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Environmental Issues in Logistics and Manufacturing

Paulina Golińska
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Technology Management for Sustainable Production and Logistics

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EcoProduction

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Technology Management for Sustainable Production and Logistics

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Preface

Progressive competition, increasing customer demand, growing production and consumption scale, as well as environment degradation cause a lot of social, environmental, and economic problems. It requires a change in managements' attitudes toward their enterprises' operation and acceptance of responsibility not only for shareholders and employees, but also for the society, environment, or suppliers. Moreover, there is a need to create new solutions that might be successfully applied to improve supply chain management in the highly volatile environment of today's global network economy.

Innovative instruments provide opportunities for making manufacturing and logistics operations cleaner and more resource-efficient. New technologies and methods focus on life-cycle engineering and life-cycle management.

The aim of this monograph is to present technology management for sustainable production and logistics within supply chains.

This monograph is valuable to both academics and practitioners wishing to deepen their knowledge in the field of sustainable management. The book covers technical, organizational, financial, and social issues connected to the implementation of various technologies. It includes:

1. Case studies from different sectors.
2. Tips on the technical and non-technical aspects of new sustainable technology implementation.
3. Main problems and challenges of new technologies introduction.

The scope of the book takes into consideration how the environmental issues emerging in management might be transformed into business practices. Therefore, the authors present, in individual chapters, innovative approaches to organization and coordination of various processes in supply chains.

In the book, emphasis is placed on three main areas:

1. Supply chain sustainability—green supplier selection; service center location; drivers, inhibitors and solutions of supply chain sustainability, and role of logistics service providers in sustainable supply chains.

2. Technologies for transportation and sustainability—smart cities; reducing truck emissions and energy efficiency of passenger transport.
3. Sustainable production—eco-innovation; ergonomics; information technologies supporting production processes.

The first chapter contains an applicable methodology for green supplier selection in the food industry. The methodology consists of criteria classification, ranking, and a supplier selection phase.

The second chapter aims to present a solution for the agricultural service center location problem using the TOPSIS, DEA, and SAW techniques. The main contribution is to consider more comprehensively the attributes in solving service facility location problems such as: technical potential of candidate locations, demand, and market location.

In the next chapter, the author describes drivers, inhibitors, solutions of supply chain sustainability. This chapter describes the process of change of attitudes toward sustainability and its consequences for manufacturing and logistics industries.

The aim of the subsequent chapter is to draw attention to the growing importance of supply chain sustainability and to present practical solutions in this field on the example of the logistics industry. In the research, literature studies, surveys, and case studies have been used.

The final chapter in this part focuses on showing the way in which the CSR (corporate social responsibility) concept is put into practice by Polish brewing enterprises and how it influences their functioning on the example of the two largest beer producers in Poland.

The second part of the book presents technologies for transportation and sustainability. The aim of the first chapter of this part is to look more closely at the subject of smart cities in view of sustainable development.

The next chapter shows the problem of truck emissions in import operations at a container terminal in a Singaporean port. The goal of this study is to develop a methodology for reducing emissions generated by trucks idling at import yards.

The aim of the final chapter in this part is to estimate the level of energy-intensity of passenger transport in the Poznan (Poland) agglomeration and the dominating individual transport. It also indicates organizational and technological activities that would contribute to lowering energy intensity and increasing the sustainability of transport.

The third part of the book focuses on sustainable production. The author in the chapter "Identifying relationships between eco-innovation and success of a product" studies the success factors identification in eco-innovation. The critical success factors are identified on the basis of the ERP database and questionnaires concerning implementation of an eco-innovation. The proposed methodology enables a merger of objective indices and subjective judgments with the use of fuzzy logic.

The next chapter shows the significance of ergonomics in sustainable production. That aspect which also relates to social responsibility is limited not only to protection of precious virtues of the natural environment, but also refers to care about employees and awareness of the fact that they are a significant part of the company.

The last chapter presents a study of the available information technology tools which support the analysis of production process efficiency in the ecological context.

We would like to thank all authors who responded to the call for chapters and submitted manuscripts to this volume. Although not all of the received chapters appear in this book, the efforts spent and the work done for this book are very much appreciated.

We would like to thank all reviewers whose names are not listed in the volume due to the confidentiality of the process. Their voluntary service and comments helped the authors to improve the quality of the manