cost rates taken from different countries should be performed.

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Anticipatory Planning for Courier, Express and Parcel Services

Marlin W. Ulmer, Jan Brinkmann and Dirk C. Mattfeld

Abstract In recent years, the number of challenges for courier, express and parcel services has grown. Today, service providers deal with dynamic changes and uncertainty. Customers can request service at any point of time in the whole service region. Technologies like Global Positioning Systems allow a more detailed and dynamic routing. Furthermore, historical data can be used to anticipate future events. To tackle the new challenges and to utilize the new resources, we suggest modeling customer locations as spatial random variables. This allows a more detailed and therefore efficient routing and decision making. Nevertheless, it requires more complex methods to anticipate future demands, because the straightforward application of graph theoretical approaches is not possible. For an exemplary problem setting in the Euclidean Plane (EP), we introduce a new anticipatory cost benefit heuristic (CBH). Additionally, we adjust techniques of approximate dynamic programming (ADP) and compare the results of CBH and ADP with a myopic approach and an optimal ex post solution. Here, both ADP and CBH outperform the myopic approach.

1 Introduction

Today, the tasks for courier, express and parcel services are challenging. In a low-margin market, they have to serve a growing number of customers faster and more flexible. Therefore, they deal with dynamic changes and uncertainty. So, short-term customer requests during the day demand an instant response. Hereby, the point of time and the location of the requests are not known in advance.

To tackle these challenges, the service providers can use technologies like Global Positioning Systems, navigation devices or onboard communication to

M.W. Ulmer (✉) · J. Brinkmann · D.C. Mattfeld
Decision Support Group, Technische Universität Braunschweig, Mühlenpfordtstr. 23, 38106 Braunschweig, Germany
e-mail: m.ulmer@tu-braunschweig.de

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improve routing and decision making. Nevertheless, these tools are not suitable for the anticipation of future events. Therefore, the analysis of historical data is inevitable to predict customer behavior.

So far, most of the theoretical approaches use a discrete set of predefined possible customer locations for solving routing and decision making problem. Here, modeling customers as vertices in a graph with a given distance matrix and request probabilities allows the application of efficient graph theoretical algorithms. However, it risks inefficient routing and decision making, since vertices may merely stand proxy for a number of customers in the vertex's neighborhood. For that reason, we introduce a new model of a stochastic and dynamic routing problem. In this model, we allow detailed depiction of customer locations by introducing spatial random variables. Hence, routing is more detailed and leads therefore to more efficient decisions, but might require more advanced techniques for anticipation.

For this new model, we present two different anticipatory approaches and compare the results for different sets of instances with a greedy heuristic. On the one hand, we use the CBH heuristic, which compares costs and benefits of a decision. On the other hand, we apply techniques of ADP. Therefore, we discretize the infinite state space to meet the requirements of the algorithm. To achieve an optimal ex post solution, we introduce a mixed integer program and a Branch and Bound algorithm.

This paper is organized as followed: In chapter two, a short review of relevant literature is presented, with its main focus on the representation of customer locations. In chapter three, an exemplary problem setting for a dynamic and stochastic vehicle routing problem is defined. In chapter four, the solution approaches and the mixed integer model are introduced. The approaches results are shown in chapter five for different sets of instances. Finally, in chapter six a conclusion and an outlook to further research are given.

2 Literature Review

The research of Vehicle Routing Problems is vast, so we confine on problem formulations modelling customer locations as random variables.

For some real life problems, the locations of possible customers are known in advance, e.g., one Less-Than-Truckload-Problem with late customer request, introduced by Meisel (2011). In this problem a (small) set of known customers can request service during the day. The service provider has to accept or reject the request immediately regarding a given time limit.

Nevertheless, Tassiulas (1996) remarked, that "for several practical problems […] the number of points requiring service is not fixed […]. The locations […] are not known in advance and have to be modelled as random quantities." This applies in particular for private customers, which may request sparsely. In those cases, planning with only a few possible customer locations leads to inefficient routing and decision making. Therefore, it is hardly applicable for those practical problems

(Ulmer and Mattfeld 2013). However, most of the existing work has focused solely on problem definitions with known customer locations.

There are a few exceptions: Bertsimas and Van Ryzin (1991) introduced the Dynamic Traveling Repairman Problem (DTRP), where customer requests can occur in the whole service region: A vehicle has to serve customers appearing over time regarding a uniformly distribution in the EP. The objective function is to minimize the average waiting time per customer while serving all requests.

During the last 20 years a lot of contributions to the DTRP have been made (e.g. Bertsimas and Simchi-Levi 1993; Tassiulas 1996; Larsen et al. 2002; Irani et al. 2004; Itani et al. 2008; Pavone et al. 2011). In this context, Larsen et al. introduced the Degree of Dynamism (DOD). This key figure indicates the relation between customers on short notice and customers known in advance. The higher the DOD, the higher the uncertainty and therefore, the more important is the anticipation of future events.

Except for the DTRP, most of the dynamic VRP and TSP models are using a discrete set of possible customer locations. Some exceptions are, e.g., works by Ausiello et al. (1995), Jaillet and Wagner (2006), Jaillet and Lu (2011). Both analyse routing problems in a metric space; in their case, the real line. Few works besides the DTRP model customers as random variables in the EP. Therefore, Ichoua et al. (2006) used representatives to cover sub regions for a VRP with Time Windows. Additionally, Branke and al. (2005) introduced a problem in the EP, where only one additional customer appears and developed positioning strategies to serve this new customer regarding a given time limit.

3 Problem Formulation

We choose an exemplary problem setting based on the routing and decision making problem by Meisel (2011) and investigate a plain courier service problem. Different to Meisel, we examine explicitly the influence of modelling customer locations as random variables in the EP on anticipatory planning.

3.1 Problem Definition

A courier service vehicle has to collect parcels from a set of customers. The locations of these early-request customers are known in advance. The vehicle starts its tour at a depot and has to return within a given time limit. During the day, more customers request the pick-up of parcels. These (late) requests can occur at any location in the service region. For each request, the driver has to decide, if it is accepted or rejected, as soon as he arrives at the next customer. Both rejection and

Table 1 Instance sets

	Exp. requests	Distribution	Time limit	Region size
I_1C	12	Clustered	120	25 km × 25 km
I_1U	12	Uniformly	120	25 km × 25 km
I_2C	100	Clustered	360	40 km × 40 km
I_2U	100	Uniformly	360	40 km × 40 km

acceptance are permanent. The objective is to maximize the number of accepted, i.e., visited customers without violating the time limit.

3.2 Instances

We examine the results for four different sets of instances, which are shown in Table 1. In one case, the location of requesting customers are uniformly distributed (*U*), in the other case, the request locations concentrate within three clusters (*C*). For both distributions we investigate the behavior of the heuristics. On the one hand, we study the results for small instances I_1 with an expected number of only 12 customers in a short time period and small region, on the other hand, for larger instances I_2 with about 100 requests for a whole workday and a larger region. For all instances, 75 % of the requests are dynamical ($DOD = 0.75$).

4 Solution Approaches

We tackle this problem with a myopic, greedy approach, an anticipatory CBH and methods of ADP. To evaluate the quality of the heuristics, we compare the results (for small instances) with an ex post optimal solution.

4.1 Optimal Solution

We use both a mixed integer program and a Branch and Bound algorithm. Therefore, we define the following notations:

$G = (V, E)$	A complete graph
n	The number of customer vertices
$V = \{v_0, \ldots, v_n\}$	The set of vertices. The depot is represented by v_0 and the customer vertices by $\{v_1, \ldots, v_n\}$
$E = \{e_{0,0}, \ldots, e_{n,n}\}$	The set of edges
T	The overall time limit

r_i	The point in time at which v_i becomes known, i.e., its customer sends the request. Since v_0 represents the depot, $r_0 = 0$ holds
$c_{i,j}$	The traveling time from v_i to v_j, i.e., the edges weight

4.1.1 Mixed Integer Programming

Decisions will be stored by the set $X = \{x_{0,0,0}, \ldots, x_{n,n,T}\}$ including decision variables $x_{i,j,t}$ for every $i, j \in \{0, \ldots, n\}$ and $t \in \{0, \ldots, T\}$. The variable $x_{i,j,t}$ indicates the leaving of v_i at t in order to visit v_j:

$$x_{i,j,t} = \begin{cases} 1 \text{ , if the vehicle leaves } v_i \text{ in direction of } v_j \text{ in time } t \\ 0 \text{ , else} \end{cases} \tag{0}$$

The objective function maximizes the sum of all vertices $v_j \in V/v_0$ being visited with any predecessor $v_i \in V$ at any time $t \in \{0, \ldots, T\}$ (1). We define the number of visits at each vertex (2, 3, 4). The depot and the customers with $r_i = 0$, i.e., the early customers, are visited exactly once. All other customer vertices are visited either never or once. If and only if a vertex is visited, the vehicle leaves it (5). The subtour elimination constraint by Miller et al. (1960) for the original TSP is adapted for our problem (6). Since the vehicle has to respect the time limit, it leaves the last customer v_j at $t \leq T - c_{j,0}$ (2). Deciding whether visiting v_i or not, we assure the arrival at the depot in time. Since the triangle inequation is valid, we add the traveling time $c_{i,0}$ to the arrival time in v_i and check whether the sum keeps the time limit (7). As the vehicle starts the tour at the depot, we guarantee that the vehicle leaves v_0 before it returns (8). However, the vehicle first arrives at any customer vertex before it leaves this respective vertex (9). Due to a customer vertex appears with its incoming request, the vehicle may leave the predecessor at $t \geq r_i$ as seen in (10).

$$\sum_{i=0}^{n} \sum_{j=1}^{n} \sum_{t=0}^{T} x_{i,j,t} \rightarrow \max \tag{1}$$

$$\sum_{j=0}^{n} \sum_{t=0}^{T-c_{j,0}} x_{j,0,t} = 1 \tag{2}$$

$$\sum_{j=0}^{n} \sum_{t=0}^{T} x_{j,i,t} \leq 1 \quad \forall i \in \{0, \ldots, n\} \tag{3}$$

$$\sum_{j=0}^{n}\sum_{t=0}^{T} x_{j,i,t} + r_i \geq 1 \quad \forall i \in \{1,\ldots,n\} \tag{4}$$

$$\sum_{j=0}^{n}\sum_{t=0}^{T} x_{i,j,t} = \sum_{j=0}^{n}\sum_{t=0}^{T} x_{j,i,t} \quad \forall i \in \{0,\ldots,n\} \tag{5}$$

$$u_i - u_j + (n+1)\cdot \sum_{t=0}^{T} x_{i,j,t} \leq n \quad \forall i,j \in \{1,\ldots,n\} \quad i \neq j \tag{6}$$

$$\sum_{j=0}^{n}\sum_{t=0}^{T} x_{j,i,t}\cdot (t + c_{j,i} + c_{i,0}) \leq T \quad \forall i \in \{1,\ldots,n\} \tag{7}$$

$$\sum_{j=0}^{n}\sum_{t=0}^{T} x_{j,0,t}\cdot t \geq \sum_{j=0}^{n}\sum_{t=0}^{T} x_{0,j,t}\cdot t \tag{8}$$

$$\sum_{j=0}^{n}\sum_{t=0}^{T} x_{j,i,t}\cdot (t + c_{j,i}) \leq \sum_{j=0}^{n}\sum_{t=0}^{T} x_{i,j,t}\cdot t \quad \forall i \in \{1,\ldots,n\} \tag{9}$$

$$\sum_{j=0}^{n}\sum_{t=0}^{T} x_{j,i,t}\cdot t \geq \sum_{j=0}^{n}\sum_{t=0}^{T} x_{j,i,t}\cdot r_i \quad \forall i \in \{1,\ldots,n\} \tag{10}$$

4.1.2 Branch and Bound Algorithm

As an alternative to the mixed integer program, we introduce a Branch and Bound algorithm and its underlying data structure. The goal of this approach is to reduce the complexity in order to gain advantage in regard of the solvers runtime. Stemming from this, we do not examine the complete set of decision variables X anymore, but confine to feasible sequences of vertices.

At first, the setting of the data structure is presented. Consider a sink tree that contains all possible solutions for a given instance. This tree is made from tree elements $\varepsilon = (v_i, t, \hat{\varepsilon})$ holding information. Each element represents a vertex $v_i \in V$ that is reached at time $t \in \{0,\ldots,T\}$ within a specific tour. Its parent element within the sink tree is $\hat{\varepsilon} = \left(v_{\hat{i}}, \hat{t}, \hat{\hat{\varepsilon}}\right)$. Thus, ε is the child of $\hat{\varepsilon}$. Regarding a specific tour, $v_{\hat{i}}$ is the predecessor of v_i. Since the vehicle should leave $v_{\hat{i}}$ as soon as possible, t has to be initialized as seen in formula (11).

$$t = \begin{cases} \hat{t} + c_{\hat{i},i} \text{ , if } \hat{t} \geq r_i \\ r_i + c_{\hat{i},i} \text{ , else} \end{cases} \tag{11}$$

The set $P(\varepsilon)$ contains all previously visited vertices within a tour as seen in formula (12).

$$P(\varepsilon) = \begin{cases} v_{\hat{i}} \bigcup P(\hat{\varepsilon}) \text{ , if } \hat{\varepsilon} \neq NULL \\ \varnothing \text{ , else} \end{cases} \tag{12}$$

The elements height $height(\varepsilon)$ is the number of predecessors of the elements vertex, i.e., the cardinality $|P(\varepsilon)|$.

Finding a tour with maximum number of customers within a given instance is the same as finding an element with maximum $height(\varepsilon)$ in the instances sink tree. Therefore, the sink tree is built as follows: Starting from the root (v_0, 0, *NULL*), we determine candidate vertices succeeding v_0 within a tour. Assume $\varepsilon = (v_i, t, \hat{\varepsilon})$ is our position. At this point, we create child elements $\varepsilon' = (v_{i'}, t', \varepsilon)$ for every $v_{i'} \in V/(v_i \cup P(\varepsilon))$. Its arrival time t' will be computed as one can see at formula (11). Now, the decision whether to branch or to bound has to be made for each child element:

If $t' + c_{i',0} \leq T$, i.e., the return trip to the depot is possible, branching: ε' is called valid and one has to keep it. Then, a new branch is created and we determine new child elements. Else, bounding: The element has to be discarded.

Furthermore, the algorithm uses an upper bound $ub \leq n$. If an element ε with $height(\varepsilon) = ub$ is created, an optimal solution is found and the whole procedure can be stopped. Standing from this, the algorithm is implemented as a depth-first search according to Cormen et al. (2009). As a result, very high elements are found quickly.

The easiest way of setting an upper bound is to define $ub = n$. If a tour containing all customer vertices is found, no other tour can beat it. A more sophisticated approach respects the time limit, the edges weights and the request times. The main idea is about to use only the lightest edges within the graph. Therefore, we create a set B that contains for every $v_i \in V$ the lightest incident edge $e_{j,i}$ that satisfies both $r_i + c_{j,i} + c_{i,0} \leq T$ and $e_{i,j} \notin B$. Now, we sum up the edges weights, starting with the lightest edge within B, until the overall sum would become larger than T. The number of summands less one is the upper bound for the given instance. Of course, this approach may be further elaborated without dropping the main idea.

4.2 Insertion and Confirmation Heuristic

For all confirmation heuristics, we choose the Nearest Insertion heuristic to build the route. This heuristic searches the "cheapest" request, i.e., the request, which extends the route at least. This request is inserted in the existing tour at the cheapest position.

We choose this heuristic for several reasons. At first, it sorts the customer requests in order that the most promising are considered first. At second, it allows to maintain the initial route design.

For the confirmation and rejection of customer requests, we implement two heuristics: a myopic, greedy heuristic and a CBH, which compares the costs and benefits of a request. The greedy heuristic confirms all requests as long as the time limit is not violated. Therefore, it ignores all future events and just concentrates on the immediate reward.

The main idea of CBH is to avoid the confirmation of customers, which locations are far off the existing route. Therefore, it compares the relative gain G_{rel} of customers to the relative costs C_{rel} of accepting the request. If $G_{rel} \geq C_{rel}$, the customer is accepted. Hereby, G_{rel} is the quotient of the new number of customers after the decision and the number of customers before. Additionally, two parameters are introduced and adapted by means of simulation regarding the set of instances. It is required to build up a route in the beginning, so the first customers are allowed to consume more time than later customers. In (13), C_{route} are the costs of the actual tour, Δd the additional costs by adding the new customer and C_{extra} the "free" costs, which are additionally allowed for every customer. If the costs of the extension Δd are smaller than C_{extra}, the customer is added in any case. The longer the route, the less is the impact of the extra costs.

$$C_{rel} = \frac{C_{route} + \Delta d}{C_{route} + C_{extra}} \tag{13}$$

Finally, the perfect ratio between relative costs and relative gain can differ regarding many parameters, e.g., the number of customers, time limit or size of the service region. Therefore, we implement a scaling S such that $S \cdot G_{rel} \geq C_{rel}$.

4.3 Approximate Dynamic Programming

The main idea of ADP is to remember, which benefit developed out of a (post decision) state in the past. Then, choose the decision, which leads to the best possible (post decision) state. Hereby, we also consider the myopic reward.

4.3.1 Learning and Decision Making

The problem can be formulated as a Markov Decision Process (Powell 2007) as displayed in Fig. 1.

State s denotes hereby the state, i.e., the decision point. After a decision d, the (deterministic) post decision state p is reached. A stochastic event e leads to the next state s'.

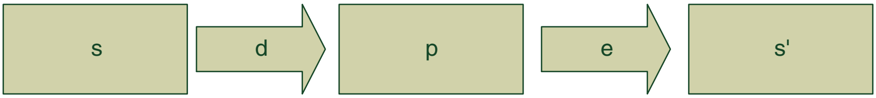

Fig. 1 Markov decision process

For this problem setting, a decision state occurs, when the vehicle has reached a customer. Therefore, in s, the actual point of time, the location of the vehicle, a number of customers still to serve and a number of requests to confirm or reject are given. After making a decision, in post decision state p only the customers to serve remain. By reaching the next customer, new requests may have occurred, which leads to the next decision state s'. This keeps on, until the final state is reached and the vehicle has returned to the depot.

In every decision state s, we choose from a set of possible decisions $d = \{d_1, \ldots, d_m\}$ by knowing the assigned post decision states p_i. To find the best decision d^*, we use formula (14).

$$d^* = \arg\max_{d_i \in D} (V(p_i) + B(d_i)) \tag{14}$$

Here, $V(p)$ is the (approximate) value of the post decision state p and $B(d)$ the immediate benefit of decision d. For our problem, $V(p)$ is the approximate number of future confirmations, $B(d)$ the number of immediate confirmations. We set all initial values to 100 to force exploration. Nevertheless, after every simulation run, the values are updated regarding formula (15).

$$V_{new}(p) = (1 - \alpha) \cdot V_{old}(p) + \alpha \cdot V_{run}(p) \tag{15}$$

Hereby, the new value V_{new} of post decision state p is formed using the previous value V_{old} and the value of the run V_{run}. The update parameter α controls the impact of the individual run to the overall value. In our case, we calculate α as shown in formula (16) to achieve an average of the individual values. Here, n_p is the number of occurrences of post decision state p.

$$\alpha = 1 - \frac{n_p}{n_p + 1} \tag{16}$$

4.3.2 State Space Design

For the efficient use of ADP, a reasonable state space design is essential. On the one hand, a very detailed design may lead to slow learning and even result in computational intractability. On the other hand, a coarse design may lead to inefficient decisions. By using a graph theoretical model with only a few possible customer locations, each of these customers can be considered in the state space particularly. But in this problem setting, where customers can request at any point within the service region, the possible geographical states are infinite. Hence, we choose to define a post decision state using only two discrete parameters: At first the point of time, second the slack, i.e., the disposable time left. So, all possible situations can be translated into this state-design.

5 Computational Results

At first, we run several learning trajectories for ADP by a given calculation time limit. Furthermore, for all the four different settings we evaluate 1.000 test runs and compare the solution of all approaches. Additionally, for the instances I_1 we calculate an optimal solution using the Branch and Bound algorithm to evaluate the absolute quality of the heuristics. (For all calculations, we use an Intel Core i5-3470 3,2 GHz with 32 GB DDR3-1333 and Windows 7.)

5.1 Optimal Solution

For the sets of small test instances I_2, the mixed integer approach (CPLEX v12.3) has an average solving time of 13.443 s, the Branch and Bound algorithms of 0.007 s. Therefore, we use the Branch and Bound for the following tests.

5.2 ADP Learning Process

For the small instances, the learning peak is reached within one hour. In the given computation time of 168 h we are able run 20.000.000 trajectories for the instances I_2U and 30.000.000 trajectories for instance I_2C. For both, a saturation is reached within the process. The different number of runs results from the in general longer distances between the customers in I_2U. So, during the (longer) travel between two customers, in average more customer requests occur. This implies a larger decision space and therefore longer computation times.

5.3 Results

For C_{extra} and S, we run a parameterization regarding the different instances. The calculated parameters and the mean objective values of the optimal solution, ADP, CBH and Greedy are shown in Table 2, best results depicted in bold.

For the set of small instances, CBH is not able to anticipate. Here, ADP reaches the best average solution of all approaches and finds in about 33.8 % of all instances

Table 2 CBH-parameter, average number of visited customers for 1.000 test runs

	C_{extra}	S	Opt	ADP	CBH	Greedy
I_1C	17.7	1.11	9.805	**8.984**	8.970	8.970
I_1U	29.2	0.81	8.986	**8.030**	7.995	7.995
I_2C	19.7	0.97	–	68.120	**68.829**	67.568
I_2U	15.3	0.95	–	**58.854**	57.498	52.048

the optimal solution. Despite the better performance of ADP in I_1 the greedy approach reaches in 2.3 % more cases the optimal solution than ADP. Nevertheless, ADP finds in 77.2 % of the cases a robust solution differing at most one customer from the optimum. Therefore, it exceeds the greedy heuristic by 18.5 %. While ADP reaches the significantly best solution in I_2U, CBH outperforms all approaches in I_2C. This probably results from the disregard of geographical information in the state space design given a heterogeneous customer distribution.

6 Conclusions

For several practical challenges, modeling customer locations not as a known set, but as spatial random variables is necessary. Nevertheless, the straightforward application of efficient, anticipatory graph theoretical approaches (e.g., ADP based on a graph) is not possible. Hence, we introduced two adapted approaches allowing anticipation. Hereby, CBH and ADP outperform the myopic approach by far. Due to the fact that dynamic and stochastic vehicle routing problems can be formulated as a Markov Decision Process, especially an approach of ADP is promising. Our studies show, that even a coarse state space design leads to good, anticipatory decisions. In future research, a further examination and an improvement of this state space design is inevitable and promising. Additionally, the adaption of ADP to different problem settings is necessary to prove the universality of the approach.

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A Coordination Mechanism for a Collaborative Lot-Sizing Problem with Rivaling Agents

Tobias Buer, Mario Ziebuhr and Herbert Kopfer

Abstract A distributed uncapacitated lot-sizing problem with rivaling agents (DULR) is introduced. The DULR considers concurrent items, i.e., items that can be produced by more than one agent. The agents are self-interested and have private information. They coordinate their local plans in order to find a joint global plan which minimizes total cost. The individual plans are coordinated by a collaborative planning approach based on simulated annealing. In addition to some well-known techniques a production responsibility assignment procedure and Shapley compensation payments computed by means of a modified characteristic function are incorporated. The proposed solution approach outperforms a reference value in 206 out of 272 new DULR instances. The approach is more efficient on small instances than on medium sized instances.

1 Introduction

Computational supported negotiations among self-interested and autonomous agents are crucial for today's inter-organisational division of labor. We consider agents representing companies in the context of a supply chain. The agents want to negotiate a joint production plan that minimizes the total production costs (global costs), that is, the sum of each agents production costs. Although the agents have a cooperative attitude, they are still self-interested and want to minimize their own costs (local costs). Furthermore, the agents are not willing to share sensitive

T. Buer (✉) · M. Ziebuhr · H. Kopfer
Chair of Logistics, University of Bremen, Wilhelm-Herbst-Str. 5, 28359 Bremen, Germany
e-mail: tobias.buer@uni-bremen.de

M. Ziebuhr
e-mail: ziebuhr@uni-bremen.de

H. Kopfer
e-mail: kopfer@uni-bremen.de

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information like the degree of capacity utilization or expense ratios (private information), see (Klein et al. 2003; Fink 2006).

A problem that fits in this category is the distributed multi-level uncapacitated lot-sizing problem (DMLULSP) introduced by Homberger (2010). It generalizes the well-known multi-level uncapacitated lot-sizing problem (MLULSP) introduced in Yelle (1979). The latter is NP-hard for general product structures (Arkin et al. 1989) and therefore computationally challenging. In addition, it features some relevant real world properties of supply chains like a multi-level production structure and a trade-off between inventory holding and setup costs. Coordination of lot-sizing decisions via agent negotiation is difficult because the agents are self-interested with private information. Existing solution approaches for the DMLULSP are based on the metaheuristics simulated annealing (Homberger 2010), evolutionary strategy (Homberger 2011), and ant colony optimization (Homberger and Gehring 2010; Buer et al. 2013).

This paper contributes by introducing a distributed uncapacitated lot-sizing problem with rivaling agents (DLUR) in Sect. 2. The DLUR generalizes the DMLULSP which takes into account competition among agents with respect to the production of some items and is therefore closer to some requirements of real world supply chains. Furthermore, a coordination mechanism based on simulated annealing introduced for the DMLULSP by Ziebuhr et al. (2013) is extended in Sect. 3 such that it also solves the DLUR. In Sect. 4 the coordination mechanism is evaluated by means of a computational study based on 278 new benchmark instances and initial results are provided which may be used as future benchmark values for other studies. Section 5 summarizes the paper.

2 A Distributed Multi-level Uncapacitated Lot-Sizing Problem with Rivaling Agents

2.1 Problem Formulation Without Rivaling Agents

The non-distributed or centralized multi-level uncapacitated lot-sizing problem (MLULSP, cf. Yelle 1979; Steinberg and Napier 1980; Dellaert and Jeunet 2000) can be considered as a special case of the distributed MLUSLP which is why we present it first. In the MLULSP there is a single agent who acts as a central decision maker. The agent is aware of all relevant planning parameters. We are given a set T of possible production periods, $T = \{1, \ldots, n\}$, and a set I of items, $I = \{1, \ldots, m\}$. The items form a multi-level product structure which is represented in a bill of materials. Final items are assembled of one or more components, components may themselves consist of other components or of raw materials. For each item $i \in I$, we are given a set $\Gamma^+(i) \subset I$ of all direct successors and a set $\Gamma^-(i) \subset I$ of all direct predecessors. Final items are characterized by $\Gamma^+(i) = \emptyset$ and raw materials are characterized by $\Gamma^-(i) = \emptyset$. Furthermore, the production coefficient p_{ij} indicates the required quantity of item i to produce one unit of item j. Without loss of generality, $p_{ij} = 1$ is assumed. Let s_i, h_i, and t_i be the setup cost, inventory holding cost, and lead time, respectively, per item i ($i \in I$) and per period. For each final item and each period, an exogenous demand d_{it} ($i \in I|\Gamma^+(i) = \emptyset$ and $t \in T$) is given.

In the MLULSP, the central decision-making agent has to decide for each item $i \in I$ with $\Gamma^+(i) \neq \emptyset$ and each period $t \in T$ which lot-size x_{it} to produce. Therefore, the endogenous demand d_{it} as well as the inventory l_{it} per item i and per period t have to be determined. Finally, this lot-size decision also includes the setup-decision, i.e., if a production of item i takes place in period t at all ($y_{it} = 1$) or not ($y_{it} = 0$). A model of the MLULSP is given by (1)–(8).

$$\min f^{nd}(y) = \sum\nolimits_{i \in I} \sum\nolimits_{t \in T} (s_i \cdot y_{it} + h_i \cdot l_{it}) \tag{1}$$

$$l_{it} = l_{i,t-1} + x_{it} - d_{it} \quad \forall i \in I, \ \ \forall t \in T, \tag{2}$$

$$l_{i,0} = 0 \quad \forall i \in I, \tag{3}$$

$$l_{it} \geq 0 \quad \forall i \in I, \ \ \forall t \in T \backslash \{0\}, \tag{4}$$

$$d_{it} = \sum_{j \in \Gamma^+(i)} p_{ij} \cdot x_{j,t+t_i} \ quad \forall i \in \{j \in I | \Gamma^+(j) \neq \emptyset\}, \ \ \forall t \in T, \tag{5}$$

$$x_{it} - M \cdot y_{it} \leq 0, \quad \forall i \in I, \ \ \forall t \in T, \tag{6}$$

$$x_{it} \geq 0, \quad \forall i \in I, \ \ \forall t \in T, \tag{7}$$

$$y_{it} \in \{0, 1\}, \quad \forall i \in I, \ \ \forall t \in T. \tag{8}$$

In the MLULSP, the goal of the central decision-making agent is to minimize the (non-distributed) total costs f^{nd} that are the sum of the setup costs and the inventory holding costs for all items $i \in I$ over all periods $t \in T$. The inventory balance is guaranteed by (2). For all items, the inventory of the first period ($t = 0$) is zero (3) and for remaining periods non-negative (4). The endogenous demands for the non-final items are determined by (5). These constraints ensure that the production of item j in period $t + t_i$ triggers a corresponding demand d_{it} for all $i \in \Gamma^-(j)$, i.e., a demand for each item i preceding item j in the multi-level item structure. Big-M constraints ensure that a positive lot-size leads to a machine setup ($x_{it} > 0 \Rightarrow y_{it} = 1$) (6).

Now, assume the MLULSP has to be solved in an inter-organisational context, e.g. a supply chain. This problem is denoted as *distributed multi-level uncapacitated lot-sizing problem* (DMLULSP, Homberger 2010). In the DMLULSP, the set of items I is *partitioned* and the items have to be jointly produced by a group of agents A. Each agent might represent an organisational unit of a supply chain, for instance. Agent $a \in A$ is responsible to produce the set of items I_a with $\bigcup_{a \in A} I_a = I$

and $\cap_{a \in A} I_a = \emptyset$. Each item is produced by one agent for which reason we say there are *no rivaling agents*. Although the agents have to cooperate to fulfill the overall goals related to the production in the supply chain, each agent is still autonomous and self-interested. Therefore, the objective function f_a of agent $a \in A$ is to minimize his or her local costs for producing the items I_a, that is,

$$\min f_a(y) = \sum_{i \in I_a} \sum_{t \in T} (s_i \cdot y_{it} + h_i \cdot l_{it}). \tag{9}$$

Furthermore, the DMLULSP assumes *asymmetric information* regarding the cost parameters s_i and h_i. That is, agent a knows the values of s_i and h_i for all items he or she produces ($i \in I_a$), but not for those items produced by the remaining agents b ($b \in A, b \neq a$) and vice versa. These parameters are considered as private information of agent a. We assume the agents try to avoid revealing private cost parameters to other agents during collaborative planning because their negotiation power might be negatively affected. However, we assume the bill of materials is public information due to some kind of common industry knowledge and therefore it is available to all agents (*symmetric information*). The DMLULSP consists of the constraints (2)–(8) and the objective function (10) which minimizes the total global costs:

$$\min f(y) = \sum_{a \in A} f_a(y). \tag{10}$$

It should be mentioned, that Dudek and Stadtler (2007) consider a similar distributed lot-sizing model that even takes into account capacities. They consider a two-tier supply chain where one seller negotiates with several buyers. The approach at hand, however, uses a mediator who generates contract proposals without relying on cost information of the agents. Furthermore, it is applied to a n-tier supply chain and it takes *rivaling agents* into account.

2.2 Generalization by Introducing Rivaling Agents

In contrast to the DMLULSP where each item can be produced by exactly one agent we now consider the case where each item $i \in I$ may be produced by more than one agent. An item which may be produced by more than one agent is denoted as *concurrent item*. Let I^C be the set of concurrent items. There may be still items that are produced by one agent only, these are denoted as *non-concurrent items*. Let I^N be the set of non-concurrent items, $I = I^C \cup I^N$. The set of agents which is able to produce item $i \in I$ is denoted as A^i.

For the DULR the decision variable r_{ia} is introduced. It is binary and defines whether agent a is responsible ($r_{ia} = 1$) to produce item i or not ($r_{ia} = 0, a \in A^i, i \in I^C$). The DULR formulation includes the objective function (10) and the formulas (2)–(4), (6)–(8), (11)–(13).

$$d_{ita} = \left(\sum_{j \in \tau^+(i)} p_{ij} \cdot x_{j,t+t_i,a} \right) \cdot r_{ia}, \forall i \in \{j \in I | \tau^+(j) \neq \emptyset\}, \quad \forall t \in T, \forall a \in A \quad (11)$$

$$\sum_{a \in A} r_{ia} = 1, \quad \forall i \in I, \quad (12)$$

$$r_{ia} \in \{0, 1\}, \quad \forall a \in A, \forall i \in I. \quad (13)$$

Formula (11) ensures that the agent a responsible to produce concurrent item i produces the total demand d_{ita} over all periods ($t \in T$). Each item is produced by one agent only (12) and (13). These constraints might be subject to future relaxations, e.g., such that the production responsibility for a concurrent item changes over time or is split among agents. However, initial computational tests on the *present instances* usually resulted in an exclusive assignment of concurrent items to agents which is why we preferred to model r_{ia} as binary variable. With these constraints the decision which agent produces which concurrent item is now part of the DULR.

3 Group Decision Making via Simulated Annealing

To solve the DULR we extend a negotiation approach based on simulated annealing with part-way resets (SAR) which was introduced by Ziebuhr et al. (2013). In Sect. 3.1, we sketch the general idea. SAR is extended by a *responsibility assignment procedure* introduced in Sect. 3.2 and a characteristic function in Sect. 3.3 that eases computing compensation payments based on Shapley value.

3.1 Outline of the Negotiation Approach

Simulated annealing is a metaheuristic based on local search (Kirckpatrick et al. 1983) which is frequently used to solve discrete optimization problems. In order to escape from a local minimum simulated annealing allows also moves that increase the objective function value. Whether an increasing move is performed depends on a probability measure which in turn depends on the objective function value of the solution and in particular on a *temperature* parameter. At first, the temperature is set to a high value which decreases (*anneals*) as the search advances. Higher temperature values cause a higher probability of accepting increasing moves.

The negotiation is controlled by a mediator. The mediator randomly generates contracts, i.e., an encoded solution (Homberger 2008). The mediator presents a new contract proposal to all agents. An agent evaluates the contract proposal. If it decreases the local cost of an agent, the agent will accept the contract proposal. If a contract proposal is accepted by all agents, the proposal becomes the new jointly accepted contract. Further search efforts by the mediator are based on this new contract. The idea of simulated annealing influences the acceptance of contract proposals, because an agent may also accept a non-improving contract by chance. Furthermore, this mechanism helps to prevent deadlocks in the negotiation process. It is supported by a part-way reset mechanism introduced in Ziebuhr et al. (2013) which may fall back to prior contracts and thus helps the search to overcome local minima.

Initially, the simulated annealing solution approach of Ziebuhr et al. (2013) was developed to solve the DMLULSP which does not deal with concurrent items. An overview of the extended SAR which is able to deal with concurrent items is given by Algorithm 3.1.

Algorithm 3.1: Extensions to the negotiation mechanism SAR (cf. Ziebuhr et al. 2013)

1. **Input:** problem data, parameters
2. mediator generate initial contract c randomly;
3. mediator (r_{ia}) ← prodRes(c); // Section 3.2
4. mediator+a ϵ A: joint contract c ← **SAR**(c); // see (Ziebuhr et al., 2013)
5. mediator (r_{ia}) ← prodRes(c); // Section 3.2
6. mediator+a ϵ A: joint contract c ← **SAR**(c); // Section 3.3

3.2 Sole Item-Production Responsibility Assignment Procedure

With respect to a concurrent item i ($i \in I^C$) the question arises, how to split the production of i among the agents A^i that are able to produce i? The production quantity of i may be split in a specific ratio among rivaling agents or one of the agents may produce i exclusively. Thanks to the missing capacity constraints of the DULR the problem narrows down to the question which of the rivaling agents in A^i produces i at lowest total cost over the planning period? The setup and inventory holding costs per item are constant over time. We suppose, that it is often more advantageous that a concurrent item is produced by a single agent solely than to split the production quantity among multiple agents, because in that case the setup costs incur multiple times as well (cf. Sect. 2.2). All in all, this presumption was approved by performing computational tests by means of the test instances described in Sect. 4.1. Therefore, we use a procedure that assigns for each concurrent item the sole production responsibility to a single agent. The item production responsibility assignment procedure outlined in Algorithm 3.2 assigns values to the decision variables r_{ia} ($a \in A, i \in I^C$).

Algorithm 3.2: proRes – production responsibilities for concurrent items

Input: problem data, contract c

1. **foreach** $i \in I$ **do**
2. Select an agent $b \in A^i$ randomly;
3. $r_{ib} \leftarrow 1$;
4. **foreach** $a \in A^i \setminus \{b\}$ **do** $r_{ia} \leftarrow 0$;
5. **foreach** $i \in I^c$ **do**
6. $b \leftarrow a$ with the property that $a \in A^i$ and $r_{ia} = 1$;
7. **foreach** $a \in A^i$ **do**
8. **if** $a \neq b$ **then**
9. $r_{ia} \leftarrow 1$ and $r_{ib} \leftarrow 0$;
10. $\Omega_{ia} \leftarrow f(c)$;
11. $r_{ia} \leftarrow 0$ and $r_{ib} \leftarrow 1$;
12. **Else**
13. $\Omega_{ia} \leftarrow f(c)$;
14. **foreach** $i \in I^c$ **do**
15. $r_{ib} \leftarrow 1$ with $b = \arg\min_{a \in A^i} \Omega_{ia}$ and $r_{ia} \leftarrow 0$ for all $a \in A^i \setminus \{b\}$;
16. **return** sole production responsibility per item r_{ia}, $\forall i \in I, a \in A$;

The procedure begins by assigning the production responsibility for each concurrent item $i \in I^C$ to an agent b ($b \in A^i$) randomly. For each concurrent item i and each agent a the total costs are computed for the case that another agent $a \in A, a \neq b$ is solely responsible to produce item i (i.e. $r_{ia} = 1$ and $\sum_{a \in A} r_{ia} = 1$). The resulting total costs are maintained in the matrix $(\Omega_{ia})^{|I^C| \times |A|}$. Finally, the actual assignment is made (lines 14–15). Item i is produced solely by that agent $b \in A^i$ which caused the lowest total cost value according to (Ω_{ia}) for i.

The calculations in Algorithm 3.2 are performed by the mediator except for the calculation of the objective function value $f(c)$ (line 10 of Algorithm 3.2) where the input of each agent is required. A drawback of the method is that the results strongly depend on an initial contract c. An advantage, however, is that the agent's are not required to reveal their costs for setup and inventory holding which are usually considered as private information.

3.3 Compensation According to the Shapley Value

The decision which agent should produce which concurrent item may involve frictions. To overcome frictions and to enhance the stability of the coalition of agents, we use cost-sharing mechanisms from cooperative game theory (see e.g. Wiese 2005). A cost-sharing mechanism distributes the cost savings obtained through cooperation to the members of the cooperation. Thorough game-theoretic analyses of lot-sizing and production games are given by, e.g., Guardiola et al. (2009) or Drechsel and Kimms (2011). However, they do not focus on asymmetric information and mediator based negotiations to find feasible lot-sizing contracts.

In the terminology of cooperative game theory, the agents which are involved in the lot-sizing supply chain game at hand are the players. The set A of all agents is called the grand coalition and each subset S of A is denoted as a coalition. Furthermore, there is a characteristic function $v(S)$ which assigns each coalition $S \subseteq A$ a value. Here, it seems natural to associate the characteristic function with costs saved due to cooperating in a coalition. This (standard) interpretation may lead to drawbacks for the DULR. For practical instantiations of the lot-sizing game, it is usually only possible to find a feasible production plan if *all* agents cooperate. Only one missing agent may invalidate a production plan.

Consider an example. Two agents a^1 and a^2 produce three items 1, 2, 3; each item has a positive demand. Item 1 may be produced only by a^1 and item 2 only by a^2. Item 3 is a concurrent item which may be either produced by a^1 or a^2. Furthermore, item 3 requires both items 1 and 2 as input. Then, only the grand coalition $\{a^1, a^2\}$ is able to generate a feasible production plan. The coalitions $\emptyset, \{a^1\}, \{a^2\}$ cannot satisfy the demand on their own. Therefore, the cost savings function of every non-grand coalition will be zero. Solution concepts from cooperative game theory are still applicable, however, their validity from a practical point of view may be damaged: if all non-grand coalitions earn a value of zero then will the Shapley value be identical for each player; with respect to the core, any complete distribution of the savings to the players will be feasible. Both cases might be unsuited in practice.

To overcome this drawback we interpret the lot-sizing game differently. The players of the game are still the agents. However, we focus on the concurrent items I^C. We assume for each coalition $S \subseteq A$ that it is always possible to produce all non-concurrent items I^N. Let $S = \{a^1\}$ be a coalition from the previous example. Now, the coalition S is able to produce the items 1, 2, 3 but item 3 has to be produced by a^1 because agent a^2 is not part of S. Hence, in this interpretation each coalition $S \subseteq A$ is always able to produce all non-concurrent items I^N but only the concurrent items of its members, i.e. the set of items given by $\{i \in I^C \cup I^N | \exists a \in A^i \text{ and } a \in S\}$.

To calculate compensation payments we use the well-known Shapley formula (Shapley 1953). Under this solution concept, each agent a receives his or her average marginal contribution to all possible coalitions. The marginal contribution of an agent $a \in A$ to a coalition $S \backslash \{a\}$ is defined as follows:

$$v(S \cup \{a\}) - v(S). \tag{14}$$

Here, $v(S)$ is the minimum total cost that coalition S achieves. An additional agent may contribute additional concurrent items to S and therefore reduce the total costs. An additional agent will not increase the total costs, i.e. $v(S \cup \{a\}) \leq v(S)$. This holds, as long as the problem is solved to optimality. However, our heuristic solution approach for the DULR cannot guarantee to find solutions that are optimal. Taking this into account, the compensation payments φ_a for an agent $a \in A$ are calculated according to the Shapley formula

$$\varphi_a = \sum_{S \subseteq A \setminus \{a\}} \frac{(|S|-1)! \cdot (|A|-|S|)!}{|A|!} \cdot [v(S \cup \{a\}) - v(S)] \tag{15}$$

where $|S|$ and $|A|$ denote the number of members in coalition S and in the grand coalition A.

4 Computational Results

The approach SAR for the DULR is evaluated by means of a computational study with new test instances. Section 4.1 describes the setup of the study together with the applied performance criteria and the generation of the test instances. Because there are no published results for the DULR, we compare our approach against well-defined reference values in Sect. 4.2 and discuss the compensation payments in Sect. 4.3.

4.1 Test Instance Generation and Performance Criterion

There do not exist test instances in the literature for the DULR. However, for the DMLULSP instances have been introduced based on MLULSP instances (Homberger 2010; Dellaert and Jeunet 2000; Afentakis et al. 1984; Afentakis and Gavish 1986). The DMLULSP instance set includes six groups of instances denoted as s2, s5, m2, m5, l2, l5 with a total of 352 instances. Instance group s2 (m2, l2, respectively) contains 96 small (40 medium, 40 large, respectively) instances in which two agents have to find a joint production plan. The instance groups s5, m5, and l5 have to be solved by five agents. We focus on the 272 instances of groups s2, s5, m2, m5 and exclude the groups l2 and l5, because the heuristic SAR performed best for small and medium sized instances. We extend the DMLULSP instances where each item is assigned to exactly one agent. First, for each item $i \in I$ we decide randomly if it is a concurrent item ($i \in I^C$) or not ($i \in I^N$). The number of concurrent items per instance is given in the second column of Table 1. For a concurrent item i, the cost parameters of the first agent are taken from the corresponding DMLULSP instance. Additional rivaling agents for i are chosen randomly. For the additional rivaling agents, the inventory holding costs h_i as well as the setup costs s_i are randomly chosen between 80 and 120 % of the original value in the corresponding DMLULSP instance. With this setting, it is always possible to compute DULR solutions with values as low as the best known DMLULSP solutions from the

Table 1 Parameter values of SAR per instance group

Group	$\|I^C\|$	r_{max}	P_{init}	Δ	p(%)	Group	$\|I^C\|$	r_{max}	P_{init}	Δ	p(%)
s2	2	5×10^4	0.90	7.5	0.25	m2	8	4×10^5	0.45	2.5	0.25
s5	5	5×10^4	0.98	2.5	0.25	m5	20	4×10^5	0.90	5.0	0.25

literature. Therefore, we denote the objective function values of the best-known solutions for the DMLUSLP as *reference values*.

SAR was implemented in JAVA (JDK 1.7) and the computational experiments were executed on a Windows 7 personal computer with Intel Core i7-2,600 processor (3.4 GHz). Table 1 shows the parameter values used for the number r_{max} of negotiation rounds, the initial acceptance probability P_{init} for a non-improving solution, the temperature increment Δ, and the storage frequency ρ of reset points.

4.2 Comparison with a Reference Value

To evaluate the performance of the extended SAR we compute solutions for DMLULSP instances and for the DULR instances. Due to the characteristics of the instances we expect that SAR computes DULR solutions with lower or at most equal total costs than the corresponding solutions for the DMLULSP.

Table 2 shows the aggregated results. Results per instance are available in an electronic appendix.[1] SAR outperforms the reference value in 206 out of 272 cases. In detail, the results for the small instances (group s2 and s5) are rather promising. SAR performs as expected and is able to unlock the additional potential to decrease the total costs due to joint items. For 76 out of 96 small instances with two agents (group s2) SAR computes superior results. SAR is even better for instances with five agents, i.e., SAR outperforms the reference value in 89 out of 96 instances. However, the performance of SAR is inferior for the medium sized instances (group m2, m5). Although the average total costs over the m2 and m5 instances are lower than the reference value, SAR is only able to unlock the cost savings potential for about half of the tested instances. In the absence of benchmark results from the literature for the problem at hand, the performance of SAR for small instances seems alright while the performance for the medium sized instances offers room for improvement.

We believe the current process of assigning production responsibilities for items to agents (cf. Algorithm 3.2) prior to the actual negotiation phase of Algorithm 3.1 might be a performance bottleneck. Therefore, we studied different points in time

[1] Instances and detailed results: http://www.logistik.uni-bremen.de/instances

Table 2 Comparison of average total costs of DMLULSP and DULR solutions

Group	DMLULSP	DULR	Outperform (or equal)
s2	812.19	802.01	76 out of 96
s5	816.08	788.06	89 out of 96
m2	266316.97	270301.08	19 out of 40
m5	294126.11	292704.11	22 out of 40

for reassigning the production responsibilities during the negotiation phase. The assignment of items to agents was recomputed (a) in each round, (b) every 500 rounds, and (c) every 10,000 rounds. However, none of these changes could improve the solution quality significantly. After reassignment of items to agents the objective function value of the solutions was usually poor. That is, the advancement of the search is to a large extend nullified by the reassignment.

4.3 Compensation Payments by Shapley Value

We used the Shapley value and a modified characteristic function for the DULR to compute distributions of the saved costs to the agents. The goal is to ensure a fair distribution of the saved costs. Table 3 exemplary presents payments for four instances (no. 25 of groups s2, s5, m2, and m5). The value $v(A)$ (2nd and 5th column) indicates the achieved cost savings due to the existence of concurrent items in the coalition. The data in the bold highlighted cells can be interpreted as follows. If no compensation payments are calculated (first line) then only agent 1 benefits from the cost savings of 29.5 monetary units achieved by the coalition. The reason is, that agent 2 produces the concurrent items at lower costs than agent 1. Without the concurrent items of agent 2 the total costs would be 29.5 units higher. Due to the compensation payments calculated by Shapley value (second line), agent 2 receives 14.8 units due to his or her ability to produce the concurrent items more efficiently than other members of the grand coalition.

Table 3 Savings distribution to agents with and without Shapley payments (instance no. 25)

	2 agents			5 agents					
	v(A)	φ_1	φ_2	v(A)	φ_1	φ_2	φ_3	φ_4	φ_5
s, without Shapley	29.5	29.5	0.0	40.1	0.0	0.0	11.6	28.5	0.0
s, with Shapley	29.5	14.8	14.8	40.1	1.3	14.3	5.8	14.3	4.5
m, without Shapley	2941.0	1251.0	1704.0	7695.7	1822.4	2197.4	430.0	1343.3	1902.6
m, with Shapley	2941.0	1470.5	1470.5	7695.7	2448.4	1098.7	1592.4	892.6	1663.6

5 Conclusions and Outlook

This paper introduced an inter-organisational lot-sizing problem denoted as DULR in which some agents are able to produce the same items and are therefore rivals. Previous distributed lot sizing models in this line of research assume that each agent produces different items, i.e., there is a disjoint allocation of items to agents. The DULR is solved by means of a simulated annealing based negotiation approach denoted as SAR which has been introduced in Ziebuhr et al. (2013) for a different inter-organisational lot-sizing problem. SAR was extended by a *responsibility assignment procedure* and a *compensation mechanism* based on Shapley value. For our benchmark study 272 new instances for the DULR have been generated. The computational results show that the extended SAR approach is able to outperform the reference value in almost all of the small instances and in about half of the medium sized instances. For future research, it appears promising to improve the performance of the negotiation mechanism by developing a more sophisticated assignment of item production responsibilities to agents. Furthermore, production capacities should be considered.

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Interactive Approach to the Inventory Routing Problem: Computational Speedup Through Focused Search

Sandra Huber, Martin Josef Geiger and Marc Sevaux

Abstract We study an *interactive-approach* to the Inventory Routing Problem (IRP) with the goal of supporting the decision maker (DM). Combining the supply chain management aspects 'inventory management' *and* 'transportation' into a simultaneous model can lead to beneficial cost reductions for both the supplier and the customer. A preference model, namely the reference point, is introduced to elicit individual preference information of the experts. Then, a subsequent *interactive-approach* is developed to solve the dynamic IRP. The comparison of the interactive-approach with an *a posteriori-approach* shows the applicability and the achieved speedup of the focused search. We also consider an *extended interactive-approach* for the benchmark test instances that is meaningful in terms of including a reservation point as a 'natural' convergence criterion.

1 Introduction

The IRP is an extension of the classical Vehicle Routing Problem (VRP) because inventory control is integrated in the routing decision. This problem arises when vendor managed inventory concepts are employed. On the one hand, this concept utilizes the supplier to determine the routing for the overall customers instead of planning them independently, and on the other hand the responsibility of the inventory is shifted from the customer to the supplier (Popović et al. 2012). According to the IRP setting, a considerable tradeoff exists between the inventory

S. Huber (✉) · M.J. Geiger
Logistics Management Department, Helmut-Schmidt-University, Holstenhofweg 85, 22043 Hamburg, Germany
e-mail: sandra-huber@hsu-hh.de

M. Sevaux
Université de Bretagne-Sud Lab-STICC – Centre der Recherche, 2 rue de St Maudé, 56321 Lorient, France

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levels, and the transportation effort. In order to analyze this tradeoff, our multi-objective IRP minimizes simultaneously *two conflicting objectives*: inventory costs which are measured by the sum of all inventory levels at each customer at the end of each period *and* routing costs (sum of all distances traveled by the vehicles in each period). The topic of simultaneously minimizing two objectives is not commonly done in the literature. For example Coelho and Laporte (2013), among numerous others, minimize the inventory and the routing costs in one objective function. However, investigating two objective functions has the advantage that the DM may examine how the reduction of delivery operations influences the inventory costs, which is an important issue in terms of tactical decision making.

In the literature, basically three methods are described to solve multi-objective problems which combine search and decision making (Hwang and Masud 1979). Each method has the aim to support the DM in selecting a most-preferred solution ($x^* \in P$) of the set of Pareto-optimal solutions P. Due to the difficulties of *a priori- and a posteriori-approaches*, our focus lies in an *interactive-approach* to the IRP. Since we are interested to obtain high quality approximations in a limited area rather than to cover the whole Pareto-front, we present a new idea for solving this problem by integrating gradually formulated preferences and incorporating this information for the subsequent computing of solutions.

The contribution of this article is twofold. First, we investigate how the preference model interacts with the local search metaheuristic. Specially, we consider the evaluation of the relative performance of the local search depending on the chosen reference point of the approximation of the Pareto-front. Second, we propose an *extended interactive-approach* which additionally uses a reservation point as a termination criterion. The applicability is analyzed and tested on benchmark instances.

2 Problem Description of the Investigated IRP

For our problem description, we may also refer to the typology of Coelho et al. (2014) and Bertazzi and Speranza (2013). Our *single-item* IRP is concerned with repeated deliveries in a distribution network with *one depot* and a *geographically dispersed set of n customers* over a *finite* planning horizon $(t,\ t = 1, \ldots, T)$. Inventory costs and capacities are taken into account at the customers, but not at the depot. According to the fleet, the size is *unconstrained* and capacitated vehicles (*homogeneous* fleet) are used.

Decision variables of the investigated IRP are: (i) the delivery quantities q_{it} for each customer $i,\ i = 1, \ldots, n$ and each period t of the planning horizon T and (ii) the VRP must be solved for each period $t,\ t = 1, \ldots, T$, including the delivery quantities q_{it} into tours for the involved vehicles.

The here considered IRP is *deterministic*. In this sense, the consumption patterns are known for each customer and each period. The demand d_{it} of customer *i* at each period *t* is served when the current inventory is insufficient. Particularly, the currently held inventory at the customers is either able to fully cover the customers' demands or the inventory is zero. In terms of the replenishment strategy, stockout situations are avoided by shipping enough goods in advance or just in time. Note that the customers' demand can vary from period to period, resulting in changing delivery quantities over the time horizon *T* (*dynamic* IRP).

As aforementioned, we assume two objectives which are clearly in conflict to each other. While small delivery quantities lead to low inventory levels over time, large delivery quantities allow a minimization of the routing costs. An alternative is evaluated by these two objective function values (outcome space) in order to determine the quality of an alternative. The DM has to take this trade-off into account when searching x^*. For a more detailed formulation of the IRP, we may refer to Geiger and Sevaux (2011).

3 Methodology

3.1 Construction and Improvement Procedure

Construction procedure: it is initially decided how much to deliver to the customer and at what time. In terms of the delivery strategy, alternatives are encoded by a n-dimensional vector $\pi = (\pi_1, \ldots, \pi_n)$ of integers. Each element π_i corresponds to a customer i and shows for how many periods the demand of customer i, $i = 1, \ldots, n$ is covered (delivery period). We assume, as an initial solution, *identical periods* for all customers, starting with 1 and increasing them by steps of 1 until the alternative cannot be added to the archive of non-dominated solutions. For example, when the 'delivery period' is defined as $\pi_i = 2$, then the exact demand of every customer is served for the next two consecutive periods. In this context, the supplier ensures that the customer does not run out of product. Therefore, a growing demand over the time horizon results in higher delivery quantities. This is a rather direct idea of representing delivery policies. Alternatively, a 'constant-delivery-quantity-approach' could be applied, which leads to changing delivery periods. A more general solution is represented in Barthélemy et al. (2012), where customers are synchronized.

Improvement procedure: a run of the local search is performed on the n-dimensional vector π. Particularly, a multi-point hill climbing algorithm is used to randomly change the values within π by ± 1, but obviously, values <1 are to be avoided. Throughout search an unbounded archive is kept which deletes solutions by dominance comparisons. Preliminary results show that the memory of a typical computer is sufficient to store the solutions.

3.2 A Posteriori-Approach

In this section, we propose our methodology for the *a posteriori-approach* based on the idea of Geiger and Sevaux (2011). Assuming that the methodology exists of two decision levels: (1) determination of the delivery quantities of each period and (2) the subsequent computation of the routing for each period, taking the already determined delivery quantities as an input. According to the underlying complexity (*NP-hard* problem) of the Vehicle Routing Problem, often, heuristic solution approaches are used for this problem (Gendreau et al. 2008). Note, the decomposition of the problem ensures a more intuitive understanding of the approach for the DM.

The identified first, rough approximation of the Pareto-front (initial solution with identical delivery periods) is used to represent different reference points $R_j = (r_{j1}, \ldots, r_{jk})$ with respect to the number of objectives k = 1, …, K. The reference point method, representing a goal attainment method (Eppe et al. 2011), was established by Wierzbicki (1980) with regard of satisfying decision making. A reference point characterizes desirable or acceptable values of the DM for every objective function g_k. In general, any point in the objective space, no matter whether it is a feasible or infeasible point can be selected. After defining a reference point, an achievement scalarizing function uses the reference point to project towards the Pareto-front (Figueira et al. 2010). After the search, the DM can select a solution in outcome space.

In principle, the *a posteriori-approach* simply takes all reference points at once and tries to converge to the entire Pareto-front without discriminating between particular search directions. In more detail: the local search uses the different reference points (identified through the identical delivery periods) as an input to approximate the Pareto-front. As a remark, the *interactive-approach* only uses one preferred reference point of the DM in order to improve this solution.

3.3 Interactive-Approach

Contrary to the *a posteriori-approach*, preference information of the DM is elicited during the search. Particularly, after the construction phase, the DM is actively involved in the intermediate decision making process. He/she selects a reference point in outcome space, thus guiding the subsequently derived search direction. The local search takes the resulting reference point R_j and minimizes the maximum distance from the computed solutions x to R_j.

$$\min\left[\max_{k=1,\ldots,K}\left\{w_k\left(g_k(x)-r_{jk}\right)\right\}+\varepsilon\sum_{k=1}^{K}g_k(x)\right] \tag{1}$$

.

Expression (1) defines the distance of each computed solution x to the reference point R_j. The objectives are denoted with g_k and a normalization of the objective functions is performed by means of w_k. This is due to the fact that the objectives are measured on rather different scales: inventory levels on the one hand and traveled distances on the other hand. For performance comparisons, normalized values are better in terms of quality comparisons of different test instances. We assume the minimum and the maximum values (estimated 'nadir point') of the computed outcomes for defining the w_k values.

3.4 Determination of ε

The additional term $\varepsilon\sum_k g_k(x)$ of Expression (1) avoids the identification of weakly-efficient solutions. In our experiments the local search maintains an archive of non-dominated solutions and eliminates weakly-efficient solutions in terms of dominance comparisons. While primarily minimizing Expression (1), maintaining an archive comes with another effect: search can continue after identifying a (locally) optimal alternative to (1).

However, if ε can be defined for our application, the archive of non-dominated solutions is not needed for further applications. The determination of ε is difficult in the general case. In this sense, ε is often described as a small positive parameter (Nikulin et al. 2012). However for our application ε in Expression (1) can be defined in more detail. Let $\Delta_k^{\min}$ be the smallest positive difference between any solution x and x′ w.r.t. g_k. Then we can easily consider the smallest positive difference of the inventory management (called 'inv') by the following relation:

$$\Delta_{inv}^{\min} = 1. \tag{2}$$

The smallest positive difference of any solution x and a neighboring solution x′ is one because we assume that products cannot be splitted.

Similar to the computation of the smallest positive difference between two inventory levels, we may derive an insight for the routing. In case of positive distances d_{ij} between customers i and j, the smallest positive difference between the length of two solutions x and x' is identical to the one of the inventory levels, which is 1. Often, and also in our application, the values of d_{ij} are measured as truncated Euclidean distances (Range 2007 and Kohl et al. 2011). If the truncation leaves one digit, we may conclude that any smallest positive difference between x and x′ cannot exceed 10^{-1}, etc.

Consequently, to the preceding description of the smallest positive differences, the minimal difference (called 'mindiff') of the inventory and the routing objective must be selected and is defined as:

$$\min \mathit{diff} = \min_k \{ w_k \Delta_k^{\min} \}. \tag{3}$$

Let LB_k be a lower bound on g_k and UB_k an upper bound on g_k. It follows, then, from our assumptions that ε must be strictly smaller than the relation:

$$\varepsilon < \frac{\min_k \{ w_k \Delta_k^{\min} \}}{\sum_k w_k (UB_k - LB_k)} \tag{4}$$

3.5 Extended Interactive-Approach

The extension of the *interactive-approach* lies in using R_j as a reference point *and* a reservation point. Particularly, after the decision maker selects a reference point, R_j is used to project towards the Pareto-front. Resulting in the solution x as illustrated in Fig. 1. Additionally, the point R_j can be used as a reservation point. From a decision maker's point of view, solutions which do not meet the minimal requirements must not be further considered. In this respect, every solution x', outside the defined cone (dashed lines) is discarded. Once this happens, a 'natural' termination criterion is reached in an interactive setting.

Figure 2 outlines the situation when the local search algorithm 'jumps' out of the cone at the beginning of the search. Conducting from the reference point R_j, the

Fig. 1 Explanation of R_j

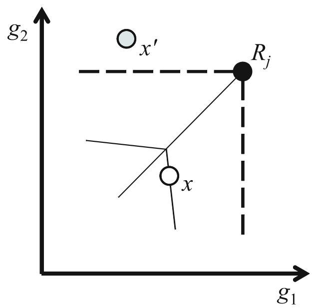
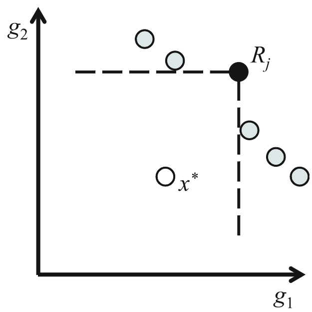


Fig. 2 Local search leaving the cone



grey points represent computed neighboring solutions. Intending to find solutions inside the defined cone, the algorithm would stop after leaving the cone, resulting in a premature termination. This implies that no or only a few solutions are found until the stopping criterion is met. Hence, the most-preferred solution x^* might not be computed because the algorithm is not allowed to jump out of the cone and move back inside. For detailed experiments see Sect. 4.2.

4 Computational Experiments

4.1 Benchmark Test Instances

Our *a posteriori-*, *interactive-* and *extended interactive-approach* have been conducted on five benchmark test instances *GS-a-01*, …, *GS-a-05* (available under http://logistik.hsu-hh.de/IRP). The test instances are characterized according to the number of customers which varies from 50 to, the more practical number, 199 customers. For every instance 30 periods are assumed. Scenario 'a' assumes a constant average demand over time. However, the actual demand of each period can vary ± 25 % of the average demand.

We simulated different types of decision makers. Therefore, we work on the assumption that the DM has expert knowledge in order to respond to the first approximation. After presenting the DM a first, rough approximation, (s)he guides the search by choosing one preferred search direction. For example, a DM being in favor of low inventory levels and therefore more frequent deliveries would take reference point R_1, and contrary, a DM preferring higher inventory levels and less frequent deliveries would select R_7 (see Table 1 and Fig. 3 for an illustration of the extreme reference point vectors). The selected reference point is then used to guide the search into the preferred (sub-)region of the Pareto-front. As a remark, the number of reference point varies from 7 to 9 for the different instances and all of them are tested for each instance.

Table 1 R_1–R_7 of *GS-a-01*

R_j	Vectors
R_1	(r_1 = 2,401 r_2 = 12,734.9)
R_2	(r_1 = 12,838 r_2 = 8,868.3)
R_3	(r_1 = 23,377 r_2 = 6,669.5)
R_4	(r_1 = 33,842 r_2 = 5,346.3)
R_5	(r_1 = 42,390 r_2 = 4,696.9)
R_6	(r_1 = 52,234 r_2 = 4,291.9)
R_7	(r_1 = 64,968 r_2 = 3,850.3)

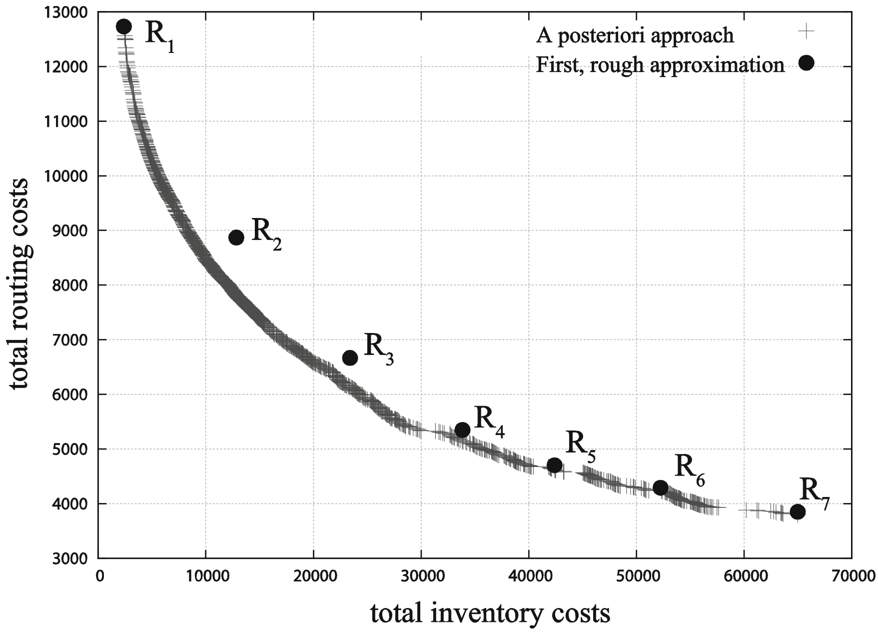


Fig. 3 First approximation and *a posteriori-approach* of *GS-a-01*

4.2 Results of the a Posteriori- and the Interactive-Approach

For each reference point, we investigate how the *interactive-approach* behaves and we compare the computational results with the *a posteriori-approach*. In this sense, we wish to verify if our focused search achieves a speedup and better solution quality.

As illustrated in Fig. 3, the bold black dots represent the first approximation with seven reference points of *GS-a-01* which is shown to the DM to help him/her to get an impression of outcome space. Note that this approximation is used for the *interactive*- and the *a posteriori-approach*. Positive is, that the approximation of P is identified fast which is helpful for the interaction of the DM with the search procedure. For example, the computational time for the approximation is 0.15 s for *GS-a-01* and 6.22 s for *GS-a-05* (the worst value). Additionally, Fig. 3 shows the estimated Pareto-frontier (small black crosses) of the a posteriori-*approach* after 838,000 evaluations (computational time of approximately 5 h) and for the *a posteriori-approach* of *GS-a-05*, the computational time of 1,000,000 evaluations is 218 h. Note that every experiment has been conducted on a single core of an Intel Xeon X5550 processor.

To compare the *a posteriori-* with the *interactive-approach*, we assume that a most-preferred solution can be computed with respect to each reference point R_j. This is due to the fact that we already know the best-known outcomes from the *a*

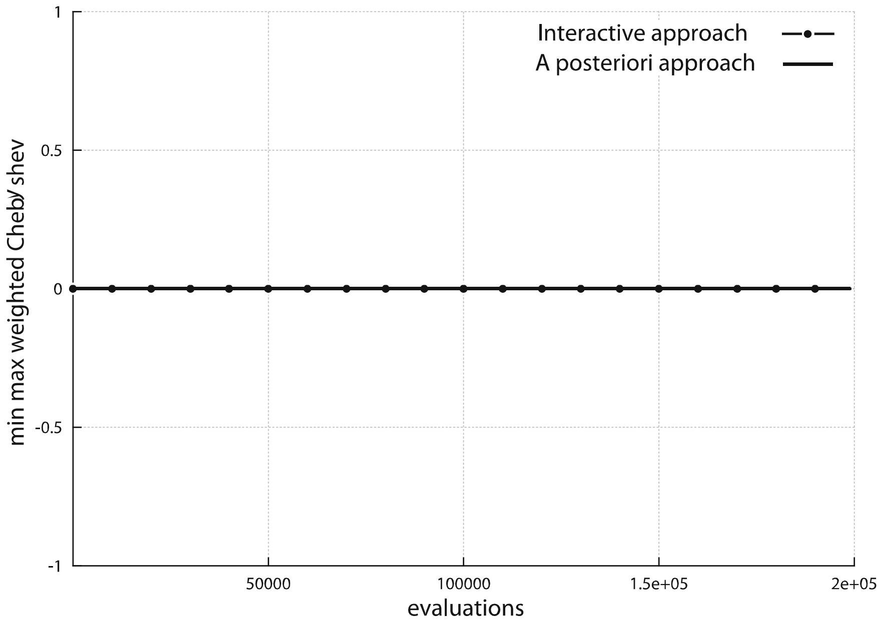


Fig. 4 R_1 of *GS-a-05*

posteriori-approach. On the basis of this solution, the distance between the currently found outcome of the *interactive-approach* and the best-known outcome of the *a posteriori-approach* can then be computed. Ideally, this distance assumes a value of 0 (once the most-preferred solution is found). In some cases, this distance can even assume a negative value. This happens when the most-preferred solution (given by the *a posteriori-approach*) is surpassed by the *interactive-approach*.

We present our observations of the computational results depending on the selected reference point. When the DM is in favor of low inventory costs, (s)he selects a reference point at the extreme end of the approximation of the Pareto-front (called R_1 (r_{11} = 2,401; r_{12} = 12,734.9) in Table 1 and Fig. 3). Unfortunately the *interactive*- and the *a posteriori-approach* terminate immediately because our implemented classical savings heuristic does not find a better solution (Clarke and Wright 1964). This is shown exemplary in Fig. 4 where the dashed and the solid line are on top of each other. This is due to the fact that the vector $\pi = (\pi_1, \ldots, \pi_n)$ cannot be improved and incidentally, a better routing algorithm as reported in Geiger and Sevaux (2011) must be used to reduce the sum of the routing costs, e.g. a more advanced record-to-record algorithm (Li et al. 2007). This behavior of the *interactive*- and the *a posteriori-approach* is consistent for the five test instances *GS-a-01*, …, *GS-a-05*.

Contrary, when the DM prefers lower routing costs and therefore higher inventory levels, (s)he chooses the other extreme reference point of the approximation of the Pareto-front. As illustrated in Fig. 5, the *interactive-approach*

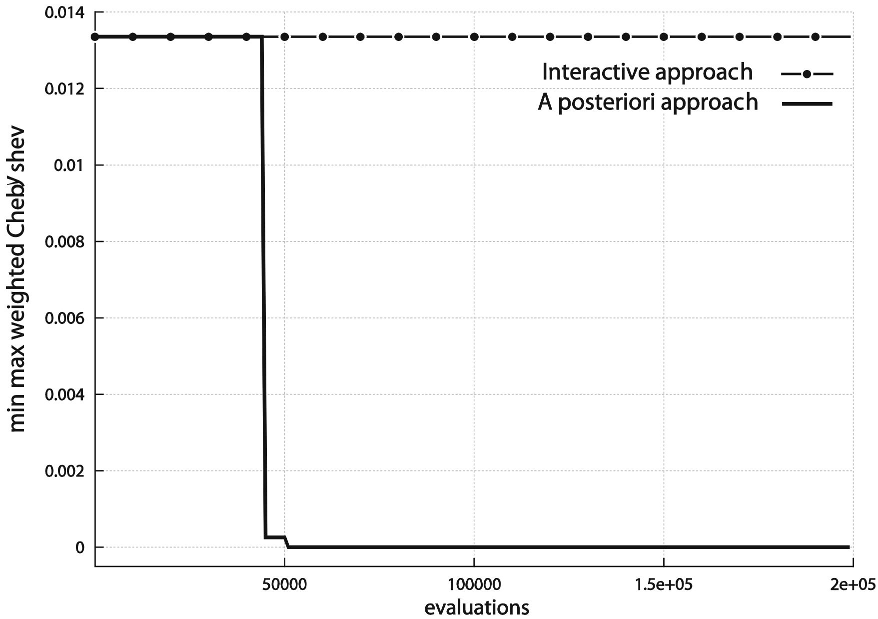


Fig. 5 R_7 of *GS-a-03*

performs worse than the *a posteriori-approach*, but only by a small value. This is in line with the analysis of *GS-a-02* and *GS-a-05* where the behavior of the two algorithms appears to be similar when selecting reference points towards the extreme ends in outcome space. Studying the compromised solutions, Fig. 6 describes the typical behavior of the *interactive-approach.* The *interactive-approach* clearly achieves a *speedup* which is indicated by the quicker declining of the dashed-curve compared to the solid line. Another effect is that the *interactive-approach* could slightly improve the already existing best-known solution of the *a posteriori-approach.* The surpassing of the *a posteriori-approach* is indicated by negative values in Fig. 6. These results are consistent for R_2, R_3 and R_4 and they do not seem to be influenced much by the instance size.

Reviewing the results of the focused search, in some rare cases the *interactive-approach* behaves as demonstrated in Figs. 7 and 8. According to R_5 of *GS-a-01*, the *interactive-approach* achieves the same solution quality as the a posteriori-*approach*. However, the *interactive-approach* can speed up the solution process, i.e. the *interactive-approach* finds the most-preferred solution after 2,000 evaluations (computational time of 23.7 s) and the *a posteriori-approach* after 183,000 evaluations (57 min). Figure 8 points out that the *interactive-approach* is speeding up the process, but falls behind the solution quality of the *a posteriori-approach* (dashed line is over the solid line). Despite the last observations, the results of the focused search show that the *interactive* search is applicable to the IRP and the computational effort can be effectively canalized towards one preferred region. As a

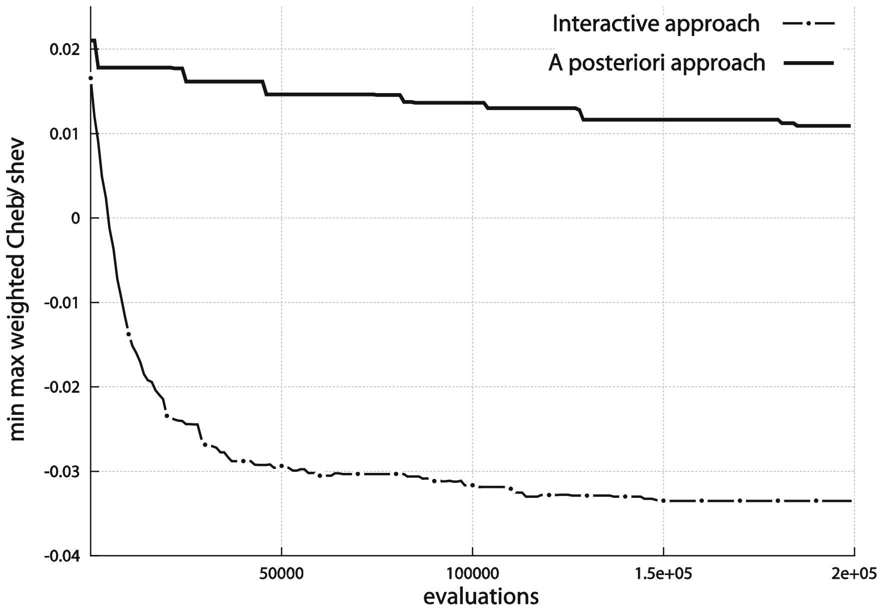


Fig. 6 R_2 of *GS-a-05*

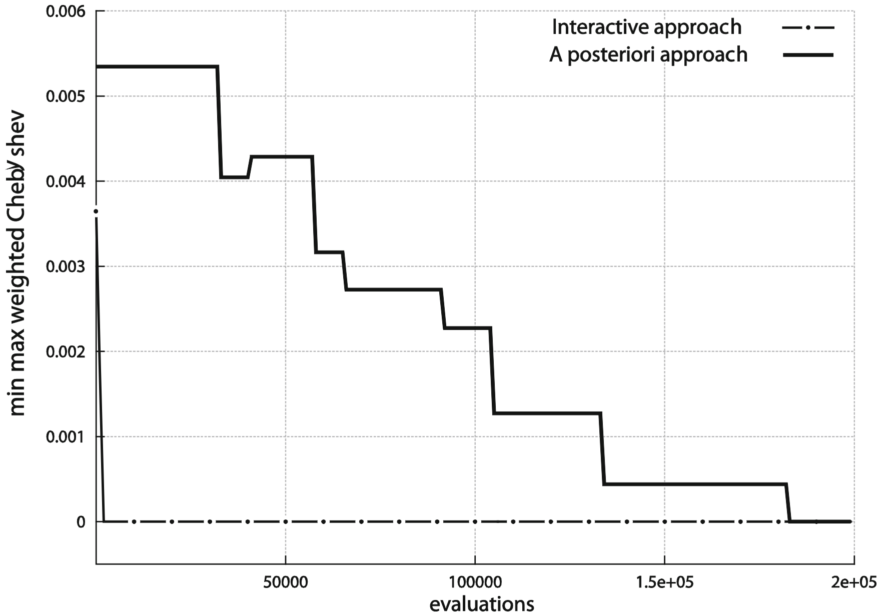


Fig. 7 R_5 of *GS-a-01*

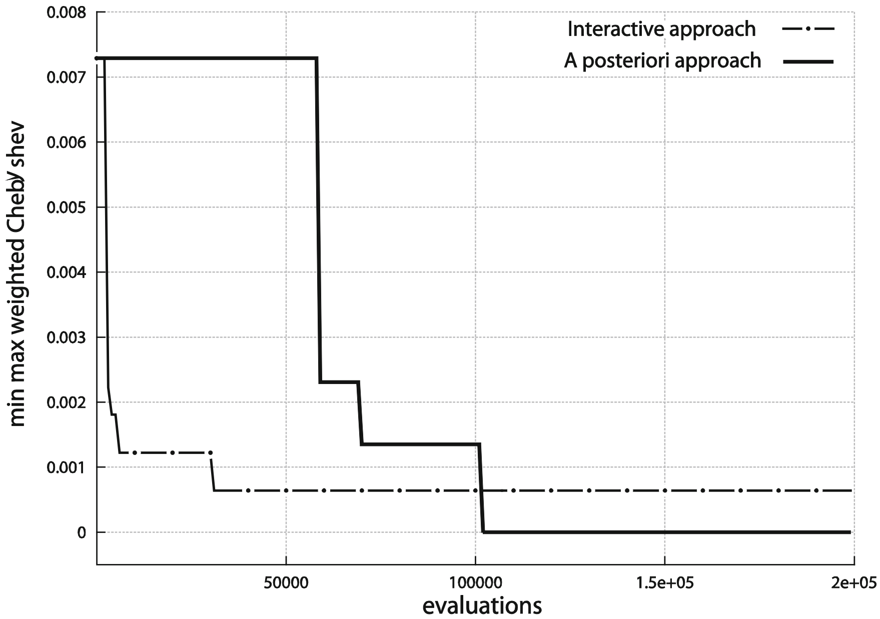


Fig. 8 R_5 of *GS-a-05*

tendency of the relative performance, the *interactive-approach* achieves a clear speedup of the search, and the solution quality could be slightly improved for more than half of all reference points.

4.3 Results of the Extended Interactive-Approach

Every R_j, acting as a reference *and* a reservation point, has been tested on the five test instances *GS-a-01*, …, *GS-a-05*. The computational results are very similar concerning the different test instances. The *extended interactive-approach* terminates immediately with the exception of R_2. As shown in Fig. 9, the computed solutions (grey triangles) are in the inside of the defined cone. The *extended interactive-approach* finds 642 solutions (after 982,000 evaluations), before leaving the cone (black lines) which results in reaching the convergence criterion. In this sense our extension seems applicable for R_2. Figure 9 also attempts to measure the quality of the estimated approximation of the Pareto-frontier. In this sense, the *extended interactive-approach* achieves a better approximation quality than the *a posteriori-approach* (grey triangles are below the black stars).

However, for the other reference points, no solutions can be found inside the defined cone. The reason for this fact is that the evolving local search first jumps out of the cone and at a later stage moves back inside the cone. Hence, if the

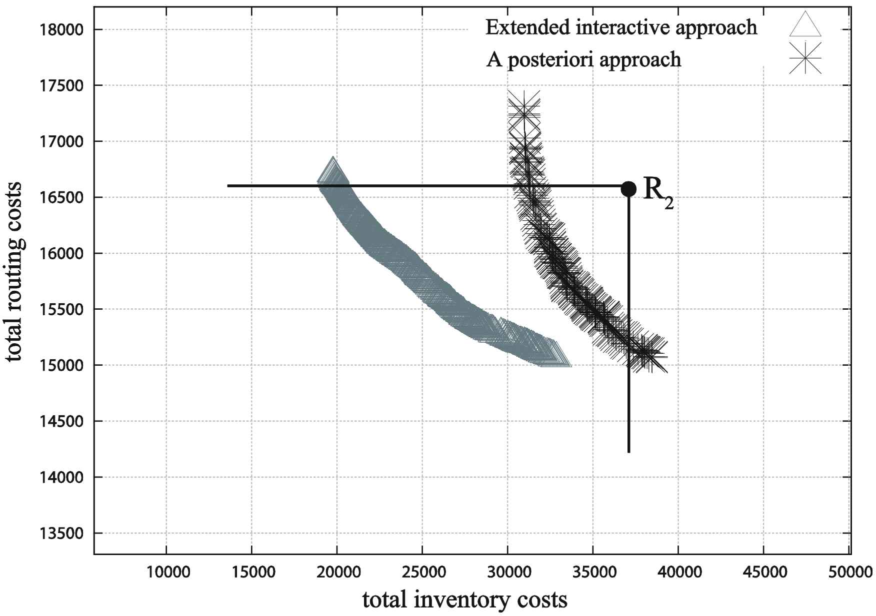


Fig. 9 R_2 of *GS-a-04* acts as a reference and as a reservation point

convergence criterion 'reservation point' is used, the algorithm prematurely terminates. Consequently, the *extension* should not exclusively applied as a stopping criterion.

5 Conclusions

The goal of our present work has been to investigate the impact of integrating preference information of a decision maker via reference points into an *interactive-approach*. We have experimentally studied the *interactive-approach* and the *extension* for five benchmark test instances.

Drawing a conclusion from the results, the combination of search and actively involving the DM is suited to the IRP. Our observations show that the *interactive-approach* achieves a significant speedup through focused search in the preferred (sub-)region. In this sense, the *interactive-approach* allows to canalize the computational effort effectively towards the DM's region of interest. Contrary, it is rather difficult to improve solutions when heading for the extreme ends of the Pareto-front. Here, the *interactive-approach* does not give an advantage to the DM.

Although most results confirm our intuition, we were not expecting the findings for the *extended interactive-approach*. The experiments show that the convergence/termination criterion of the *extended interactive-approach* can only be applied at a later stage of the search.

Despite these encouraging results, future research questions arise: It might be helpful for the DM to state more than one reference point at the beginning of the search in order to investigate different search directions (Deb and Kumar 2007). To address this issue, we want to study the option that the DM can choose multiple reference points simultaneously. The underlying problems of the different reference points can then be solved independently which is well suited to parallel computing (Figueira et al. 2010).

Additionally, the computational time can be separated for the preferred reference points by ordered classes. For example *category A: preferred search direction* achieves more computational time than *category B: interesting search direction,* and *category B* more than *category C: avoided search direction.* From a technical point of view, our method can be adapted to this idea because we have only used one single core for our experiments.

For future research, the computational time should be separated and computed parallel on different cores at once. Regarding the decisions of the DM, it has also to be taken into consideration what happens when he/she makes inconsistent decisions or changes them arbitrarily.

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Contract Design of Logistics Performance-Based Contracting: A Morphological Box

Julia Micklich and Rainer Lasch

Abstract Although strategic outsourcing concepts for collaborative, flexible and innovative contract models in logistics are often discussed, research and practice require more holistic models and no further task-oriented arrangements (Vitasek and Manrodt in Strateg Outsourcing Int J 5:4−14, 2012) Performance-based contracting (PBC) provides an effective approach to confirm partnerships with common purposes and high value-in-use for customers. Based on contracting theory, economical requirements and specific PBC principles, a conceptual framework is developed to establish robust outsourcing relationships in logistics arrangements. The key aspect is to identify alternatives in logistics performance-based contracting (LPBC) and to deliver individual solutions for application on different restrictions and specific customer requirements. Therefore, the purpose of the paper is to develop a morphological box (MB) to enable a holistic contract design for implementing LPBC. The MB bridges the methodical gap of incomplete contract design frameworks in logistics with integration of both supplier's and customer's point of view. Moreover, it supports both academics and practitioners with a heterogeneous business model based on existing established models in logistics outsourcing, which results in a wide acceptance and efficient synergies.

Keywords Strategic outsourcing · Performance-based contracting · Contract design · Logistics service performance contracts

1 Introduction

Increasing complexity along the supply chain requires efficient concepts to stay competitive in dynamic markets. Strategic outsourcing in logistics is often a subject, which has become an active research field in the last decade. Nowadays,

J. Micklich (✉) · R. Lasch
TU Dresden, Fakultät Wirtschaftswissenschaften, Lehrstuhl für Logistik,
Münchner Platz 1/3, 01069 Dresden, Germany
e-mail: rainer.lasch@tu-dresden.de

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logistics service providers (LSP) offer from traditional transport and warehousing to transshipment activities more comprehensive functions and customer-specific services such as financing. Hence, higher risks and responsibilities are transferred to suppliers (Lukassen and Wallenburg 2010; Selviaridis and Spring 2007; Domberger 1999). Although strategic outsourcing concepts for collaborative, flexible and innovative contract models in logistics are often focused, research and practice require more holistic models and no further task-oriented arrangements (Vitasek and Manrodt 2012). PBC provides an effective approach to establish partnerships with common purposes and a high value-in-use for customers.

However, PBC is often discussed in defense industry, public services and capital-intensive production areas (Kim et al. 2007; Geary and Vitasek 2008; Hefetz and Warner 2012), the adaption in logistics is still in its early stages (Vitasek and Manrodt 2012). Nowadays, logistics service performance contracts (LSPC) use incentives to coordinate integrated parties along the supply chain (Wang 2002). The measurement on logistics service performance is usually based on individual key performance indicators (Tsay et al. 1999). PBC is not transaction-oriented but depends rather on overall results and achieved performance levels in long-term cooperation (Buse et al. 2001; Patton and Bleuel 2000; Belz and Wuensche 2007). In order to fulfill customer's requirements it is necessary to shift ownership and responsibilities on suppliers' field of action. Multi-juristic relationships need a contract framework to point out the basic rules and guiding principles, which are grounded on several local contracts. The contractual design has a significant impact on success during and after the term of validity and desires a proper analysis (Barthelemy 2003; Siedel and Haapio 2010). However, all the listed aspects and models refer to isolated solutions in outsourcing of logistics processes. Hence, there is an identified gap on research for contract design of complex logistics arrangements (Olander and Norrman 2012; Forslund 2009; Jané and Ochoa 2006; Selviaridis and Spring 2007).

The purpose of the paper is to develop a MB to enable a holistic contract design for implementing LPBC. The approach closes the gap of incomplete arrangements in LSPC with integration of both supplier's and customer's point of view.

The huge body on literature requires an accurate and comprehensive analysis. A primary search was executed in scientific databases like ScienceDirect, Elsevier Scopus and Emerald Insight. We conducted an additional research in Google Scholar to extend the focus of publications. In prior research we covered basic PBC concept ideas. Most established keywords such as "Performance(-Based) Contracting/Contract(s)", "Outcome-Based Contracting/Contract(s)", "Operator Model(s)" and as German keyword "Betreibermodelle" [equivalent term of PBC (Freiling 2003)] were used to supplement the words "logistics" and "contract design". After studying the underlying concepts, we analysed further leading journals such as *European Management Journal, Industrial Marketing Management, International Journal of Operations and Production Management, International Journal of Physical Distribution and Logistics Management, International Journal of Production Economics, Journal of Business and Industrial Marketing, International Journal* *of Service Industry Management and, Journal of Purchasing and Supply Management* to precise the topic and aggregate ideas from similar concepts.

The paper is structured as follows. First, we transfer PBC principles from defense and manufacturing areas to logistics environments. The methodology section brings together essential contract elements based as well on legal as on economical requirements in outsourcing contracts. Out of these fields we identify, compare and combine essential contractual components, which are needed for both customers and performance providers. This is used to construct the MB for various intersectoral applications. Exemplary a business model was demonstrated based on the requirements of the chemical industry. After a discussion on benefits and advantages of the MB, conclusion and further research implications are presented.

2 Transformation of Performance-Based Contracting to Logistics Arrangements

Performance-based contracting is characterised as a strong service supporting business concept. The target is to ensure the availability of products in capital intensive industries while the payment is based on the delivered performance in long-term cooperation (Patton and Bleuel 2000; Kim et al. 2007). Central aspects refer to ownership and responsibility of contract objects (Cunic 2003). The individuality of various projects shall be achieved by differences in objects and process-related service elements as well as by the range of services (Glas et al. 2013; Belz and Wuensche 2007; Buse et al. 2001). Based on these aspects, we define LPBC in the deeper sense as a business concept to achieve an optimal material availability while fulfilling customer's requests under commitment of all relevant process inputs (fixed and working assets). In broader sense LPBC describes a service-oriented model delivering customer's flexibility under provision of fixed assets in logistics (Wildemann 2008). In contrast to traditional outsourcing concepts, LPBC forces a stronger integrity of collaboration through high shared value thinking and interdependencies (Vitasek and Manrodt 2012). Customers' interests to outsource more and more processes and to convert high investments into variable costs can be realised (Hypko et al. 2010).

The transformation to logistics principles is needed because of the modified circumstances in this area. The great difference is on the one hand the holistic integration of many components and subsystems in logistics and therefore various participated firms. On the other hand machinery and manufacturing areas focus on one or few high expensive tools and equipment. Hence, the coordination in logistics needs much more attention. For that reason a stronger focus on economic theories is necessary. Moreover, PBC in machinery industry offers the product and services as one bundle. The natural outputs of logistics are services. Therefore, the inclusion of services has a higher priority. Next to fixed assets which consider IT systems in logistics and infrastructure components like buildings, carriers and transportation systems working assets play an essential role in logistics processes in contrast to capital-intensive areas. Working assets include inventory of raw materials, semi-finished and finished goods as well as auxiliary materials and the corresponding financial flow.

Services achieve a stronger focus than fixed assets in logistics whereas tools and equipment are often provided by the supplier. In general the responsibility for working assets is in charge of the customer. An advantage of LPBC is the integration of working assets next to physical and management activities as well as fixed assets (Wildemann 2008).

The project relations of LPBC can be managed in different ways. The literature embedded only the customer as one party of the contract relationship (Buse et al. 2001). The part of the performance provider can be delivered by one or more LSPs. A further alternative is the establishment of an Operating Joint Venture (OJV) as a project-specific consortium of multiple participated parties in an independent business unit. The overall coordination of all transactions around the LPBC can be managed by the OJV which arises in higher synergies esp. in complex projects. Advantages of the latter option is to integrate more project partners, reduce redundancies and enforce transparency. For these reasons we prefer an OJV as central instance in LPBCs.

The resulting model is based on a multiparty network of specialised companies to achieve synergies and reduce risks for each party (see Fig. 1).

Currently, customer reasons for PBC are primarily grounded in financial aspects. It implies the transfer of huge fix costs like personal and infrastructure to cost variabilisation (Hofmann and Freichel 2010). Suppliers benefit from high profits achieved by a sophisticated service orientation and by providing comprehensive solutions (Gebauer et al. 2008).

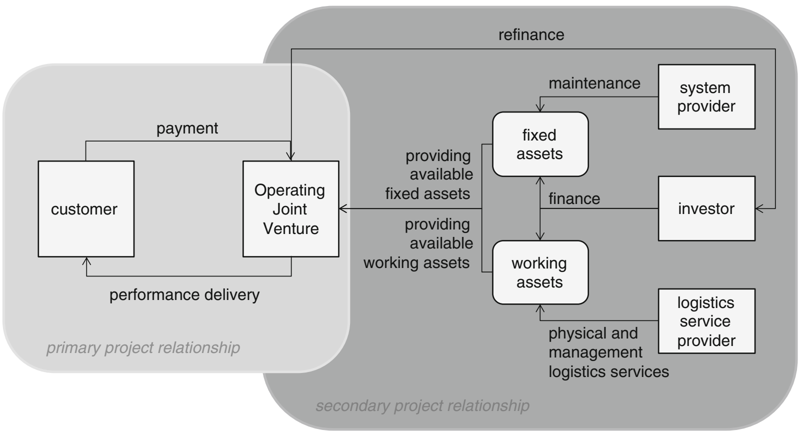

Fig. 1 Organisational structure in LPBC (in accordance to Schenk and Wirth 2004)

3 Morphological Box for Logistics Performance-Based Contracting

A key success factor in robust outsourcing partnerships is the control of complexity in the contractual relationship. We discuss both legal constraints of logistics service contracts and economical requirements on logistics contracts and identify essential LPBC elements.

3.1 Legal Requirements on Contracting

Research on primary legal regulations in contracts did not obtain attention for a long time in business science (Woolthuis et al. 2005; Fuhr 2007; Ryall and Sampson 2003). Nowadays, contract relations expand on both interacting parties along the supply chain and transaction activities. According to this development contracts become more and more comprehensive constructs in which well performing coordination mechanisms have to be stronger focused (Luo 2006).

However, in this paper contracting as outsourcing strategy provides a superordinate framework with embedded parties and their executed operations, responsibilities, rights and duties (Domberger 1999). Contract components refer to structure and content and have to fulfill requirements on completeness, preciseness and balance (Parkhe 1993; Saunders et al. 1997; Kern et al. 2002; Barthelemy 2003). Thereby contracts satisfy no one-side interest but a global optimum for all parties (Buriánek 2009).

Furlotti (2007) divides legal contract elements in two main groups—procedural and transactional elements in relational contracts. Process-oriented criteria coordinate the collaboration—rights and duties, control mechanisms and flexibility in contractual changes. Transaction-related criteria describe the content of the contract relationship such as necessary resources, claimed results, payment model and duration (Buriánek 2009). Both categories were used in our morphological box.

3.2 Economical Aspects in LPBC

A key success factor is trust in each other and working on common purposes (Di Matteo 2010). Therefore, the first step is to reduce control losses and increase transparency rights. Especially complex contractual relationships such as LPBC have a high necessity to implement well performing control mechanisms. Here, economic theories are able to find efficient solutions. The following established economic theories in outsourcing relationships were identified to apply in LPBC: Principal-Agency-Theory (PAT), Resource-based view (RBV) and Transaction cost theory (TCT) (Belz and Wuensche 2007). According to the nature of LPBC, some key issues are determined in the discussion.

The bundling of various competencies offers high synergy effects to all participated companies (Wernerfelt 1984). LPBC strictly refers to specific know-how arrangements, whereas the RBV provides efficient network strategies. Moreover, the high degree of task sharing requires a coordination instance, which is the OJV in LPBC environments. TCT addresses this problem in an efficient way (Buse et al. 2001). Nevertheless, the complex service offer leads to high dependencies and trust between the OJV and the customer. Regulation mechanisms are provided by the PAT in order to reduce information asymmetries.

Obviously, this small selection on grounded theories cannot cover all problems in this complex relation. Rather the interaction of these theories accomplishes a high range on elementary but also well performing aspects without constructing a too detailed and infeasible model.

The RBV addresses the particular skills of firms to establish competitive advantages (Penrose 1959). Resources next to physical objects are intangible items, as well as financial and organisational resources (Bamberger and Wrona 1995). Project resources are first of all the individualised investigation in fixed assets. PBC delivers performance results which include services around the investments such as financial issues, maintenance and operating. Each scope of competencies will be attached to specialists to achieve bundling effects and synergies. Due to the high degree on heterogeneity of participated firms clearly assigned responsibilities are substantial.

The often specific investments in LPBC lead to interdependencies and inbalanced information asymmetries. Here, the PAT gets its starting point to reduce opportunistic behavior. In our context the customer is the principal and the OJV represents the agent. Three different main issues arise in this theory—adverse selection (hidden characteristics) (Akerlof 1970), moral hazard (hidden action and hidden information) (Pauly 1968) and hold up (hidden intention) (Klein et al. 1978; Williamson 1985) problems. These mechanisms are considered directly as contract elements within the MB.

Transactions are a result of economic activities in the market process and the exchange of commodities and services (Coase 1937; Williamson 1975). Economic exchanges are associated with costs which are often a decision indicator for efficiency. The multiparty network structure creates a high transaction volume. The organisational instance of the OJV bundles transactions and diminishes correspondent costs. The reduction of opportunistic behavior through information asymmetries refers to the same instruments as the PAT.

After filtering of all relevant aspects of legal and economic requirements, we can assign the specific criteria of LPBC. The results are visualised in Table 1. We match to each contract aspect the specific criteria for LPBC. Following, we listed examples for the alternatives of LPBC-options.

Further necessary extensions of the aspects in Table 1 are practical reference model for the implementation of LPBC. Hence, we operationalise the characteristics to applicable business solutions. It implies the identification of possible business models and options in literature and practice to each of the listed criteria and the adjustment of alternatives with LPBC principles. Thus allows the user to select best suitable options for specific requirements.

Table 1 Relevant aspects in LPB contract design

Contract aspect	LPBC-criteria	LPBC-options (examples)
Transactional elements		
Resource input	Know-how of the OJV Hypko et al. (2010) Werding (2005)	4PL, LLP Zadek et al. (2004)
		Selviaridis and Spring (2007)
	Ownership during usage Kim et al. (2007)	Customer, asset-based LSP, non asset-based LSP Hartel (2006)
	Ownership after usage von Garrel and Dengler (2010)	Customer, IT producer, IT SP Joos (2006)
	Responsibility of service and operating personnel Kim et al. (2007)	Customer, Infrastructure producer, Independent SP Lay et al. (2009)
Definition of performance results	Depend on payment model Lay et al. (2009)	
Performance fee	Payment model Lay et al. (2009)	Usage-, performance-, value-based Cunic (2003)
Contract duration	Depend on usage Buriánek (2009)	
Procedural elements		
Performance measurement	Key performance indicator systems Goo (2010)	Key performance indicator systems Goo (2010)
Dynamic changes	Flexibility in contract modification Goo and Huang (2008)	Medium/high relevance Harrison (2004)
Reduction of asymmetric information		
Reduction of moral hazard	Profit-sharing Kieser and Ebers (2006)	Qualitive/monetary incentives Sols et al. (2007), Asdecker et al. (2012)
Reduction of adverse selection	Quality assurance ex ante Siemer 2004	Signalling, Self-Protection Pleier 2008
Reduction of hold up	Ownership structure Siemer 2004	Property rights Ripperger 2003

3.3 Configuration of the Morphological Box

The purpose is to conduct a MB for LPBC which consists of the key contractual aspects and their individual options represented in Table 1. In order to give a comprehensive visualisation of all relevant criteria and characteristics for possible LPBC arrangements, we find the MB is particularly suitable for our purpose.

The benefit of the MB is the configuration of a business model which consists of suitable LPBC-options for every criteria. Furthermore, we submit independent business models in several criteria such as 3PL and consignment warehouses. It is important to consider interdependencies between the criteria which need to get further research attention. The results are shown in Fig. 2.

Criteria				Options				
Transactional-oriented	Know how OJV			Infrastrucuture producer	4LP	LLP		
Transactional-oriented	Ownership	during usage	Infrastructure	Customer	Infrastrucutre producer	asset-based LP	Joint Venture	Logistics company
Transactional-oriented	Ownership	during usage	IT	Customer	IT producer	IT SP		
Transactional-oriented	Ownership	during usage	inventory	Customer	asset-based LP	non/ asset-based LP		
Transactional-oriented	Ownership	after usage	Infrastructure	Customer	Infrastrucutre producer	asset-based LP	Joint Venture	Logistics company
Transactional-oriented	Ownership	after usage	IT	Customer	IT producer	IT SP		
Transactional-oriented	Personell		Infrastructure	Customer	Infrastructure producer	independent SP		
Transactional-oriented	Personell		IT	Customer	IT producer	IT service provider		
Transactional-oriented	Personell		operator	Customer	asset-based LP	non/ asset-based LP		
Transactional-oriented	Payment model			usage-based	performance-based	value-based		
Transactional-oriented	Location		operation	Customer	fence-to-fence	asset-based LP	non/ asset-based LP	
Transactional-oriented	Location		IT	Customer	Software provider			
Transactional-oriented	Location		storage	Customer	asset-based LP	non/asset-based LP		
Process-oriented	Rights of Use		Infrastructure	single	multiple			
Process-oriented	Rights of Use		IT	single	multiple			
Process-oriented	Performance measurement			Key Performance Indicator				
Process-oriented	flexibility			medium relevance	high relevance			
Reduction of information inbalance	Reduction adverse selection			Signalling	Self-Protection			
Reduction of information inbalance	Reduction moral hazard			qualitative incentives	monetary incentives			
Reduction of information inbalance	Reduction hold up			Property right son operating objects				
				LPBC in the broader sense (service-oriented)			LPBC in the deeper sense (material availability-oriented)	

Fig. 2 Morphological box in logistics performance-based contracting

According to the results of Sects. 3.1 and 3.2 the MB is separated into the components transactional- and procedural-oriented aspects as well as the reduction of information inbalance. Transactional components consider both legal and economic requirements, esp. TCT and determine all essential contract parameters. Procedural elements base on legal aspects and are conducive to shape a robust relationship during the contract relation. The instruments to diminish information inbalance are derived from the PAT and also reduce asymmetries described in TCT.

As discussed in Chap. 2, the core components in logistics are fixed and working assets. A separate consideration of IT systems in logistics and infrastructure components as parts of fixed assets is necessary to allocate different specialised performance providers and requirements. For this reason we examine all contract aspects under consideration of the components inventory, infrastructure and IT systems.

The deeper and wider definition of LPBC is integrated in the MB, whereas the broader definition describes a task-sharing with stronger customer involvement. The closer the specification, the higher the degree of specialisation on involved parties. A relevant extension of the MB delivers the integration of working assets and is a further distinguishing feature in both definitions. Customers reach a comprehensive utilisation level and therefore a higher material availability when inventory will be managed and financed by suppliers. The extended meaning is represented on the left side in the MB. The more the options are positioned on the right, the closer the definition.

3.4 Application of the Morphological Box

The MB offers a holistic model consisting of various established business models such as asset and non asset performance providers, supply chain financing models and consignment warehouses. The conjunction of these independent business models generate further synergies.

We examined existing independent business models in literature and practice for each of the contract components and evaluated the fulfilment on LPBC principles. Suitable business models were positioned in the MB in between the deeper and wider definition.

Compatible business models according to individualised requirements are provided under commitment of the MB. Therefore, the holistic approach can be applied in intersectoral industries, several project volumes and contract values, different numbers on participated task areas and firms and the various integration of the customer. The flexibility is given through different options of each criteria and the allocation to a specialised or extended meaning.

Moreover, this MB can be used by both customers and performance providers to present their own interests and subsequently combine a collaborative business model with common purposes.

The high number of tasks and finance volume requires a widely ramified organisational structure to integrate subcontractors. Hence, a specialised task area can be spread over several firms. For example to ensure machinery availability an independent service provider manages the fleet and another supervises the storage systems.

Moreover, vertical cooperations were enforced which lead to a more strategic collaboration along the supply chain. Advantages of the MB are the high potential benefit in practical application because all relevant aspects of LPBC are considered.

In Fig. 2 we represent an exemplary business model for the chemical industry which is embedded in an industry park (emphasised with a black background). The sector makes high demands to quality, security and environmental awareness (Seeger and Suntrop 2011). Therefore, all participated parties need a substantiated know-how on handling of chemicals. The selection of each option results from both customers' and suppliers' interests which have been considered separately in the first step. Afterwards, it is necessary to find a harmonious matching with a high congruence of both interests to achieve a robust relationship.

4 Conclusion

LPBC is regarded as long-term vision. The proposed MB is suitable for long-term, strategic logistics projects with sophisticated core competency task areas. The MB bridges the methodical gap of incomplete contract design frameworks in logistics. In the paper we adapt the existing contract design principles in high capital-intensive areas to logistics arrangements. The great difference is on the one side the holistic integration of many components and subsystems in logistics and therefore various participated firms. For that reason a stronger focus on economic theories took place. Nevertheless, efficient instruments exist to strengthen relationships. The most successful aspect is trust in each other and common interests (Jané and Ochoa 2006). Furthermore, we identify elementary contract aspects in logistics and merged this component with LPBC principles.

However, the paper gives a more strategic point of view. There is a need to examine the contract element in detail and identify well performing interaction between the components in every criterion. Moreover, the evaluation in different industry sectors is necessary to get further implications and to illustrate best practices for different application areas. Implications for future research should focus on legal aspects in supply chain contracts.

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Strategies in Public Procurement: Is There a Deficit?

Literature Analysis and First Empirical Findings

Michael Eßig, Markus Amann and Andreas H. Glas

Abstract Purpose—The purpose of this paper is to explore the strategic nature of a current legislative initiative on supranational (European Union) level, which suggests the reform of public procurement law to better support joint political objectives. It represents one stage of an on-going research initiative aimed at providing a framework for a systematic understanding of the linkages between public policy making and public procurement strategies. Design/methodology/approach-Articles published between 2002 and 2012 in ten selected journals from supply management and public administration journals are analyzed and classified using an analytical framework for public supply strategies. Findings—The results show that most of the literature on public procurement strategies relates to the strategy content of legal, procedural or macro-economic (environmental) dimensions of the strategy framework. Largely undiscovered is the strategy content on a category level and the linkto other functional strategies. Additionally the strategy process, the making of policies and public procurement strategies, although addressed in literature, are still hardly explained. Implications—From the analytical framework, propositions for future research are presented through a research roadmap for public procurement strategies. Originality/value—By distinguishing several dimensions of public procurement strategies, the paper provides a framework for future research to enhance knowledge related to public procurement strategies and to develop a better alignment of political, legal, and economic initiatives of a public procurement reform.

1 Introduction

Public procurement is facing the dilemma of competing priorities and goals such as cost efficiency, legal conformity as well as the advancement of environmental protection and the promotion of innovation. Politically dominated public procurement

M. Eßig (✉) · M. Amann · A.H. Glas
Research Center for Law and Management of Public Procurement,
Bundeswehr University Munich, 85577 Neubiberg, Germany
e-mail: michael.essig@unibw.de

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strategies focus on these targets increasingly but in most cases an alignment with a business strategy is missing, at least in terms of a business administrational understanding. According to this, the paper analyzes the status quo of public procurement strategies using a systematic literature review. By means of an analytical framework for public procurement the investigation is based on a selection of ten management journals from 2002 to 2012. Only a small number of papers are found that fit to our subject; most of them are classified as normative and political driven, with less elements of a strategy for public procurement. Further, the idea of a strategy process combining normative targets with detailed procurement and awarding activities has almost been neglected so far. Additionally, the paper draws an agenda for further research needs in the field of public procurement in order to align political and functional strategic levels. We conclude with recommendations for public procurement managers in terms of closing strategic gaps of public procurement.

2 Goal Congruence in Public Procurement: Towards the Need of a Procurement Strategy in the Public Sector

The discussion about the relevance of strategic management in the field of industrial procurement started in Germany in the 1970s (Grochla 1977; Grochla and Kubicek 1976; Arnold 1982; Hamann and Lohrberg 1986). Again, in the 21st century the discussion gathered momentum analyzing the strategic influence of procurement (Ramsey 2001a, b) and strategy content (Essig and Wagner 2003).

Just like a mirror image to the restart of the strategic discussion in the field of industrial procurement, public procurement is recently confronted with strategic goals and the dilemma of competing targets. The discourse comprises the sense and transferability of main targets which at least partially compete with each other. Such goals are for example the cost efficiency, the legal conformity with procurement law and the support of superordinate priorities such as the advancement of women in business, the promotion of regional companies or SMEs in general and the protection of the environment. The latter can be understood as strategic (and politically set) goals of public procurement (Schapper et al. 2006). Figure 1 illustrates the necessity of integrating different target dimensions of public procurement into a system of objectives. Procurement is classified as public in the case that the contractor is a public entity fulfilling public tasks and thus bounded to procurement law (functional understanding of the status of a contractor). Consequently, not only public authorities are categorized as public contractors, but also private Ltd. owned by the state.

Foremost, the strategic relevance of public procurement is mirrored in high procurement volumes of the public sector. The contracting volume for goods and services of European member states amounts 16.3 % of the GDP on average and 21.5 % on top (EU 2007). In total, public entities in Europe spend about 1,550 billion Euros, excluding process costs for the fulfillment of public tenders. In Germany for instance process costs for public procurement are estimated to equal 19 billion Euros

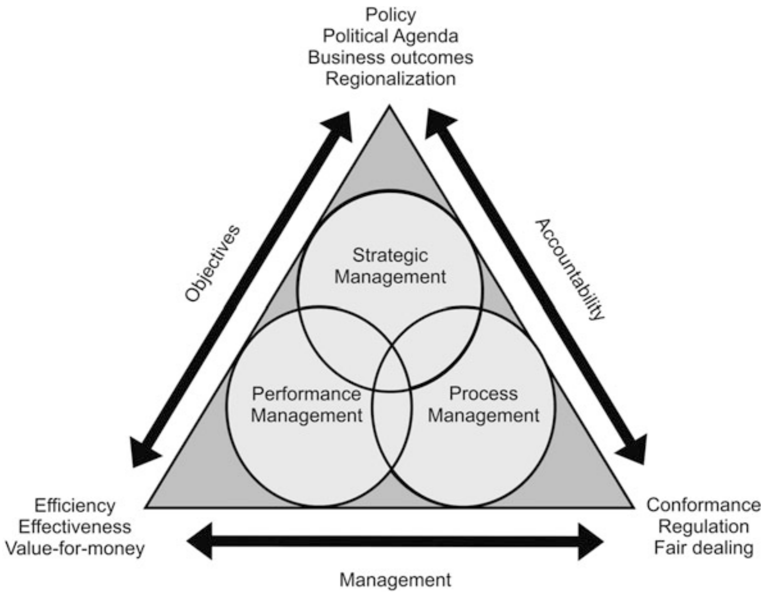

Fig. 1 Target dimensions of public procurement

per year (Kröber et al. 2008). Furthermore, efficiency and effectiveness of public procurement are frequently criticized (Bundesrechnungshof 2012) indicating a promising potential for savings. Because of the high public procurement volumes an increase in efficiency of only 0.5 % would release billions of Euros which are urgently needed for the realization of the above mentioned political goals.

Recent discussions in public procurement practice concentrate on the way of realizing strategic (political) goals through public procurement. According to this, the EU gives several recommendations such as the "EU 2020 Strategy". A further EU proposal for reform comprises five modernization areas combined with twenty detailed suggestions for improvement. Several advices mention public procurement as instrument for the achievement of political goals. This argument follows the idea of a procurement conception with corresponding objectives, strategies and instruments which in turn are hierarchical organized, but also interrelated to each other (Becker 2009). Consequently, procurement strategies represent the framework for action for goal achievement and the coordinated use of operational procurement instruments.

As a result, the EU proposal for reform focuses on procurement strategy content; procurement strategy process actually appears to be neglected. Further, only a weak alignment of the political-normative level demanding political goals with the management of public procurement and contracting authorities respectively becomes evident. Keeping this initial suspicion in mind, the paper uses a systematic literature review in order to identify the status quo of public procurement strategies. Finally, we seek to disclose strategy dimensions and strategy gaps in public procurement to derive recommendations for future research activities.

3 Method and Analytical Framework for the Analysis of Public Procurement Strategies

The analytical approach of the literature review is twofold: we investigate papers from scientific journals in the field of public administration and new public management; additionally, selected scientific journals in the field of industrial management with a focus on PSM (purchasing and supply management) are also part of the analysis. According to this, ten selected journals are systematically investigated for papers subject to public procurement strategies; five from the field of industrial PSM and five from the field of public administration. The selected industrial PSM journals are International Journal of Integrated Supply Management, Journal of Business Logistics, Journal of Purchasing and Supply Management, Journal of Supply Chain Management, Supply Chain Management: An International Journal. The selected journals in the field of public administration /new public management are Public Policy and Administration, Public Administration Review, Public Administration: Research and Theory, Journal of Public Procurement and Public Administration: An International Quarterly. The literature review concentrates on publications in the time frame from 2002 to 2012; selected papers published before 2002 are also included in the case that public procurement strategies are the main topic (Erridge and Murray 1998; Cope 1995).

The different and combined search strings used for the identification of relevant papers are related to the three dimensions “strategy”, “procurement” and “public sector”. Therefore, we used the terms “strategy”, “strategies”, “strategic” for the first dimension, “purchasing”, “procurement”, “sourcing”, “acquisition”, “contracting”, “materials management”, “supply”, “supply chain” for the second dimension and “public”, “administration”, “defence”, “federal”, “government”, “governmental”, “municipality”, “state”, “regional”, “city”, “cities” for the fourth search dimension. Predominantly, the search strings for journals in the field of public administration concentrated on the dimensions “strategy” and “procurement”. The proceeding of the literature review is based on Levy and Ellis (2006) in combination with Denyer and Tranfield (2011).

The result of the literature search based on the different search strings are 150 papers in total; after a careful investigation of the individual abstracts of the papers only 26 relevant contributions for the systematic review are identified. Even if the number of paper appears to be relatively low, the review includes a few basic contributions on public procurement strategy (Erridge and McIlroy 2002; Matthews 2005) and papers that discuss individual elements of a procurement strategy for the public sector (Fearne and Martinez 2012; Wagner et al. 2003).

The systematic content analysis of the identified papers is based on the integrative approach of Hart (1992), as well as Essig and Wagner (2003) in terms of procurement strategy. According to this, exogenous factors of the environment or the market (procurement environment) are differentiated from endogenous strategy dimensions within the public sector. In this regard, the make-or-buy decision and the contracting authorities respectively represent the main interface to the supply

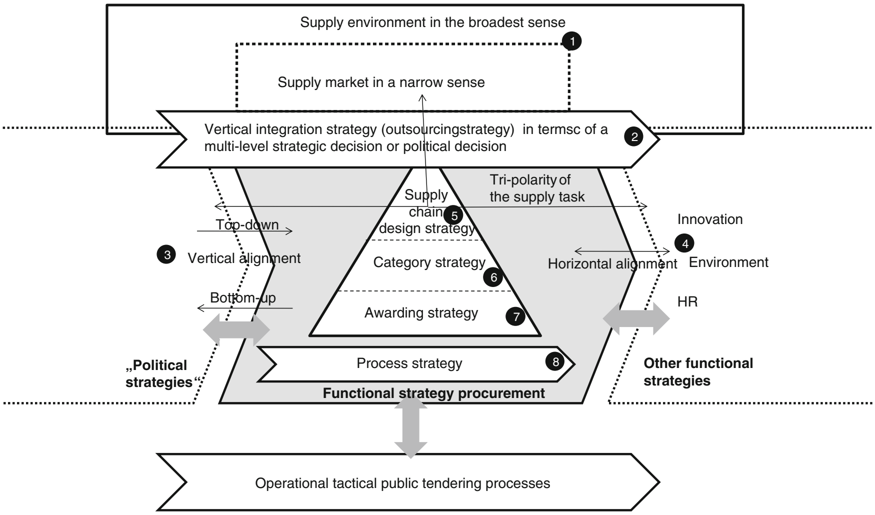

Fig. 2 Analytical framework for the literature review

markets (Weiss 1993). Based on the assumption of a procurement conception public procurement strategies are routines for action for the realization of superordinate (political) goals. For this reason, the underpinning approach of the systematic content analysis considers interfaces to the political level and to other functional strategies (HR, Innovation etc.). Moreover, structural requirements in terms of the organization of the purchasing department (supply chain design-strategy) or the purchasing category level and the contract awarding respectively are essential dimensions of a public procurement strategy reflected in the present approach. In addition, strategy process represents the counterpart of strategy content (Miller 1989; Ketchen et al. 1996) aligning and coordinating all available strategy dimensions (Essig and Wagner 2003). Figure 2 illustrates the analytical framework of the systematic literature review; the included numbers for the strategy dimensions refer to the following tabulation.

4 Results

4.1 Essential Findings Regarding the Content

The findings of the literature review are based on a total of 26 papers showing that only a low number of contributions relates to procurement strategies but with a strong focus on strategy content. Topics such as procurement law or macroeconomic strategy dimensions are focal points, while other information remains largely untouched, such as e.g. purchasing categories. An example of a macro-economic analysis is the contribution of Handfield (2004) who examines the impact of a statutory deregulation of the energy market on procurement strategies.

A need of explanatory research becomes evident concerning the problem of strategy development, in particular the coordination of political and functional strategy levels. According to this, the contribution of Khalfan et al. (2007) recommends an “alignment of a coordinated communication” between all stakeholders on the objectives, results and activities of the contract awarding in terms of big (public) construction projects. Breul (2010) discusses the manner in which such coordination should take place. He selectively focuses on individual elements of the procurement strategy such as sourcing policy, competitive sourcing or crowd sourcing from a public procurement perspective. A further topic of the investigated papers is the influence of political action on public procurement. Murray (2007) analyzes the “role of local politicians” in the strategic sourcing process using the example of the UK. He defined the concept of strategic public procurement and derives stages and tasks of a strategic public procurement process. Matthews (2005) describes existing limitations and barriers to public procurement in order to develop a strategic discipline.

A number of authors analyze the awarding of contracts through public authorities with regard to the implementation of policy objectives into contracting agreements. Preuss (2009) examines the realization of environmental, social and economic objectives by local procurement agencies. Fearne and Martinez (2012) discuss the design of sustainability strategies in supply chains in general, while Romzek and Johnston (2005) only investigate social aspects. In this regard, service contracts of public authorities with private providers are evaluated in terms of the inclusion of social performance standards. Thus, social standards have been sufficiently reflected in supplier contracts, but an implementation of adequate measures for assessing social standards is still missing. Cope (1995) examines the impact of a “politically intended” outsourcing decision on employees. A business case of cleaning services is able to clarify that, although from the client perspective, a cost reduction could be achieved, but this was at the expense of socially responsible public procurement representing a strategic goal. Cleaning services are mainly characterized by the cost of manpower. The supplier could only realize an optimization by employing service staff at significantly worse conditions. Malatesta and Smith (2001) analyze public contracts and their design using insights of the resource dependency perspective. According to this, mutual dependencies between customer and supplier require contracts with more flexibility (cost-plus). Very similar is Watts’ (2005) approach of “Strategic Service Delivery Partner-ships” outlining a supplier relationship for public contractors. His approach is characterized by aspects such as long-term, result- or outcome-orientation and risk sharing. He also reflects the implementation difficulty provided by the procurement legislation. Lonsdale et al. (2010) investigate opportunism and exploitation in the context of public procurement using an example of the UK health sector. Thus, the foundation of the Department of Health’s Purchasing and Supply Agency (PASA), which deals with procurement policy in health care, reduced opportunistic supplier behavior and shifted contracts towards a more relational mode. La Noue and Sullivan (1995) examine how the “North American jurisprudence” has responded to a ban on discrimination of minorities in the context of public procurement. They present different programs to encourage minorities within their paper. Nabatchi (2007) describes an administrative reform in North America (Administrative Dispute Resolution Act—ADR) using economic theories. In this regard, public procurement with respect to ADR is analyzed. A further North American reference point represents the work of Nollet and Beaulieu (2003) analyzing "public purchasing cooperation" (here in the healthcare sector). The paper draws an explicit strategy-structure relationship in which the cooperation as a structural element and procurement strategies are in a mutual relation.

The paper of Suárez (2010) is special since it refers to the group of "non-profit organization" as some kind of extraordinary public contractor. Non-profit organizations only possess the status of a public authority if their organization receives public funding. Further, the paper refers to "procurement" as to the acquisition of public funding. He concludes that a high degree of professionalism results in a higher chance of success. Almost similar to Suárez's paper is the contribution of Wild and Zhou (2011); they concentrate on procurement strategies for specific organization forms for humanitarian enterprises shaping a framework for "ethical sourcing".

The contribution of Wagner et al. (2003) is highly focused addressing public authorities in the context of "local councils". According to this, local councils intend to support the implementation of an electronic procurement strategy in SMEs. Even Stanton and Burkink (2008) look at individual aspects of public procurement strategy, here for small and medium-sized farms in the U.S. The derivation of recommendations for the procurement practices also represents a thematic focus of some of the considered publications. Globerman and Vining (1996) develop a valuation approach for outsourcing decisions in the public sector. Herein, transaction costs are determined investigating specificity, complexity of tasks and vulnerability in terms of competitive intensity. The approach of Girth and Hefetz (2012) demonstrates an empirical analysis of management options in "extensive competitive service markets" from the perspective of the public sector. They conclude that different competitive conditions in the procurement market require an individual management by public purchasers. Finally, Yeow and Noble (2012) classify the sourcing of innovation as an "highly complex management task" and demand the use of project management techniques with reference to a case study in the healthcare sector in the UK.

Only the contributions of Erridge and McIllroy (2002), Erridge and Murray (1998) and Kamann (2007) have a business administrational understanding of strategic procurement management. This is especially true for the Erridge and Murray (1998), who try to transfer the approach of "lean supply management" to the public sector. The core of their approach is to achieve the so-called "best value" for citizens as end-customers of public services and therefore public procurement. Politicians carry the interests of citizens; this understanding requires the consideration of political goals (so-called "socio-economic goals", Erridge and McIllroy 2002). Kamann (2007) attempted to solve the problem of the exchange relationship between citizens and the state using the stakeholder approach, which defines various interest groups for the management of public procurement.

4.2 Matching the Results with the Analytical Framework

Matching the findings with the eight framework dimensions enables an aggregation of the individual observations in order to derive recommendations for action. Table 1 provides an overview of this classification supporting three key statements.

First, strategic priorities of public procurement focusing on make-or-buy decisions and the implementation of political goals become evident. This finding also mirrors the pressure politics is actually facing. Due to existing financial constraints, an increase in outsourcing of public tasks and ultimately rendered by private enterprises is still taking place (Reichard 2004). In addition, politics identified public procurement as an effective lever for the realization of strategic (political) goals (Kahlenborn et al. 2011).

Further, the structured content analysis illustrates that an inclusion of other functional strategies, purchasing category strategies and, astonishingly, the awarding strategy has been neglected within public procurement so far. None of the investigated papers investigates these dimensions as a main topic. Consequently, public procurement still needs to align the procurement strategy with other functional strategies (Venkatraman 1989). In terms of other functional strategies a threat between functional and procurement objectives becomes evident, with significant effects on the performance of an organization. At the same time a missing purchasing category strategy reveals that public procurement products or product groups are not connected with a higher procurement strategy; promising success potentials remain unexploited. A missing awarding strategy demonstrates a strategic gap of public procurement. Although procurement legislation represents a normative framework for public procurement, the existing awarding authorities are challenged to determine a unified procurement strategy for their organization.

The consideration of the methodology illustrated that research in the field of public procurement has a strong focus on procurement practice. Consequently, empirical research methods are used. The structured content analysis is able to show that procurement strategies currently concentrate on outsourcing and the implementation of policy goals as dimensions of public procurement. Finally, all dimensions of the analytical framework are at least explicitly mentioned within the investigated papers, even those dimensions are reflected that currently do not represent a main topic.

5 Deriving a Research Agenda for Public Procurement Strategy

The debate on the strategic importance of procurement and thus on formulating procurement strategies mentioned in Sect. 1 is still ongoing. So far, it is surprising that this discussion is very little referred to, when developing almost the same topic for the public sector. Given the already outlined high empirical relevance (procurement volumes of public procurement agencies), it is imperative not to leave the

Table 1 Findings from the systematic literature review

		1	2	3	4	5	6	7	8
Author(s)	Method	Supply environment	Make-or-buy decision	Political strategies	Other functional strategies	Supply chain design strategy	Category strategy	Awarding strategy	Process strategy
Breul (2010)	Conceptional	(+)	+	+	(+)	(+)	–	(+)	–
Cope (1995)	Empirical (case study)	+	++	++	–	–	–	–	+
Erridge and McIlroy (2002)	Conceptional und empirical (analysis of contracts)	–	–	++	–	+	+	+	–
Erridge and Murray (1998)	Conceptional and empirical (quantitative study and interviews, as well as action research)	–	–	+	–	+	–	+	–
Fearne and Martinez (2012)	Conceptional with reference to case studies	+	–	–	–	+	–	–	+
Girth et al. (2012)	Empirical (interviews and survey)	+	++	–	–	–	–	+	–
Goberman and Vining (1996)	Conceptional	++	++	–	–	+	–	–	–
Handfield (2004)	Empirical (interviews) and conceptional (theory based)	+	–	+	–	–	–	–	++

(continued)

Table 1 (continued)

		1	2	3	4	5	6	7	8
Author(s)	Method	Supply environment	Make-or-buy decision	Political strategies	Other functional strategies	Supply chain design strategy	Category strategy	Awarding strategy	Process strategy
Kamann (2007)	Conceptionai	–	–	(+)	+	+	–	–	+
Khalfan et al. (2007)	Empirical (case study and quantitative interviews)	–	–	–	–	(+)	(+)	–	(+)
La Noue et al. (1995)	Conceptional	–	(+)	++	–	–	–	(+)	–
Londsdale et al. (2010)	Empirical (case study)	(+)	–	–	–	(+)	(+)	+	–
Malatesta and Smith (2011)	Empirical (case study, regression analysis)	(+)	–	–	–	+	–	(+)	–
Matthews (2005)	Conceptional	+	–	–	–	–	–	+	+
Murray (2007)	Conceptional and empirical (case studies)	–	+	+	+	–	–	(+)	++
Nabatchi (2007)	Conceptional	–	–	+	–	–	–	(+)	–
Nollet and Beaulieu (2003)	Empirical (interviews)	–	+	–	–	+	+	–	+

(continued)

Table 1 (continued)

		1	2	3	4	5	6	7	8
Author(s)	Method	Supply environment	Make-or-buy decision	Political strategies	Other functional strategies	Supply chain design strategy	Category strategy	Awarding strategy	Process strategy
Nordin and Agndal (2008)	Conceptional (literature review)	–	(+)	–	–	(+)		(+)	(+)
Preuss (2009)	Empirical (interviews)	–	–	+	+	+	+	+	(+)
Romzek and Johnston (2005)	Empirical (case studies)	(+)	++	+	–	–	–	–	–
Stanton and Brukink (2008)	Empirical (survey)		–	–	–	++	+	–	–
Suárez (2010)	Empirical (quantitative interviews)	+	+	(+)	+	+	–	–	+
Wagner et al. (2003)	Empirical (interviews)	+	–	–	–	–	+	–	+
Watt (2005)	Conceptional (theory based)	+	++	+	+	+	–	+	+

(continued)

Table 1 (continued)

		1	2	3	4	5	6	7	8
Author(s)	Method	Supply environment	Make-or-buy decision	Political strategies	Other functional strategies	Supply chain design strategy	Category strategy	Awarding strategy	Process strategy
Wild and Zhou (2011)	Empirical (case studies and interviews)	+	−	−	−	+	−	+	(+)
Yeow and Edler (2012)	Empirical (case study)	(+)	−	(+)	+	−	−	−	−

++ is the main topic of the paper
+ is explicitly considered within the paper
(+) is almost implicitly considered within the paper
− is not considered within the paper

discussion about anchoring a public procurement strategy exclusively to the political-normative level. Strategy content has to be connected with methods of strategy development in terms of environmental, innovative and socially responsible objectives (Kahlenborn et al. 2011). For the outline of further research this work refers to widely accepted approaches, which distinguish between strategy process and strategy content research (Miller 1989; Ketchen et al. 1996).

5.1 Strategy Content of Public Procurement

Basically, a procurement strategy defines what and how a certain supply need will be met (Nordin and Agndal 2008). This demand fulfillment concerns several dimensions of the applied analytical framework, in particular the make-or-buy decision, the supply chain design, the purchasing category and the awarding strategy (dimensions 2, 5, 6, 7). Recently, the focus of research on (industrial) procurement is on these strategy dimensions. Sourcing concepts, procurement portfolios, etc. provide important insights into the strategy content of the procurement function (Van Weele 2009). Other issues, for example about global sourcing or the design of supplier relationships, etc. play an important role in the outlined "how" procurement satisfies demand. On the one hand, strategy content provides guidance for the operational procurement processes and on the other hand, outlines how the procurement function contributes to the overarching organizational (firm) objectives.

Surprisingly, purchasing category strategies (dimension 4) and awarding strategy (Dimension 6) are hardly discussed within the public sector. Further, the question of the alignment of procurement with other organizational functions (dimension 4), for example, in the context of an Early Purchasing Involvement is also rarely considered.

Instead, the normative political settings dominate strategy content. In Europe—and thus even in Germany, which is subject to the public procurement regime of the European Union—these strategies are clearly defined (Kahlenborn 2011): Public procurement must develop to become more supportive in the dimensions of social responsibility, environmental sustainability and the promotion of innovations. The idea is that public procurement contributes to the objectives of the overarching organization (European Union), which for instance promotes innovation that reduces environmental impacts and increase social standards following the framework of the EU 2020 strategy. A further example is North Rhine-Westphalia, where the federal government achieved the goal of higher social standards. This objective was fulfilled by means of a uniform minimum wage through public procurement initiatives (among other initiatives), as a new law for "tariff loyalty" and "public awards of contracts" was adopted.

5.2 Strategy Process of Public Procurement

From the perspective of business administration, the scientific debate about the development process of public procurement strategies is too much dominated by procurement legislation and the strategy process is hardly discussed in business literature. This corresponds to the analysis of dimension 8 "process strategy", but also refers to the horizontal and vertical coordination processes (analysis dimensions 1, 3 and 4). The core of the strategy development process includes the decision-making process of an organization to determine the need for products or services, to identify and evaluate alternatives to meet the demand, and to select (Webster und Wind 1972). Already in the 1990s, the strategy process was identified as a central element of strategy research (Pettigrew 1992). In fact, only few sources deal with this issue and combine strategy process with the context of "governance", which is a necessary structural model to define rules, power and relationships to efficiently and effectively allocate financial, material or human resources (Fearne und Martinez 2012; Gereffi et al. 2005). In the process of strategy formulation it is recommended to form cross-functional teams of all involved stakeholders. Only the stakeholders are able to evaluate the importance of purchasing categories in terms of different areas of the public sector and to discuss and develop objectives or strategic alternatives (Handfield 2004).

6 Conclusion

Summarizing the results of the our literature review on strategy content and process significant deficits are in particular the lack of connectivity between the political strategy setting and the strategic contribution of public procurement, at least from the perspective of business administration. Currently, procurement strategies are defined by the policy and "given" by way of the public procurement law and its procurement agencies. The result is a top-down approach, which is also in political science (at least in its "pure form") not entirely uncontroversial (Sabatier 1986).

As a result, political strategy objectives are named in the context of public procurement as "awarding-external aspects" (DIHK 2007). These objectives are classified as "awarding-external" to public procurement because they serve the enforcement of general policy objectives. According to this, these objectives are not the primary business or macroeconomic objectives that attend (a) public procurement according to the principle of economy, (b) the restriction of market power of the public sector and (c) the liability of effective competition in the awarding of public contracts.

In fact, however, it is widely accepted that a strategic supply management must contribute to the strategic objectives of an organization (Large 2009). Transferring this understanding of procurement strategy to the public procurement authorities, then formal (economic) goals do not longer dominate tangible (political) goals.

So, for example, if the German Federal Government commits to reducing CO2 emissions as a strategic goal, public procurement must also contribute to this objective.

The problem, therefore, is not the existence of strategic (policy) goals and the fact that this must be taken into account by the procurement function. This is also reflected in the analysis dimension (3). The actual dominance of political strategies in the analyzed literature becomes evident. Further research is rather needed on the question of how a process looks like, that leads to the strategy definition.

The sketched top-down approach limits the influence of the public procurement function in terms of self-identified potentials (savings, performance) within the (political) strategy formulation. The deficits in purchasing category- and awarding strategies (dimensions 6 and 7) as well as the lack of alignment with other functional strategies (dimension 4) show the existence of insufficient interaction between the political and the level of procurement management. It is likely that this issue is still largely unexplored, because the analysis of political decision-making takes place in the political sciences. An important step would be the implementation of interdisciplinary research approaches to further explore strategic management of public procurement.

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Using Capability-Based Planning for Designing Cooperation Between Automotive Manufacturers and Logistics Service Providers

Carsten Böhle, Bernd Hellingrath, Dennis Horstkemper and Dennis Rabe

Abstract Automotive Original Equipment Manufacturers (OEMs) are constantly establishing new manufacturing plants in various countries. The establishment of new plants offers plenty of opportunities to the OEM but at the same time the problem to integrate these new plants into its global production and logistics network is posed. One way of handling this problem is to outsource some of the needed capabilities (macro level business functions, e.g. warehouse management) to Logistics Service Providers (LSPs). The OEM is then faced with the question, which capabilities to outsource when establishing a new plant. The LSP on the other hand has to evaluate which products and services to offer to an OEM. The purpose of this paper is to outline the development of a methodology based on techniques from Enterprise Architecture (EA) and more specifically Capability-based Planning (CBP) that helps answer these questions.

1 Introduction

Automotive Original Equipment Manufacturers (OEMs) are constantly establishing new manufacturing plants in various markets like Asia, South America or Eastern Europe, in order to cope with market trends and increased competition. Volkswagen

C. Böhle (✉) · B. Hellingrath · D. Horstkemper · D. Rabe
Lehrstuhl für Wirtschaftsinformatik und Logistik, Westfälische Wilhelms-Universität Münster, Leonardo-Campus 3, 48149 Münster, Germany
e-mail: carsten.boehle@wi.uni-muenster.de

B. Hellingrath
e-mail: bernd.hellingrath@wi.uni-muenster.de

D. Horstkemper
e-mail: dennis.hostkemper@wi.uni-muenster.de

D. Rabe
e-mail: dennis.rabe@uni-muenster.de

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for example opened its 100th manufacturing site worldwide in Silao, Mexico in 2013 (Agence France-Presse 2013). The establishment of new plants offers plenty of opportunities to the OEM, for example a higher production volume, a shorter time-to-market or benefits from lower wages or subventions (Schonert 2008, pp. 290–309). At the same time the OEM is faced with the problem of integrating these new plants into its global production and logistics network. One way of handling this problem is to outsource some of the needed capabilities (macro level business functions, e.g. warehouse management) to Logistics Service Providers (LSPs). The OEM is then faced with the question of which capabilities to outsource when establishing a new plant. The LSP on the other hand has to evaluate which products and services to offer to an OEM depending on the characteristics of the aspired collaboration scenario. This might require changes of existing products and services of the LSP or the development of new services and products that can be offered to the OEM. The purpose of this paper is to outline the development of a Design Science-oriented methodology based on techniques from Enterprise Architecture (EA) and more specifically Capability-based Planning (CBP) that helps answer these questions. Its applicability is demonstrated based on a case study from the automotive industry with input from practitioners. For this purpose, different collaboration scenarios of an OEM and an LSP are analyzed, outsourcing candidates are identified, and service packages to be offered by an LSP are developed. The case study was conducted with the help of an LSP and a consulting company.

Research for this paper followed the guidelines for Design Science in Information Systems Research. First, data on strategy, products, and decisions in the context of the international expansion of automobile manufacturers was collected via literature research and in-depth interviews with industrial experts. This information laid the basis for the case study. Then, applicable knowledge in the form of models and methods was extracted from the field of Enterprise Architecture in general and leading methodologies such as TOGAF and CBP in particular. Finally, useful artifacts, e.g. capability maps, were built to codify the acquired knowledge. These were then extended and refined to allow for the set goals, i.e. the planning of strategic alliances. The methodology's development process contained several iterations including presentations to stakeholders which allowed for the timely integration of feedback.

The remainder of this paper is structured as follows: in chapter two the concept of capabilities and Capability-Based Planning is introduced. In chapter three the developed methodology is presented with small examples from the case study. The paper concludes with a summary and an outlook in chapter four.

2 Capability-Based Planning

2.1 Definition of Capability

In order to create a common understanding of CBP, it is important to first define its basic elements: business capabilities. Business capabilities can be conceived as

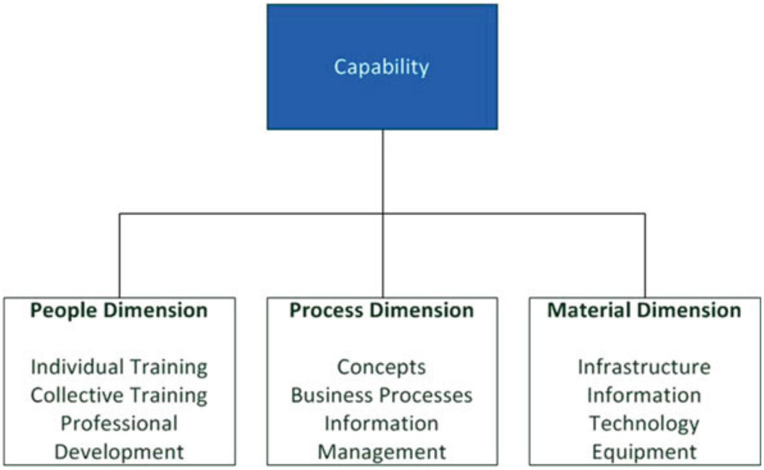

Fig. 1 Capability dimensions (The Open Group 2011, p. 322)

modules in an enterprise context (Cherbakov et al. 2005, p. 655), which refer to the capacity of an organization to achieve a specific outcome (Amit and Schoemaker 1993, p. 35). In order to achieve this outcome, a combination of organization, people, processes and technology is required within a capability (The Open Group 2011, p. 23). According to The Open Group, a capability consists of three dimensions: People, Processes and Material (see Fig. 1). These dimensions can be different for each individual organization and they define the content of a capability (The Open Group 2011, p. 321) In summary, capabilities can be considered to be the building blocks of an organization, which are derived from the organizational model and capture the business interests (Cameron and Kalex 2009).

2.2 Capability-Based Planning

The most cited definition of CBP is the one of Davis who defines CBP as "planning, under uncertainty, to provide capabilities suitable for a wide range of modern-day challenges and circumstances while working within an economic framework" (Davis 2002, p. 1). The Open Group defines CBP as focusing "on the planning, engineering and delivery of strategic business capabilities to the enterprise" (The Open Group 2011, p. 319). It can be applied in all industries and is especially useful when the ability to respond quickly is required and resources, e.g. people, processes or materials are "involved in multiple capabilities" (The Open Group 2011, p. 319).

There are a variety of views and methods that are of high importance in the context of CBP. The most common method is the capability map, which is "a visual representation of the main functions in the enterprise which are necessary to support the company's business model and which reflect the company's strategic direction"

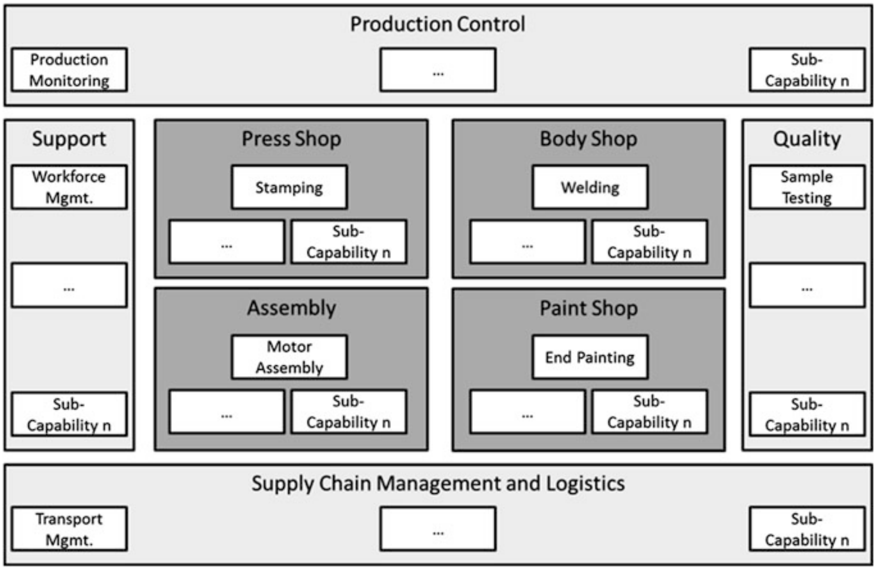

Fig. 2 Capability map OEM

(Freitag et al. 2010, p. 5). In a capability map, the different capabilities of an enterprise are represented on different levels of detail, starting on a very high level, which is often similar to the different functions of an enterprise. The sub-capabilities can then be visualized by placing them within the high level capabilities. This concept can then be applied to the sub-capabilities as well until the needed level of detail is reached (for an exemplary capability map please refer to Fig. 2). Capability maps can be used as input for a gap analysis in which differences between two different capability maps can be depicted (see Sect 3.3).

3 The 5-Step-Approach

In the following, the methodology developed during the case study is introduced. On the one hand, it aims at supporting the decision process of an OEM on what to outsource to an LSP when opening a new production plant. On the other hand, it provides an LSP with a specific set of products and services that can be offered to an OEM in a scenario. It also enables the identification of gaps between the products and services demanded by the OEM and the products and services that can be offered by the LSP. It is based on CBP and consists of five steps which will be introduced in the following.

3.1 Step 1: Identification of Scenarios

In the first step, scenarios in which an OEM is planning to establish a new production plant have to be developed. For that purpose, characteristics, which are of high importance when establishing a new plant, have to be identified. Each of the characteristics is then provided with a set of different options, from which one or multiple options can be chosen in order to describe a scenario. The characteristics can be divided in two groups. The first group of characteristics describes the scenario from an OEM's point of view. It includes:

- Strategy: what is the strategy behind the OEM's decision to build a new plant at the location? Options include for example: Increase capacity and volume of production, expand to new market, etc.
- Size: what is the planned size of the new plant? Options include low production volume (<100.000 cars/year)—high production volume (>300.000 cars/year).
- Competition: are there plants already established in the area of the chosen location or is the OEM the first to locate a plant? Options include first mover, existing plants of the OEM, and existing plants of competitors.
- Sourcing: three possible modes of sourcing exist: regional sourcing, national sourcing, and international sourcing.
- Distribution: the same options as in Sourcing can be assigned.
- Market: refers to the size and type of the market of the selected region. Options are future emerging market, emerging market, and mature market.

The other group of characteristics refers to the location at which the new production plant is going to be established. It includes:

- Region: the geographic location of the selected region, consisting of Latin America, Europe, Asia-Pacific, North America, and Africa.
- People: refers to the level of labor skills and knowledge available for hiring in the selected region. Options include high-skilled, medium skilled, and low-skilled.
- Laws and Regulations: refers to the local regulations for automotive products when borders are crossed as well as of government support for OEMs. Options include, e.g., high, medium, or low taxes.
- Security and Risk: refers to the risk level within the specific region. The security level of the supply chain through which supply parts are being delivered to the OEM plant are also considered.

After the scenario characteristics have been identified, specific scenarios can be constructed by using the different options assigned to each characteristic and by confirming the relevance of the created scenarios through a literature research of actual real-world scenarios. For the case study, the two most relevant scenarios were selected by taking into account the interests of the participating LSP.

3.2 Step 2: Outsourcing

After the different scenario characteristics and specific scenarios were identified in the first step, potential outsourcing candidates of an OEM in the different scenarios have to be identified. This is done with the help of CBP by applying a decision theory-based procedure model for capability sourcing to the two scenarios, which was developed at the University of Münster (Nguyen 2012).

The general idea of the procedure model is to enable companies to flexibly acquire capabilities from external sources in order to meet changing business requirements by assessing to what extent the capability in question qualifies as a candidate for outsourcing. The procedure model consists of five phases, which are described in detail in the following:

Modularization: In a first phase, the organization is divided into separate capabilities in order to provide a capability map of the existing business capabilities of the organization. The procedure model mainly focuses on the process dimension. It limits the material dimension to information technology and puts less emphasis on the people dimension.

Outsourcing Criteria Definition: In the second phase, outsourcing criteria have to be identified which guide the assessment of the different business capabilities. They depend on the objectives of the decision makers and enable the comparison of alternative options when considering the solution for a specific problem (Laux 2005, p. 23). Furthermore, it is suggested to focus on the following criteria:

- Strategic Impact
- Value Contribution
- Cost Advantage
- Performance Excellence

In the next phase, the criteria "Strategic Impact" and "Value Contribution" are used as input for the strategic exploration of business capabilities, while "Cost Advantage" and "Performance Excellence" are used as a contribution to the operational exploration of business capabilities.

Exploration of Business Capabilities: The next phase is divided into three sequential sub-phases:

- Strategic Exploration of Business Capabilities: Aims at identifying capabilities of strategic importance for the company, which rather should remain in-house as they are a core competency of the company. All other capabilities are then potential candidates for outsourcing.
- Operational Exploration of Business Capabilities: Goal of this phase is the analysis of all business capabilities on an operational level.
- Creating Exploration Report: Aims at creating a comprehensible report that gathers and presents the findings of the previous steps. For each capability that is a possible candidate for outsourcing, the results are visualized in an assessment profile.

Evaluation of Capabilities: Goal of this phase is to create a ranking of all business capabilities which were identified as being candidates for outsourcing. As a method for achieving this goal it is proposed to use portfolio maps which rely on the results of the previous steps.

Choice of Capabilities: In the final phase, one or more actual capabilities are chosen by the decision makers of the sourcing organization.

The procedure model is used within the case study as a general guideline to identify outsourcing candidates among the OEM's capabilities. The first phase of the procedure model is used to identify and describe the capability maps of an LSP and an OEM (for an exemplary capability map please refer to Fig. 2). This was done based on the feedback of decision makers from the participating automotive consulting company and the LSP. The maps were devised to the needed level of detail, meaning that for example "Supply Chain Management" and "Logistics" capabilities were drilled down to the fourth level whereas core competencies like "Press Shop" and "Body Shop" were only drilled down to the second level. Furthermore, the impact of the identified scenario characteristics and the chosen scenarios on the capabilities of an OEM was evaluated in the first phase. E.g., in a scenario with high production volume, the strategic importance of the capability "Material Planning" increases in comparison to scenarios with low production volume. A result of the impact analysis of the specific scenario characteristics is a similar set of outsourcing candidates when comparing similar scenarios and a differing set of outsourcing candidates when comparing dissimilar scenarios.

In the second phase, outsourcing criteria and assessment methods are defined which guide the distinction of possible outsourcing options. In order to determine outsourcing candidates of an OEM, the Outsourcing Decision Matrix was chosen as the tool to be used during the case study. The Outsourcing Decision Matrix takes into account the strategic importance of a capability on the y-axis and the operational performance of a capability on the x-axis. The capabilities can be positioned in one of four quadrants: form strategic alliances, retain, eliminate or outsource (see Fig. 3).

Capabilities which are placed in the quadrant "Form strategic alliances" are capabilities which are of high strategic interest, but affect the operational performance of the OEM insignificantly. For example, an OEM could form an alliance with an advertising agency for "Marketing". The manufacturer needs to be in close contact to the agency, but the advertising has little impact on the day-to-day operational performance of the company. Capabilities, which represent core competencies of the OEM, are placed in the quadrant "Retain", as they should be kept in-house. An example is the assembly of a car model in the case of an OEM. Capabilities, which are crucial for the operational performance but are of low strategic importance, are placed in the quadrant "Outsource" to represent potential outsourcing candidates. Capabilities like "Container Logistics", which have high impact on the operational performance but little on the strategy, are candidates to outsource to an LSP. The last quadrant "Eliminate" covers all capabilities which are neither important on a strategic nor an operational level. Although the capabilities cannot be eliminated completely, the OEM should check existing reasons for their

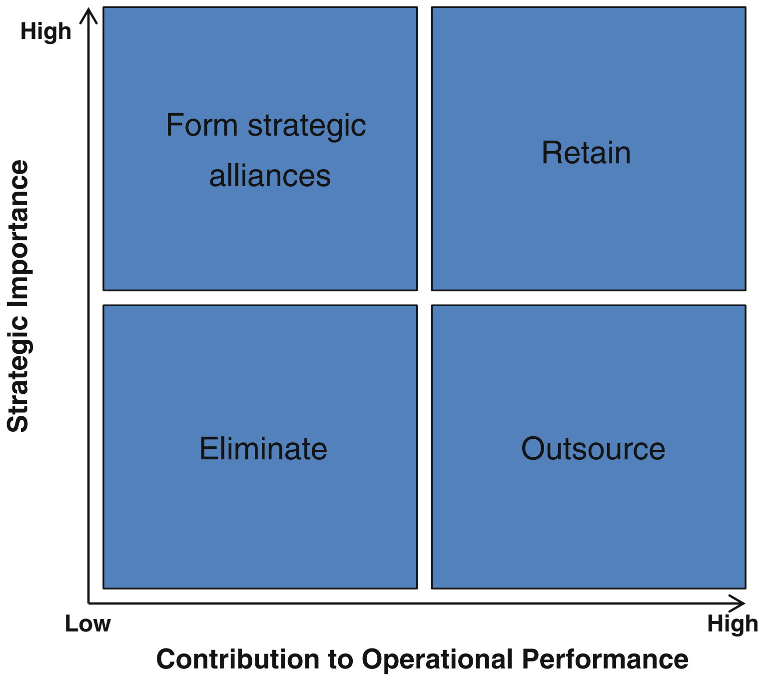

Fig. 3 Outsourcing decision matrix (Mindtools 2012)

existence and whether the capabilities are possible candidates for outsourcing (Mindtools 2012).

In a third phase, the capabilities of an OEM identified previously are assessed with the help of the Outsourcing Decision Matrix. The strategic importance and contribution to operational performance of the different capabilities was determined by conducting interviews with experts from the automotive industry as well as from the LSP participating in the case study.

In the fourth phase, the capabilities, which are considered to be outsourcing candidates according to the previous phases are identified and highlighted in the capability map. In the final phase, the capabilities, which are to be provided by the LSP have to be chosen as a basis for the next step.

3.3 Step 3: Gap Analysis

After the outsourcing candidates of an OEM in a specific scenario have been identified, they have to be matched with the capabilities of an LSP. This can be done by performing a gap analysis as proposed by The Open Group (The Open Group 2011, p. 290), resulting in a gap matrix consisting of all capabilities of an

Table 1 Gap matrix

OEM / LSP	Workforce Management	Strategic Transport Planning	Equipment Maintenance	…	Outsourcing candidate n
Skill Management	Match (green)				
Supply Chain Planning		Partial Match (yel.)			
…				…	
Capability n					
New			Gap (red)		Gap (red)

LSP on the horizontal axis, including a final row named “New”, and of columns for every outsourcing candidate of the OEM. The outsourcing candidates are then matched with the capabilities of an LSP by marking matches in green, partial matches in yellow, and gaps in red (for an exemplary Gap Matrix please refer to Table 1).

As the capability maps of the OEM and the LSP differ, the major challenge is to overcome these differences when matching the outsourcing candidates from the OEM’s maps to the capability map of an LSP. Some of the typical challenges during the case study were: matching capabilities in different domains, matching capabilities that had different names or different descriptions, and matching capabilities that partially matched or that matched with more than one capability. Those difficulties were overcome during the case study by conducting expert interviews and thus clarifying any inconsistencies.

As a result of the third step, an LSP is provided with a clear understanding of which capabilities can already be offered to an OEM in a specific scenario while at the same time partial gaps and gaps between the requirements of an OEM in a specific scenario and the capabilities of an LSP are identified. These gaps serve as the starting point for the next step.

3.4 Step 4: Products

Based on the gaps and partial matches of the gap analysis in the previous step, a set of products has to be developed in the fourth step. Each product has to be described by a set of attributes consisting of:

- Name: unique name that is easy to understand.
- Statement: summarizes the fundamental idea of the product.
- Rationale: describes the basic concept of the product and highlights potential benefits.

Table 2 Packaging

Attribute	Description
Name	Packaging
Statement	Support customers with complete packaging solutions from design to execution
Rationale	An LSP provides packaging services/technology and develops packaging solutions for the automotive industry
Affected OEM's capabilities	Packaging planning, packaging execution
Implications for the LSP	Develop a capability that enables an LSP to execute the packaging of parts and cars for an OEM. This includes packaging machinery, software to run this machinery, the development of required processes and expert knowledge in the field of packaging
Scenarios	The product was applicable in both scenarios considered during the case study

- Affected capabilities: identifies capabilities of the OEM (mainly outsourcing candidates) that are covered by the product.
- Implications for the LSP: comprises requirements of an LSP from a business and IT perspective to successfully deploy the product.
- Scenarios: evaluates the feasibility of the product in specific scenarios.

In summary, the products comprise capabilities that need to be developed by the LSP in order to fully meet the requirements of the OEM in specific scenarios. In the context of the case study, six different products were proposed to and approved by the participating LSP (for an exemplary product please refer to Table 2).

3.5 Step 5: Assessment of Products

The previously identified products are then assessed according to five criteria in a last step in order to determine the sustainability and feasibility of the products. The assessment criteria include "Strategic Fit" which evaluates in how far the proposed product fits to the current strategy of the LSP and if it can provide the LSP with a competitive advantage over other LSPs. Another criterion is "Ease of Implementation", evaluating how fast and with how much effort the proposed product can be implemented. In addition, "Degree of Benefit", evaluating the potential benefits of the products, "Main Capability Fit", evaluating in how far the product can already be covered by existing capabilities, and "Risk Assessment", evaluating potential risks of the product, are used as additional criteria.

Each criterion is split into multiple questions, enabling the evaluation of different aspects of the criterion. Each question is assigned with a scale (e.g. Strategic Fit: In how far does the product provide a competitive advantage to the LSP: 1 (very unlikely)—5 (very likely)). Each product is then assigned an individual grade,

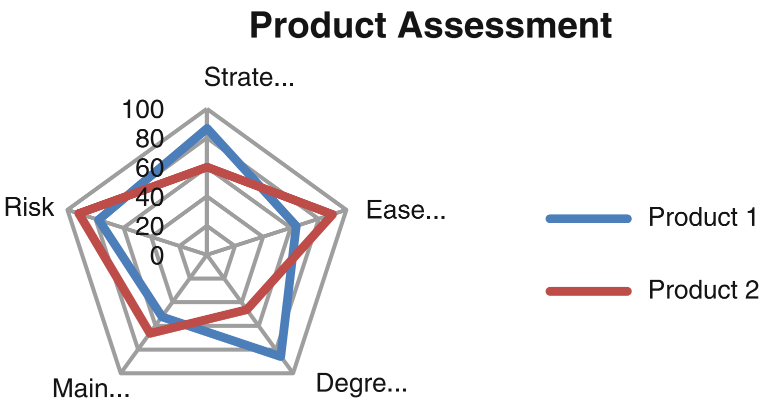

Fig. 4 Product assessment

enabling a comparison of the different products (see Fig. 4 for an exemplary product assessment). During the case study the different products were assessed according to the feedback from numerous experts of the participating consulting company and the LSP.

In general, the assessment of the products supports the decision making process of the LSP upon which investments are to be made in the future by providing a thorough comparison of the different products. Depending on which criteria are valued higher by the LSP, not only the decision on what products to implement is supported but also the decision in what order to implement the different products is supported.

4 Summary and Outlook

In summary, the usage of CBP for designing cooperation between an OEM and an LSP is demonstrated in this paper. The developed methodology consists of five steps. They are demonstrated by applying them to a case study from the automotive industry. In the first step, scenarios in which an OEM establishes a new plant are developed. In a second step, CBP is used to identify capabilities, which can be outsourced to an LSP in selected collaboration scenarios. This is done by applying a decision theory-based procedure model for capability sourcing to the two scenarios. In the third step, a gap analysis is conducted; the outsourcing candidates of the two scenarios are matched with the capabilities of an LSP. In the fourth step, the results of the gap analysis are taken to determine a set of products and services that can be offered to the OEM by the LSP. In addition, the identified gaps serve as a starting point for the development of new products and services which need to be acquired by the LSP in order to be able to offer a full range of products and services needed by an OEM. The new products and services are then assessed in a final step. Thus, the concept of EA and especially CBP is exemplarily introduced to the scenario of new plants in the automotive industry. It is applied successfully in the developed methodology and has proven to be a promising methodology from both an academic and practical perspective. If applied in a clearly defined context, the methodology allows the explication of implicit knowledge, e.g. from business experts, and it can help to cope with the inherent complexity of the field of application, support the process of decision making, and improve decision quality.

The evaluation of findings is based on the feedback of decision makers in the automotive consulting and logistics industries. They fully approved of the concept and aim at integrating it in their decision processes, thus its potential to be a new instrument for strategic decision making is confirmed. The paper is limited in so far as it focuses on the methodological aspect and uses an abstract set of decision parameters. A long-term validation was not possible due to the strategic nature of the topic. The development of a CBP-based methodology in the context of logistics is a unique approach as publications on CBP, especially in the context of logistics, are still scarce and more research is needed. To the best of knowledge, no previous work exists which specifically aims at supporting strategic decision making in the context of new plants. Last, the developed methodology can serve as an example and a guideline on how to use CBP in logistics research and to apply its concepts to real-world logistics and Supply Chain Management use cases, not only in the automotive industry but in other industries as well.

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Supply Chain Risk Management for Pharmaceutical Manufactures

Impacts of Drug Shortages and Product Recalls

Andreas Aschenbrücker

Abstract The occurrences of drug shortages and product recalls have increased in recent years. One reason is the characteristic of the pharmaceutical supply chain itself: being lean and highly complex and, therefore, more vulnerable to any local disturbances. Despite that, the special characteristic of the pharmaceutical supply chain is not integrated appropriately in supply chain risk management yet. This paper analyzes the impact of drug shortages and product recalls on the pharmaceutical manufacture using event study methodology. Statistical significant abnormal stock returns were found for product recalls, as well as signs of negative impacts of drug shortages.

1 The Risks of Drug Shortages and Product Recalls

Supply chains are networks fulfilling a business task more efficient than a single enterprise by concentrating on the core competences of each supply chain partner (see Chopra and Meindl 2013). The purpose of the pharmaceutical supply chain (PSC) is to provide sufficient drugs for a population (cf. Savage et al. 2006, p. 1). This includes two main aspects: drug safety and drug service security.

Drug safety focuses on the quality, effectiveness and integrity of drugs. Drug service security is achieved if the demand of drugs is met at any time (cf. Kaapke et al. 2007). Failures in those two aspects lead to product recalls or shortages. Drug shortages occur if all manufactures cannot meet the demand of drugs with a specific pharmaceutical ingredient. A product recall is necessary if taking drugs can cause harm to patient's health. Impacts of drug safety as well as of drug service security may be costs for recalls, compensation for patients, indirect costs of lost sales and lasting damages to public company image. These costs have to be beard mainly by

A. Aschenbrücker (✉)
International Performance Research Institute gGmbH, Königstr. 5, 70173 Stuttgart, Germany
e-mail: aaschenbruecker@ipri-institute.com

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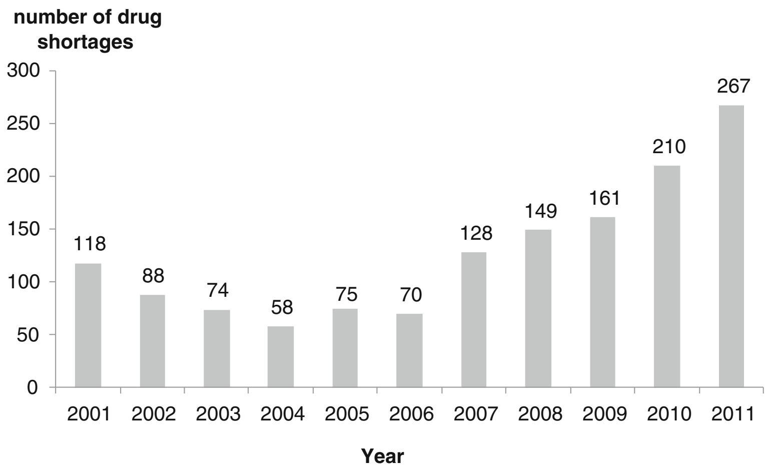


Fig. 1 Number of shortages reported by ASHP per year

the pharmaceutical manufacture licensing the products (cf Musalem et al. 2010 or Chu et al. 2005).

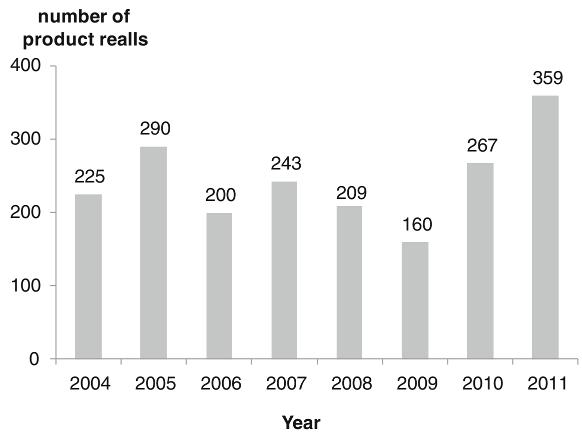
Numerous national and international organizations supervise the approval of drugs and oblige pharmaceutical manufactures to implement specific guidelines, e.g. "Good Manufacturing Practices" (GMP). Nevertheless, drug shortages and product recalls occur frequently.

In the United States, drug shortages are systematically observed since 2001 and reported to the American Society of Health-System Pharmacists (ASHP). Since that point in time, there has been an overall number of nearly 1,400 reported drug shortages in the U.S. with ever-expanding frequency (see Fig. 1). In 2011, ten percent of all registered pharmaceutical ingredients were unavailable (see Le et al. 2011). This problem is not just restricted to the U.S. In summer 2012 it reached Germany as well. First signs are shortages of the beta-blocker "Metoprololsuccinat" or various antibiotics.

In the United States, product recalls were published by the U.S. Food and Drug Administration (FDA). Since 2004, there has been an overall number of more than 2,000 product recalls. As shown in Fig. 2, most recalls occur in 2011 with over 350 cases.

The risks of drug shortages or product recalls are mainly determined by the characteristic of the PSC itself. In consequence of rising customer claims regarding cost, quality and availability of products and an increasing competitive pressure, the PSC as well as other Supply Chains have become lean and highly complex. Characteristics of these Supply Chains are optimized flow of goods, liquidity and information, high capacity utilization and minimized total lead times (see Ewers and Mohr 2010 for the PSC or Blackhurst et al. 2005 or Christopher and Peck 2004 for supply chains in general). Being lean and highly complex, the PSC is increasingly vulnerable to local disturbances. The more vulnerable a supply chain,

Fig. 2 Number of product recalls of drugs reported by FDA per year



the higher the probability of disturbances or failures and the more extensive their negative impacts (see Svensson 2002). Failures in business activities of a single company have influence on all supply chain partners and evolve supply chain risks (see Kersten et al. 2007). Therefore, the supply chain risk management (SCRM) has become crucial within supply chains in general and especially in the PSC since the special characteristics of the PSC are not appropriately integrated yet in supply chain risk management (cf. Breen 2008).

This paper is part of a research project which will make a contribution to develop SCRM for the specific risks of the PSC, drug shortages and product recalls. Improvements will be recommended based on investigation of the influence of supply chain design and supply chain competency on the risk of drug shortages and product recalls. The first step of the research project presented here focuses on the impact of product recalls and drug shortages occurring within the PSC. In the context of drug shortages this will be analyzed for the first time. The impact of product recalls will be examined on a much broader database not restricted to few announcements in public newspapers. An outlook on further research is given at the end of the paper.

Interest in the field of drug shortages has increased in recent years, but the impact on pharmaceutical manufactures was not focused yet. Instead, studies have spotlighted the impacts of drug shortages for patient care in hospitals (cf. Griffith et al. 2012; Kaakeh et al. 2011; Baumer et al. 2004 or Fox and Tyler 2004). Main causes for drug shortages are supply chain disruptions, manufacturing and quality problems, increased demand, or, business decisions to withdraw approved drugs from the market (cf. Fox et al. 2009 and Yurukoglu 2012). As Hendricks et al. (2009) have shown, supply chain disruptions are fostered by optimized and complex supply chains. The influence of supply chain design on the occurrence of drug shortages has not yet been investigated in supply chain risk management.

In literature, a variety of studies exist about product recalls in different industries (an overall view provide Cheah et al. 2007). Also, several studies have analyzed the impact of product recalls on pharmaceutical manufacturers, but only for recalls with

Table 1 Studies about the impact of drug recalls on stock prices

Author(s)	Database	Findings
Jarrell and Peltzman (1985)	36 recall announcements published in *WSJ* (1974–1982)	Large negative impact mainly in the 2 weeks surrounding the event day. These losses were not recovered in observed period until 3 months after event day
Pruitt and Peterson (1986)	32 recall announcements published in *WSJ* (1968–1983)	Stock prices show direct negative reaction on recall announcements. Shareholders react immediately after the event and lower stock prices reflect these reactions to new information
Marcus et al. (1987)	5 recall announcements published in *WSJ* (1974–1982)	The authors explain the loss in stock value (documented by Jarrell and Peltzman) by an increasing of systematic risk after a product recall. Stock value falls in fact of lower expected future earnings per share
Chu et al. (2005)	52 recall announcements published in *WSJ* (1984–2003)	Negative abnormal return on announcement day and the day before without persistent effect in entire post-announcement period

high public attention. As shown in Table 1, former studies consistently documented a negative impact on stock prices. This reaction of shareholders was limited to the days near by the recall both ex ante and ex post. For the remaining post event period, neither positive nor negative abnormal returns were identified. Limitations of former studies are the concentration on product recalls published in *Wall Street Journal* (WSJ) and, linked to this, the small number of events with high public attention.

The reason for product recalls has been investigated from four different perspectives: recalls based on faults in product developments, in fact of quality failures, through outsourcing manufacturing to low-wages-markets and an insufficient management of the supply chain (cf. Muralidharan and Bapuji 2009). Contributions of qualitative studies on supply chain management and product recalls are integration of risk aspects into common cost-based decision models and sophisticated control processes of suppliers (cf. Lyles et al. 2008; Berman and Swani 2010; Roth et al. 2008; Novak and Stern 2008 or Grackin 2008).

2 Method

The financial impact of product recalls and drug shortages on the pharmaceutical manufacture could be analyzed using the method of event study. This method tests whether there is an "abnormal" stock price effect caused by an unanticipated event (McWilliams and Siegel 1997, p. 626). Using abnormal changes in stock prices rather than other economic measures such as profit or income has three advantages: First, given rationality in the marketplace, stock prices reflect the impacts of an event immediately. Second, stock prices are a common measure of the true value of a firm, taking all discounted future cash flows and all relevant information into account. And third, stock prices are no subject to manipulation by corporate insiders (cf. MacKinlay 1997, p. 13; McWilliams and Siegel 1997, pp. 626–627).

2.1 Database

The data necessary for an event study comprise a sample of relevant firms, their stock prices over the analyzed time period and the event dates. The sample for this research consists of 100 pharmaceutical manufactures. Selection criteria have been Sub-Industry-Code (35202010), traded on U.S. stock market, a market value greater than $100 Million, and, an availability of stock prices for more than half of trading days between the beginning of 2002 and the end of 2011. Daily stock prices were sourced from the Compustat database.

The FDA, among others, recorded all drugs recalls since 2004, the recalling firm and the exact date when the recall was first published. Based on this data pool 512 recalls could be assigned to the sample firms.

A third dataset recorded by ASHP includes more than 1,000 drug shortages from 2001 to end of 2011. The data includes the active pharmaceutical ingredient (API) being short and the starting date and duration together with the reason of the shortage. Because of the reasons, occurrences are separable into three groups: Manufacturing problems (including insufficient raw material), increasing demand and a third group of shortages without a reason. In the majority, various drugs exist, including one and the same API. Therefore only 88 shortages affecting a drug with an API distributed by a single manufacture of the sample firms are taken into account. Otherwise it is not possible to differentiate between firms responsible for a shortage and firms which are able to supply a drug containing an API being short.

2.2 Calculating Abnormal Returns After Product Recalls and Shortages

The methodology used within this analysis is based on the one that is used by several other research projects in the field of product recalls (see Sect. 1) and the event study methodology in general (see McWilliams and Siegel 1997; MacKinlay 1997 or Hendricks et al. 2009). The expected return r_{it} of stock i on day t is calculated using the single factor market model in Eq. (1). r_{mt} is the return of the market portfolio, α_i is the intercept and β_i the slope of the relationship between the market portfolio and firm I, and ε_{it} is the error term.

The security prices p_{it} and the number of shares outstanding s_{it} of the hundred pharmaceutical manufactures selected are used to determine the market portfolio and, further, the return of the market r_{mt} on day t, by using Eqs. (2) and (3).

To ensure the robustness of the event study results, the parameters of the market model alpha and beta are calculated in three different ways. First, ordinary least square parameters are estimated by minimizing the error term in Eq. (1).

$$r_{it} = \alpha_i + \beta_i * r_{mt} + \varepsilon_{it} \tag{1}$$

$$r_{mt} = \frac{p_{mt} - p_{mt-1}}{p_{mt-1}} \tag{2}$$

$$p_{mt} = \frac{\sum_{i=1}^{100} (p_{it}^{*}(s_{it}^{*} p_{it}))}{\sum_{i=1}^{100} (s_{it}^{*} p_{it})} \tag{3}$$

Scholes and Williams (1977) have shown that nonsynchronous trading can cause biased and inconsistent estimators of market model parameters. Therefore, secondly, OLS-parameters were adjusted using the procedure presented by these authors (cf. Marcus et al. 1987; Chu et al. 2005).

One main assumption of OLS-regression is the homoskedasticity of the residuals. Otherwise, in case of heteroskedasticity, the standard errors of the estimated parameters are not appropriate (see Stock and Watson 2012, pp. 164, 200–201). There are two possibilities to deal with heteroskedasticity: Calculating robust standard errors or using sophisticated estimation methods such as autoregressive conditional heteroskedasticity (ARCH) models. In this study, a third estimation of parameters is done using a generalized autoregressive conditional heteroskedasticity (GARCH) model (see Stier 2001).

For estimating parameters of the market model and abnormal returns, two different time-periods are necessary. As shown in Fig. 3 (case 1), an estimation period from day −100 to −20 prior to the event serves for estimating parameters. If two events follow each other less than 220 days (case 2), parameters estimated in estimation period 1 are also used for event 2. For two events occurring within 120 days (case 3), event period 1 ends 1 day prior to event day 2. Here, estimation period 1 is also used for both events. As we will see in the following section, this outcome reduces observations for analyses of mean (cumulative) abnormal returns but is necessary to separate the impact of observed events from compounding effects of other events.

Estimated parameters are used to calculate abnormal returns as the difference from observed return to expected return, as shown in Eq. (4). For further analysis the Mean Abnormal Return (MAR) and Mean Cumulative Abnormal Returns (MCAR) are additionally computed, as expressed in Eqs. (5) and (6).

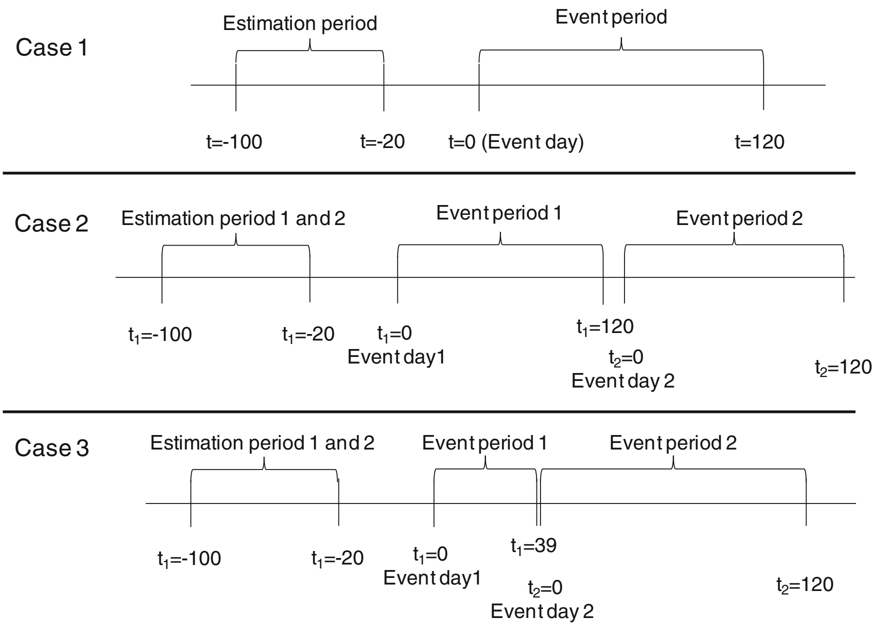


Fig. 3 Estimation and event period for three different cases

$$A_{it} = r_{it} - \hat{r}_{it} = r_{it} - (\hat{\alpha}_i + \hat{\beta}_i^* r_{mt}) \tag{4}$$

$$MAR(t) = \frac{\sum_{i=1}^{n} A_{it}}{n_t}, \text{ or } MAR(t_1, t_2) = \frac{\sum_{t=t_1}^{t_2} \sum_{i=1}^{n} A_{it}}{\sum_{t=t_1}^{t_2} n_t} \tag{5}$$

$$MCAR(t) = \frac{\sum_{i=1}^{n} \sum_{0}^{t} A_{it}}{n_t} \tag{6}$$

3 Results

Table 2 represents the distribution of all MARs for product recalls and drug shortages from day 0 to 119. The latter one is additionally separated in three groups by various reasons. For product recalls the MAR for 67.5 % of all days is negative. The average of −0.046 % (respectively −0.042 %) is significantly different from zero at the 0.1 % level. For drug shortages, no significant effects are observed. The average MARs of the 120 days after the announcement of a drug shortage does not differ significantly from zero, neither for all occurrences, nor divided into groups of the different reasons. The negative impact of product recalls is confirmed in Fig. 4 where MCARs for shortages and product recalls are graphed. While MCAR is

Table 2 Distribution of mean abnormal returns from day 0 to day 119

		OLS			GARCH			Scoles Williams		
	Obs	Avg	SD	*p*-value	Avg	SD	*p*-value	Avg	SD	*p*-value
Recall										
	120	−0.00046	0.00116	<0.0001***	−0.00042	0.00116	<0.0001***	−0.00046	0.00118	<0.0001***
Shortage										
All	120	−0.00003	0.00170	0.8660	0.00006	0.00169	0.6860	−0.00001	0.00178	0.9612
Demand	120	−0.00052	0.00343	0.0979*	−0.00032	0.00344	0.3110	−0.00050	0.00346	0.1189
Manufacturing	120	−0.00005	0.00316	0.8643	0.00000	0.00322	0.9892	0.00002	0.00333	0.9514
Unknown	120	0.00017	0.00199	0.3406	0.00025	0.00199	0.1682	0.00015	0.00204	0.4124

The symbols *, **, *** denote statistical significance at the 10, 5 and 1 % levels, respectively (two-tailed test)

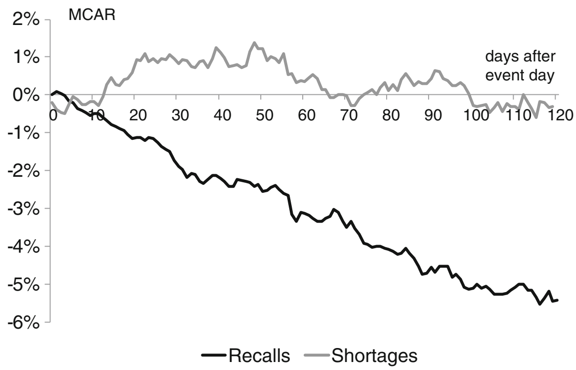


Fig. 4 Mean cumulative abnormal returns (MCARs) for day 0 to day 119 after product recall respectively announcement of drug shortage

declining continuously for product recalls, MCAR is not clearly distinguishable from zero for drug shortages.

In order to test whether the negative effect of product recalls and the obvious missing effect of drug shortages is statistically significant, *p*-values for MARs and MCARs are calculated for different intervals in the event period. In Table 3, results of statistical tests concentrate on product recalls as no significance could be proven for drug shortages.

Negative MARs are observable for all selected time intervals, except for the first 4 days. For one period of 15 days from day 4 to 19 and a second period of 20 days from day 60 to 79, the MARs are negative with statistical significance on a 5 % level. As it comes to MCARs, the negative impact of product recalls is significant on a 5 % level for all intervals until day 99, and, again, except for the first 4 days. Until the end of the event period, MCARs have declined to −4.8 %, with significance on 10 % level (respectively −5.1 % on 5 % level). As the results in Tables 2 and 3 are almost identical for all three chosen methods conclusions are not altered by the choice of event study methodology.

For further insights on the financial impact of drug shortages, MARs and MCARs were calculated for the shortages where a reason (increasing demand or manufacturing problems) is well-known. Results including *p*-values are summarized in Table 4. Starting from day 4 to 9 shortages in case of an increasing demand result in negative MARs for five of six intervals of around −1 %. From the same interval on, MCARs are constantly negative and decreasing. But, probably in fact of a very small sample size, neither MARs nor MCARs are statistical significant. Shortages caused by manufacturing problems have an immediate negative impact on the first day after an event, resulting in an MCAR of −1.7 % for the period of the first 4 days (statistically significant on a 5 % level).

Table 3 Mean abnormal return and mean cumulative abnormal return for product recalls

		OLS			Garch			Scoles Williams		
	Obs	Avg	SD	*p*-value	Avg	SD	*p*-value	Avg	SD	*p*-value
Recall MAR										
−5 to −1 days	512	**0.0021**	**0.0270**	**0.0776***	**0.0026**	**0.0269**	**0.0279****	**0.0031**	**0.0270**	**0.0090*****
0 to 0 days	512	0.0001	0.0141	0.9177	0.0002	0.0141	0.7895	0.0002	0.0143	0.6987
1 to 3 days	512	0.0003	0.0211	0.7710	0.0000	0.0211	0.9788	0.0002	0.0209	0.8672
4 to 9 days	480	**−0.0049**	**0.0319**	**0.0009*****	**−0.0044**	**0.0320**	**0.0030*****	**−0.0049**	**0.0327**	**0.0011*****
10 to 19 days	414	**−0.0055**	**0.0493**	**0.0233****	**−0.0048**	**0.0493**	**0.0462****	**−0.0052**	**0.0493**	**0.0319****
20 to 39 days	**354**	**−0.0085**	**0.0886**	**0.0718***	**−0.0076**	**0.0885**	**0.1086***	**−0.0086**	**0.0879**	**0.0655***
40 to 50 days	257	−0.0087	0.1014	0.1706	−0.0080	0.1018	0.2079	−0.0083	0.1017	0.1911
60 to 79 days	211	**−0.0085**	**0.0607**	**0.0436****	**−0.0080**	**0.0618**	**0.0631***	**−0.0102**	**0.0612**	**0.0162****
80 to 99 days	182	−0.0102	0.0857	0.1109	−0.0099	0.0842	0.1138	−0.0094	0.0851	0.1396
100 to 119 days	161	−0.0030	0.0857	0.6606	−0.0030	0.0865	0.6578	−0.0035	0.0857	0.6035
Recall MCAR										
0 to 0 days	512	0.0001	0.0141	0.9177	0.0002	0.0141	0.7895	0.0002	0.0143	0.6987
0 to 3 days	512	0.0002	0.0252	0.8525	0.0002	0.0252	0.8635	0.0001	0.0251	0.9359
0 to 9 days	480	**−0.0049**	**0.0405**	**0.0085*****	**−0.0040**	**0.0406**	**0.0316****	**−0.0046**	**0.0413**	**0.0157*****
0 to 19 days	414	**−0.0094**	**0.0675**	**0.0050*****	**−0.0079**	**0.0675**	**0.0183*****	**−0.0087**	**0.0678**	**0.0091*****
0 to 39 days	354	**−0.0184**	**0.1172**	**0.0034*****	**−0.0162**	**0.1169**	**0.0096*****	**−0.0181**	**0.1166**	**0.0038*****
0 to 50 days	257	**−0.0227**	**0.1747**	**0.0380****	**−0.0205**	**0.1745**	**0.0613***	**−0.0226**	**0.1736**	**0.0376****
0 to 79 days	211	**−0.0307**	**0.2045**	**0.0302****	**−0.0280**	**0.2059**	**0.0492****	**−0.0331**	**0.2033**	**0.0189****
0 to 99 days	182	**−0.0395**	**0.2640**	**0.0452****	**−0.0371**	**0.2638**	**0.0591***	**−0.0414**	**0.2615**	**0.0342****
0 to 119 days	161	**−0.0487**	**0.3294**	**0.0623***	**−0.0488**	**0.3297**	**0.0622***	**−0.0519**	**0.3255**	**0.0446****

The symbols *, **, *** denote statistical significance at the 10, 5 and 1 % levels, respectively (two-tailed test)

Table 4 Mean abnormal return and mean cumulative abnormal return for drug shortages caused by manufacturing problems and increasing demand

	Reason: demand				Reason: manufacturing			
	Obs	Avg	SD	*p*-value	Obs	Avg	SD	*p*-value
Shortages MAR								
−5 to −1 days	16	0.0001	0.0203	0.9836	30	0.0069	0.0552	0.5017
0 to 0 days	16	0.0027	0.0118	0.3745	**30**	**−0.0082**	**0.0169**	**0.0128****
1 to 3 days	16	0.0029	0.0138	0.4110	30	−0.0089	0.0322	0.1419
4 to 9 days	16	−0.0117	0.0369	0.2246	30	0.0110	0.0423	0.1646
10 to 19 days	15	0.0053	0.0293	0.4972	30	0.0093	0.0518	0.3343
20 to 39 days	13	−0.0241	0.0500	0.1082	30	0.0111	0.0689	0.3860
40 to 50 days	13	−0.0084	0.0676	0.6604	29	−0.0119	0.0817	0.4376
60 to 79 days	13	−0.0099	0.0503	0.4893	27	0.0096	0.0787	0.5335
80 to 99 days	13	−0.0127	0.0496	0.3759	27	−0.0120	0.0912	0.4988
100 to 119 days	13	−0.0074	0.0411	0.5305	25	−0.0050	0.1023	0.8077
Shortages MCAR								
0 to 0 days	16	0.0027	0.0118	0.3745	**30**	**−0.0082**	**0.0169**	**0.0128****
0 to 3 days	16	0.0056	0.0138	0.1254	**30**	**−0.0171**	**0.0456**	**0.0495****
0 to 9 days	16	−0.0061	0.0397	0.5493	30	−0.0061	0.0524	0.5305
0 to 19 days	15	−0.0040	0.0382	0.6896	30	0.0032	0.0715	0.8077
0 to 39 days	13	−0.0257	0.0647	0.1770	30	0.0143	0.1051	0.4629
0 to 50 days	13	−0.0342	0.1205	0.3264	29	−0.0032	0.1443	0.9067
0 to 79 days	13	−0.0441	0.1205	0.2115	27	0.0106	0.1924	0.7765
0 to 99 days	13	−0.0568	0.1349	0.1549	27	−0.0014	0.2516	0.9768
0 to 119 days	13	−0.0641	0.1616	0.1778	25	−0.0440	0.2661	0.4166

The symbols *, **, *** denote statistical significance at the 10, 5 and 1 % levels, respectively (two-tailed test)

4 Conclusions and Outlook

According to previous research, a negative impact of product recalls on stock prices was examined. Contrarily to e.g. Chu et al. (2005) this effect was observed during the entire post-event period; negative MCAR is statistically significant on a 5 % level until day 99. One reason might be that the recalls analyzed were not limited to cases published in journals with high public attention and high danger for patient health, e.g. the database also included many cases of wrong labeling. Therefore, stock prices may not immediately reflect all information or effects of rising costs or declining sales are influenced by stock prices with time lag.

The impact on drug shortages was examined both for all shortages in one sample and separated by reasons, if given. For the overall sample, no significant effect was proven. For shortages due to manufacturing problems, a statistical significant negative effect was observed for the event day and 3 days afterwards, but no abnormal return during entire post-event period. In case of increasing demand, a negative abnormal return was observed from day four on, but not on a statistically significant level.

Manufacturing problems occur at a precisely determinable day. Shareholders may react directly after firms announce the probability of a shortage caused by manufacturing problems. Therefore, the stock price immediately reflects all available information. Opposed to that, demand may increase slightly over a longer time period and the negative impact evolves over several weeks.

Limitations of the research are in the first point the concentration on firms listed on U.S. stock markets because small and medium enterprises are not included. The main problem is that they are not listed on stock markets and, therefore, event study methodology is not applicable. Secondly, the research is limited to a few number of drug shortages with the special characteristic of one solely supplier. Especially in the case of an increasing demand as a reason for a shortage, this is resulting in a not satisfying number of events. For further insights a broader database would be necessary, supplemented by shortages of non-exclusive manufactures. A third limitation is that product recalls are not separated by reason. In this analysis, all types of recalls are included. It is not distinguished e.g. between recalls because of quality problems resulting in hazards for patient health and recalls because of a label not concurrent to the drug approval. Latter one may be harmless for patient health. A detailed analysis of the causes of recalls can also provide deeper insights on the impacts of product recall on pharmaceutical manufactures.

In summary, both product recalls as well as drug shortages affect pharmaceutical manufacturers in a negative way. To improve supply chain risk management especially in the case of drug shortages and product recalls, a next step would be to analyze the impact of supply chain issues on the probability of the occurrences of both events.

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The Role of Instore Logistics and Shelf Ready Packaging for On-Shelf Availability

Herbert Kotzab and Samira El-Jafli

Abstract With this paper, we want to add to the existing discussion on retail store execution and retail store operations by emphasizing on how shelf-ready-packaging (SRP) impacts the shelf-filling-process and consequently the on-shelf-availability (OSA). The discussion includes a theoretical conceptualization of the interrelationships between SRP, OSA and instore logistics based on literature analysis as well as a discussion of the results of two empirical field studies.

1 Introduction

1.1 Problem Background

The avoidance of shelf gaps in a retail store is a central issue when it comes to the optimization of grocery supply chains as consumers expect well stocked shelves in the store (see Kuhn and Sternbeck 2013). Therefore, the terms out-of-stock (OOS) and on-shelf-availability (OSA) are crucial elements.

An OOS can be defined as a percentage of articles that are not on a shelf at a given point in time (Aastrup and Kotzab 2010). Or, from a shopper's point of view, an OOS is seen as the number of times a shopper looks for products in a store and does not find these products on the expected shelf (see Gruen 2007 or Placzek 2007).

OSA can generally be seen as a probability that a product is in stock when a customer order arrives (Chopra and Meindl 2007). In the context of grocery retailing, OSA can also be defined as *the measure of a product being available for*

H. Kotzab (✉) · S. El-Jafli
Lehrstuhl Für ABWL Und Logistikmanagement, Wilhelm-Herbst-Str. 12,
28359 Bremen, Germany
e-mail: kotzab@uni-bremen.de

S. El-Jafli
e-mail: samira@uni-bremen.de

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sale to a shopper, in the place he expects it and at the time he wants it. (Mitchell 2011, 2). This means that products need to be within a consumers' reach, in an order-ready state, and consumers should be aware of this. If this is not the case, the consumer perceives an OOS. Consequently, OSA and OOS are two sides of the coin shelf-gap, depending on which perspective one observes.

The consequences of low OSA and consequently high OOS are significant for store operations. When facing an OOS, 70 % of consumers either postpone their purchase or try to purchase another brand or a different size of the article. The remaining 30 % of the consumers will either go to a different store or decide to decline their purchase (ECRE 2003). These two customer reactions directly lead to lost sales that impact the retailer as well as the manufacturer of the product (see also Corsten and Gruen 2003).

Both measures, OSA and OOS depend on the execution of instore logistics (Studer and Greco 2009, 52). Fisher et al. (2006), Corsten and Gruen (2003) or Raman et al. (2001) showed for example that better order management, better management of promotions and inventories, better shelving processes and improved processes in the receiving areas, as well as better integration with upstream supply chain partners and their activities, lead to higher OSA and consequently to lower OOS. So it seems that something appears to be flawed inside the retail stores and several studies have already pointed to store-related failures causing a non-satisfactory OSA (see e.g. Helm et al. 2008; Fisher et al. 2006; Corsten and Gruen 2003 or Gruen 2007). And even these problems are known, grocery retailers are still unable to improve this OSA problem (see Klock 2010).

Recently, shelf ready packaging (SRP) has been introduced as one additional way to successfully decrease OOS and further increase OSA. However, even though a lot of manufacturers and retailers use SRP, we can still find gaps in the shelves (Haubenreißer 2013).

1.2 Purpose of the Paper

So far, OOS/OSA research has examined either consumer reactions or the root causes for OOS (see e.g. Aastrup and Kotzab 2010).

In this paper, we explore the relationship between OSA and SRP from an instore logistics perspective. Our discussion is based on theoretical-conceptual arguments that are enhanced with empirical results from projects that were undertaken with a large grocery hypermarket in Bremen.

The remainder of the paper is as follows: First we discuss instore logistics and SRP and combine it with the notions of OSA/OOS. Thereafter, we propose a model in which the interrelationships of these three elements are described (Sect. 2). Second, we translate our ideas into empirical research designs (Sect. 3) and show the key results of on-going empirical projects that were executed in close cooperation with a leading German grocery retailer (Sect. 4). The paper closes with a critical discussion of our preliminary findings and an outlook for future research.

2 Theoretical Conceptualization

2.1 Instore Logistics and Its Relation to OOS/OSA

Instore logistics is the internal logistics system of a retailer and refers to all logistics processes at the point-of-sale (POS) (according to Kotzab and Teller 2005). The overall goal of instore logistics is to achieve a steady order fulfillment preparedness by ensuring a continuous demand-driven OSA (see Fisher et al. 2006 or Kotzab et al. 2007). This includes the processes at the delivery entrance, in-storing, storage, shelf stacking and replenishment and commissioning (see Gudehus and Kotzab 2012). For Fisher et al. (2006), instore logistics is a vital part of retail store operations which has major consequences for the performance of a retail store.

There have been some studies conducted which implicitly examine the relationship between OOS/OSA and instore logistics, such as:

- Helm et al. (2008) or Corsten and Gruen (2003) who show that OOS situations and consequently unsatisfactory OSA levels are caused by poor execution of instore logistics processes.
- Brockmeulen et al. (2004), Van Zelst et al. (2009), and Curşeu et al. (2008) who investigate how the shelf stacking process and shelf replenishment affect OSA.

According to Curşeu et al. (2008) stacking of new inventory, grabbing and opening of case packs, and waste disposal are critical activities in the total process. These processes are also very much dependent on the physical dimensions of products as well as of the stores (i.e., shelf dimensions). Proper stacking of shelves can help to hasten the replenishment process and, thus, help to decrease process costs (Broekmeulen et al. 2004; Van Zelst et al. 2009). As we show in the subsequent section, this are dimensions of SRP.

This leads to the assumption that high-quality instore logistics processes positively impact OSA.

2.2 Shelf Ready Packaging and Its Relation to OOS/OSA

The term SRP describes a product that arrives at the point of sale in ready to sale packaging size (ECRE 2006). A ready merchandised unit is a package unit that is easy to identify, easy to open, easy to dispose, easy to shelve and easy to shop (=5 SRP easies; Bergmann 2008).

To improve the efficiency of instore logistics processes, it is necessary that staff members are able to identify the merchandise quickly by offering high visibility of necessary information. For shelving items quickly, it is recommended that trays can be opened easily and to be shelved easily so that the filling process can be speeded up. Empty trays shall be quickly disposed and finally, consumers should be able to locate and take products without problems from a shelf (ECRE 2006).

SRP can thus be seen as an optimization tool for instore logistics, as the overall goal of SRP is to develop readily merchandised package sizes that enable simple processes at the POS (ECRE 2006). In other words, SRP helps to offer retail stores readily packaged units for simple shelf replenishment (e.g. Hertel et al. 2011, 220). SRP requires stronger coordination and harmonization effort for package standardization (Hua 2007). Until recently, it has not been clearly defined if a simple tray replenishment, in form of moving secondary packaging into shelves can be defined as SRP or if it also includes merchandising units, throw away packages or reusable packaging (ECRE 2006, 16).

Some studies have conceptually examined and discussed the relation between OOS/OSA and SRP, such as:

- Krasutzki (2007) and Bergmann (2008) who discuss the positive impact of SPR on costs as SRP minimizes the process costs for shelf stacking by creating a proper product presentation in the store.
- Hua (2007) who presents the advantages and disadvantages of the SRP concept as standardization of packaging by showing that it is not possible to use SRP for all product categories.
- Korzeniowski (2009) has shown the consumer expectations of SRP.
- Jackson and Burge (2008) who examined the savings potential of SRP by mapping replenishment processes on a superficial level within six retailing companies.

The efficiency gains through SRP are intended to lead to a higher OSA and consumers are able to better identify products (ECRE 2006). SRP can also help to reduce the high costs that are involved with instore logistics where McKinnon et al. (2007), Van Zelst et al. (2009) or Gerking (2009) indicate them to be higher than 50 % of the total logistics costs of a retailing store.

This leads to the assumption that high-quality SRP positively impacts OSA.

2.3 Subconclusion

Based on existing findings, we can summarize the scientific discussion as follows:

- OOS/OSA is a highly critical performance measure for grocery retailing which is relevant for all supply chain members.
- The goal to be achieved is to avoid OOS as much as possible by superior OSA management.
- To improve OSA and avoid OOS, it is suggested that better instore logistics are implemented and managed, with the additional use of SRP as an optimization tool.
- Existing work either focuses on the causes of OOS/OSA or on the (theoretical) benefits for OSA due to SRP.

Based on our understanding of the topic, we were interested in investigating how SRP may positively affect OSA thus reducing OOS. We therefore propose that the quality of SRP plays a major role in affecting OSA and consequently OOS.

In order to learn more about the subject matter, during the period of the last two years, we executed two empirical projects within in a large hypermarket of a leading German retailer in the Bremen area. Their purposes and research designs are discussed in the following section.

3 Methodology

3.1 Purpose and Research Design of the Shelf-Stacking-Study

The specific purpose of this project was to learn about the shelf stacking process as a part of instore logistics. We were especially interested in how this process is affected by SRP. Based on the experiences of Hofer (2009), Van Zelst et al. (2009) and Curşeu et al. (2008), we decided to apply participant observation in combination with standardized interviews. Consequently, we developed an observation form and a questionnaire that were used to examine the shelf stacking process as well as the perceptions of the involved employees, who were employees of a specific instore logistics service provider.

Our observation approach was divided into three phases. In Phase 1, we examined the incoming merchandise in the delivery entrance, where products were prepared for shelving. Here, incoming pallets were transformed to stacking pallets. In Phase 2, we followed the individual pallet which contained the items to be filled onto the shelves. In Phase 3, we examined the SPR quality of the individual products that were replenished.

We observed all dry assortment deliveries to the store for a period of two weeks (3 deliveries per week). During this period, the hypermarket received a total of 101 pallets out of which, 15 pallets referred to our product category. Overall, more than 500 individual product items were examined. As for the self-assessment of the involved employees, we asked questions regarding the perceived process quality of the shelf stacking and replenishment processes during and at the end of the stacking process. A total of 78 employees of the service provider were involved in the process.

With the chosen approach, we were able to examine the duration and quality of the total process from an objective (= observer) and a subjective (= employee) point of view. Due to work council restrictions, we were not allowed to perform any time and motion studies such as conducted by Van Zelst et al. (2009) and Curşeu et al. (2008). Additional qualitative data was collected by taking photographs during the observation process. Uni- and bivariate analysis methods were applied to analyze the quantitative data.

3.2 Purpose and Research Design of the SRP-OSA-Study

The purpose of our second project was to identify the specific optimization potentials that SRP offers for avoiding OOS. We therefore measured OSA as well as SRP quality of selected products in the hypermarket.

Together with the management of the retailer, 18 packaged products were selected: coffee (4), oil (2), orange juice (3), rice (4), tomato sauce (3) and pasta fix (2). All categories included branded and private label products and they represented SRP and non-SRP product categories. The OSA of these products was measured three times a day during opening hours on six days.

For the OSA measurement, we opted for a physical measurement of OSA as suggested by Helnerus (2007), Placzek (2007) or Sauerberg (2009). For the assessment of the SRP-quality, we adapted a checklist developed by ECR Switzerland (2012) by distinguishing between handling dependent and handling independent SRP processes thus calculating a SRP quality index. Furthermore, the handling processes of selected items were modelled and analysed, based on Business Process Model and Notation 2.0. Here, we intended to identify differences between different types of packaged goods.

In addition, we analysed the POS data for the analysed products for the analysed period of time as well as for the business year 2011. Additional qualitative data were collected by taking photographs during the observation process.

Finally, we examined how employees perceive SRP and OSA issues in this store by interviewing them. The questionnaire was checked by the local work council and then distributed to 49 employees via the work council. 26 fully completed questionnaires were returned. We also conducted qualitative interviews in the break room with several employees. Uni- and bivariate analysis methods were applied to analyze the quantitative data.

4 Presentation and Discussion of Results

4.1 Key Results of the Shelf-Stacking-Study

We divided the total stacking process into the three sub processes of preparation, stacking and removal. 14 people were working on average at the good entry dealing with the incoming pallets. Preparation of pallets took between 6 and 20 min (on average 11 min). The stacking was done on average in 84 min, spanning from 41 to 130 min. Removal time was difficult to measure as this was done continuously during the stacking. Comparing these results with the self-estimated times by the employees, we were not able to find significant differences.

The analysis of the photographs of the incoming pallets especially documented the apparent difficulties for the preparation process. The content of the incoming pallets was not always recognizable as too many different product categories were put onto a pallet. Additionally, products were not always placed on the pallet in an orderly manner. However, due to their experience level, employees still indicated their ease in recognizing the type of product so that the allocation to a certain product category could be done. They however indicated a medium satisfaction level with the quality of the incoming pallets. Looking at the other SRP easies (easy to open, easy to shelve and easy to dispose), employees were not so much satisfied with the opening, shelving and disposing processes.

A general analysis of the shelving duration and the SRP levels showed a slight tendency that the better SRP is implemented, the shorter the duration it takes to stack the items. But, when looking at the individual product level, we were able to see a huge variety of product characteristics. While the average weight of the units was 420 g, the span was between 20 g (bread spread) and 3 kg (sunflower oil). Most of the products were shelved in trays. This may be the reason why the overall SRP evaluations varied significantly. In fact, we were not able to identify one single product that fulfilled all the five SRP easies.

4.2 Key Results of the SRP-OSA-Study

During the observation period of six days, the OSA levels of the 18 selected products were physically measured three times a day. Figure 1 shows the average OSA levels and compares them with the total sales volumes. The OSA ranged between 223.7 and 10.1 (both private label products) while the sales volume ranged between 1 (branded article) and 252 sold items (private labels).

Interestingly, we were not able to identify any OOS, but, this was secured by a very high provided OSA level. Looking at the sales pattern of the fastest selling product amongst the selected products, sales peaked only on one day (which was Saturday). However, the daily OSA-/Sales ratio of this product was between 2.2 and 10.9 meaning that there were at minimum twice as much, and at maximum up to more than ten times more items provided than actually required. As for the comparable branded article, the ratio levels ranged between 5.1 and 16.5.

An initial thought of our interpretation led to the assumption that the OSA was ‘manipulated’ by giving special attention to these products. However, when further comparing the OSA with the POS data, we recognized that the analyzed products were very slowly moving. This was validated by checking the annual sales volume to check whether the sales numbers was in line with annual sales numbers. Taking all this into account, we question the high OSA levels that were provided. Feedback from store management however showed the ‘dilemma’ that retail managers might face here. Even if sales volumes are low, consumers expect full shelves.

Table 1 summarizes the results of how the respondents viewed and evaluated specific SRP statements. When it comes to the results of the SRP impressions by employees, 24 of 26 people stated that the share of replenishment activities, in relation to the total working time, is more than half of their working time.

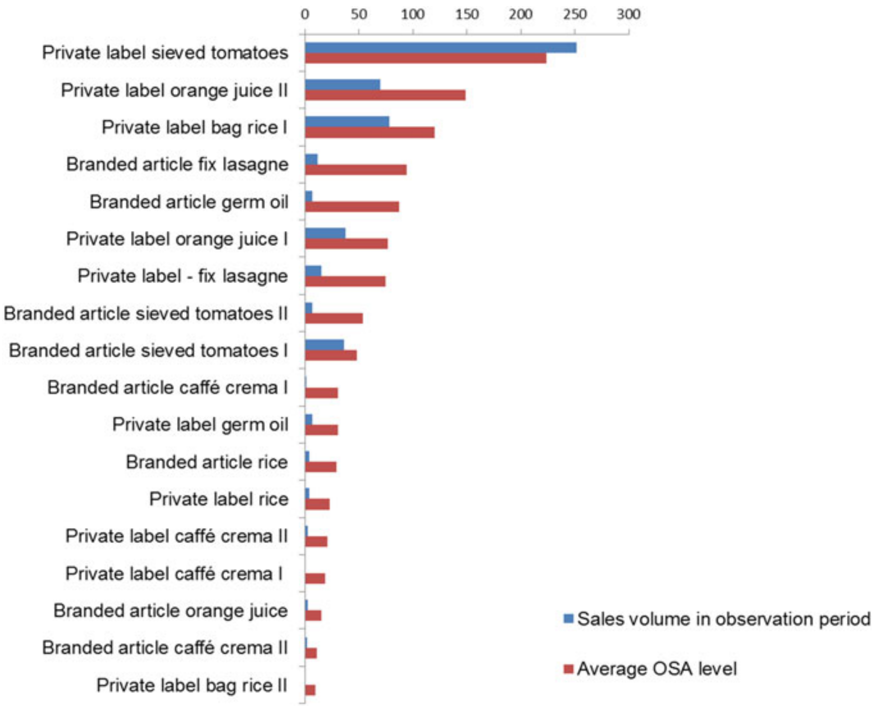

Fig. 1 Observed OSA-levels and sales volumes for the sample products

The majority of the respondents were aware of the three levels of SRP (trays, merchandising, and reusable packaging) and the internal guidelines for replenishment. However, only half of the people confirmed easy opening of trays as well as of problem-less handling with SRP. The majority of the respondents reported that the trays need further handling processes in order to make the product easy to shop. This leads to hold-ups in the process.

The results of the SRP-quality assessment can be summarized as follows: The handling-dependent SRP quality index ranged between 0.76 and 0.95, with an average of 0.89 (std.dev. 0.06). The handling-independent SRP quality index was a little bit lower ranging between 0 and 0.76, with an average index value of 0.62 (std.dev. 0,2).

Overall, we were not able to distinguish a significant difference between either SRP and non-SRP or branded or private label products. Unfortunately, it was not possible to evaluate the SRP quality in an objective manner, as trays were not always used in the same manner. We also faced problems in the observers' evaluations as they also perceived the situations differently.

Furthermore, we observed that the SRP trays did not meet all requirements of the store. Occasionally, the front side of some trays was scrapped in order to have better

Table 1 The employees' view on SRP

Please rate the following statements using a scale of 1 = not relevant at all and 5 = totally relevant	N	Min	Max	Mean	Std. dev.
The share of SRP products is high when I fill the shelves	24	2	5	3.04	0.806
When I fill the shelves with SRP products, the handling is always easier	25	2	5	3.56	1.003
When I fill the shelves with SRP products, the shelving process is physically relieved	24	2	5	3.63	0.924
It is easier for me to identify gaps in the shelves if products are prepared in an SRP manner	25	1	5	3.68	1.069
I support the idea to use more and more SRP	25	1	5	3.68	1.180
I am overall satisfied with the use of SRP in this store	25	2	4	3.32	0.627
I have the impression that filling shelves with SRP products reduce the number of gaps in the shelves as compared to filling the shelves with loose products	24	2	5	3.21	0.833
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The share of SRP products is high when I fill the shelves	24	2	5	3.04	0.806

store presentation. In other cases, the full potential of SRP was not utilized as products were taken out of half empty trays and put in front of full trays.

The results of the specific replenishment processes that were chosen for process modeling showed very sobering results. Overall, it was not possible to see a significant difference in the process flow between SRP and non-SRP products. Differences were on a very detailed sub activity level, which did not influence the total process significantly.

5 Discussion, Conclusions and Outlook

The purpose of our paper was to gain more insight into the interrelation between SRP, OSA/OOS. Our literature analysis showed that the positive correlations between these variables are implicitly stated so far. With our attempt, we wanted to test this hypothesized relationship explicitly in an empirical way.

Based on the results of our ongoing empirical research, our findings so far can lead to an adaption of a quote by Shaprio and Heskett (1985) into: Instore logistics is (still) a difficult field to study and a difficult field to manage.

We were able to confirm the difficulties of a lacking SRP standard as mentioned by Hua (2007). It was very challenging to identify products with an assumed different SRP profile as it took the management of the retailing company some time to select appropriate products. And despite their choice, we were astonished that the SRP quality indices for handling-dependent and handling-independent indicators did not show substantial differences between the analyzed products. Here it seems that there is still a huge effort necessary for harmonizing packaging standards with shelf and store dimensions.

Due to lacking SRP standards, we were so far unable to empirically prove the positive relationship between SRP and the quality of instore logistics. Some insight was gained through our empirical process flow modeling approach. However it would be necessary to examine this in more depth as one can expect that the execution of the process flow can differ depending on the employee's ability to execute the process.

We also found out that it was very difficult to measure a direct effect of SRP on OSA in the given setting of a hypermarket. We were expecting different patterns in sales volumes that have an effect on OOS and OSA. Here, we were confronted with a slow moving sales pattern.

Taking this into account, our results present valuable pilot study insights into the analysis of the relationship between SRP and OSA. Although our results show an improvement potential through SRP, no explicit cause and effect path can be identified so far.

In a further step, we are interested analyzing the efficient execution of SRP following the suggestions of Reiner et al. (2013) and use their DEA-approach idea. As an input to the DEA model, we suggest one input factor describing the SRP-quality, the timely effort for shelving and the individual number of facings to be shelved, and another input factor including the number of facings in the shelves and the shelve dimensions. Both factors would represent capacity indicators. The output factors would refer to the OSA and the sales volumes.

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Modelling Impact of Key Success Factors in Humanitarian Logistics

Hella Abidi, Matthias Klumpp and Sander de Leeuw

Abstract Recently the authors have explored strategic, tactical and operative key success factors for the humanitarian supply chain. Moreover, they have developed and tested a holistic and applicable performance measurement system for the humanitarian supply chain. Based on these results the impact of key success factors on performance is investigated: An impact model of key success factors on key performance indicators is developed and formulated. The evaluation of the model will be based on sequential qualitative system analysis for a first testing and analytical insights. Findings reveal that performance measurement in humanitarian logistics and humanitarian supply chains is still an open area of research, especially compared to the commercial logistics and supply chain sector. Moreover, it highlights how to identify and measure success in humanitarian supply chains. The results help humanitarian logistics and humanitarian supply chain actors to conduct further research in this area and to develop key performance indicators and measurement frameworks that suit the humanitarian logistics sector.

1 Introduction

In today's environment the number of natural and man-made disasters has increased significantly. Due to climate change there will be more disasters (Oloruntoba 2005; Dupont and Pearman 2006). Thomas and Kopczak expect a steady fivefold increase

H. Abidi (✉) · M. Klumpp
FOM ild, Research Institute for Logistics and Service Management, 45141 Essen, Germany
e-mail: hella.abidi@fom-ild.de

M. Klumpp
e-mail: matthias.klumpp@fom-ild.de

H. Abidi · S. de Leeuw
VU University Amsterdam, 1081 HV, Amsterdam, The Netherlands
e-mail: sander.de.leeuw@vu.nl

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for the number of natural disasters over the next fifty years (Thomas and Kopczak 2007). In 2006, the United Nations also confirmed that natural disasters over the next years will become more severe, often and destructive (UN 2006), recently proven by the Taifun Haiyan in the Philippines. In 2011, natural disasters killed 30.773 people and caused 244.7 million victims worldwide. Economic damages from natural disasters were estimated at US$ 366 billion. The earthquake and tsunami disaster in Japan was the most expensive natural disaster ever recorded, with estimated economic damages of US$ 210 billion. Furthermore, droughts and consecutive famines caused many victims in Ethiopia (4.8 million), Kenya (4.3 million) and Somalia (4.0 million) (Guha-Sapir et al. 2012). The increasing number of natural disasters and the resulting complex humanitarian emergencies put pressure on Humanitarian Aid Agencies (in the following HAA) to deliver humanitarian aid in an appropriate and cost effective way (Van Wassenhove 2006; Oloruntoba and Gray 2006; Kovács and Spens 2007).

Based on the identified strategic, tactical and operative key success factors and objectives (Abidi et al. 2013) as well as performance measurement system (Santarelli et al. 2013) for the humanitarian supply chain we developed a first conceptual framework. This gives a plain insight about the research on the impact of key success factors on performance measurement indicators. Therefore the main research questions derived from the conceptual framework (Fig. 1) are as follows:

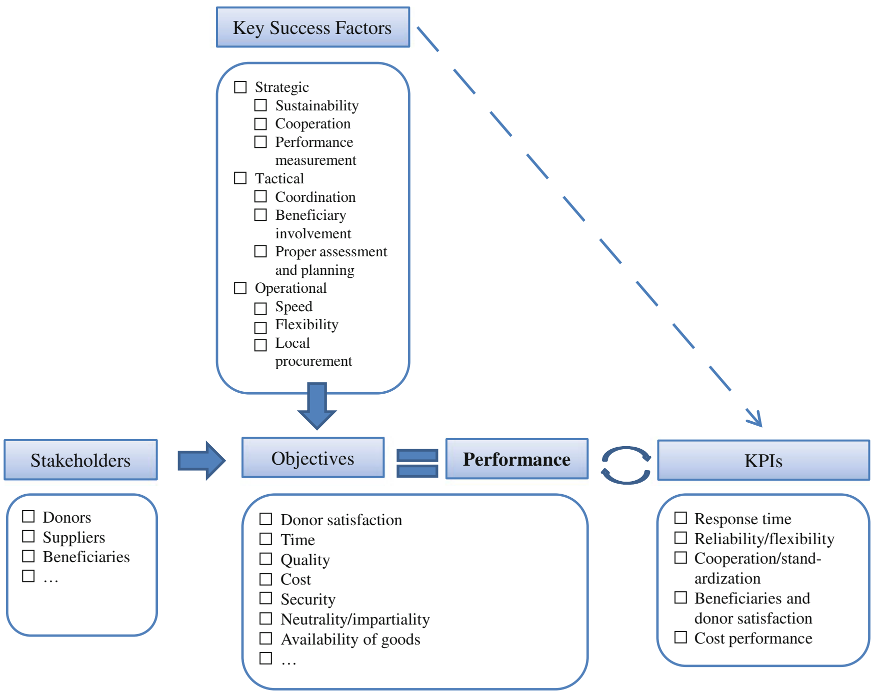

Fig. 1 Conceptual framework of the impact of key success factors on key performance indicators

RQ1: Do the key success factors influence the key performance indicators?
RQ2: With which intensity are the key performance indicators influenced by the key success factors?

This research paper attempts to identify and to evaluate the impact of *key success factors* on *key performance indicators*. The paper is structured as follows: In Sect. 2 basic definitions of performance measurement, indicators and systems in humanitarian logistics are described. Section 3 presents the identified key success factors. Furthermore Sect. 4 provides the developed and evaluated impact model of key success factors in humanitarian logistics and the analysis of the generated results by using a sequential qualitative system analysis. Sect. 5 presents a conclusion.

2 State of the Art on Performance Measurement in Humanitarian Logistics

Neely et al. (1995) defined performance measurement as the process to quantify the efficiency and effectiveness of an operation. Although there is an increasing interest in humanitarian logistics topic, performance measurement has been considered rarely in humanitarian supply chain (Altay and Green 2006; de Leeuw 2010; Kovács and Spens 2007; Tomasini and Van Wassenhove 2009). In the period from 1970 till 2012 only 23 publications has been found, and only 12 of these deal with performance measurement systems and indicators. The remaining papers show e.g. an analysis of the performance of different post-disaster humanitarian logistic structures (Holguin-Veras et al. 2012). Chang and Nojima (2001) developed a post-disaster performance measurement system and used them to the urban rail and high transportation systems in Japan and facilitated the understanding the effects of historic disasters and preparing for future hazards. Chang and Nojima (2001) focused more on risk management and risk assessment by construction a mathematical model. Helbing and Kühnert (2003) focused by using a mathematical model more on evaluating the impact of optimization measures or failures on the system and the investigation of catastrophes, in particular to the temporal development of disasters (catastrophe dynamics). The aim of Helbing and Kühnert (2003) was to simplify the study of the effects of measures taken by the emergency management or the local operation unit. Medina-Borja et al. (2007) presented one of the first large-scale implementations of data envelopment analysis (DEA) and defined a conceptual model to measure performance in non-profit sector. The system evaluated more than 1,000 field unit operations devoted to disaster relief, emergency communication and life-saving skills training. In the same year Moe et al. (2007) proposed a balanced scorecard (BSC) approach to apply to natural disaster, in order to maximize the possibilities of desired outcomes from projects. The approach was tested on a real disaster. In 2008 Beamon and Balcik (2008) discussed the two different supply chain types namely humanitarian and commercial supply chain and adapted an existing performance measurement framework developed for supply chain considering the unique characteristics of relief chain. The presented framework consists of resource, output and flexibility indicators. The designed indicators by Beamon and Balcik (2008) are clear but they were not empirically tested. A significance increase of interest in the topic performance measurement in humanitarian logistics and humanitarian supply chain can be seen in 2009. Blecken et al. (2009) developed a process reference model for humanitarian supply chains with the purpose to support humanitarian organizations in several activities, from which the measurement of their performance. A top-down approach was followed in which modular process element were developed and relevant performance measures were identified. Lin et al. (2009) demonstrated how to apply the model developed to a case study. A series of sensitivity analysis was conducted in the paper to provide insights to the influence of various parameters settings to the performance of a disaster relief operation, such as the depot location, the number of vehicles, and the number of clusters chosen. Mwenja and Levis (2009) elaborated a study that examines three theoretical perspectives. These can be utilized to connect the different dimensions of board performance and organizational performance. Schulz and Heigh (2009) described the tool developed by the Federation of Red Cross and Red Crescent Societies to guide and monitor continuously the performance of humanitarian organizations. The paper followed a descriptive approach and was supportive to build a system indicator. Van der Laan et al. (2009) identified a number of necessary conditions to implement an effective measurement system for the performance of humanitarian supply chains. They realized a case study to investigate whether these conditions were met or not. De Leeuw (2010) presented an approach in order to develop a reference mission map based on a method in industry. Subsequently the author analysed four mini case studies to demonstrate each of the four perspective of the BSC. Based on a study, Rongier et al. (2010) proposed a method assisting the humanitarian actors in their choices while carrying out a performance evaluation of the activities during the crisis in the response process. The authors of the paper have taken into account the methodology explained by Rongier et al. (2010) in order to define the KPIs for humanitarian supply chains.

3 Key Success Factors in Humanitarian Logistics

Compared to commercial supply chains, key success factors in humanitarian supply chain are rarely investigated. The first work that focused on key success factors to humanitarian supply chains is of Lu et al. (2006) and Pettit and Beresford (2009). The suggested key success factors in humanitarian supply chains of Lu et al. (2006) and Pettit and Beresford (2009) are based on the work of different authors from the commercial supply chain sector:

(1) Gunasekaran and Ngai (2003) who outlined four key success factors to a small logistics enterprise, namely strategic planning, transportation planning, capacity planning and information management.

(2) Power et al. (2001) who defined success factors to an agile supply chain, namely human resource management, information and technology management as well as utilization, inventory management, collaboration as well as continuous improvement and just in time concept.
(3) Thus of Razzaque and Cheng (1998) who determined key success factors specific to outsourcing of logistics function to logistics service provider.

Summarized Lu et al. (2006) and Pettit and Beresford (2009) identified key success factors namely strategic planning (including corporate strategy, centralized or decentralized distribution centers, outsourcing of non-score activities, budget and deployment of resources), inventory management, transport and capacity planning, information management and technology utilization, human resource management, continuous improvement and collaboration and supply chain strategy. Oloruntoba (2010) investigated the key success factor for a relief chain based on document analysis and semi-structured face to face interviews with directors and mid-ranking managers of three significant civil response organization to evaluate the management of relief operations during the cyclone 'Larry' in Australia. Oloruntoba (2010) grouped the key success factors into two categories:

(1) Preparedness and readiness in form of prior cyclone awareness and education, accurate and specific early warning as well as effective prioritization and planning.
(2) Unity of direction and whole of government response.

Komrska et al. (2013) identified recommendations that can be seen as key success factors to improve the ready-to-use therapeutic food (RUTF) supply chain of UNICEF. The five delineated key success factors being implementation of key performance indicators, pre-position buffer stock, diversification the RUTF supplier base, improve inter-agency and donor collaboration and improve information flow and forecasting.

From the above key success factors for humanitarian supply chains it becomes apparent that there are more specific key success factors which have to be outlined for the ultimate success of humanitarian supply chains and applicable to all HAA and other humanitarian actors with similar objectives and strategies. In a previous research the key success factors were explored by applying a case study with two German and two Dutch HAA (Abidi et al. 2013).

In the case study, four HAA—different in size, goods, number of staff, number of projects, received donations and corporate identity—consistently consider the main role of the supply chain to ensure the right items, in the right place, at the right time, at the right cost, in the right condition, and in the right quantities. All four organizations act neutral in the field, are non-profit and provide beneficiaries with aid. The targets are efficient supply chain or logistics; improving and promoting the supply chain, saving much more people that are affected by natural or man-made disasters and becoming much more transparent for the stakeholder. The results related to the key success factors are presented in Table 1.

Table 1 Identified key success factors (Abidi et al. 2013)

Strategic	Tactical	Operational
Sustainability	Coordination	Speed
Cooperation	Beneficiary involvement	Flexibility
Performance measurement	Proper assessment and planning	Local procurement
Standardization of relief items, processes	Qualified and experienced staff	Order management
Growth	Inventory management	Cost efficiency
Security	Long-term contracts	Enough staff members in the field
Independence and impartiality	Quality management	Availability of relief items
Continuum of care		

4 Impact of Key Success Factors in Humanitarian Logistics

To address the research question the method of qualitative system analysis (QSA) is used (Wiek et al. 2008). QSA is a constructivist method that is similar to conceptual modelling approaches to generate analytical insights (Mingers and Rosenhead 2004; Grosskurth and Rotmans 2005). Two key stages are considered in this research: (i) identification and determining of system factors and (ii) qualitative analysis to explore the effects as well as interactions among the system factors by i.e. applying impact analysis and visualizing the results in a system grid.

4.1 Identification and Determining of System Factors

In this research the emphasis was put on the holistic conceptual framework presented in Sect. 1 and not on single factors. The preliminary set of factors is the 21 key success factors (Table 1) that were modified in a previous research with two German and two Dutch humanitarian organizations (Abidi et al. 2013).

The second proposed manageable set of factors was elaborated in an adequacy analysis and the results were tested in five humanitarian organisations by Santarelli et al. (2013).

Santarelli et al. (2013) have defined and analysed a performance measurement system focusing on humanitarian supply chains during disaster. They defined quantitative and qualitative indicators. Moreover, the quantitative indicators can be financial and non-financial. The system can be used as a basis to measure performance of humanitarian organizations in terms of response time, service quality, and technical and cost efficiency. The table in Appendix I presents the identified five categories in detail: (a) Response time, (b) reliability/flexibility, (c) cooperation/standardization, (d) beneficiaries and donors satisfaction, (e) cost performance.

The impacts of each factor on the others were described using an impact matrix (example Table 2). Each cell of the matrix contains information about the strength of the impact between two factors. Each of key success factors are categorized in column in Table 2. In the row the factors of each category from the key performance indicators are defined i.e. Table 2. We have investigated the impact of key success factors on the key performance measurement indicator response time that contains five measurement indicators such as goods-to-delivery time or delivery date reliability. For each key performance measurement category we have defined an impact matrix. The grey marked cells indicate the active and passive sum. To measure the strength of the impact between two factors we have determined an ordinal scale from 0 to 3. 0 means no or very weak impact, 1 a weak impact, 2 an essential impact, 3 an absolute high impact. In this study we have judged the strength of impact between two factors based on individual expert estimates of the authors. After the evaluation the adequacy of each factors against the requirement of thematic sufficiency we calculated the sum of each row and each column. The sum of the column shows the passive sum, it means how strongly the factor e.g. *response time* is influenced by 21 key success factors and as a holistic system. The sum of the row shows the active sum that means how strongly each key success factor influences the key performance indicator e.g. *response time*. Based on these the results of the impact matrix are visualized in a grid system (Fig. 2).

4.2 Impact Analysis and Results

The grid system is mostly used in the sector of business science in the innovation management segment to analyse different scenarios (Reibnitz 1991; Geschka and Hammer 1997; Albers and Broux 1999). Grid system is a coordinate system with the activity sum in the y-axis and with the passivity sum in the x-axis. The grid system is divided in four categories namely active, ambivalent, buffering and passive. Active means that the factors strongly influence the other factors, passive means that the factors are strongly influenced by the other factors, ambivalent means that the factors are strongly influenced and strongly influence the other factors and buffering means that the factors are slightly influenced (Reibnitz 1991).

The point of intersection in the coordinate system is calculated by dividing the activity sum through the numbers of factors and dividing the passivity sum through the numbers of factors. Hereby a horizontal line is the arithmetic mean of the active scores and the vertical line is the arithmetic mean of the passive scores (Scholz and Tietje 2002; Lang et al. 2006; Wiek et al. 2008).

RQ1: Do the key success factors influence the key performance indicators?

The results of the impact analysis show (Fig. 2)—connected to the defined research questions—that the key performance indicators *cooperation/standardization* and *flexibility/reliability* are in the active sector. Thus they play a dominant role in the whole system. *Response time* is in the ambivalent sector and can be seen as less central

Table 2 Impact matrix for the key performance indicator response time

Response time	Sustainability	Cooperation	Standardization of relief items, processes	Growth	Security	Independence and impartiality	Continuum of care	Coordination	Beneficiary involvement	Proper assessment and planning	Qualified and experienced staff	Inventory management	Long-term contracts	Quality management	Speed	Flexibility	Local procurement	Order management	Cost efficiency	Enough staff members in the field	Availability of relief items	Active sum
Duration of the project	3	3	2	0	2	3	1	3	2	2	3	1	0	3	2	3	3	2	3	2	3	46
Average response time	1	0	2	3	1	0	3	2	3	2	3	1	2	3	3	3	2	2	1	1	3	41
Delivery date reliability	3	3	3	1	1	1	1	3	0	2	3	3	3	3	3	3	2	2	2	1	3	46
Goods-to-delivery time	3	1	3	3	2	0	3	3	2	3	3	3	3	3	3	3	3	3	2	1	3	53
Presence of the warehouse in the affected area	3	3	3	3	1	2	3	3	0	2	3	3	3	3	1	1	3	3	3	0	3	49
Passive sum	13	10	13	10	7	6	11	14	7	11	15	11	11	15	12	13	13	12	11	5	15	

Legend (0) = no or very weak impact (1) = weak impact (2) = essential impact (3) = absolute high impact

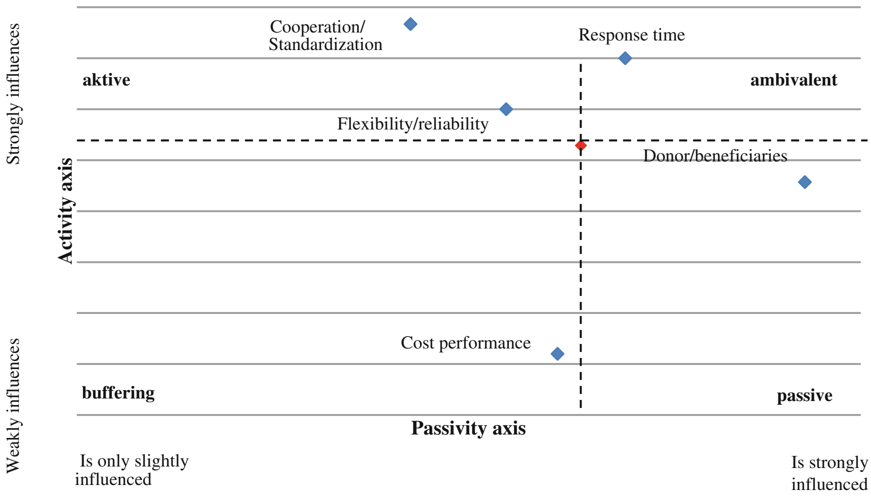

Fig. 2 System grid of impact of key success factors on performance measurement system

but it is strongly influenced by the key success factors. *Cost performance* is placed in the sector buffering and indicates that it is only slightly influenced by the key success factors and the key performance indicators *donor/beneficiaries* is strongly influenced by the key success factors.

> **RQ2:** With which intensity are the key performance indicators influenced by the key success factors?

The focal key performance indicator in this study based on the results is *cooperation/standardization* because in the humanitarian supply chain the cooperation and exchange of data between actors involved in a disaster are indispensable in order to effectively respond to the emergency. Moreover, the standardization of procedures (e.g. the way to delivery and distribute goods to people affected by a disaster, the way to use hygiene kits, etc.) could accelerate and improve the resolution of the disaster. Furthermore the results show that the key performance indicator *flexibility/reliability* plays a fundamental role. We have to take into account that the humanitarian organizations have to be capable in being flexible in delivery different typologies of goods as well as quantity (even it is unpredictable). Furthermore the humanitarian organizations have to be reliable in delivery date and quality.

The key performance indicators *response time* is located in the ambivalent sectors even it is the most critical measure of performance. And it is strongly influenced by the key success factors. We have to take into account that these factors can contribute to relief chain response time, including relief organizations assessment, procurement and delivery strategies, supplier location, transportation choice, safety, and infrastructure.

The key success factors have a high impact on the key performance indicator *donor/beneficiaries*. On the one hand the financial donors and mainly the beneficiaries are the most important stakeholders. Non-profit and humanitarian organizations should act according to the will of the donors and mainly should help the beneficiaries during the emergency and support them to come back in their normal life. On the other hand this key performance indicator has to be criticized because it has to be separated from each other and to observe separately the indicators for the donors and beneficiaries. They cannot be seen as a unit and be observed as a unit i.e. customer like the counterpart commercial supply chain.

Cost performance is only slightly influenced by the key success factors because the costs are not the predominant resource metric as in the commercial supply chain, in the humanitarian supply chain is important to evaluate the costs (e.g. cost of goods, transportation cost, warehousing cost, etc.). Due to the unpredictable demand, the evaluation and control of costs are difficult. This kind of performance indices can be evaluated only after the disaster occurrence and restoration of normalcy.

5 Conclusions

Within the described research we have proposed method for analyzing the impact of identified key success factors on key performance indicators in humanitarian logistics. This research approach is certainly in line with the increasing trend towards quantifying methods and approaches within management, especially humanitarian logistics management. The results of the impact analysis show that the key performance indicators such as *cooperation/standardization* and *flexibility/reliability* are evaluated most important and therefore future research approaches in performance and success questions as well as business practice management concepts could focus on these two areas. Further research also should test these results from the QSA approach with competing methods for establishing connections between the areas. Furthermore the results help the humanitarian logistics and humanitarian relief community to develop key performance indicators and measurement frameworks that suit the humanitarian logistics sector.

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Appendix I

Category	KPIs	Description	Equation	Type		
				Qualitative	Quantitative	
					Financial	No-Financial
Response time	Duration of the project	The indicator measures the duration of the project	Number of months			☐
	Average response time	The indicator measures the average response time between the occurrence of the disaster and arrival time of the organisation's first supplies (personnel and goods)	Average number of days (personnel)			☐
			Average number of days (goods)			
	Delivery date reliability	The indicator measures the accuracy of delivery date of goods to the disaster area both in the first aid and at steady-state	*First aid* (<3 months) $\frac{\text{Number of deliveries on time}}{\text{Total number of deliveries}}$			☐
			Steady-state (>3months) $\frac{\text{Number of deliveries on time}}{\text{Total number of deliveries}}$			
	Goods-to-delivery time	The indicator measures the time between when goods are purchased and when they arrive at the disaster site	Average number of days to purchase goods			☐
			Average number of days to transport goods from the organisation's ware-house to the disaster area			
			Average number of days to deliver goods to the staging area			
	Presence of organisation's	The indicator expresses the presence of a warehouse with prepositioned materials in a	Yes/no			☐

(continued)

(continued)

Category	KPIs	Description	Equation		Type		
					Qualitative	Quantitative	
						Financial	No-Financial
	warehouse in loco	radius of 200 km around the disaster area					
Reliability/ Flexibility	Volume flexibility	The indicator measures the organisation's ability to respond to different magnitudes of disasters	[1–5] (1 very low; 5 very high)		☐		
	Mix flexibility	The indicator measures the organisation's ability to change the variety of goods sent to the disaster area	[1–5] (1 very low; 5 very high)		☐		
	Percentage of prepositioned goods	The indicator measures the percentage of goods (drugs and no-drugs) prepositioned in organisation's warehouses, both at regional and international level	Drugs	$\frac{\text{Number of prepositioned goods at regional level}}{\text{Total number of goods}}$			☐
				$\frac{\text{Number of prepositioned goods at international level}}{\text{Total number of goods}}$			
				$\frac{\text{Number of no-prepositioned goods}}{\text{Total number of goods}}$			
			No-Drugs	$\frac{\text{Number of prepositioned goods at regional level}}{\text{Total number of goods}}$			
				$\frac{\text{Number of prepositioned goods at international level}}{\text{Total number of goods}}$			
				$\frac{\text{Number of no-prepositioned goods}}{\text{Total number of goods}}$			

(continued)

(continued)

Category	KPIs	Description	Equation	Type		
				Qualitative	Quantitative	
					Financial	No-Financial
Cooperation/ Standardisation	Degree of information sharing	The indicator measures the degree of information sharing between actors of the organisation, involved in the disaster	[1–5] (1 very low; 5 very high)	□		
	Degree of cooperation	The indicator measures the degree of cooperation between actors of the organisation, involved in the disaster	[1–5] (1 very low; 5 very high)	□		
	Degree of standardisation	The indicator measures the degree of standardisation of procedures	[1–5] (1 very low; 5 very high)	□		
Beneficiaries and donors satisfaction	Number of relief workers	The indicator measures the number of relief workers (national and international staff) employed during the resolution of the disaster	Number of relief workers at national level Number of relief workers at international level			□
	Percentage of people engaged on dispensing aid	The indicator measures the percentage of people engaged on dispensing aid (doctors and health personnel, logisticians, etc.)	$\frac{\text{Number of workers engaged on dispensing aid}}{\text{Total number of workers}}$			□
	Total dollars spent	The indicator measures the organisation in financial terms	Dollars given by institutional donors Dollars given by private donors		□	

(continued)

(continued)

Category	KPIs	Description	Equation	Type		
				Qualitative	Quantitative	
					Financial	No-Financial
	Number of people helped	The indicator measures the efficiency of the organisation in terms of people helped (direct and indirect beneficiaries)	Number of people helped			□
	Donor's auditing	The indicator expresses if donors monitor the work of the employees	Yes/no			□
	Spending capacity	The indicator measures the ability of the organisation to respect the account of money requested to institutional donors	$\frac{\text{Dollars spent given by institutional donors}}{\text{Total dollars requested to institutional donors}}$		□	
	Satisfaction level	The indicator measures the satisfaction level of donors	[1–5] (1 very low; 5 very high)	□		

(continued)

(continued)

Category	KPIs	Description	Equation	Type		
				Qualitative	Quantitative	
					Financial	No-Financial
Cost performance	Cost of goods	The indicator measures the percentage of the cost of goods on the cost of the project	$\frac{\text{Cost of goods}}{\text{Total dollars spent}}$		□	
	Transportation cost	The indicator measures the incidence of the transportation cost (by air, sea and truck) during the whole period in which the organisation stays in the disaster area	$\frac{\text{Transportation cost}}{\text{Total dollars spent}}$		□	
	Warehousing cost	The indicator measures the percentage of the warehousing cost to store goods in the surroundings of the disaster area on the cost of the project	$\frac{\text{Warehousing cost}}{\text{Total dollars spent}}$		□	
	Percentage of claims	The indicator measures the percentage of claims	$\frac{\text{Number of orders claimed/year}}{\text{Number of orders/year}}$			□
	Percentage of goods not distributed	The indicator measures the percentage of goods (drugs and no-drugs) not distributed	$\frac{\text{Number of drugs not distributed}}{\text{Total number of goods}}$ $\frac{\text{Number of no} - \text{drug goods not distributed}}{\text{Total number of goods}}$			□

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Information Categories for Infrastructure and Logistic Resource Assessments in Humanitarian Logistics

Exploring Practical Sources with Inductive Category Development

Daniel Link, Bernd Hellingrath and Christian Bültemann

Abstract Humanitarian logistics assessment aims at quickly gathering accurate information about a disaster-affected area. This includes information about the infrastructure and logistic resources which are required to execute a humanitarian operation. Assessment thus provides a decision basis, e.g. to plan aid deliveries. Despite its relevance, assessment has hardly been researched. This paper structures practical knowledge and makes it accessible to the research community. Accordingly, it is based on documents from practice, exploring assessment tools and guidelines of humanitarian aid organizations regarding infrastructure and logistic resources. Furthermore, it structures the knowledge contained in them. Inductive Category Development, a qualitative research approach, is used to split the documents into comparable information fragments. On that foundation, we consider three assessment phases: preparedness, rapid response and on-going response. We give an example to illustrate which information to assess during each phase and explain how the assessments in these phases are connected. The findings provide a foundation for developing comprehensive theories on infrastructure and logistic resource assessments, as well as impulses for humanitarian aid organizations to standardize their assessment tools. The standardization can increase the speed of assessment and facilitates information sharing between organizations.

D. Link (✉) · B. Hellingrath · C. Bültemann
Information Systems and Supply Chain Management, European Research Center for Information Systems (ERCIS), Leonardo-Campus 3, 48149 Münster, Germany
e-mail: Daniel.Link@ercis.de

B. Hellingrath
e-mail: Bernd.Hellingrath@ercis.de

C. Bültemann
e-mail: Christian.Bueltemann@ercis.de

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Keywords Humanitarian logistics · Assessment · Infrastructure and logistic resource assessment · Information requirements · Inductive category development

1 Introduction

The Centre for Research on the Epidemiology of Disasters (CRED) defines a disaster as a “situation or event which overwhelms local capacity, necessitating a request to the national or international level for external assistance, or is recognized as such by a multilateral agency or by at least two sources, such as national, regional or international assistance groups and the media” (Guha-Sapir et al. 2004, p. 16). During disasters the affected people often depend on being supplied with relief goods. Procuring, storing and transporting those items are important tasks in humanitarian logistics (Blecken 2010, p. 61). In order to comply with those tasks, much information is required regarding the situation at the disaster site. Previous to and during disasters, this information is collected by the use of so called assessments, which provide the cornerstone for any planning (Tufinkgi 2006, p. 218). This includes information about the infrastructure and logistic resources that humanitarian logistics operations require. In this paper, infrastructure is understood as traditional supply networks, such as roads and electricity (Hellingrath et al. 2011, p. 3). Logistic resources are understood as any kind of mobile equipment that is substantial for carrying out logistic operations and that complements infrastructure, e.g. handling equipment and vehicles. Assessment is done in all phases of disaster management. It can begin before a disaster strikes, i.e. for disaster preparedness, and it is continuously done during a disaster response operation.

Despite its relevance, Infrastructure and Logistic Resource Assessment (ILRA) has hardly been researched. To advance research in this area, we have explored documents from practice, i.e. assessment tools and guidelines of humanitarian aid organizations, regarding infrastructure and logistic resources. With Inductive Category Development, a qualitative research approach, the knowledge contained in the documents is structured towards the development of a standardized assessment tool. In accordance with The Sphere Handbook, we consider three assessment phases: preparedness, i.e. before the occurrence of a disaster, rapid response, i.e. the first days after the occurrence of a disaster, and on-going response, i.e. the weeks following a disaster (The Sphere Project 2011, p. 62f.). On this foundation we developed an ILRA structure which describes the range of information that has to be assessed during each phase. The results can be used for developing comprehensive theories on ILRA, as well as they can give impulses for developing improved assessment tools. It is worthwhile repeating that our analysis focuses on the assessment of infrastructure and logistic resources. Information about the needs of the affected population and about relief items thus falls out of scope. It is also important to note that the resulting category system is only a subset of all possible infrastructure and logistic resources. It is the subset that humanitarian aid organizations (HAOs) consider important enough to include it in their assessment tools and guidelines.

This paper is structured as follows: Section 2 introduces the research method, Inductive Category Development, which is used to explore the different documents from practice and introduces the documents themselves. Section 3 describes the main categories that result from our research. In Sect. 4 an example is given for the specific characteristics of the preparedness, rapid response and on-going response phases and their implications for ILRA. Section 5 discusses the presented findings. Section 6 draws conclusions and gives an outlook for further research.

2 Research Method

We use Inductive Category Development (ICD) (Mayring 2010, pp. 83–85) as a qualitative research method for analyzing documents from practice. ICD employs a detailed methodological procedure that has the advantages of high reliability and objectivity. It splits the documents into comparable information fragments, the so called categories.

The first step of ICD consists of a detailed description of the research problem, the examined documents and their background, which is addressed by Sects. 1–3. In a second step, the pre-conditions for relevance and for creating comparable and generally applicable categories are set. For this purpose, the ICD constructs "selection criterion" and "degree of abstraction" are defined. The selection criterion determines the selection of text passages that are relevant for developing the categories. The degree of abstraction defines how the selected text passages are transformed into analytical categories. With those definitions at hand, the material is analyzed and categories are formulated as depicted in Sect. 3. Each time a passage occurs that meets the conditions of the selection criterion, it either forms the basis for formulating a new category or it falls within the scope of a category that already exists. After having processed the documents, both selection criterion and degree of abstraction are modified based on what has been learned from the analysis. This process is repeated until the objectives of the analysis, an adequate selection criterion and a suitable degree of abstraction are reached. As a last step, the categories are analyzed regarding both their quantity and quality, as described in Sect. 4.

For the analysis we have reviewed various documents from practice that are publicly accessible, i.e. assessment handbooks and guidelines published by various HAOs. Among these are the organizations participating in the Inter-Agency Standing Committee (IASC), a network of the leading HAOs from within United Nations (UN) and from outside of the UN system. In addition to IASC members, we considered documents published by the United States Agency for International Development (USAID), thereby including the national economy with the highest financial contribution to humanitarian aid, by far exceeding the financial contribution of the entire European Union (Global Humanitarian Assistance 2012, p. 12).

The final selection of documents represents the relevant actors within the UN, a joint initiative of several international non-governmental HAOs and USAID. The selected documents are, in particular: The *UN Disaster Assessment and Coordination* (*UNDAC*) *Handbook*, the USAID *Field Operations Guide for Disaster Assessment and Response* (*FOG*), the Logistics Cluster's *Logistics Capacity Assessment* (*LCA*) Template and *Rapid Logistics Assessment Tool* (*RLAT*), the UN Children's Fund (UNICEF) *Supply/Logistics Assessment Checklist* (*SLAC*), the *UNICEF Logistic Rapid Assessment* (*ULRA*) and *The Sphere Handbook* that was created by The Sphere Project. This selection is close to Darcy's and Hofmann's (2003) selection that focused on needs assessment.

Our final selection criterion can be formulated as follows: A certain text passage is considered relevant if it is about the assessment of the infrastructure or logistic resources of the disaster-affected country or a transit country and if the assessed information has implications for the logistic planning of HAOs.

The final degree of abstraction in this paper consists of main categories and sub categories. We define main categories as categories that correspond to the different parts of relief supply chains, to supporting functions, or to background information. In contrast, each sub category belongs to one main category and represents a thematic area with direct operational or administrative implications.

3 Main Categories

The main categories split the assessed information into functional areas. The following main categories result from our analysis:

- Airport
- Seaport
- Road Transportation
- Railway Transportation
- Inland Waterway Transportation
- Warehouse
- Customs
- Local Suppliers of Relief Goods
- Flour Mill
- Fuel Supply
- Electric Power Supply
- Telecommunications
- Additional Handling Equipment
- Staff Accommodation
- Country Overview

The main category *Airport* refers to international and national airports for commercial flights and furthermore to any possible landing site for both airplanes and helicopters. Similar to airports, the main category *Seaport* covers any type of landing site for overseas shipments. *Road Transportation* covers roads, vehicles and trans-loading points for intramodal transshipment. *Railway Transportation* covers tracks, vehicles and stations. *Inland Waterway Transportation* covers waterways, vessels and jetties. While airports and seaports are mainly used for transporting relief goods into the affected country, road, railway and inland waterway transportations are also used to transport relief goods within the country.

The main category *Warehouse* refers to suitable buildings as well as to any area that can be used for storing relief goods intentionally. It is important to keep in mind that this does not mean the same as storage, a term that is part of several sub categories within various main categories and that refers to unintended disruptions of the flow of relief goods.

Customs covers regulations, procedures and restrictions for shipping relief goods to the affected country or a transit country. It incorporates general information on the national customs system, which is complemented by specific details for each point of entry into the country.

A *Local Supplier of Relief Goods* is an independent market agent, external to any HAO. The documents do not define where suppliers have to be located exactly for being considered local suppliers. For this analysis, suppliers are regarded as local if they are located significantly closer to the disaster site than the HAO's home country.

Flour is central to fighting hunger and therefore assumes an outstanding position among food relief goods. Flour can either be procured locally or shipped to the disaster-affected country. Alternatively, HAOs might produce flour from grain in a *Flour Mill*. Hence, milling infrastructure and resources have to be considered.

Fuel Supply is crucial to running supply chains, and the according category covers types of fuel and their supply.

Electric Power Supply is essential for operating transshipment points, warehouses and communication equipment and also covers power generation.

Telecommunications is required for intra-organizational as well as for inter-organizational coordination and covers both general telecommunication issues and the different technologies that are potentially used.

Additional Handling Equipment covers any handling equipment that does not belong to one of the above main categories. If the handling equipment of a transshipment point, e.g. a forklift truck, breaks down it can be replaced by additional handling equipment, e.g. a rented forklift truck. Alternatively, it can be used for increasing the handling capacity of an existing transshipment point or establishing a new one, or during transportation.

The main category *Staff Accommodation* covers the accommodation for HAO staff during humanitarian operations. This includes field logisticians, but is not limited to them.

The general *Country Overview* provides indispensable basic background information on the disaster-affected country, such as the political situation, that is not covered by one of the other main categories.

4 Mapping of the Range of Information to Phases of Disaster Management

On the basis of the developed main category Airport, we show the range of information to be assessed in the preparedness, rapid response and on-going response phases, respectively. The *Preparedness ILRA* collects information before a disaster occurs and forms the basis for the other ILRAs. In the immediate aftermath of a disaster, the *Rapid ILRA* updates the most important parts of the Preparedness ILRA and adds disaster-related information. In this phase, the focus lies on the effectiveness of operations. Once the most urgent needs have been attended, the efficiency of operations gains importance (Van Wassenhove 2006, p. 480). Accordingly, the *On-going Response ILRA* extends the scope of the Rapid ILRA by regarding information that helps to increase efficiency. After the response phase, the preparedness phase begins anew. That is, the Preparedness ILRA incorporates the findings from the On-going Response ILRA and extends it towards a comprehensive description of the new baseline situation.

The assignment of sub categories to the different phases is based on frequency analysis, i.e. the number of times a certain sub category occurs in the documents. We assume that a sub category that appears in the documents more often can be seen to be more widely acknowledged and important. It is therefore also necessary to assess it right after a disaster has occurred. Accordingly, a sub category is regarded as relevant for the Rapid ILRA if it is mentioned by all documents. Any sub category that is mentioned by three or more documents is considered for the On-going Response ILRA. This ensures that categories are only considered, if at least two different HAOs mention them. If at least two documents consider a certain sub category, it becomes part of the Preparedness ILRA. Categories that occur only once are not regarded. This is a trade-off decision between including as much information as necessary and keeping the Preparedness ILRA as concise as possible. The Sphere Handbook's position is unique in this regard because although contributing meaningful information to the qualitative analysis, it does not explicitly address ILRA. Thus, this document is not taken into consideration for the quantitative analysis. The frequency of occurrence in documents does not necessarily reflect a category's importance for the different assessment phases. However, it is a useful, objective indicator for the relevance of a category (Mayring 2010, p. 51), providing a first conception of which sub category to be assigned to a certain phase. Exceptions from this general rule might be necessary when considering the content of a sub category.

As an example for the results of the analysis, Table 1 displays the sub categories of the main category Airport and their assignment to the different phases of assessment. Qualitative considerations may lead to certain sub categories being excluded entirely, which are nevertheless shown for documentation purposes.

For the rapid response phase, no changes seemed to be required.

For the on-going response phase, *Annual performance* is omitted. This is because the annual performance is a long-term measure that provides important

Table 1 Proposition for a phase-specific ILRA regarding the main category airport

	Rapid response	On-going response	Preparedness
Basic information	●	●	●
Annual performance		–	⦿
Overall capacity			○
Overall operativeness		○	–
Current condition of facilities	●	●	●
Runway characteristics	●	●	●
Cargo handling	●	●	●
Operating hours	●	●	●
Labor force details		⦿	⦿
Storage facility details		⦿	⦿
Airport accessibility		⦿	⦿
Approach/departure zone obstructions		○	○
Parking area size	●	●	●
Taxiway size		⦿	⦿
Availability of helicopter landing zone		⦿	⦿
Security		⦿	⦿
Seasonal effects		⦿	⦿
Relevant entities contact details		⦿	⦿
Procedures		⦿	⦿
Regulations		–	⦿
Possibility of priority to relief shipments			–
Level of weather forecasting support			○
Cost of airport usage		+	+

● Included and mentioned by all of the documents
⦿ Included and mentioned by at least three different documents
○ Included and mentioned by at least two different documents
+ Included for qualitative reasons
– Excluded for qualitative reasons

baseline information but cannot be obtained in the wake of an unusual event like a disaster. It is thus replaced by *Overall operativeness*. In contrast to the exclusion, *Approach/departure zone obstructions* are added to response, because they potentially limit the number of aircraft that can land and thus affect airport operations. *Regulations* are omitted from response, as they are not subject to change after the occurrence of a disaster.

During the preparedness phase, the *Possibility of priority to relief shipments* is excluded because it strongly depends on the magnitude and effects of the disaster at hand.

Once the most time-critical phase, rapid response, is over, costs turn into an important criterion (Van Wassenhove 2006, p. 480). Therefore the *Cost of airport usage* is assessed during the on-going response and preparedness phases.

5 Discussion

Most sudden on-set disasters are hard if not impossible to predict. As a consequence, Preparedness ILRAs have to be carried out and updated for a large number of countries. To minimize the effort that is needed to do the initial assessments and keep the collected information up-to-date, Preparedness ILRAs should be kept as concise as possible. This also makes it easier to quickly focus on the most relevant information once a disaster strikes. To give a simple example, road traffic volume could be omitted from the Preparedness ILRA. The effort to collect this information is quite high, and it is likely that a disaster would quickly render previously collected data obsolete.

If a sub category has been assessed by a Preparedness ILRA, the following Rapid ILRA can focus on those sub categories that lack information or need updating. This can contribute to the Rapid ILRA's efficiency.

The proposed On-going Response ILRA contains many categories, which are meant to hold detailed information. To improve the efficiency of the On-going Response ILRA, categories can be excluded after the rapid response phase. For instance, if the Rapid ILRA pointed out that the railway system cannot be used for transporting relief goods at all throughout response operations, the railway system category can be omitted from the On-going Response ILRA. Before excluding any category, it is important though to verify the results of the Rapid ILRA. Otherwise the exclusion of categories could make the On-going Response ILRA less effective. This is emphasized, in general, by the fact that rapid assessments partly rely on estimated figures that are not statistically significant (Tufinkgi 2006, p. 220; Assessment Capacities Project 2012, p. 7).

Our analysis is completely based on publicly accessible documents. Several HAOs use internal handbooks and guidelines that are not publicly accessible, and considering such sources might lead to different findings.

One might disagree on the threshold level that we chose for categories to be assigned to the assessment phases. This is in part controlled for by the qualitative analysis.

6 Conclusions and Outlook

Based on the exploration of documents from practice using Inductive Category Development, we proposed information categories for Infrastructure and Logistic Resource Assessments in humanitarian logistics. In addition to the proposition of main and sub categories, the sub categories have been assigned to the relevant assessment phases, i.e. preparedness, rapid response and on-going response. This has been exemplified using the main category Airport. Further research can use these results in order to develop advanced theories on humanitarian logistics assessment. To contribute to the development of improved assessment tools, our future research aims at providing a method for prioritizing categories and their contents according to the situation at hand.

Our results include a general set of categories for all relevant phases of Infrastructure and Logistic Resource Assessment in humanitarian logistics and the range of information to be assessed during each phase of assessment. Incorporating these results into assessment tools can make the results of assessments more easily comparable. The described links between assessment phases, together with the general range of information, can yield considerable time savings. This is an advantage especially during the immediate rapid response phase, where practitioners see the greatest need for faster information (Assessment Capacities Project 2011, p. 2). Another advantage of increased ILRA standardization is the reduced complexity of sharing ILRA results between HAOs.

The next steps for our research are to discuss the results with humanitarian logisticians and assessment experts and to improve the ILRAs accordingly. For instance, the rules for assigning sub categories to assessment phases and the manual changes are subject to future revision.

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A Decision Support System for "Re-design for X" of Production Processes: Particular Focus on High Tech Industry

Sophia Keil and Rainer Lasch

Abstract Main target of product design is to develop excellent products, while considering a multitude of optimization goals which can overlap; be contrary or interdependent. Hereby, a large variety of Design for Excellence (DfX) techniques is available to support product developer. The approaches focus mostly on new products and a specific virtue or life phase. A major part of work is the further development of existing products which are not yet in focus of current DfX-approaches. Therefore, within the contribution a decision support system for "Re-Design for X" of production processes instead of products is developed with the aim of a holistic integration of criteria from different scientific perspectives by using a case study from semiconductor production.

1 Introduction

It is well known that during the design stage of products about 70–80 % of the product life cycle costs are determined (e.g. Dowlatshahi 1996). For this reason scientists from various disciplines try to utilize this time and propose a high number of criteria—summarized under the term "Design for X" (DfX)—to develop successful products. There is a high number of different "DfX" perspectives (Chiu and Okudan 2010). Thereby optimization goals can overlap; they can be contrary or interdependent. The decision situation becomes more complex when the aspects of cross enterprise engineering due to decreasing value added depths, the need for short development times and low development costs are taken into account. Moreover in this context it is important to know that development of new products forms only a minor part—10–30 %—of the work of product developers (Schulze 2011). A major part of the work is further development of existing products.

S. Keil (✉) · R. Lasch
Department of Business Management and Economics, esp. Logistics, Dresden University of Technology, 01069 Dresden, Germany
e-mail: Sophia.Keil@tu-dresden.de

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Therefore, the reverse engineering of the legacy products workflow—in this context understood as "Re-Design for X"—represents a very specific leverage for boosting overall company goals (time, cost, quality, agility). Following these thoughts the main research question of the contribution is: How a decision support system (dss) should be designed to support staff to make the right decisions within product development and re-design of production processes? For answering the question the paper is organized in the following manner: after this introduction Sect. 2 includes a short introduction into DfX-approaches and theory of decision making. Section 3 comprises a description of the new approach for "Re-Design for X" of production processes and Sect. 4 contains its application by using a case study of semiconductor production. Lastly, a conclusion and outlook for future tasks are put forth.

2 Design for X and Decision-Making

2.1 DfX-Approaches

In general "Design to X" and "Design for X" approaches can be divided. "X" is a variable that stands in case of "Design to X" mostly for objectives, e.g. costs. In case of Design for X, "X" is an expression for feasibility and virtue, e.g. for manufacturing. Chiu and Okudan (2010) categorize DfX-approaches in methods with (1) product scope [e.g. design for quality (DfQ), reliability (DfRe), assembly (DfA), manufacture (DfM) etc.]; (2) system scope [e.g. design for logistics (DfL), supply chain (DfSC) etc.]; and (3) eco-system scope [design for sustainability (DfS) etc.]. Contributions with respect to design for X (to X) vary in the range of qualitative guidelines, metrics, feasibility checks and detailed software tools (Holt and Barnes 2010). Within this article general guidelines, esp. design criteria of different DfX-approaches are in center. Literature analysis showed that DfX-approaches are focused mainly on products instead of processes; furthermore they emphasize the introduction of new products instead of legacy products although only a minor part of the work of product developers is new product development. Furthermore they focus mainly on one or at most two aspects of the product [e.g. DfQ or design for manufacture and assembly (DfMA)]. A holistic integration of criteria from different scientific perspectives in a general information and knowledge system is missing which is also remarked e.g. by Holt and Barnes already (2010) or Schulte (2011). Therefore a comprehensive usage of different DfX-criteria is cumbersome, esp. for users from business practice as knowledge is spread over a high number of publications from different scientific perspectives. Table 1 gives—without claiming to be exhaustive—by an exemplary listing a short introduction into different DfX-criteria by using representatives for the mentioned three perspectives.

In general the approaches aim towards reaching strategic company targets like production cost and cycle time reduction, quality enhancement of products and reducing of environmental consequences of product design (Fabricius 1994). From the exemplary listing (Table 1) it can be seen, that complexity dimensions

Table 1 Examples for DfX-criteria

DfX	Criteria	Source
DfA	Minimize part count (5), (8), (9); minimize variety of parts, materials; use standard parts; design for simple part orientation, handling, automated assembly; consider size, weight and simple shape of parts	Boothroyd and Alting (1992)
DfM; DfMA	Minimize part count and variety of parts, materials; simplify the product structure; consider modular designs; do not overspecify tolerances; efficiency in personnel and investment (2)	Boothroyd (1994), Bogue (2012)
DfQ; DfRe	Robust design (3); redundant design; use of proven components and preferred designs; identification, elimination of critical failure modes, impending failures	Kuo et al. (2001)
DfL; DfSC	Standardization of parts, products and processes (1); part commonality and modularity; minimize number of variants; delay product differentiation (postponement); localization of entities in supply chain; optimization of packaging/transportability; concurrent processing and decoupling of tasks (6), (7); optimization of parts with respect to value, weight, volume, shape	Mather (1992), Lee (1992), Dowlatshi (1996), Schulze (2011), Gubi (2001)
DfS	Modular design; design for material substitution (4); waste source reduction design; disposability, reusability, undesirable substance reduction	Ljungberg (2007)

multiplicity and diversity (Reiß 2011) are addressed by different DfX-approaches, see e.g. criteria of DfA: minimize part count and variety of parts; or criteria of DfL: minimize number of variants etc. Also standardization plays a key role within the approaches, see DfL: standardization of parts, products and processes. It is the most effective way and can be seen as embodiment of DfX-compliance. The challenge is to enable a large variety of products and at the same time minimal internal complexity of all business processes. Well known answers for this are DfL/DfSC-criteria (Gubi 2001), e.g. using part/product commonalities, delayed product differentiation (postponement). Although a similar direction between criteria is visible (e.g. consideration of part characteristics within DfA and DfL) there are goal conflicts, see e.g., construction of products: integral design can be beneficial for short cycle times but unfavorable for recycling. Here, decision theory, which is the topic of the next section, can contribute to make the right choices. Besides combination of DfX-approaches with decision theory the originality/value of the contribution is that criteria for legacy processes instead of new products are derived with the aim of a holistic integration of these criteria from different scientific perspectives by using a case study from semiconductor production in Sect. 4.

2.2 Decision Support Systems

A decision can be regarded as judgment. It is a choice between alternative courses of action (Drucker 1975)—in this case in presence of multiple, maybe conflicting criteria. The decision making process includes the phases problem recognition and definition, alternative generation, model development, alternative analysis, choice and implementation. "Decision support systems are computer technology solutions that can be used to support complex decision making and problem solving" (Shim et al. 2002). The focus is set on the question on how information technology can improve efficiency and effectiveness of decisions. DSS use Multi-Criteria Decision Making approaches (MCDM) for enabling the decision. Those can be divided in Multi-Attribute Decision Making (MADM) and Multi-Objective Decision Making (MODM) approaches. MADM includes the choice of the "best" alternative from a discrete solution space whereas MODM deals with a continuous solution space. We focus on MADM as a limited number of alternatives exists. There are numerous MADM approaches (see e.g. Tzeng and Huang 2011) and the selection of the most appropriate approach is also a decision problem. By using the questionnaire of Sun and Li (2010) we choose the analytic network process (ANP) in the new method (see Sect. 3) which can support esp. alternative analysis and choice phase. The most important reason for using the ANP is that the approach incorporates interrelations between criteria. Within ANP a decision problem is structured as a network, then a system of pairwise comparisons is used to measure the weights of the components of the structure, and finally to rank the alternatives in the decision. A detailed description is not given here as the proceeding is well known and often described in academic literature (e.g. Yang et al. 2010; Chung et al. 2005; Saaty 2004). Two other reasons for using ANP are the ease of use and the available software support as ANP-networks can be modeled by using the software super decisions which can be downloaded for free from website: www.superdecisions.com.

As a second instrument we need a group support system (GSS) to enhance the communication-related activities of team members. GSS can be described "along the three continua of time, space, and level of group support. Teams can communicate synchronously or asynchronously; they can be located together or remotely; and the technology can provide task support primarily for the individual team member or for the group's activities" (Shim et al. 2002). Here, MS-SharePoint 2010, which is a web application of Microsoft, is used to support group decisions and virtual collaboration by using a common web interface. It bases on SharePoint Foundation technology. One main function is central document repository and administration (Larisch 2011). Besides that esp. the integrated workflow function is the main reason for using SharePoint. A workflow is characterized by automation of activities. Single activities are combined to a process. It is defined which persons execute which tasks by which means and information. A workflow can be started manually or automated. An initial point can be for example uploading of defined documents, reaching of a specific date or change of a document. Consequently, directives for action follow. A workflow is being executed as long as a previously defined goal or end is reached. Therefore, it is a suitable mean for standardizing progress of the project.

3 Approach for "Re-design for X" of Production Processes

3.1 Requirements and Design Science

Requirements of approaches with focus on redesign of production processes have been discussed for example by Singh et al. (2006) and Wu (1996), whereas Singh emphasizes the importance of enabling and facilitating group work as well as consistent decision-making without subjective influences and Wu technical aspects. Further important requirements proposed by Singh et al. (2006) and Wu (1996) are: efficiency with respect to time and effort required by each team; quantitative and objective data analysis should be enabled; a holistic, systemic perspective of investigation object should be adopted. With respect to design science the new approach is developed on basis of thoughts of Simon (1996) and generally known logic of problem solving process, see e.g. Spalten problem solving methodology in the product development (Albers et al. 2005) with phases situation analysis, problem containment, search for alternative solutions, selection of solutions, analysis of the level of fulfillment, make decision/implement, recapitulate/learn.

3.2 Outline of the Approach

The new approach is a sequence of four steps, which are shortly described below. The focus of this contribution lies on step 4 which will be described more in detail in Sect. 3.3 after the overview in this section.

1. *Preparation, building of flow families and strategic preliminary decisions*
   Within the preparation phase targets, project team and field of investigation have to be defined. In general, the focus is not design but "Re-Design for X", which means reverse engineering of the legacy products workflow (not the product itself) is the scope of the new approach. "Re-Design for X" of the whole manufacturing sequence for all products and steps in parallel is in case of a multi-variant serial production not possible. Therefore, via a product range analysis (with tools like ABC analysis or portfolio techniques) we identify the most important products (with the highest revenue for example) and build flow families. A flow family (FF) is a united chain of consecutive single process steps which are similar within different product processes of record's (POR), including the following similarities: sections of complete POR, same or replacing tool types with similar process times for single process steps, and length as well as sequence. A description of the proceeding of building flow families is not the focus of the contribution. The further interested reader is referred to Keil et al. (2009).

In addition strategic decisions need to be made regarding applied Design for X-criteria. That means with regard to which requirements should the process section of the FF be optimized? This is necessary to assure a purposeful analysis, evaluation and re-design phase. In literature it is recommended to use a limited number of DfX-approaches in parallel—namely five to nine—to reduce complexity of requirement system (Huang 1996). Parallel selection of DfX-approaches could be done by using the matrix approach of Watson et al. (1996) which includes six steps: (1) selection and weighting of context suitable DfX techniques by using cost estimates for each life cycle area, (2) categorization of DfX techniques in general design rules or specific design strategies and assignment to the product development phase where it should be used, (3) weighting rules and strategies with respect to relevance in the regarded case, (4) identifying guideline interactions, (5) determining the overall value of design strategies/rules and generating a ranked list with most important strategies for the designer, (6) utilizing the list during design. Another approach is sequential use of DfX-approaches (Gubi 2001). Gubi (2001) proposes for example that DfL can be applied when the product architecture is ready whereas DfM and DfA should not be used in this phase since the detailed design is not complete. For this procedure speaks that DfX-approaches are developed for different design phases, whereas the major portion of the approaches has been developed for late design stages (Chiu and Okudan 2010). But every applied DfX-approach limits the theoretical solution field of the approaches which are applied in the following. Conditions are set and maybe through absence of a holistic view on all design criteria right from the beginning goal conflicts and interrelations cannot be taken into consideration. Therefore, and because criteria of different approaches are overlapping (see Sect. 2.1) as well as for the reason that the field of investigation is product workflow of legacy products a limited number of DfX-approaches is used in parallel here. Requirements which result from applied DfX-approaches should be collected in a criteria catalogue and be described in a standardized form, e.g. as requirement profile. This profile includes according to Klute et al. (2011) information about: reference (regarded property and its characteristics), source (DfX-approach), relations (description of interdependencies), weight (relative importance of requirement) and situation (date of recognition and percentage of completion).

In the following it is assumed that a criteria catalogue is available, e.g. in an excel-based document. Now every team member decides which criteria of this catalogue should be used with respect to the object of investigation. Helpful in this connection can be a prepared excel-sheet, which can be easily implemented in the workflow. The team-leader saves this document on the ms-share-point and every team member has access to it. Therefore, the most frequently mentioned criteria can be easily identified by the team leader. For executing steps like "selection of criteria" there are defined timeframes foreseen within the workflow. When the time span is exceeded, the user is automatically informed via e-mail to complete this step. When every team member has chosen the criteria a team-meeting follows. Here, the team leader presents the most frequently mentioned and maybe newly formulated criteria for discussion. Result of the meeting should be a consensus with a definition of the criteria which are the basis for the following analysis, design and evaluation phase. Relations and weighting of criteria are analyzed within evaluation phase (Sect. 3.3).

2. *Analyze flow families: technology, DfX-criteria and operations*
   Major steps within the analysis phase are: examination of technology and fulfillment of DfX-criteria as well as analysis of operations with focus on process organization. Main focus of technology analysis is similarity observation. As mentioned one result of step 1 are clusters of different flow families and each includes similar sections of POR's. The sections within a cluster will be compared in detail to detect all variations of available process flows. The variations will be compared with respect to characteristics as used unit processes, process times, kind of applied equipment types and their location in the facility layout. As each variation results in further complexity increasing for all business processes, the focus is set on the question of technological necessity, inflexible customer requirements, capacity constraints of a mature fabrication facility, but also historically grown definitions. The goal is to identify preference technologies to reduce complexity within production system (Gräßler 2004; Keil 2012). As the analysis step is not focus of this contribution the further interested reader is referred to Keil et al. (2013).
3. *Re-Design of alternative future process flows within FF-compliant to DfX-criteria*
   As a result from the analysis phase alternative standard process flows which could be used in the future as new standard reference are generated in re-design phase. As reflected through DfX-criteria from Sect. 2.1 the most effective way and the embodiment of DfX-compliance is homogenization. Besides the efforts toward homogenization for legacy products, the process flows here are re-designed in the manner of business reengineering. This means reviewing the arrangement of process steps of the whole workflow with respect to options regarding elimination, integration, parallelization, swapping, splitting and maybe enlargement due to quality issues. Resulting is a description of re-design options with respect to the requirement list from step 1, that means a description of alternative new process flows for the FF which have to be evaluated in step 4 (Sect. 3.3).

3.3 Step 4: Evaluation of Alternative Flow Families as Focus of the Contribution

3.3.1 Analysis of Interrelations and Identification of Goal Conflicts

On basis of the re-design options which result from step 3, the goal of the evaluation phase is to find the best alternative for the new process flow, which is best in line with company objectives. Aim of this substep is to identify goal conflicts between DfX-requirements (conducted in step 1), which necessitates an analysis of its interrelations. Thereby, it is investigated how a fulfillment of one requirement acts on the other requirements of the system. Four kinds of interrelations can be divided (Rommelfanger and Eickemeier 2002): neutrality (fulfillment of a requirement has no impact on fulfillment of another requirement), symmetrical complementarity (fulfillment of a requirement enhances degree of fulfillment of another requirement), asymmetrical complementarity (fulfillment of first requirement enhances degree of fulfillment of the second requirement, but this does not apply in the reverse direction) and competition (fulfillment of one requirement affects the fulfillment of another requirement, it exists a conflict of goals).

In the first step, interrelations should be analyzed individually by each team member. Then the project leader evaluates the results and invites the group to a meeting where results are discussed with the goal to find a consensus. For illustration of interrelations a correlation matrix can be used (Ponn and Lindemann 2011). Hereby, symmetrical relations should occupy only one half of the matrix to easily identify asymmetrical relations. After identification of interrelations the team-leader explains the ANP-approach and the software super decisions (see Sect. 2.2) to the team and models a network of criteria and interdependencies by using the software. This network is the basis for the following evaluation of alternatives by each team-member.

3.3.2 Evaluation of Alternatives by Using ANP

The project leader uploads the file of the network to the MS-SharePoint folder of the team. Now every team-member uploads the network, e.g. to software super decisions and executes the pairwise comparisons of criteria and alternatives.

3.3.3 Assessment of Results of ANP and Choice of the Most Excellent FF

The project leader assesses the results of the ANP. One main requirement of the general approach (Sect. 3.1) is to avoid subjective influences of single team member. Hereby, esp. variability in evaluations of each single team member is of interest. With respect to this requirement the classical ANP could be enhanced by using standard measures from statistics, e.g. coefficient of variability (CoV) which is a suitable measure to quantify variability (Hopp and Spearman 2000). The normalization allows comparison of variables with big and small averages. The CoV should be computed for the resulting weights (from ANP) for each single re-design criterion. After computing, values can be evaluated by variability classes of production (Hopp and Spearman 2000). In case of moderate and high variability values project leader should open debate in a kind of delphi-process which is “a method for structuring a group communication process” (Linstone and Turoff 1975): first with single team member where deviation occurred and afterwards within the whole group to understand the reasons for deviation. Maybe one team member considered critical aspects that were neglected by the others. As consequence there is the opportunity for individuals to revise views until a consensus is reached.

4 Application by Using a Case Study of Semiconductor Industry

4.1 Characterization of the Case Study

Characterization of the case study is done by using the quality criteria transferability, truth value and traceability for case study-based research from Pedrosa et al. (2012). For short, transferability includes theoretical aim, unit of analysis and justification of the case study as well as number of cases used; truth value contains a description of the data analysis process; traceability comprises a documentation of the research process and data sources.

The theoretical aim of the study is testing the described procedure (Sect. 3). Units of analysis are mature multi-product semiconductor fabrication facilities which produce several hundred products within one facility. This case is used because semiconductor production is regarded as one of the most complex production processes in existence today (Sturm 2007), whereas an easier transfer from complex to simpler cases is assumed. Furthermore, there is a high necessity of logistical improvement. Every product can require more than a thousand single process steps. Studies revealed that the value adding process time in semiconductor production is not more than 2 % (Töpfer 2008), whereas a high proportion of time is transport, handling and storage. Compliant to DfX means here esp. avoidance, reduction and mastering of handling, transport and storage times to reduce high lead times and proportion of non-value adding time by providing simultaneously high quality of products with minimal production costs and energy consumption.

As the length of the complete process flow exceeds in depth analysis at once, flow families are built (see step 1, Sect. 3.2). Regarding truth value: 101 POR’s of two technology nodes have been analyzed via cluster analysis to identify the most promising FF for analysis. Similarity observation shows that a FF with 31 process steps out of the copper metallization module, where transistors of integrated circuits (ICs) are connected, is suitable for two reasons: there are great similarities within process sections of POR’s both within one technology and trans-technology. Due to the cyclical pattern of the semiconductor manufacturing process with re-entrant material flows the FF even is repeated within one POR up to four times. Furthermore, the section is located downstream at the end of the whole manufacturing process where the product has already a high value and therefore should leave the factory as soon as possible. Thus, this study is based on one case of one semiconductor fabrication facility. Nevertheless, the used copper metallization-process section is used by most semiconductor manufacturers for many products in a similar way.

Regarding traceability the informant selection within the case study is based on following thoughts: we choose three process integrators from department of technology development which have a deep understanding about the whole FF. They can estimate the effects of changes of one single process step to the remainder. Furthermore, we had four process engineers (which are responsible for single processes within production) as representatives for the identified process types (see Sect. 4.3). Additionally we selected one employee of production logistics, one from accounting and one from IT which could assess the changes with respect to their core competencies. Moreover we were four representatives from the chair of business administration, esp. logistics. As data collection techniques we used interviews and company internal data based on manufacturing execution system.

4.2 Re-Design Criteria with Respect to Processes

Within the regarded company no design criteria catalogue for re-design of production processes was available as the approach has been applied for the first time. The criteria were derived from literature and adapted both—to special requirements of processes instead of products and to needs of semiconductor production. The criteria were discussed within team meetings with the mentioned representatives (see step 1, Sects. 3.2 and 4.1). Results are criteria for the three categories manufacturing process, sequence and system which are listed in Table 2. Hereby, in column "source" of Table 2, number 1 to 9 show in connection with Table 1, column "criteria" the origin of the new criteria for processes. As most DfX-researchers focus on products instead of processes, criteria for manufacturing systems with respect to process organization within operations and machines could not be identified from literature.

4.3 Re-design Alternatives

As mentioned in Sect. 4.1 a FF with 31 process steps is regarded. Following the thoughts of Sect. 3.2 analysis and carving out of re-design alternatives is task of step 2 and 3. In the initial situation the whole flow has the following structure: 8 main technological process steps (T), 8 cleaning steps (C), 11 measurement steps (M), 4 wafer logistics steps (L). Figure 1 gives an overview of all re-design options (alternatives 1-3) which are described in the following. Hereby, two technologies (TN 1 & TN 2) with their PORs are compared schematically.

Re-Design alternative 1 (A 1): Within A 1 three re-design options are possible, numbered with 1a-c in Fig. 1: in two instances (1a, b) two cleaning steps are in succession with the difference that in the first instance (1a) technology 1 does not

Table 2 Re-Design for X criteria for processes within case study

Cluster	Re-design for X-criteria (node)	Source	Symbol node	Influencing nodes
Manufacturing process	Standardization of unit processes within the flow family of one technology and technology-comprehensive, m.t. # unit process variation/unit process step of flow family	DFL (1)	$d_{2.1}$	$d_{2.4}$
	Technology comprehensive pooling of capacity, m.t. capacity/unit process step of flow family; whereas the total number of tools remains constant before and after re- engineering	DfM (2)	$d_{2.2}$	$d_{2.1}$,$d_{2.4}$,$d_{4.3}$
	Robustness of unit processes, m.t. cp and cpk values	DFQ, DfRe (3)	$d_{2.3}$	$d_{2.1}$,$d_{2.4}$, $d_{3.4}$,$d_{4.1}$, $d_{4.2}$,$d_{4.3}$
	Substitution possibility of unit processes	DFS (4)	$d_{2.4}$	
Manufacturing sequence	Shares of cleaning, measurement and wafer-logistic processes in contrast share of main technological unit processes, e.g. number of measurement steps/total number of steps	DFA (5)	$d_{3.1}$	$d_{2.4}$,$d_{3.4}$,$d_{3.5}$
	Order flexibility, m.t. number of order-flexible steps which can be supported via IT	DfL, DfSC (6)	$d_{3.2}$	$d_{2.2}$,$d_{3.3}$,$d_{3.4}$
	Parallelisation possibility, m.t. number of steps which can be executed in parallel during operation	DfL, DfSC (7)	$d_{3.3}$	$d_{2.2}$,$d_{3.2}$
	Integration possibility, m.t. number of steps which can be integrated	DfA (8)	$d_{3.4}$	$d_{2.4}$
	Care of wafer-logistic steps, m.t. number of steps in between since last wafer-logistic step	DFA (9)	$d_{3.5}$	$d_{3.2}$,$d_{3.4}$,$d_{4.3}$
Manufacturing system	Spatial flow of sequence, m.t. transportation time demand	Not yet in literature	$d_{4.1}$	$d_{2.2}$,$d_{3.1}$, $d_{3.2}$,$d_{3.3}$,$d_{3.4}$
	Flow supporting tools, m.t. number of batch tools		$d_{4.2}$	$d_{2.4}$
	Standardization of production equipment at unit process step, m.t. number of different tool types at one step		$d_{4.3}$	$d_{2.1}$,$d_{2.4}$, $d_{3.1}$,$d_{4.2}$

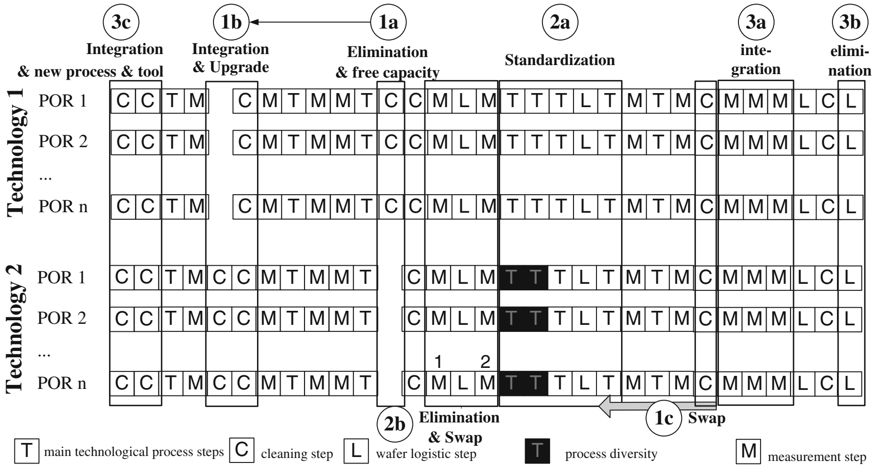

Fig. 1 Re-Design options

require the first cleaning step and in instance 1b the second technology. Analysis showed that with a new process concept the first cleaning step of technology 1 can be eliminated resulting in free available machine capacity. This allows a new process concept for the two cleaning steps of technology 2. They can be integrated as the former process can be done by the free machine type. The third instance (1c) analyzed with technology guys shows that the backside cleaning process causes splashes on wafer-frontside. With swapping this step in front of a technological main process (CMP) this can be polished while quality is improved. Result would be 29 steps (8 T, 6 C, 11 M, 4 L) with a cycle time reduction potential of 8 % compared to the initial situation.

Re-Design alternative 2 (A 2): In addition to measures 1a–c within A 2: the homogenization of two consecutive main technological process steps (2a) across TN 1&2 was investigated. Unit process (UP) diversity value would change from five different processes to three different processes at these two consecutive steps. Also a pooling of capacity (CA) would be possible. Before TN 1 had five tools and TN 2 three. Afterwards both TN's could use eight tools which reduces waiting time within operations. In instance 2b a re-design of the flow with swap of measurement steps would enable a significant reduced transport time as well as a better quality assurance because results of measurement step 2 are needed earlier in production flow. Moreover, the wafer-logistical step between the measurement steps could be eliminated, because informational tracking of material is sufficient. The result would be 28 steps (8 T, 6 C, 11 M, 3 L) with a cycle time reduction potential of 10 % compared to initial situation.

Re-Design alternative 3 (A 3): In addition to measures of A 1 and 2 within A 3: in case 3a three measurement steps are in succession. They could be integrated within POR to one step and be flexible within operating. Furthermore, belonging different tool-types of measurement steps should be concentrated in measurement isles. The advantages can be illustrated by following the example: a production lot must be processed at step 1 for measuring defect density. The belonging tool is not available. When steps are integrated and flexible within operating the non-value adding storage time for the lot can be reduced. When the tool for the next measurement step would be available and the lot switches the order of these two steps, utilization of tool capacity could be enhanced, feedback loops would be shorter and transport time portion would be reduced due to the fact that all measurement tools are in one area. In case 3b elimination of a wafer-logistic step is possible with a new IT-concept. In case 3c integration of two consecutive cleaning steps could be done, when a new machine generation which enables a new technological process would be purchased. Result would be 27 steps (8 T, 6 C, 11 M, 2 L) with a cycle time reduction potential of 13 % compared to initial situation.

4.4 Evaluation of Alternatives and Choice of the Most Excellent FF

Step 4 of the described approach (see Sect. 3.3) includes evaluation of alternatives. Before evaluation by using the ANP, the project group examined interrelations between re-design criteria with the result which is depicted in Table 2 (influencing nodes). Due to the shortness of this article this cannot be described in detail. Table 3

Table 3 Results of ANP with respect to re-design criteria

Node	Normalized by cluster	Limiting
A 1	0.12385	00.083036
A 2	0.41238	0.276481
A 3	0.46377	0.310932
$d_{2.1}$ standardization	0.11207	0.021731
$d_{2.2}$ technology comprehensive pooling of capacity	0.09894	0.019185
$d_{2.3}$ robustness	0.00000	0.000000
$d_{2.4}$ substitution possibility	0.78899	0.152990
$d_{3.1}$ number of cleaning, measurement and wafer-logistic steps	0.30116	0.024056
$d_{3.2}$ order flexibility	0.15770	0.012597
$d_{3.3}$ parallelisation possibility	0.07976	0.006371
$d_{3.4}$ integration possibility of steps	0.30908	0.024689
$d_{3.5}$ care of wafer-logistic steps	0.15231	0.012166
$d_{4.1}$ spatial flow of sequence	0.00000	0.000000
$d_{4.2}$ flow supporting tools	0.43137	0.024056
$d_{4.3}$ standardization of production equipment at single process step	0.56863	0.031711

shows the results of the ANP of the whole project group after the Delphi-process. In the previous phase where team leader evaluated results of each member (which executed ANP as described in Sect. 3.3.2 first by their own) variability (see Sect. 3.3.3) occurred esp. regarding re-design criteria of flexibility within operations (see case 3a, Sect. 4.3) with a value of 1.5 of an IT employee. On enquiry of the project leader, the employee responded that establishing order flexibility within MES-system would provoke extremely high IT-efforts. As a result the whole team carried out a further profitability and risk analysis as well as the ANP with the result that A 3 is with a weight of 0.46 the choice of the group with respect to DfX-redesign criteria. Furthermore, it can be seen that $d_{2.4}$, $d_{4.3}$ and $d_{4.2}$ are the re-design criteria with highest priorities.

5 Conclusion and Outlook

The result is an approach for "Re-Design for X" of production processes. Re-Design criteria from different scientific perspectives can be included and prioritized by combining classical DfX-approaches with methods of decision support systems like ANP. Hereby, esp. alternative analysis and choice phase of the decision making process are supported. The approach is verified by a case study of semiconductor industry. A research implication is that a major challenge is to find the right "master" criteria which reflect needs of various scientific disciplines for individual case studies as these criteria represent the fundamental input data for the new decision support system. Furthermore, overlap, contrariness or interdependence between existing criteria must be examined before the criteria are applied. Future work lies in the development of industry-specific or product and process type-specific catalogues of criteria which consider needs of various scientific disciplines.

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Design for Logistics in the Automotive Industry

The Example of the After-Sales Division

Ingrid Göpfert and Matthias D. Schulz

Abstract To meet the rising demand for excellent logistics service, companies leverage the influence of product design. In this paper, the current state of logistics' integration into the automotive industry's product development process is examined with special regard to the after-sales division. The operative result of such measures is illustrated via case example. The embodiment of core enablers and initial problems and challenges is examined to highlight key factors of both success and failure and assist interested companies in implementing the ideas described here.

Keywords Design for logistics · Product emergence process · Variance management · After-sales logistics · Integrated product development

1 Logistics Integrated Product Development

In a complex business environment, the significance of logistics as a compensating function in the supply chain rises (Göpfert and Schulz 2010, pp. 40–41). Increased customer expectations force companies to find new ways of improving the observable operative quality and efficiency in every step of the value-adding process and the respective logistics processes (Göpfert and Schulz 2013, pp. 509–511). It is of great interest to analyze how best-performing companies reach these targets despite such challenging conditions.

It is commonly assumed that at least 70 % of the costs and customer value are determined during product development (Ehrlenspiel et al. 2010, pp. 10–13; Nevins and Whitney 1989, pp. 2–3). This applies to logistics as well: the product's properties, including structure, variance, dimensions, and sensitivity of surfaces demand specific process characteristics that may conflict with the logisticians' idea of an "ideal" systems design (Göpfert and Schulz 2013). Vice versa, studies show

I. Göpfert · M.D. Schulz (✉)
Lehrstuhl für ABWL und Logistik, 35037 Marburg, Germany
e-mail: matthias.daniel.schulz@gmail.com

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that companies who align supply chain and product design can achieve better logistics service and reduce inefficiencies (Khan and Creazza 2009, p. 314). Thus, in many companies, logistics aspects are accounted for during product development (Göpfert and Schulz 2012a, pp. 21–22). The degree to which logisticians are able to influence physical products is therewith determined by the amount of their functional department's contribution to the overall success of the company or supply chain (Zacharia and Mentzer 2007).

In this matter, automotive OEMs are known to be companies strongly depending on high-class logistics. A modern car contains ca. 30,000 parts (MacDuffie and Fujimoto 2010, p. 23), many of which are provided by one of several hundreds of suppliers from different branches. The operative performance needed to reliably combine these parts into a sophisticated product that fulfills very high standards at acceptable costs requires very professional logistics systems. Since automotive manufacturers have often been pioneers in the fields of logistics and supply chain management (e.g. regarding lean production, occurrence of challenges, globalization, division of labor etc.), (Göpfert and Schulz 2011, p. 5), it is interesting to analyze the relationship between product development and logistics/supply chain management in the Product Emergence Process (PEP) of these companies. In this matter, the after-sales division seems to be the most likely organizational unit to excel at variance management, due to mainly three reasons:

- As a result of a voluntary self-commitment, German OEMs make the spare parts available for 15 years after the end-of-production of a vehicle. Assuming that product development takes 5 years and a car is produced for ca. 7 years, this means that decisions in the early stages of the innovation process affect the after-sales division even 20 years later.
- Some OEMs have to make available several hundreds of thousands of parts while competing with independent spare-parts suppliers that are able to focus their activities on A-parts with a high demand. Some manufacturers report that 6 % of their spare parts account for 90 % of the sales volume while there are up to 200,000 parts being sold less than six times a year depending on the OEM.
- The after-sales service contributes to a high degree to customer satisfaction. If the functionality or safety of a car is depending on the part subject to the defect, this part's unavailability can mean a customer will not be able to operate his vehicle for some time. Thus, an OEM's after-sales service is essential to maintaining customer loyalty.

Thus, representatives from five German OEMs (Audi, BMW, Daimler, Opel, and Volkswagen) were interviewed on their perspective on the integration of logistics into the development process of new products. To gain a complete view on the matter, the interview sample consisted of execute logisticians and managers from many different functional divisions (including spare parts logisticians from three OEMs) as well as members of contiguous departments (e.g. production, development, procurement). To extend the focus, managers from a small selection of suppliers and one engineering service provider were included in the sample as well. In total, ca. 25 respondents participated in this study. To the majority, the interviews were carried out at the respective firm, yet some were telephone-based, partly supported by previous or later contact via email. Questions and answers were recorded and transcribed when permitted, or noted during the interview.

2 The Product Emergence Process in the German Automotive Industry

The product emergence process in the German automotive industry can be divided into four main stages as shown in Fig. 1 (Göpfert and Schulz 2012b, pp. 242–250): At project launch, a reference model is chosen (often the preceding model), planned deviations are elaborated and important information about the project (e.g. timeline etc.) are given. This marks the start of ‘Target Definition’, a stage in which the future customers’ requirements are documented. During ‘Fuzzy Front End’, the product-specific development begins. In an iterative process, technical solutions to the previously stated customer requirements are identified and described (e.g. distinct components). In both stages, the product properties are written down in certain technical documents that become more and more detailed and mandatory. During ‘New Product Development’, the upcoming car and the related manufacturing processes are refined to meet the high standards of mass production (e.g. reliability, efficiency etc.). The ‘Ramp-Up’ is a phase where these processes are then tested with several trial series that more and more resemble the later production, for example with regard to batch size and the tools used. This is done to test the processes, school the workers and apply changes in certain details if necessary.

The logistics systems are designed concurrently (Göpfert and Schulz 2011, pp. 7–9). At start, the functional division’s requirements are gathered based on comparable products to avoid harmful decisions. For this, some OEMs have implemented a continuous process while others have defined an explicit subprocess

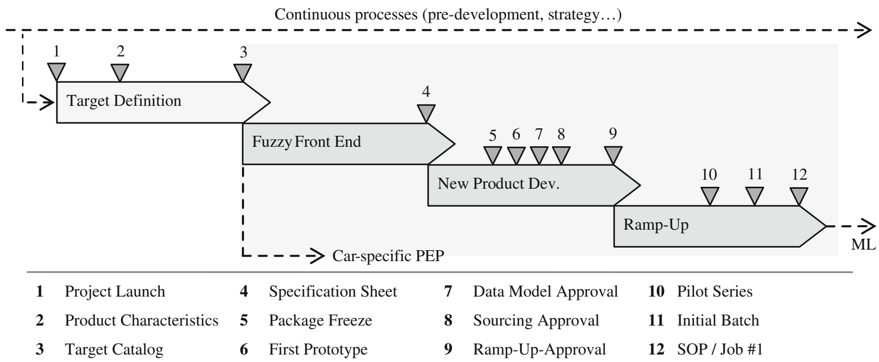

Fig. 1 The product emergence process in the German automotive industry. *Source* Göpfert and Schulz (2010, p. 43)

of ca. 10 months duration that is carried out during Target Definition (Göpfert and Schulz 2010, p. 45). Afterwards, a factory is selected. By matching the profile of the product and the plant (e.g. existence of a press shop, paint shop etc.), the amount of material that needs to be procured externally can be calculated. Based on the transport costs, suppliers can be chosen while the present factory structure allows estimates regarding the necessary investments.

Logisticians usually begin influencing product design to a larger degree after the first container simulations, which reveal many problems in the systems. These are carried out only after a sufficient amount of information is available. Later, the systems are fine-tuned. More and more suppliers are selected and the processes are tested just as described above. For example, Volkswagen is modeling the work stations with cardboard boxes to provide a more realistic impression of the later production situation and apply experimental changes in the layouts at little cost and with small effort.

3 Enabling Factors in the Automotive PEP

Khan and Creazza (2009, pp. 314–316) have identified four 'enablers' that allow companies to align supply chain and product design:

- Firstly the project teams should include members of all functional divisions. This is already realized in all teams responsible for the development of cars, regardless of the hierarchical level (Göpfert and Schulz 2010, pp. 41–42). Logisticians in particular are integrated in the PEP at German OEMs since approximately the year 2000 and are today accepted as full members, yet not major players compared to other departments that account for a larger budget (e.g. manufacturing) or are considered more crucial to customer perception (e.g. design), (Göpfert and Schulz 2011, pp. 5–6, 2013). Thus, logisticians usually use potential cost savings in their operative processes as an argument in negotiations (Göpfert and Schulz 2013).
- Secondly, the concurrent design teams should be geographically co-located or communicating on a daily basis. How this can be achieved is best illustrated with the example of BMW. The center for research and innovation ("Forschungs- und Innovationszentrum", FIZ) houses both development engineers as well as representatives from other concerned functional divisions. Communication among these employees is supported by the buildings' architecture.
- Thirdly, other members of the supply chain (e.g. suppliers) should be involved in the design process. At automotive OEMs, external partners are included in the Simultaneous-Engineering Teams (SETs) that are responsible for the execution of tasks related to distinct parts. Additional members can be added depending on the current assignment (Göpfert and Schulz 2010, p. 42). The most important of these are the suppliers: Firstly, since these companies account for at least 70 % of the supply chain's costs and performance (Göpfert and Schulz 2011, p. 5), an

Fig. 2 Clamping bushes for the repair of exhaust systems (courtesy of BMW product management parts)

optimization in the early stages of the value-adding process holds great potential for an improvement of the overall competitive situation. Secondly, suppliers' logisticians are most familiar with the externally procured parts and thus best suited to identify possibilities of improvement. Figure 2 shows clamping bushes designed to facilitate the repair of exhaust systems by connecting the spare part with the intact piece of pipe. A small selection of these bushes can be used for any of the related repair activities across vehicle brands, and due to its scalable character, new diameters can easily be approved without greater testing efforts. Noticeably decreasing variety in After-Sales, this design helped reduce logistics costs. Its development is based on a supplier's suggestion.

In general, suppliers are integrated in their customers' PEP from the beginning of Fuzzy Front End to ensure full adjustment. The manufacturers collaborate very closely with their partners' logisticians since these specialists usually have more detailed knowledge regarding the to-be-delivered assembly and the respective logistics structures at the source. However, this only applies to companies providing complex modules like control units, windscreen wipers or frontends. Simpler parts that are procured externally are often designed by the OEM themselves. After the vehicle's development is completed, the car's properties are fixed, which is called a "design freeze" (ca. 2 years before SOP). Subsequently, suppliers are nominated, and after a brief testing period, the design is finally approved and the respective sources are selected bindingly. This is carried out ca. 18 months before the start-of-production depending on the subsection (e.g. press shop, assembly). While the distinct design elements are still monitored and verified, this time in collaboration with the suppliers, it is unlikely that logisticians from those companies will influence product design—to some extent, this is because the transport costs are often calculated and covered by the OEM (contrary to just-in-sequence processes, which are the standard delivery form for very complex modules).

- Lastly, a 'product champion' should overlook the development process to guarantee the correspondence of product and supply chain structure. At automotive OEMs in Germany, this person is called the 'product manager' or 'project manager'. Leading the project team that coordinates the development, they themselves answer directly to the board of directors. In addition to a number of product-related decisions, they can approve minor cost deviations (Göpfert and Schulz 2012a). However, due to the increased use of platform concepts, many of the above mentioned decisions connected with the product-in-development may in fact be the responsibility of the manager overlooking the platform's costs and investments.

4 Current Problems and Possible Solutions

As shown above, the examined part of the automotive industry has greatly brought forward the integration of logistics into product development into product development. However, some challenges yet remain. Companies interested in implementing the above mentioned ideas should seek to avoid some of the initial problems that occurred at automotive OEMs and partly still exist today.

Firstly, since logistics accounts for a relatively small share of the overall costs, little resources have been made available towards influencing product development (Göpfert and Schulz 2011). Specifically, there are often very few people involved in the product emergence process so that sometimes a single person is in charge of a large number of new cars. In practice, contiguous departments often assist logisticians. For example, the department responsible for reparability and disassembly informs logisticians from the after-sales division of important decisions or current developments (Göpfert and Schulz 2013, pp. 515–516). A stronger focus on logistics performance—instead of the reduction of logistics costs—would justify assigning additional human resources and thereby reduce the risk of missing opportunities.

To improve upon the above mentioned issue of the insufficient integration of suppliers' logisticians—despite their above mentioned great potential—it is very important to create appropriate incentives for the supplier. If, for instance, the transports are the sole responsibility of the OEM, the suppliers might not benefit from measures of optimization and thus not be interested in identifying potentials of improvement (Göpfert and Schulz 2013, p. 513). Also, the respective possibilities should be a criterion when deciding which suppliers are nominated early in the PEP and which are nominated rather late. On the other hand, the OEMs' logisticians should focus more on coordination and super-ordinate aspects to reduce the risk of isolated optimizations instead of the improvement of singular parts.

Lastly, target conflicts often appear in product development. Logistics' interests do not necessarily need to be fully met. In many cases, other divisions' goals appear to be more important (Göpfert and Schulz 2011, pp. 5–6). However, decisions should always be made in awareness of the logistics consequences. To ensure a company-wide optimum, the cost systems should be designed to avoid wrong incentives. In sourcing of parts, certain OEMs in Germany differentiate between the component's price and logistics costs (e.g. transport, customs duty) to indentify potentials of optimization. While the sourcing decision is still based on the landed costs (e.g. the sum of both components), the costs of the product itself are paid by the procurement division while the logistics department covers the transportation costs. If two suppliers' offers are equal, the procurers might try to influence negotiations so that the supplier is chosen that weights their budget less (Göpfert and Schulz 2013, p. 513). Other companies, for example Suzuki, do not make this differentiation.

5 Conclusions

The integration of logistics into product development can help improve the logistics costs and performance situation. How this can be achieved has been shown from different perspectives and illustrated using current examples from the after-sales divisions of German OEMs. Initial problems and possible solutions have been highlighted to allow companies that seek to implement the above mentioned ideas to avoid said difficulties.

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Using Educational Games to Explore Supply Chain Infrastructure Development Options in India

Helen Rogers, Jannicke Baalsrud Hauge and Martin Hofstetter

Abstract India is currently experiencing a brisk rate of economic development, with sustained GDP growth rates and a corresponding increase in freight volume forecasts for the foreseeable future. For these growth rates to be realised, an extensive and efficient infrastructure network is a pre-requisite. Hence, building a world class logistics infrastructure is a key requirement to global competitiveness. Despite the compelling evidence, a number of challenges and obstacles remain before significant improvements can be achieved. The use of serious games is a way to raise the awareness and understanding of a scenario such as this at both a business school and executive training level. For example, through simulations in a gaming environment, one can investigate how specific technologies can be used as support and/or how different infrastructure development strategies impact on its environment. Through gaming, participants can experience the boundaries and challenges facing supply chain stakeholders in India, as well as seek to tackle and overcome some of these issues. Hence, this paper discusses the design and development of a serious game based on supply chain infrastructure development in India.

1 Introduction

This paper first outlines the current situation of India's transport infrastructure focusing on the main modes of roads, railways, seaports and airports. It then offers possible solutions on how to strategically develop the existing assets to support

H. Rogers · M. Hofstetter
FAU Erlangen-Nürnberg, Lange Gasse 20, 90403 Nuremberg, Germany
e-mail: helen.rogers@wiso.uni-erlangen.de

J.B. Hauge (✉)
Department C-Business in Enterprise Networks, BIBA, Applied Information and Communication Technology for Production, Bremen, Germany
e-mail: baa@biba.uni-bremen.de

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economic growth, before looking at strategies open to the Indian government in order to improve the infrastructure. This review concludes that a failure to significantly improve India's infrastructure network would considerably slow down the country's growth trajectory. This in turn provides an input to the learning goals for a serious game based on this situation. The second part of the paper then discusses how to design and develop a game to address this issue. This part is based on state of the art development methodologies for simulation-based serious games. The learning concept we use is based on the theory of constructivism and a blended learning concept. The paper concludes by outlining the game design, learning goals and a suggested syllabus.

1.1 India Infrastructure and Economy

As evidenced by Fig. 1 India relies excessively on its road network, which represents 64 % of traffic by volume. Furthermore, Fig. 2 shows that the national highways only account for about 2 % of the total road network. The biggest share is rural roads, which are in poor condition and mostly unpaved. Table 1 indicates that capacity issues also exist in seaports where usage is already approaching maximum capacity.

Fig. 1 Traffic volume by mode of transport

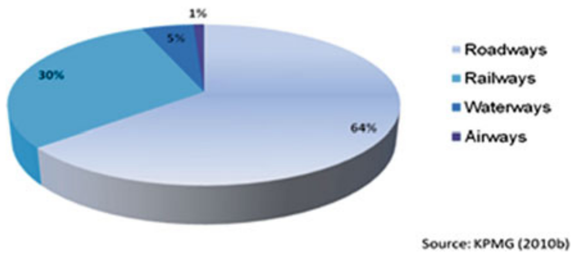

Fig. 2 The Indian road network

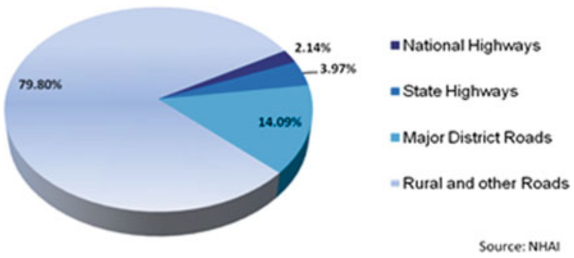

Table 1 Indian port utilisation (adapted Evalueserve 2010)

Year	Traffic handled (in million tons)	Capacity (in million tons)	Percent Utilization (%)
2005–06	423	456	92.76
2006–07	464	505	91.88
2007–08	519	532	97.56
2008–09	530	575	92.17
2009–10	561	617	90.92

1.2 Critical Factors in the Indian Transport Infrastructure

The main components of a country's transport infrastructure are the road network, railways, seaports and airports. Infrastructure is the backbone through which an economy achieves growth. Although the urgency to develop India's logistics infrastructure has been recognized by its government, achievements in creating quality and capacity have to date been disappointing. India's logistics infrastructure remains insufficient, and ill-equipped to support the expected growth rates in GDP over the next decade. The predicted 2.5-fold growth in freight traffic will further raise the stakes (McKinsey 2010). Furthermore, the Indian transport network will have to cater to the country's expanding population, which exceeded 1.2 billion in the 2011 Census (Government of India Planning Commission 2011). Capacity expansion and associated improvements such as better maintenance and new technologies are clearly needed. In order to achieve international standards, a structural shift towards increased rail transport and standardization is necessary.

The current logistics expenses of India equate to 13 % of the country's GDP. This high figure (by world standards) also bears witness to deficiencies within the system. Inefficiencies are a result of poor core infrastructure, diverse geographic conditions, sub-optimal port handling facilities, an outdated rail network, congestion of freight and passenger corridors, as well as missing last mile links. All of these factors lead to high transportation, storage and service costs (KPMG 2010). India has the opportunity to address these issues, as more than two-thirds of the future infrastructure network capacity has yet to be built (McKinsey 2010). To improve the situation, structural changes in the transport system are urgently needed. In particular, it will be beneficial to focus on freight transport through rail, which exceeds road transport in some aspects. India has still a rather low vehicle density (2.5 vehicles per km^2) as compared to other developing countries such as Brazil (4.06) and to other developed economies (46.5 in the US, 101.4 in the UK). However, the majority of these vehicles circulate in a few high-density corridors. Therefore, approximately 25 % of state and national highways are heavily congested, with corresponding high accident rates. This situation will further intensify, as the number of vehicles on Indian roads continues to grow. Consequently, the current average truck speed is a slow 30–40 km/h (developed countries experience approximately double this level). This means that it can take a truck 4–5 days to travel the distance of 1,500 km from Delhi to Kolkata. A quarter of this time is devoted to the truck being held up at state border check points (Business Monitor 2011). India is not only facing road infrastructure challenges, but also with the railways. This has to a large degree remained the same since colonial times, and is thus ill equipped to play a larger role for freight transport in the future.

Last-mile links are stretches of up to 100 km which connect key production, consumption and transit locations such as mines, ports and industry clusters to the corridors and connectors. Ports and railways will be the main beneficiaries of quality last mile roads. Up to now, ports and railways suffered most from missing hinterland connectivity and barriers to intermodal transport. Furthermore, under-use of ITS and other ICT applications has contributed to low transport efficiency.

1.3 Educational Games

So far we have outlined the challenges India faces regarding the development of its transport infrastructure and discussed the negative impact this may have on the sustainability of the Indian economy. It is clear that India does not have the capacity to develop all infrastructure aspects at the same time, so consequently, key infrastructure projects have been selected. The challenge is to be able to understand the impact that this selection will have on the environment and how various solutions will influence the economic, societal and environmental sustainability (and in which way). India's carbon footprint will, for example, be influenced by the overall infrastructure capacity. It is important to note that it is not only road, railways, and ports that have to be considered. By implementing different technologies as part of the infrastructure improvement program can lead to better monitoring and control of traffic and thus reduce congestion, the number of accidents, to name but a few. All these factors affect the efficiency and sustainability of the Indian infrastructure. Consequently, this becomes a very complex system, making it difficult to predict in advance the impact of the decisions. Simulation can help here, but any such simulation model needs to contain all the dependent variables. This will in turn make it difficult for an individual to decide.

Experiential learning theory allows students to construct their knowledge based on what they experience—often in a safe environment with reduced complexity—and has long been the inspiration for building computer-based learning environments (Lainema 2003). Serious Games are a tool that can be used for increasing the awareness of specific problems or solutions, in which the complexity can be reduced, i.e. often being less detailed and specific than several simulations. They are all about 'leveraging the power of computer games to captivate and engage end-users for a specific purpose, such as to develop new knowledge and skills'. Zyda (2005) argues that Serious Games are more than just 'story, art, and software'. It is the addition of pedagogy (activities that educate or instruct, thereby imparting knowledge or skill) that makes games 'serious'. Serious Games have been used to mediate skills on complex systems for several decades in military education (Hays and Singer 1989) and since the 1950's there has been an increased use of games also for civil purposes (Wolfe and Crookal 1998). The term Serious Games refers to games that are primarily designed for non-entertainment purposes, such as: education, training, simulation, health-care and advertising. According to Corti (2006, p. 1) Serious Games are mostly used for teaching purposes. Educational Games and simulations are experiential exercises (whereby experiential learning relates specifically to adult learning) and some results on learning outcomes are available (Cheetham and Chivers 2001).

In the area of logistics and transport, Serious Games have been developed for mediating skills on problems such as the Bullwhip Effect (Bunse and Ziegenbein 2007) and for providing insights and additional understanding across the supply chain (Hauge et al. 2012). Games can be very similar to pure simulations, thus educational simulations that can be enhanced with gaming features. In particular they enable learners to cope with real problems and authentic situations that are close to reality (Bellotti et al. 2012; Narayanasam et al. 2006; Kriz 2001). Thus we expect that a Serious Game should help to increase awareness of the critical situation and also to simulate how various alternatives will have a different impact on the abovementioned critical factors. Although the shortcomings of the Indian transport infrastructure have been well documented, there appears to be little, if any, evidence of simulations of the transport infrastructure and/or simulation games that are transferable to the Indian situation. Thus, the next section will describe an approach for designing a Serious Game based course covering topics that are relevant to the Indian supply chain infrastructure situation.

2 Research Approach

Based on the Indian infrastructure challenges described above, the first step in developing a new teaching syllabus that includes a Serious Game is to identify the requirements of students and professionals on a game for awareness raising. In a second step, the syllabus needs to be developed. Based on this, the game requirements are derived and the game development process starts. We have used an agile development process in order to develop a mock-up and a first prototype.

2.1 User Needs, Requirements and Syllabus

There are several surveys stating the need for vocational and educational training within the field of transport and logistics, both within transportation, as well as on broader topics (e.g. business aspects, supply chain management, use of RFID technologies, etc.). However, most of these do not focus on the needs of emerging economies such as India. We were not able to identify any courses, with or without simulations and simulation based games that cover the specific infrastructure need of India. In the current case it is important that the users experience the impact of various standards of roads, modes of roads, use of ICT along the SC infrastructure. This should be in terms of efficiency, emissions, safety and security issues so that the user can compare different solutions, both for long distance transport, as well as for the last mile. Based upon this, it is clear that it is necessary to develop a tool, with which all transport processes can be modeled in detail. Secondly, it is also necessary to combine the simulation of the transport possibilities with the calculation of emissions, efficiencies, accident rates and thirdly, it is necessary to be able to select different ICT solutions.

2.2 Learning Objectives and Target Groups

The main objective of a teaching course running a simulation-based game is to visualize both advantages and challenges connected to improvement of the Indian infrastructure for all transport modes. It should also demonstrate the impact that the use of advanced Information and Communications Technology (ICT) may have on sustainability, from an economic, environmental and societal perspective. Such a course seeks to increase the awareness of the possibilities and limitations that different options might have. The specific learning objectives of a course based featuring Serious Game in this context is to:

1. Increase awareness of how different infrastructure projects will impact Indian society and in turn the competitiveness and efficiency of Indian industry.
2. Provide an overview of applicable ITS services, as well as other advanced ICT solutions and under which circumstances their implementation will be useful.
3. Understand how the underlying technologies of ITS systems work.
4. Understand how improvement of infrastructure can contribute to increases in societal, economic and environmental sustainability by reducing costs, emissions and the number of accidents and also increase the efficiency making the Indian supply chain infrastructure more competitive.
5. Be able to estimate the impact that different infrastructure actions has on greenhouse gases, safety, efficiency, etc. using methods such as carbon footprinting.

The target groups are students and young professionals. They often have limited SCM experience and on how different infrastructure impact both efficiency and environment, thus a blended learning concept has been inserted so that needed theoretical topics can be mediated prior to gaming. The concept integrates various elements such as a lecture, a Serious Game and a workshop.

2.3 Instructional Plan

The seminar is planned to last around 30 h. Even though it is not expected that the students have specific knowledge of Indian supply chains, it is pre-requisite to have basic knowledge of general supply chain management and also on ICT. On the first day lectures are about supply chain management in India, and also provide all information on the supply chain infrastructure in India, intermodal transport, cross-docking concept, ITS, etc. This establishes the theoretical basis. The last part of this session is a tutorial to become familiar with the gaming environment. During the hands-on session, the students become familiar with the graphical user interfaces, as well as with the tasks and challenges they face during the gaming session. In the next session, after a short recap, the participants play the first level of the game. This game is scenario-based, starting with a basic task description and with a given goal, being consistent with the learning objectives of the course. The first games scenario lasts around 3 h, followed by a group reflection phase and group discussion. This part combines cognitive and constructive learning paradigms, since it comprises both elements of PBL and experiential learning. A high level of involvement of the participants is important, as this is the '*sina qua non*' (necessary precondition) for learning to take place. The learning outcome for a passive participant will tend towards zero. Directly after completing the game the participants meet for debriefing and reflection. They reflect on what they experienced, what went wrong, where challenges occurred etc., as well as the preparation of the task carried out for the presentation to the other participants. Typically within the debriefing phase, problems are identified and initiated events, discussed, with a focus on any unexpected impacts (e.g. on sustainability) as well as how well they met the challenge. Problem solutions are developed together, in order to improve awareness of how infrastructure selection has differing impacts according to the sustainability criteria.

As the game evolves, the players experience more complex scenarios including being challenged in terms of deciding which of the sustainability criteria should get the highest priority, since they cannot all be met. This prioritisation is context based and will therefore change depending on the given scenario. In order to internalise the knowledge acquired during the class, the students meet 1 week afterwards to explain the tasks and analysis they needed to carry out during the gaming sessions. The intention of this is firstly that the level of knowledge increases if you need to explain methods and tasks to others and secondly, not every participant has faced the same challenges and made the same choices. In this way students learn from eachother. Finally, the last step for the participants is to prepare a report in which they reflect on the problems experienced and to assess strategies they developed at the start in order to avoid them next time.

As outlined above, the reflection phase is very important for the success of an experiential learning process. During a simulation game, participants glean information from a range of parameters such as emotions, strategies, data, graphs and discussions. These experiences are then recollected and reconstituted through a process known as debriefing. The literature distinguishes between military, psychological and educational debriefing (Ledermann 1992). The first is the most ancient appearance of debriefing and takes place after military operations or related games. The second is rooted in experimental psychology and deals with informing the subjects about the real aims of the experiment after they had been deceived. For obvious ethical considerations, post-experimental debriefing should bring back the participants to their original pre-experimental emotional state (Stewart 1992). The last considers the process of debriefing for educational purposes. An example of this is the debriefing sessions after playing a simulation game in order to maximise learning.

2.4 Game Concept

Based on the given syllabus, the game concept necessitates a facilitated multi-player game in which teams can compete. Players compete in a team to form different supply chains, and different teams will compete against each other. The game players are provided with the necessary information on sustainability factors such as costs, efficiency, emissions (for each transport mode, but not for each engine or rail type), number of accidents (statics values), time, congestions, traffic jams etc. Based on this information and by comparing these with the goal stated in his task description, they can select how they would like to configure the future infrastructure, including the use of ICT. This new game is based on previous games we have developed. The main contribution comes from a game that features a generic simulation model to map the different scenarios into the game. It is based on the disjunction of time and space and has been developed at the University of Bremen and implemented in a network based multiplayer game called SECONDS. The main objects of the model are the entities 'process' and 'resource', where the process simulates time and the resource represents an entity in space. Both objects are linked to eachother; the process manipulates resources, which in turn are used for other processes, as demonstrated in Fig. 3.

The process in this case basically transforms resources from one to another. For example, a production process takes money, energy, etc. and turns it into a product. Unlike models that are based on a bill of material, this model supports multiple outputs. That means a process can produce more than one product, which is especially helpful when hard and soft goods are simulated. For example, a production process can have the product as one output and an increase in knowledge or experience as another. Processes can be deterministic or stochastic, depending on the educational requirements. In most cases, deterministic algorithms are preferred because educational simulations often need to be repeatable. A learner should be

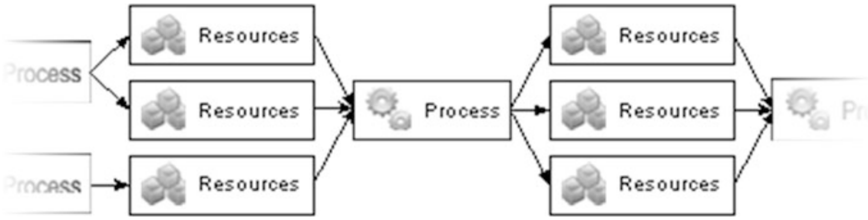

Fig. 3 Example of a process chain

able to try out different approaches in the same setting, thus he/she should be able to depend on repeatable outcomes. Stochastic processes on the other hand are helpful (for examples) in the teaching of risk management.

2.5 Fuzzy Values

To simulate real-world problems such as unknown quantities or unknown locations of a specific entity, the model features a concept called ‘Fuzzy Values’. In most simulation games the player is always informed about the state of the handled products. For example, in the game Transport Tycoon, the player always sees where his transportation vehicles are, what they deliver and when they will arrive. This is different in reality. Without advanced communication technologies, it is difficult to obtain such detailed information. In the game, this information is divided into real and expected values. For example, a truck can hold a specific amount of a certain product. The amount is a numeric value. The game stores the value twice; the real value and the expected value. When the truck is loaded, both values should be the same. When the truck starts the transport process, the real value can decrease, for example to simulate loss during transportation. The expected value will stay the same as the initial value, because the loss is unnoticed by the player. When the truck arrives at the destination, the real and the expected value is different. The player expects to get a specific amount of goods, but he instead gets a slightly smaller amount. Without doing any checks, the difference will not be noticed by the player. He can continue the supply chain with the expected values if he wants to.

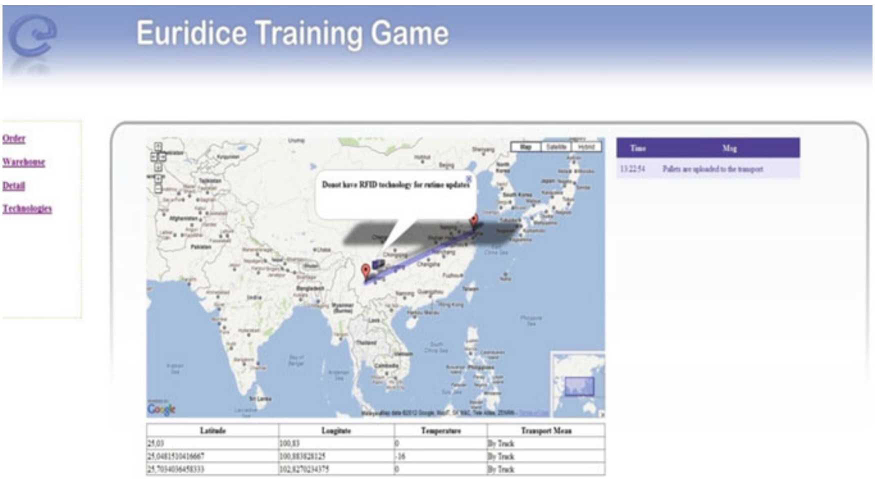

Fig. 4 Example of user interface

At the end of the supply chain the real values are taken into account and when they differ too much from the expected value, the player has to pay extra fees.

The game is web-based and has the following requirements on the server side: MS SQL Server, IIS 6.0 or higher; ASP.NET 3.5. There are no special requirements on the client side. The game uses standard HTML without Flash or other plug-ins. The player can choose between different roles and different levels of difficulty, and the facilitator can configure the game by using an authoring tool. Figure 4 shows an example of a user interface.

3 Results

The game is still under construction, but an initial 'mock-up' in which we have modeled a simplified version of India's supply chain infrastructure has been developed. A main concern here is the level of detail. At the current stage it is possible to model all modes, as well as to model different types of roads. However the level of detail for harbor modeling is not yet satisfactory. In addition, an important issue is to calculate the carbon footprint, as well as to look at the fulfillment of different sustainability criteria. In a first mock-up we have added indicators on energy consumption, emissions and number of accidents. In 'Seconds' itself it is not possible to calculate emissions and carbon footprint for the distance travelled in the games, so to see how this will work and which additional learning impact this may have, we exported the data from the gaming environment to a tool suitable for this calculation. We actually intended to import these back in order to have a single entry, but this was not possible at the current stage of development, due to restrictions in the gaming environment. However, even with these limitations we tried the set-up (including introduction and 2 gaming rounds) with a group of 6 students. They reported that the gaming scenario improved their understanding of India's challenges, as well as gave them insights into how they would select infrastructure projects. However, since no real tests have been running it is too soon to evaluate the learning outcome. We should also mention, that a better solution for exporting and importing the data for the carbon footprint calculation has to be found, as here this was carried out by the facilitator. This meant that it was not possible to provide instant feedback. A developed and 'joined up' infrastructure is one of the major requirements for inclusive and sustainable growth, as well as being a key factor towards improving global competitiveness. This paper indicates—through the use of Serious Games—how awareness and understanding of logistics infrastructure issues can be raised in an educational context. Players can increase their understanding of the situation through 'learning by doing' by developing and implementing different infrastructure development strategies in a safe 'non-business critical' environment.

4 Conclusions

This paper demonstrates how a serious game can be designed and implemented to support awareness-raising for infrastructure development, in this case using India as an illustrative example. It also indicates how the participants can experience the impact, the limitations but also the opportunities with the Indian transportation network from a supply chain perspective. Previous work has shown that the use of experiential learning methods with high user involvement have a positive effect on understanding the impact of specific decisions in supply chains and also for awareness-raising, so it is expected that these results can be transferred to this scenario. Even though the game concept as such can be applied in a variety of contexts, the first prototype comprises a reduced version of possible infrastructure development strategies in India and will only be applicable for certain (simplified) types of supply chains. The concept is sufficiently general, so that new gaming scenarios adapted to different supply chains can in turn be developed to add to the learning implications.

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Interdisciplinary Perspective on Knowledge Management in Logistics

Hongyan Zhang, Nagham El-Berishy, David Zastrau, Safdar Nawaz Khan Marwat, Yi Tan, Javier Palafox-Albarrán and Ingrid Rügge

Abstract Logistics services are increasingly complex and knowledge intensive in today's dynamic competitive environment. Knowledge assets have become critical for logistics enterprises to attain performance goals. Thus, it is crucial to implement the knowledge management (KM) for developing sustainable competitive advantages. KM research and implementation have grown rapidly in recent years. So far, various disciplines have studied KM from their own perspectives. However, there is only limited systematic effort to study the interfaces and the collaboration of KM from an interdisciplinary perspective. The goal of this paper is to identify the interface of KM in logistics from the perspectives of these disciplines: business studies and economics, production engineering, computer and information technology. For each discipline, the difference of the concepts as well as three key aspects of KM namely knowledge representation, acquisition and application will be described by means of literature review. Furthermore, this paper introduces a four stage model, which applies the collaborative KM in logistics and presents the connection from an interdisciplinary perspective. The connection shows that

H. Zhang (✉) · N. El-Berishy · D. Zastrau · S.N.K. Marwat · Y. Tan · J. Palafox-Albarrán · I. Rügge
International Graduate School for Dynamics in Logistics (IGS), University of Bremen, 28359 Bremen, Germany
e-mail: zhang@isl.org

N. El-Berishy
e-mail: elb@biba.uni-bremen.de

D. Zastrau
e-mail: davidz@tzi.de

S.N.K. Marwat
e-mail: safdar@comnets.uni-bremen.de

Y. Tan
e-mail: tan@biba.uni-bremen.de

J. Palafox-Albarrán
e-mail: jpalafox@imsas.uni-bremen.de

I. Rügge
e-mail: rue@biba.uni-bremen.de

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different disciplines can cooperate together in KM process, from objective setting, planning and execution to feedback phase. This paper will stimulate more discussions of KM from multidisciplinary viewpoints and implicates the importance of collaboration in KM practice. The model gives a guideline to logistic enterprises to apply their KM, for different functions, departments, and business processes, as a collaborative project with perspectives of different disciplines.

1 Introduction

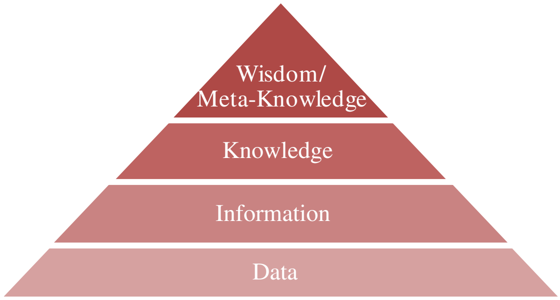
Since the 1990s, logistics have been playing an important role to succeed in the dynamic competitive environment. Most enterprises recognize the importance of knowledge based resources for attaining enterprise performance goals and their sustainable competitive advantages (Haasis 2008; Lee and Hong 2002). Knowledge flow is a crucial value chain in logistics, from suppliers to customers. Logistics processes and systems need to cope with the increasing diversity of logistics problems in supply chain networks (Neumann and Tomé 2006). Therefore, the implementation of knowledge management (KM) techniques and systems within logistics service providers are essential to hold the potential of developing sustainable advantages (Haasis 2008). Within an organization, KM describes everything from the application of new technology to the harnessing of intellectual capital (Sallis 2002).

The theoretical foundation of KM has already emerged from a wide variety of disciplines such as organizational theory, business management, artificial intelligence, social science, engineer science, etc. (Haasis and Kriwald 2001; Shang et al. 2009). The objective of this paper is to discuss KM in logistics from different disciplinary perspectives and to identify possible links between them. It is organized as follows: Sect. 2 introduces the main topics of knowledge and KM, Sect. 3 discusses knowledge and KM in four disciplines, and Sect. 4 presents collaborative KM in logistics between different fields. Finally, Sect. 5 summarizes the findings and outlook.

2 Knowledge and Knowledge Management in Logistics

Ackoff (1989) introduces the data-information-knowledge-wisdom hierarchy (DIKW), referred to the 'knowledge pyramid' shown in Fig. 1. It is one of the fundamental and widely recognized models in the KM literature. He offers the following definitions of data, information, knowledge and wisdom, and their associated transformation processes (Rowley 2007, p. 166):

Fig. 1 Knowledge pyramid; adapted from Rowley (2007)



- 'Data are defined as symbols that represent properties of objects, events and their environment. They are the products of observation. But are of no use until they are in a useable (i.e. relevant) form.'
- 'Information is contained in descriptions, answers to questions that begin with such words as who, what, when and how many. Information systems generate, store, retrieve and process data. Information is inferred from data.'
- 'Knowledge is know-how, and is what makes possible the transformation of information into instructions. It can be obtained either by transmission from another who has it, by instruction, or by extracting it from experience.'
- 'Wisdom is the ability to increase effectiveness. Wisdom adds value, which requires the mental function that we call judgment. The ethical and aesthetic values that this implies are inherent to the actor and are unique and personal.'

In the information science literatures, the wisdom tier is also called meta-knowledge tier, which means the knowledge of knowledge (Bolloju et al. 2002; Hendriks 1999).

Logistics originally meant the 'physical network for transportation and distribution' (Sutton 2008, p. 2) but it has now come to include the 'integrated management of supply and distribution chains'. Logistics is 'the procedure to optimize all activities to ensure the delivery of products through a transport chain from one end to the other' (Sutton 2008, p. 2). With the fast development of information technology and the global market, collaboration between different functional units in a supply chain becomes one of the most successful factors for the global rapid changes of customer needs. Effective collaborations need support of knowledge sharing and transfer. Collaboration therefore increases the efficiency of the whole supply chain (Scholz-Reiter and El-Berishy 2012).

In logistics organizations, knowledge is embedded in documents, publications, organizational procedures, techniques, industrial base and commercial practices. It is acquired from internal or external individuals, groups, or organizational routines either through structured transfer channels or through person-to-person contacts. Knowledge is acquired through three main ways: communication by talking to somebody, transaction buying a document, transferring of a certain form of property rights, such as patents or copyrights, and cooperation: working together on a project. These processes can be classified into two ways: personalization strategy or people-to-documents strategy and codification strategy which is person-to-person strategy (Ng et al. 2012).

In essence, KM in logistics organizations is designed to support specific strategic, operational or tactical decision-making processes, inter-organizational communications, cooperations, and interactions. The main contributions of managing knowledge in logistics is to improve decision-making processes, quality and responsiveness, efficiency and effectiveness of logistic support, and cost saving and profit maximization (Cheng et al. 2008). Moreover, by applying KM in logistics, organizations transform into knowledge-based organizations (Neumann and Tomé 2005). Commonly, KM application areas in supply chains are outsourcing, decision support, new product development, and risk management (Marra et al. 2012).

3 Interdisciplinary Perspectives

The representation of data, information, knowledge and wisdom/meta-knowledge as well as the transfer process from data to knowledge is different, depending upon different disciplinary perspectives. In this section, we will present KM in logistics from four different disciplines. Our discussion will focus on representation, acquisition, and application of knowledge.

3.1 KM in Economics and Business Studies

From the perspective of economics and business studies, knowledge has the use value and value, which can produce economic benefit. Knowledge is the strategic resource and intellectual capital of an organization. Knowledge is the mix of data, information, experience, context, knowledge in value creation process of organizational activities. In logistics management, various forms of knowledge exist in strategy, management, and operation processes. For example, data includes customer database, information includes specifications of the products customer required, knowledge includes decision making on business development strategy, and project management from tender, plan to operation. More specific, knowledge includes logicians' experience, ideas, insights, methods and know-how in business processes. There are different ways to classify knowledge as shown in Table 1.

Knowledge is a key strategic resource in logistics and supply chains. Today's logistics processes and systems have become increasingly complex and required global networking to cope with the growing diversity of logistics problems (Neumann and Tomé 2006).

Logistics services require particular knowledge, e.g. distribution, warehousing management, logistics center planning and operations. KM aims at providing the right knowledge of the right quality and with the right costs at the right place and

Table 1 Knowledge classification; extended from Boppert (2008), Maier and Remus (2002)

Basis	Knowledge classification
Form	Explicit, tacit (implicit)
Source	Internal, external
Unit	Individual, group, organizational, inter-organizational
Type	Know-what, know-how, know-who, know-why, know-where, know-when
Domain	Market, customer, partner, product, norms, standards, rules, organization, methods
Level	Data, information, knowledge, meta-knowledge, wisdom
Process	Knowledge about the process, knowledge within the process, knowledge derived from the process
Competency	Core knowledge, advanced knowledge, innovative knowledge
Life cycle	Existing/New knowledge
Organization	Strategic/Operational knowledge, public/confidential knowledge

time (Neumann and Tomé 2005; Rajesh et al. 2011). Core KM activities are: acquisition, production, warehousing, representation, distribution, and application.

Knowledge representation is critical for KM, as it influences the access of knowledge acquisition, the way of knowledge warehousing, the effect of knowledge distribution, and the convenience of knowledge application. Examples of knowledge representation are the intellectual capital statement, Balance Scorecard (Haasis 2004), decision tree, operation manual, knowledge mapping and knowledge bank. Knowledge is usually represented in different repositories: traditional or multimedia documents, database, intranet and internet.

The way of knowledge acquisition depends on the nature of knowledge. For explicit knowledge, it is possible to obtain it from documents (e.g. operation manual for order processing), checklist, knowledge map, Wiki, FAQ, experts directory. While for the tacit knowledge, more communication and learning activities are required, e.g. customer transmission integration, after action review, discussion forum, coaching, idea card, etc.

Knowledge can be applied for various aspects in different ways. In logistics practice, knowledge application contributes to business process improvement and logistics performance, such as daily work of transport, project management of contract logistics; value added service and consulting, customer service, e.g. customer claim. The application can be realized through training, coaching, best practice, case study, instruction, information portal, methods framework, etc.

3.2 KM in Production Engineering

In this section, we introduce a new trend in production scheduling, which uses KM of computers to enhance the efficiency of scheduling methods. This KM acquires knowledge from computers and scheduling methods. The acquired knowledge will

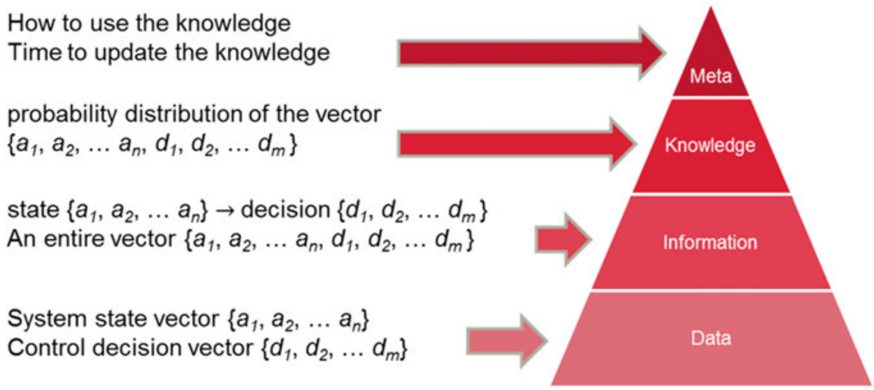


Fig. 2 Knowledge representation in production scheduling

be used to support the computers and scheduling methods in making further decisions. During this process, it is not necessary to require any human actions. Witten and Frank (2008) call this KM by computers as machine learning.

Knowledge is represented in the way demonstrated in Fig. 2. Data are represented by two vectors consisting of parameters. The system state vector describes states of a production system with parameters $\{a_1, \ldots a_n\}$. A parameter a_i of this vector is e.g. the utility of the production machines or the progress of the customer orders, whose values could be e.g. from 0 to 100 %. The control decision vector $\{d_1, \ldots, d_m\}$ supplies all possible decisions to be made. An example for d_i is the priority dispatching rules. A priority dispatching rule evaluates the customer orders waiting in the queue of a resource and gives these orders priorities. The order with highest priority will have the resource. The value of d_i is e.g. the priority rule FIFO (First In First Out) or the rule EDD (Earliest Due Date).

The *data* are not connected, while the *information* represents the connected *data*. A KM process analyses the scheduling problems in the past and their schedules calculated by time-consuming scheduling methods. Then, it connects the system states $\{a_1, \ldots a_n\}$ extracted from the problem with the decision $\{d_1, \ldots d_n\}$ extracted from the schedule to the information state $\{a_1, \ldots a_n\} \rightarrow$ decision $\{d_1 \ldots d_n\}$. It means that the decision was made by the scheduling method state in the past.

Afterwards, machine learning methods, such as Naïve Bayes classifier and Neural Network (Witten and Frank 2008), are applied to acquire knowledge from the information. The knowledge represents the probability distribution of each connection of system states and decisions. The following example makes it easier to understand the representation of the knowledge. For a value {0.9, …, 0.2} of the system state vector, using the priority rule EDD as the value of the decision vector $\{d_1\}$ is with the probability of 60 % appropriate, using the rule FIFO is with the probability of 40 % appropriate.

$$\{0.9, \ldots, 0.2\} \rightarrow \text{EDD} \quad 60\,\%$$
$$\{0.9, \ldots, 0.2\} \rightarrow \text{FIFO} \quad 40\,\%$$

There is a significant difference between the *information* and the *knowledge*. Since the KM process only considers a limited number of data in the past, the information cannot cover all possible values of the system state vector. In comparison with information, the knowledge covers all possible values of the system state vector. It means, for each possible system state, the knowledge can suggest the probability distribution of the appropriate decisions.

The *meta-knowledge* defines the way to use the *knowledge*. In a production process, when more than one customer orders are waiting for a resource and a decision has to be made to assign the resource to one order, the knowledge will be used to choose the most appropriate priority rule to select a customer order. Furthermore, the meta-knowledge defines the time to update the knowledge, while more new data are being collected during the on-going production process.

Tan and Aufenanger (2011) report that the knowledge-based scheduling approach approximates the scheduling quality of the time-consuming tested approaches and significantly reduces the computational effort. Hence, this approach is particularly suitable for solving real-time production scheduling problems.

3.3 KM in Computer Science

In computer science, knowledge is often defined by an ontology. An ontology defines a shared vocabulary, which is used by multiple agents (Wooldridge 2002) to exchange information in a common domain. This is necessary because 'people can't share knowledge, if they don't speak a common language' (Davenport 2000). An ontology is a medium to describe some section of the real world. This section might be the knowledge base of a robot or background information about websites in the Semantic World Wide Web (Fischetti 1999). Historically ontologies have been the focus of a discipline in philosophy that has been trying to find out what existence is. When computer scientists adapted the research field in the second half of the twentieth century, they were more concerned about how to model existence in an appropriate way. Gruber (1993) defines an ontology as 'a formal explicit specification of a shared conceptualization'. First of all, this means that there is a shared conceptualization between multiple agents to model a domain. The notion of an explicit specification means that the underlying vocabulary and semantics is interpretable by a machine. Thus the grammar's terminology must be unambiguous with respect to words such as 'intelligence', which may refer to a property of higher animals or an intelligence apparatus.

The semantics of an ontology base upon concepts that are distinguished by attributes and connected be relations (see Fig. 3). Attributes may have properties such as their type, cardinality and domain. There is a multitude of types of relations

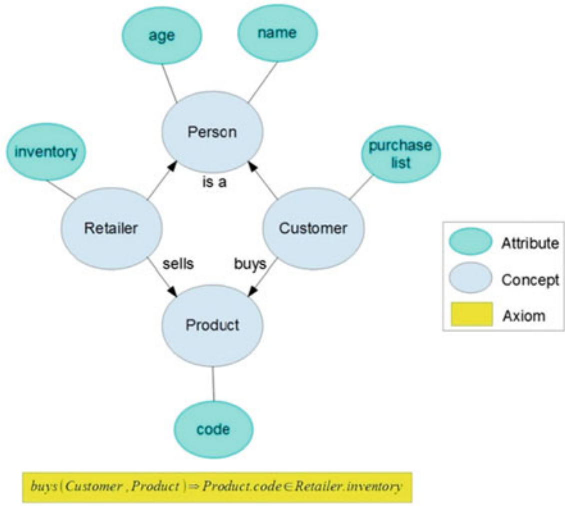


Fig. 3 UML diagram of an ontology

to model different kinds of connections between multiple concepts and attributes. Taxonomies (is-a), partonomies (part-of) and meronomies (is-a-superclass-of) are a few examples.

Furthermore, axioms can be defined via logical expressions to create general rules for the ontology based on relations. Axioms infer new contexts from existing knowledge, thus creating new knowledge. For example if customer X buys a product Y from retailer Z than obviously the retailers' inventory must contain the products' code. Such implicit information is automatically generated and its volume grows exponentially with the number of relations in the ontology. Thus the performance of expert systems, search engines and other reasoning systems depends on a semantic, machine interpretable model of the data that is provided by an ontology. The expressiveness of an ontology is bound by the limits of the specification of the modeling language. For this reason common standards such as the Resource Description Framework (RDF) or the Web Ontology Language (OWL) for web modeling languages have been defined and there is a lot of ongoing research to extend and approve those standards.

3.4 KM in Communication Engineering

In the area of communication engineering and networks, KM is applied for the developing and enhancing communication networks, devices, architectures, topologies and protocols. Communication is the transmission of messages over a network or medium from one point to another. The network could be based on wired or wireless devices. This interchange of messages becomes possible by utilizing the latest available technology, devices and network equipments. Network operators provide communication infrastructure for the subscribers. Network designers are generally interested in enhancing the network capacity, in order to facilitate the ever increasing number of users, devices, applications and data requirements efficiently (Holma and Toskala 2009). The concepts of data, information, and knowledge can be realized from two different viewpoints. The first viewpoint is based on conceptual notion. The second one is based on physical perception.

According to the first viewpoint, data are unorganized facts or parameter values (Watkins and Leigh 2009). Such kind of data is acquired by performing measurements, tests, simulations etc. Examples are the strengths of the received and transmitted signals of a mobile device or a temperature measuring sensor in a container at a particular location, the end-to-end delay time of a signal, system capacity in terms of maximum users or sensors served at a particular time. The second viewpoint is that data are bits (e.g. voice, image etc.), which are transferred over a network as data traffic and can be stored on recording mediums. In order to be able to transmit such kind of data over a modern telecommunication network, the raw data is converted from analogue into digital form (Barry et al. 2003). The digital form of data is then coded, modulated and encrypted before transmitting it to the receiver. The received signal is decrypted, demodulated, decoded and reconverted to analogue form. The network performance can be evaluated by determining the average number of bits that can be transmitted in unit time.

Information is the determination of characteristics and nature of the available data. In accordance with the first view point mentioned above, cell coverage is the information acquired by determining the nature of data available about signal strength. From the second viewpoint, the quality of service requirements of data traffic to be transferred from one point to another over a network gives the information about characteristics of data traffic, such as delay sensitivity, accuracy, etc.

Knowledge is the understanding of available information to facilitate the decision making process. The information available about coverage in a cell can be utilized to discover new methods of enhancing cell coverage. Similarly, the information about the quality of service requirements of various data traffic types can be applied to improve user experience in a cellular network.

4 Collaborative KM in Logistics

Research nowadays demands knowledge advancing not only within the core of single disciplines but increasingly on the interface or combination of disciplines. Therefore, interdisciplinary research cooperation is to develop more comprehensive knowledge. Learning such knowledge from others, and transfer knowledge from one discipline to another is the target. This research takes into account the cross-sectional character of the combination of economics and technical research in this application area. In this paper, we present a collaborative point of view to illustrate how different disciplines can cooperate together to utilize the knowledge in the logistics field based on the presented parameters in Fig. 4:

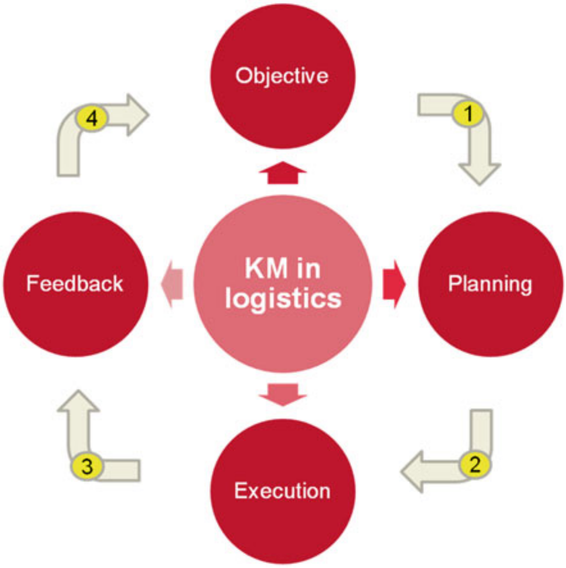


Fig. 4 Collaborative KM in logistics

① From the objective setting phase to the planning phase: using the available knowledge through the definition of logistics objectives is mainly an interdisciplinary task. These objectives integrate economic, environmental, and social objectives. The setting of the logistics objective is targeting to define logistics structures, the attributes of the system state and the decision vectors. Moreover, scientists transfer practical problems into computer science problems to maximize system data rate, increase revenue generation, balance workload of resources, to minimize re-handling movements, waiting time of trucks, and to define customers' needs.

② From the planning phase to the execution phase: Logistics activities can be planned by using the appropriate algorithms to acquire knowledge, design software based on theories (formulae, hardware, statistics, and measurements from mathematics, electrical engineering and physics), procedures, mathematical models and simulation techniques. This planning needs many inputs such as: real time data, manufacturing and production planning, interfaces, visualizations, artificial intelligence, knowledge acquisition, design and simulation tools. All of these inputs are a combination of different disciplines.

③ From the execution phase to the feedback stage: Knowledge is an essential input to move from the execution to the feedback phase. Feedback is generated directly by interviews and statistics and indirectly by software usage. Users and experts review network performance to assist the environmental and health aspects, questionnaires, online-surveys and interviews. Feedback can be extracted by communication tools, and electronic decision making to evaluate the economical objective and to get feedback from the execution.

④ From the feedback stage to the objective setting phase: based on the feedback, we can adapt the objectives, goals, algorithms, data aggregation and closed loops. In addition, we can reuse objectives, update the meta-knowledge and vector attributes, scenarios and theories. We can also improve the network configuration and algorithms, evaluate, and update the network design to achieve higher sustainability and customer satisfaction.

As we can notice from this point of view, collaborative KM in logistics needs an interdisciplinary view. This integrated view involves different disciplines that come together and share their methods and results. The consequential dialogue has broadened the mutual understanding of the different aspects of problems and creative solutions in logistics which often requires interdisciplinary knowledge. The whole extracted knowledge has greater value than the sum of its components.

5 Conclusion and Outlook

In this paper, we discussed KM from different disciplinary perspectives. We presented an overview of KM from the viewpoints of business studies and economics, production engineering, computer science and communication engineering. In each discipline, knowledge can be defined from different scope and level, and KM is acquired, represented, and applied in different ways. Based on the discussion of concepts of knowledge and application of KM activities, we provided a collaborative KM insight under the cycle of objective setting, planning, execution and feedback phases. Moreover, we highlighted the interdisciplinary tasks involved in the transition from one phase to another in the closed loop. In this process, different disciplines can cooperate together to improve the KM performance. In modern logistics, the implementation of KM within logistics service providers are essential of developing sustainable advantages The result implicates that KM application is an interdisciplinary and collaborative project, which requires communication and cooperation between different organizations, departments, and business processes in logistic networks.

However, as this work is an initial exploration, it leaves several interesting prospects for future research. First, our future goal will extend the interdisciplinary research towards elaborating the collaborative framework for KM in various disciplines. Second, we will also expand our research to the cross-cultural perspectives of KM. Logistic processes require the cooperation of individuals from diverse cultures with each other. Cross-cultural KM is crucial to success in maintaining long-term business success in the global market of logistics.

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LogisticsArena—A Platform Promoting Innovation in Logistics

Nils Meyer-Larsen, Jannicke Baalsrud Hauge and Anna-Sarah Hennig

Abstract Over the past decade, several research initiatives have researched and proposed innovative solutions for transport logistics, but the level of adoption in the transport industry has been low, in particular in comparison with other industry sectors. This is on one side related to the transport industry itself, facing issues like market fragmentation, price pressure and a high degree of outsourcing, and on the other caused by a lack in dissemination strategies towards relevant stakeholders being indentified in several logistics innovation projects. The EU-funded project Loginn—Logistic Innovation Uptake aims at coordinating and supporting research, technology and development (RTD) projects in the logistics area to improve their capabilities to bridge the gap between pilot implementation and marketable solutions. At the same time, the project aims at disseminating innovative logistics practices, technologies and business models to the logistics community, thus establishing an information hub for logistics innovation and contributing to education and training of logistics enterprises' employees. Based on the research results, Loginn will develop a "Logistics Innovation Action Plan" for Europe.

Keywords Innovation · Up-take · Logistics infrastructure · Strategy · Learning

N. Meyer-Larsen (✉) · A.-S. Hennig
ISL Institut für Seeverkehrswirtschaft und Logistik, Barkhausenstraße 2,
27568 Bremerhaven, Germany
e-mail: meyer-larsen@isl.org

A.-S. Hennig
e-mail: hennig@isl.org

J. Baalsrud Hauge
Department C-Business in Enterprise Networks, BIBA, Applied Information and Communication Technology for Production, Bremen, Germany
e-mail: baa@biba.uni-bremen.de

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1 Introduction

Innovation is a key factor for the competitiveness of the European industry and has historically played a vital role in increasing efficiency (e.g. the containerization of the industry), and numerous further innovations are needed to nurture intermodality and co-modality, as road transport continues to grow (Behrends 2009). While other industry sectors have experienced rapid growth of productivity, the transport logistics industry has seen relatively small improvement in terms of efficiency. One main factor is the lack of interest in innovation in freight transport, compared to other sectors.

1.1 Background

Research shows that other industry sectors spend from 4.8 to 17.8 % of their turnover on research and innovation, compared to only 1.1 % for the transport industry (Wagner 2008). The adoption level of innovative solutions for transport logistics thus is significantly lower compared to other industry sectors.

However, Europe 2020 (European Commission 2010) has formulated a set of very ambitious goals in the areas of smart, sustainable and inclusive growth, and further decomposed them into seven flagship initiatives. Among the goals to be achieved, one should mention the 3 % target of investments in R&D and innovation and the 20/20/20 goal (i.e. to reduce greenhouse gas emissions by at least 20 % compared to 1990 levels, to increase renewable energy consumption to 20 %, and achieve a 20 % increase in energy efficiency).

The provisions of Europe 2020 substantiate major trends in linking Society and the Environment, Technology and Economy and Research with Innovation. In all the priority areas of Europe 2020 such as climate and energy, health and nutrition, mobility, security, and communication, “new” logistics will be required in order to catalyse the progress.

1.2 Research Question and Purpose of the Paper

The main objective of Loginn is to create a platform to stimulate discussion and consensus building amongst main public stakeholders, market players and researchers in the intermodal and freight logistics domain in order to facilitate and accelerate the commercial uptake of logistics innovation, by turning knowledge and research into investment in innovation. To achieve a better information flow of innovative solutions and also to foster their uptake by logistics enterprises, the project Loginn has set up a collaborative platform, the LogisticsArena (LogisticsArena 2013), to allow the main stakeholders of the logistics domain (industry, SMEs, public authorities, investors and research organizations) to work together on promoting innovative transport logistics solutions aiming at increasing efficiency and with a particular focus on intermodal transport. The project addresses the following issues:

- raising the profile and understanding of intermodal and freight logistics innovation
- identifying policies, regulatory measures, financial mechanisms and socio-economic aspects that are required in support of accelerating the development and diffusion of logistics innovation
- encouraging greater involvement in and acceptance of innovations in the public as well as private sector.

This paper describes the Loginn approach to establish the collaboration platform and the project activities to access relevant partners in the logistics community in order to disseminate innovative solutions and foster related exchange of information. Loginn drives innovation adoption in transport logistics by taking a holistic approach that considers several mutually reinforcing aspects of innovation: business models, logistics practices and technologies. This approach favours the customisation of RTD results towards industrial demand solutions, supporting the development of sustainable business plans for European RTD projects, exploiting synergies between European RTD projects to enable a seamless exchange between RTD projects and logistics stakeholders and finally enabling and supporting the access to Investors.

2 Psychological Aspects of Innovation Uptake

Questions regarding drivers and barriers of innovations are very important in the context of stakeholder/user acceptance—a concept which should get more room in future research approaches, most of all in the form of acceptance research during development. Even though it can definitely be valuable to get insight in those issues from retrospective (Did people use the new solution/tool/process? Were they reluctant? Are they happy with the new solution?), such questions should preferably be addressed at an earlier stage: Which factors come into play when the individual and organisational decision to employ or neglect an innovation in daily work is made? When questions like these are addressed, the psychological perspective can be considered to be crucial since it provides the frameworks and methodologies to tackle the often overlooked human factors of innovation management (Frey et al. 2006). A tool like the LogisticsArena, the platform developed during the Loginn project, can facilitate communication and networking processes amongst dedicated stakeholders and can thus be expected to be valuable in the efforts to enhance such a perspective on innovation processes—even more so because the platform also aims at involving people who deal with the innovative techniques or procedures in their everyday practices.

Which factors play a role in stakeholder decisions to employ a project-driven innovation approach in day-to-day business processes or to return to "business as usual" or individual day-by-day solutions instead? In general, this question cannot be extensively answered merely by pointing to technological flaws or external hindrances. Past research and development projects have brought the insight that social and psychological aspects of innovation management, especially the pre-conditions of innovation acceptance within the user group, are not treated with sufficient attentiveness. As Flint et al. state, "innovation is inspired by actors responding to and interpreting a dynamic environment, continuously reflecting on their interpretations, the interpretations of others, and responses by others to their actions (i.e., innovations). From this perspective, innovation processes become more iterative and less linear as (often) implied" (Flint et al. 2005). Therefore it needs to be asked what aspects of social interaction and relationships impinge upon the innovation process. It has been found that features of the task itself (e.g. control, strain, creativity, complexity) as well as the individual person performing it (e.g. attitude, skills, motivation, mood), the team involved (e.g. heterogeneity, team climate) and the organisation (e.g. resources, structures, communication, culture of management and leadership) play a role here.

When a new technological or organisational solution is being developed, such issues are often neglected until the final evaluation. However, at this point, the RTD work is usually finished and the involved institutions, companies or user groups do not see themselves in a position to re-evaluate and amend the solution in question on their own terms. As a consequence, the business goes back to the traditional processes they were actually aiming to improve by joining the project in the first place, while a technically promising innovation is rejected and the resources spent on its development could even be seen as lost. To reduce the risk of such failures, it is necessary to take questions like the following into account when designing the work programme of an RTD project (see Rogers 1995):

- Which parties (beyond management level) are involved in the decision process when an actual innovation is to be employed in a specific work process? The actual users should be informed of the upcoming measures and taken "on board" as early in the process as possible. Communication can be considered crucial.
- Which measures are taken to support the stakeholders' commitment to the process? Properties of the planned innovation/modification which are important in the context of acceptance, most of all the perceived usefulness and perceived ease of use, should be enhanced. Research into acceptance issues has resulted in a couple of key factors which are found to be crucial for innovation acceptance. Some of them can be assessed with tools like the TAM (technology acceptance model) (Davis and Venkatesh 2004) which is used to forecast the use of various software applications. Also acceptance tests by using simulations can be recommended.

3 The Loginn Project and Its Methodology

As outlined above, the Loginn project is supporting the development and up-take of innovations in the area of logistics, thereby taking into account the psychological aspects mentioned in Sect. 2. In order to support the Loginn objectives throughout its duration, a discussion and consensus building platform, the so-called LogisticsArena (LogisticsArena 2013) was set up at the beginning of the project, aiming at bringing the potential stakeholders and providers together, fostering information exchange and thus inclusion of the users in the development phase, if the projects bring their ideas into the platform at an early stage. This approach is coming from the co-creative product development approach (Schumacher 2013). Development of innovative solutions for transport logistics has much in common with classical product design and even more with service design, thus it can be expected that the same concepts can be used. For quite a while, user involvement was limited to observation and not active participation (Sanders and Stappers 2008). However, in order to be able to fit the users' needs in a better and more efficient way, a new way of product development occurred that directly included the involvement of the workers to get access to their experience (Bødker 2005). The change towards more user oriented development processes is also imposed by the emerge of open software development, bringing a new culture attitude regarding information sharing and co-operative development into the development process, as well as fostered by the increased use of ICT, allowing spatial separation of cooperation partners. Thus, the emerging of a new culture imposed by the open software development approach has imposed more user involvement in the design and development process.

Loginn will concentrate its activities on certain categories of stakeholders, representing the major players of the logistics innovation development and deployment. These are in particular:

- Associations and research bodies, which are expected to contribute to the discussion with their knowledge on the state of the art innovation and R&D in logistics and in their specific sector of interest
- ICT providers, which are expected to contribute in particular to the discussions on innovative technology
- Logistics Service Providers (LSPs), which are expected to contribute in particular to the discussions on logistics practices
- Shippers, which are expected to contribute in particular to the discussions on business models
- Authorities and investors, which are expected to contribute in particular with their expertise and knowledge on policies, mechanisms to push for innovation uptake and integration in companies, and expectations from innovation in terms of ROI.

3.1 The LogisticsArena as a Means for Discussion and Consensus Building

The LogisticsArena is dedicated to the development of discussions and consensus building around the three dimensions of innovation: innovative business models, innovative technology solutions, and innovative logistics practices. It will be structured in discussion areas, each providing public content, posts and discussions open to the comments of the users that will be made public after the administrator's approval. The discussion area will be structured in channels as for a forum to proper support all the relevant themes and to provide an organic, immediate and catchy organization of the content and of the comments received.

In particular, each of the dedicated discussion channels of the Arena will provide the users with the necessary tools to:

- write new contributions and read the contributions of other users
- follow discussions and search for specific arguments
- choose the most recent contribution or the most interesting contribution (based on the community interest)
- add comments to interact with the author and the rest of the community and build a discussion over the topics tackled in the author's contribution
- express the own interest over a contribution, a comment, a discussion, with a score
- express the own judgement over uncontrolled content
- share the content on other web channels (e.g. in social networks), thus helping the visibility of the LogisticsArena and attracting new users
- survey the community to collect opinions on strictly focused topics.

By means of voting mechanisms, the ideas and contributions that the community perceives as most important are highlighted and immediately spotted on the Arena. On the other side, uncontrolled content (which might originate, e.g., from users intending to abuse of the Arena to advertise the own products) will be filtered out through reputation mechanisms. Similar communities, although with a different focus and a different structure and supply of tools, can be found at Kinaxis (2013) and Logistikfocus (2013). Both are examples of crowdsourced platforms, enriched by a community of active readers and writers.

3.2 State-of-the-Art of Innovation in Logistics

In the following sections, we will describe the Loginn approach investigating the state-of-the-art of logistics innovation. The respective analyses are based on a literature review and analysis of relevant project results in three different thematic dimensions: business models, logistics practices and technology solutions.

3.2.1 Inventory of Innovative Logistics Business Models

The business model concept became prevalent in the 1990s. The emergence of the Internet played a significant part in that, as it gave companies (and supply chains) the ability to find additional ways of creating additional value for their customers. Other drivers include the rapid growth in emerging markets and the interest in "bottom of the pyramid" issues. Examples can be found e.g. in Fugate and Mentzer (2004), Fulconis et al. (2006), and Pires et al. (2001). Although various definitions of what a business model is do exist, within the scope of this project we will consider the business model as a representation of the way the members of a supply chain use their competencies and resources to increase customer and shareholder value. Thus, innovative logistics business models should consider:

- innovative ways to reach the customer (e.g. DHL's Bring.Buddy initiative (Forbes 2013) employing crowdsourcing for urban deliveries, etc.)
- innovative configurations of the supply chain providers (e.g. the migration from the large transport operator to the 3PL and 4PL provider, to the Lead Logistics Provider and to the flexible networks of smaller 3PL providers, the emergence of virtual supply chains, etc.)
- innovative supply chain coordination mechanisms (e.g. the evolution from the centralised to distributed monitoring and control provided by the "installation" of knowledge on the cargo itself).

3.2.2 Inventory of Previous Research on Adoption of Innovative Logistics Practices

The transport industry has in recent decades adopted many innovative logistics solutions that have increased the industry and in particular specific companies' competitiveness. One example is Collaborative Planning, Forecasting & Replenishment (CPFR) (Andraski and Haedicke 2003). The knowledge about these innovative practices is rather local; within specific industrial segment, within operators' size segment or geographical area and unfortunately rarely reaching SMEs. Therefore there is a need to make an inventory of these practices to enable a knowledge transfer throughout the European freight transport industry. This will be done by harvesting knowledge from previous and ongoing projects, from documented industry adoptions and collaborative innovation theory. Another important source of input will be the various small regional SME organizations such as haulier associations that are disseminating innovative transport logistics practices to their member firms.

Although the term "inventory" might lead to the idea of a pure data collection exercise, this is not the case here. The lack of a commonly accepted term for a "business model" and the vague boundaries between a business model and a logistics practice will require extra effort in order for the project to avoid double counting or wrongly classifying specific cases of relevance to the project. This lack of clarity becomes evident just from a simple search of the term "business model" in the relevant literature. Looking at previous EU projects, we recognise that the majority of previous research projects although using the term "business model", actually refer to exploitation models of the additional information provided by some ICT applications or even exploitation of the ICT development itself.

3.2.3 Inventory of Innovative Technology Solutions

Another part of the Loginn project focuses on the identification of new technological developments (in terms of ICT) that are able to improve overall functionality of freight transportation on European level. This part covers a wide spectrum of areas, from information and communication technologies, to engine technologies, to intermodal transhipment and material handling technologies, virtual enterprises management techniques to internet of things. Examples can be found e.g. in Tsai et al. (2010) and Wu and Subramaniam (2011). The Logistics for LIFE (L4L) project (Logistics4LIFE 2013) coordinating and synthesizing research results on innovative ICT solutions will be used as a starting point to that direction. L4L has developed a series of tools that are of specific value to Loginn such as the L4L Knowledge Base and the L4L Solutions Collections. Other examples will be previous studies and projects in the area of future ICT developments, as well as best practice collections from current and recent projects such as Posmetrans (2013), Innosutra (2013) and BestFact (2013). Available solutions, e.g. the Common Framework initiative (Pedersen 2011) to handle the interoperability issue and the eFreight project (eFreight 2013) aiming at the creation of an appropriate framework to allow tracing goods in real time, ensure intermodal liability and promote clean freight transport will also be taken into account.

3.3 Identification of Drivers and Barriers for Business Model Innovation Market Uptake

Considering the interrelations between business models, logistics practices and technologies, it is becoming clear that some of the barriers experienced in one dimension will have a cause/effect relationship with barriers in another dimension. The barriers identified within each of the three dimensions are examined also in view of their relationship and impact to the barriers of the other two dimensions, and are brought together in the form of "barrier cases". These cases will be market segment specific. The purpose of this task is to generate a comprehensive and refined list of the identified barriers and drivers for market uptake of innovation and provide a guide towards mitigating barriers to the adoption of specific innovation in the three dimensions.

For each of the identified innovative business models, the main environmental parameters and trends linked to their emergence and also the major drivers having an impact on their future development will be analysed. An assessment will be made regarding their current level of penetration/diffusion and the existence of potential barriers across a number of areas, e.g. policies and regulations, financing, standardisation/harmonisation, innovation management, penetration mechanisms, etc.

For example, crowd-sourcing might prove in the future to be a major way for bringing efficiency and sustainability requirements in freight transport operations. However, a number of questions arise for instance when looking at the Bring. Buddy example (Forbes 2013). What is the legal status and how a company and an individual can enter into such a sporadic business relationship in legal/institutional terms? Has there been funding for assessing its impact on a large scale? Has there been a best practice dissemination strategy? All these are potential barriers in relation to the specific innovation, and overcoming them will need specific actions to be undertaken. These actions are to be included in the action plan that will be developed in the frame of the project.

Identifying the essence of each business model (e.g. drivers, barriers, critical success factors) is crucial but many of these characteristics are difficult to be identified as they are pretty much case specific and subtle, and the more precisely these are defined the easiest will be to draw realistic initiatives for overcoming them.

The focus is to identify knowledge on what the drivers for successful logistics innovations are and how the barriers to innovation adoption can be mitigated and transferability increased between different sizes of operators, small to large, type of operation and geographical location in Europe. The drivers of successful logistics innovation implementation include increased revenues, cost decrease, increased service, decreased environmental impact, positive social impacts, etc., but differ between types of innovation. Decreasing costs and increasing revenues are obviously two major drivers, but many other exist and these need to be identified and grouped based on relevance. Failed market uptake as well depends on a variety of different factors and thus it is necessary to provide a structured innovation analysis to identify the barriers with the logistics innovative practices dimension, as well as in the dimension of business models and technology. Consequently based on the findings in the areas of technology, business models, and practices, we are aiming at developing a holistic view which encompasses:

- all interlinked, mutually reinforcing dimensions of logistics innovation (business models, practices, technologies),
- the required initiatives for accelerating and enhancing innovation market uptake and
- the integrated view (consensus) of the various stakeholders involved from the creation of an innovation to its market uptake.

3.4 Development of the "Logistics Innovation Action Plan"

Loginn is offering a bottom up learning procedure providing information from the industry excellence in innovation achievement, in combination with the identified barriers and gaps. This will culminate in a "Logistics Innovation Action Plan" for Europe, which will aim at answering the following questions:

- What is the current state and expected developments on intermodal freight transport and logistics research and innovation?
- Which are the observed drivers and barriers for logistics innovation market uptake?
- How to overcome these barriers?
- How can investments be attracted in accelerating logistics innovation?
- How can technologies (ICT in particular) support these processes?

This "Logistics Innovation Action Plan" will integrate the proposed initiatives for accelerating logistics innovation market uptake into a comprehensive, straightforward form with a precise initiatives-to-do list. Among its added value characteristics one can distinguish its specific orientation towards intermodal and freight logistics and also its built-in consensus in relation to the initiatives proposed, as these will be the outcome of employing the Loginn virtual arena mechanism. The Logistics Innovation Action Plan will be a practical tool to help policy makers and stakeholders in drawing a realistic strategy for accelerating logistics innovation in Europe. It will especially take into account the Strategic Transport Technology Plan (STTP) (EC 2013) whose goal is to better align transport research and innovation with EU objectives. The STTP aims at proposing solutions for improved instruments of transport research, innovation and technology deployment processes at all levels of government and among all stakeholders (e.g. private, public, Member States, EU), including the definition of a governance structure for implementing the STTP. In addition to the action plan, which is of more strategic importance, Loginn will provide an "Innovative Solution Toolbox" that will put logistics innovation into practice. The goal of the logistics toolbox is to gather the information from previous projects in a logistics solutions toolbox which enables the reconfiguration and matching of the project results in order to upscale the potential of these pilot implementations and provide full solutions to the logistics stakeholders. This information will be supplemented by the insight and experiences of real-life case studies to be brought in the project by the LogisticsArena. For SME firms operating in transport logistics, the toolbox will provide a source of information and practical hands-on guidelines of how to add or use new innovative business models, practices or technologies. The psychological preconditions outlined above will provide a profound basis for the respective efforts and will support the successful implementation of the "Innovative Solution Toolbox".

4 Conclusions

Innovation is a key factor for the competitiveness of the European industry and has historically played a vital role in increasing efficiency. The transport logistics industry has seen relatively small improvement in terms of innovation. Research shows that other industry sectors spend from 4.8 to 17.8 % of their turnover on research and innovation, compared to only 1.1 % for the transport industry. Several research initiatives are currently investigating the reasons for this discrepancy and are proposing measures to improve this situation. One of them is the EU co-funded project Loginn which has the main objective to create a platform to stimulate discussion and consensus building amongst main public stakeholders, market players and researchers in the intermodal and freight logistics domain in order to facilitate and accelerate the commercial uptake of logistics innovation. The project Loginn has set up a collaborative platform, the LogisticsArena, to allow the main stakeholders of the logistics domain to work together on promoting innovative transport logistics solutions aiming at increasing efficiency and with a particular focus on intermodal transport.

In this paper we describe the Loginn approach to establish the collaboration platform and the project activities to access relevant partners in the logistics community in order to disseminate innovative solutions and foster related exchange of information. Loginn drives innovation adoption in transport logistics by taking a holistic approach that considers several mutually reinforcing aspects of innovation: business models, logistics practices, and technologies. This approach favours the customisation of RTD results towards industrial demand solutions, supporting the development of sustainable business plans for European RTD projects, exploiting synergies between European RTD projects to enable a seamless exchange between RTD projects and logistics stakeholders and finally enabling and supporting the access to Investors. Furthermore, our paper investigates the psychological aspects of innovation uptake, especially addressing the question which factors play a role in stakeholder decisions to employ a project-driven innovation approach in day-to-day business processes or to return to “business as usual” instead.

Loginn is offering a bottom up learning procedure providing information from the industry excellence in innovation achievement, in combination with the identified barriers and gaps. Based on these efforts, this will culminate in a “Logistics Innovation Action Plan” for Europe. Loginn will provide an “Innovative Solution Toolbox” that will put logistics innovation into practice. The goal of the logistics toolbox is to gather the information from previous projects in a logistics solutions toolbox which enables the reconfiguration and matching of the projects results in order to upscale the potential of these pilot implementations and provide full solutions to the logistics stakeholders, thereby especially taking into account the requirements of SME enterprises.

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Competences and Qualifications of Logistic Managers—An Empirical Analysis of Job Postings in Germany

Herbert Kotzab and Sebastian Wünsche

Abstract This paper discusses the primary and secondary qualifications for logistics jobs in two different labor markets (business logistics and logistics service providers). For this purpose, a theoretical frame of reference was developed in which two samples of job postings representing more than 1,400 logistics jobs in Germany, were screened. Our empirical findings show that professional experience is the most important qualifier for an employment position in logistics. Depending on the hierarchy level of the posted position, additional education or managerial experience is required.

1 Introduction

Logistics plays an important role for Germany. In 2011, the German logistics industry generated a total turnover of €223 billion and employed approximately 3 million people (Kille and Schwemmer 2012). The logistics performance index of the World Bank shows Germany amongst the top five performing countries since 2007 (LPI 2013). These two results indicate the strategic importance of the logistics sector in Germany.

Depending on the general development of the economy, logistics can be seen as a growth industry with a huge demand for employees, in particular for logistics/ supply chain managers and qualified personnel (see e.g. BVL 2013).

Logistics is significantly affected by major technological developments in automation for material flow systems and IT, which lead to different required qualifications and competency profiles of future logistics employees as compared to

H. Kotzab (✉) · S. Wünsche
Lehrstuhl für ABWL und Logistikmanagement, Wilhelm-Herbst-Str. 12,
28359 Bremen, Germany
e-mail: kotzab@uni-bremen.de

S. Wünsche
e-mail: swuensche@uni-bremen.de

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today's qualification profiles (Katz and Margo 2013). Additionally, due to demographic shifts in society, we can expect a 'war for talents' in the logistics sector as qualified people are become an increasingly scarce resource given that the German logistics sector is expected to hire significantly more people in the future as compared to companies from other sectors.

Today, the German Logistics Association already recognizes problems in hiring especially skilled personnel and logistics managers.

From that perspective, we were interested examining the qualifications and competences that a logistics manager is supposed to have. As Schulte (1995, p. 343) points out, excellent logistics process execution requires adequate employees with profound qualifications and skills. For the human resource management of a company, it is crucial to identify the requirements for each position in the company in order for them to be filled properly. This may be difficult for the field of logistics because of the broad field of activities.

So far, different studies present quite exhaustive qualification and skills requirements which have been mainly based on the self-assessments of logistics and supply chain managers (e.g. Murphy and Poist 1991 or Gammelgaard and Larson 2001).

When it comes to the professional and commercial education paths in logistics in Germany, there exist more than 40 recognized occupations requiring formal training. These occupations can be grouped into commercial professions (e.g. forward merchant, shipping agent), skilled workers for warehousing and commissioning, skilled workers for transport and delivery (see e.g. Hildebrand and Roth 2008).

Furthermore, a range of certified training programs in logistics are offered (e.g. certified business economist within traffic and logistics, certified logistician, certified business administration specialist in traffic management, certified specialist in maritime logistics, certified export manager; certified warehousing technician) and university degree programs with a special focus on logistics within the areas of business administration and industrial engineering (see e.g. Baumgarten 2008).

As the main purpose of our study was to gain additional insight into the subject matter, we wanted to explore the relevant job market for logistics positions. Looking at the market volume of the German logistics sector, we can see that nearly 50 % of all logistics activities are outsourced to logistics service providers (Kille and Schwemmer 2012). Here we argue that companies that keep logistics in house, as well as specialized logistics companies are searching for employees. We therefore defined two independent project approaches by generating two separate samples of logistics job postings.

Based on this, we were interested in seeing how these companies define their needs in terms of a profile of required qualifications and competences. This was achieved by analyzing the content of job postings based on two structured frames of references that were built upon the notions of the European Framework of Qualifications (EFQ) and the German Federal Labor Market Authority (GFLMA) and Hildebrandt and Roth (2008).

The remainder of the paper is structured as follows. After having shown the background of the problem, we introduce our theoretical understanding on skills, competences and qualifications. Afterwards we develop our frame of reference that was used for screening job advertisements that represented the business logistics and logistics service provider oriented labor markets. Selected results of our analysis are presented in Sect. 4. There we show the variety of logistics skills and competences that are sought by companies and how these skills and competences are related to professional groups of logistics experts, specialists and skilled workers. In Sect. 5 we discuss our results from the perspective of existing research. The paper closes with a summary of our paper, limitations and an outlook for future research.

2 The Conceptual Framework Based on Professional Skills, Qualifications and Competences

2.1 Job Qualification and Competences

Bramming (2004) or Tippelt and Schmidt (2009) understand a qualification as a certificated and standardized skill. A skill is defined by the European Commission (2008) as the ability to think logically, creatively and/or intuitively (=cognitive skills) as well as the ability to use methods, tools and/or material (=practical skills). In order to gain a qualification, one has to pass an evaluated exam (see Preissing 2001). This ensures that a person is afterwards able to execute relevant actions within a special profession on a given standard (see Tippelt and Schmidt 2009). Overall, qualifications, in terms of documenting skills on a specific level, are used to certify that an applicant is able to utilize particular cognitive and practical skills for a relevant position (see Müller 2008). Thus qualifications are very important for starting a career (Witt 1999).

In order to cope with the dynamics of work flows and job contents, it is necessary to further develop and maintain additional abilities or competences, which refer to individual personality aspect (Bramming 2004). Competences are dependent on action and can only be obtained by application (North 2007). Even though competences can be trained and taught, they remain individual and cannot be imitated (Müller 2008). A typical differentiation of competences refers to professional, methodological, social and self- and personal competences (see Fölsch 2010; Erpenbeck and Heyse 2007). When it comes to job competences, these can be grouped into primary and secondary competences. Primary competences refer to the content of the professional practice, while secondary competences enable the effective performance of a job (see Bartram and Roe 2005).

To allow a comparison of qualifications and competences on a European level, the European Commission developed the European Qualification Framework (EQF). By developing this framework, the European Commission intended to strengthen international competitive ability and the comparability of qualifications (Müller 2008). The EQF is separated into eight different types of levels, regarding qualifications (in this framework called knowledge), skills and competences. Starting with level 1 and low requirements, the requirements rise on every next higher level.

2.2 Development of the Conceptual Frameworks

Based on the general thoughts on skills, qualifications and competences as outlined in the previous sections we constructed a general framework for our intended analysis.

Employment positions within a company are subject to different hierarchical management levels. As a consequence, different positions also demand a different set of required skills, qualifications and competences (see Meyer and Stopp 2004). Hence we link the hierarchical levels of a company with the EFQ profile to the following (see also Fig. 1):

- Top management level includes the most important executives in the managing board requiring EFQ levels 8 and partly 7 as decisions made at this level require insights and special knowledge in different areas as well as authority and accountability.
- Upper management level contains head executives of special departments who convert the strategic goals into strategic and tactical department tasks. Here, authority and accountability are important, and information and correlations are complex. This requires a level 7 EQF-profile (with some overlap to level 8).

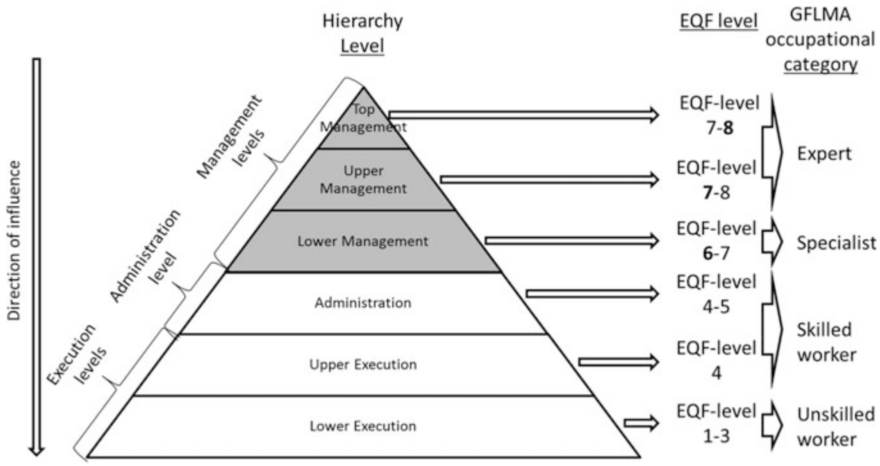

Fig. 1 Assignment of hierarchy levels, EQF level profiles and occupational categories (based on Meyer/Stopp 2004, 63)

- Lower management contains division managers whose objective is to execute the corporate policy of the organization within their areas. Authority and accountability are important, but less than on higher Management-levels. Information and correlations are complex, but given by decisions and the instructions of higher levels. This requires a level 6 EQF-profile (with an overlap to level 7).
- Administrators then conduct, organize and execute business operations. This level links management and execution. At this level the cognitive and practical skills required to generate solutions to specific problems are important. A level 5 or 4 EQF-profile can be linked to the Administrations level by the comparing tasks and demands to manage them.
- We can further differ between upper and lower execution depending on the authority level. Here, commercial professions can be found often.
  - At the upper execution level, authority and accountability are important, but only within the special field. There is no accountability for any business issues. Information and correlations are not as complex as they are on higher hierarchy levels. They are restricted to a special field of functions. This requires mostly a level 4 EQF-profile.
  - On the Lower-Execution level, employees execute orders within a special field of functions. Special knowledge within a field is not always needed correlations are given, but are generally not very complex. Employees do not have authority and accountability as the EQF-levels 1–3 are adequate.

Moreover, in our conceptual framework we considered different occupational categories, which we also linked with the EQF levels to hierarchy levels by using the four occupational categories of experts, specialists, skilled workers and unskilled workers as published by the GFLMA (2011).

A differentiated linkage of management levels and skills, especially for logistics service providers, has been suggested by Hildebrand and Roth (2008). They distinguish between six different levels that require more or less management experience, professional experience and specific logistics skills. For our purpose we broke them down to four different levels. Management positions that require long-term managerial experience, holistic logistics knowledge and analytical skills. Administrative and execution levels that require less managerial experience, but long-term professional experience (=administrative), knowledge of basic logistics tasks and organizational skills (=execution). The lowest level of simple operative tasks includes all jobs that do not require any specific education and refer to single warehousing and/or transport activities. These requirements mirror the occupational categories of the GFLMA as introduced before. These thoughts can be modeled as shown in Fig. 2.

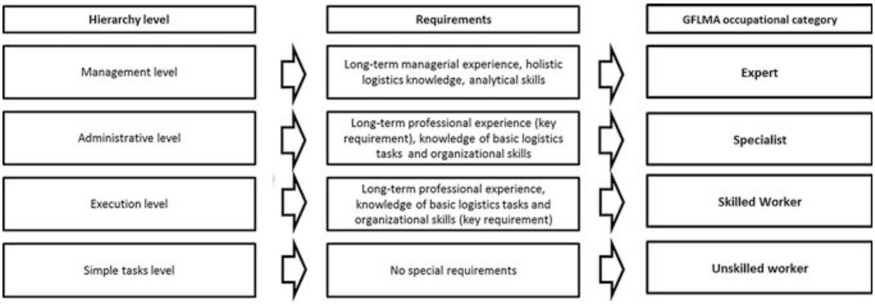

Fig. 2 Assignment of hierarchy levels, requirements and occupational categories in the field of logistics providers (based on Hildebrandt and Roth 2008, 72)

3 Methodology

Summarizing from the previous section, we distinguish between primary qualifications as certified and standardized skills, and secondary competences as important factors that describe the ability of an employee to fill an advertised/open position. These can be special kinds of competences as explained before.

The primary qualification for a logistics position was measured with the occupational category on an ordinal scale level referring to the classification of professions by the GFLMA (2011). This led to four different qualification levels depending on the qualification profiles for each occupational category, namely university degree, professional education with continuing education, professional education and non-skilled.

The secondary competences were adapted from the EFQ (2008) and measured on a nominal scale level. The logistics related competences in our study refer to

- foreign language competence,
- mathematical competence and basic natural-science competence,
- basic computer competence,
- advanced computer competence,
- learning competence,
- social and citizen competence,
- self-initiative and entrepreneurial competence,
- intercultural experience, and
- flexibility.

We also added professional experience, driving license and driving license for forklift truck. With this index we wanted to identify secondary competences for a logistics job.

Data collection for the two approaches was organized as follows:

- As for the in house logistics labor market, we analyzed a sample of 1,000 job advertisements that were posted in three German online job portals between October 8th, 2012 and February 3rd, 2013. We opted for online job portals as 40 % of all job services are already listed via online job portals (Brickwedde 2012).
- For the logistics service provider labor market, we generated a sample of 409 online job postings that were listed on the homepages of the twenty largest German logistics service providers (as measured by Kille and Schwemmer (2012)) and of the three next following German logistics service providers from the list of the largest European logistics service providers (Kille and Schwemmer 2012). Job postings were collected from Mid November to Mid December 2012.

4 Presentation and Discussion of Key Results

4.1 Required Qualification and Competence Profile of the in House Logistics Sample

We applied the framework as shown in Fig. 1 to analyze the job advertisements for this sample. We were able to see that most of the advertisements refer to the occupational categories of experts (n = 439) followed by skilled workers (n = 280) and specialists (n = 230). The companies sought for executive employees (n = 188), supply chain managers (n = 79) and supply chain consultants (n = 70). Taking these rather high level jobs into account, we were not surprised that most of these postings demanded a university degree (n = 432), a professional education (n = 262) or both (n = 202). Here, we were able to identify a significant relationship between the sought occupational category and the required primary qualification since postings for high level employments demand high level education (chi-square; $p < 0.001$).

The five most wanted secondary competences, that were sought in the job postings are shown in Fig. 3 where interestingly mathematical competences, flexibility and advanced computer competences were not amongst the most needed competences.

However, depending on the occupational profile required, we were able to see some differences in the sought after competence profile. Professional experience and basic computer competence are much more required for a skilled worker position than for an expert (chi square; $p < 0.01$). The group of specialists more often demand foreign language competence than others (chi square; $p < 0.05$). And the experts require more mathematical competence than other groups (chi square; $p < 0.001$).

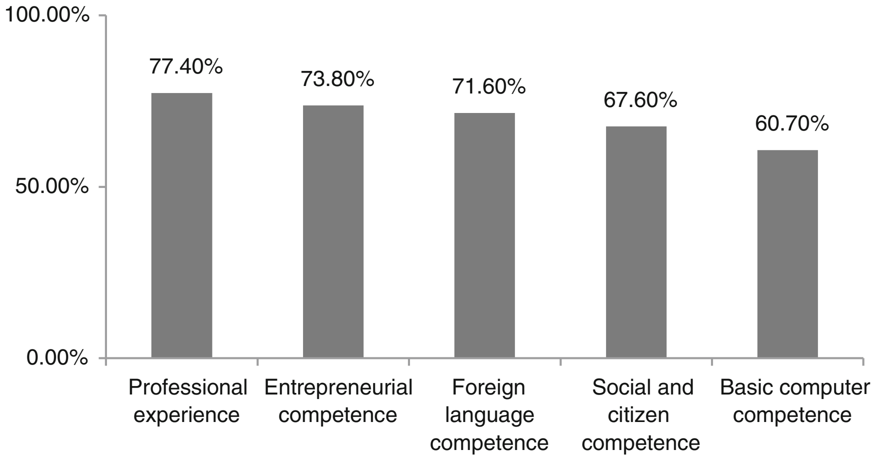

Fig. 3 Relative frequency of secondary competences within the sample

4.2 Required Qualification and Competence Profile in the Logistics Service Provider Sample

For this analysis, the framework as shown in Fig. 2. was applied. Most of the identified advertisements refer to the occupational categories of skilled workers (n = 232) followed by non-skilled (n = 84), specialists (n = 76) and experts (n = 14). When looking to the primary qualification, we were able to see a confirming pattern, as most of the postings required professional education (n = 164), university degree (n = 125) or continuing education (n = 12). In 93 of the 409 postings, no primary qualifications were required. The most wanted competence was professional experience with 81.13 % as shown in Fig. 4.

Interestingly enough, the subsequent four secondary competences were considerably behind and showed similar results. Overall, these results are in line with the sought after hierarchy levels. Looking into the category 'professional experience' we were able to see that first, experience is mostly required, followed by professional experience over several years and managerial experience. This does not go fully in line with the sought hierarchical levels.

4.3 Discussion

One of the goals of human resource management is to meet the qualified labor demands of the organization (see Holtbrügge 2010). When it comes to the logistics labor market, Klumpp (2009) identified some major challenges due to the dynamic character of logistics as a function that continuously leads to changing qualification requirements (Kersten and Schröder 2012). This may explain why we were not able

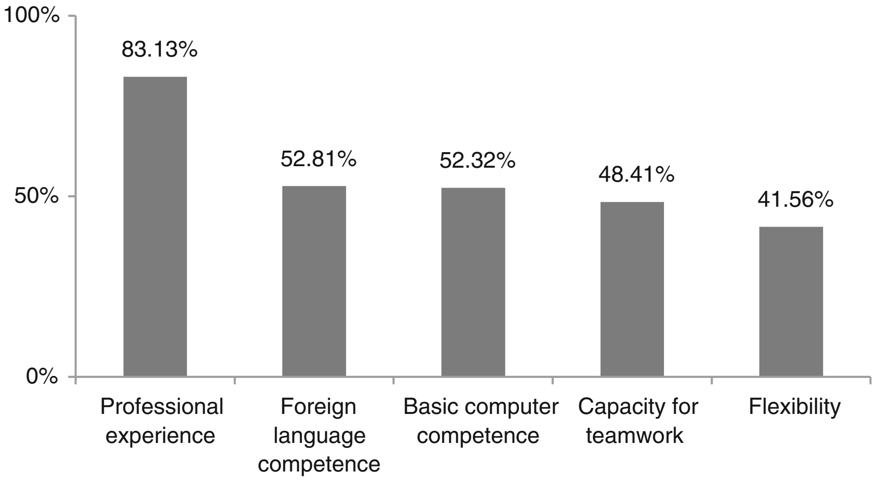

Fig. 4 Presents the findings on the required secondary competences

to identify 'the one and only' qualification profile for a logistics job. Our findings also support the notions of Murphy and Poist (1991), Gammelgaard and Larson (2001) and Thai et al. (2011) as our sample included more or less job postings for higher management levels.

Some interesting findings require further examination. In both samples we were able to identify professional experience as the most important qualifier for a logistics job. Interestingly enough, other competences such as advanced computer knowledge, language skills or analytical skills were not listed amongst the most required qualifications and competences. From the perspective of the logistics service provider industry this is interesting as due to increasing globalization, one could expect more global activities thus requiring language competences.

Looking at the business logistics postings, we observed that companies were looking for more management skills than business skills, which may be due to the fact that most of the job advertisements in this sample referred to higher level positions. However, also here, we were expecting a different mix of required secondary competences.

Overall, our findings to the primary qualifications confirm the expectations of the German Logistics Association, which we presented in the beginning of the paper. It was however interesting to see that a professional education in combination with certified/advanced training offers greater career possibilities in the field of logistics.

5 Conclusion and Outlook

The purpose of this paper was to gain more insight on how companies translate their need for logistics personnel by examining the qualification and competence profile for logistics positions from the perspective of job searching companies.

Our findings point out that professional experience is a qualifier for logistic careers. Depending on the sought after management levels, professional education and/or university degrees are a must criteria for a logistics career. Not all secondary competences though are related with the hierarchical management level of a logistics job. Here we see a pattern that business skills and management skills differentiate the type of sought after job. Comparing our results with the results of existing studies, we identified differences that were due to the chosen perspective. Job advertisements reflect the view of the company that is conducting the search.

One limitation of our, as well as of previous studies, is the focus on higher level logistics job. Here we suggest having a look at lower level logistics jobs at the assistant or unskilled worker level.

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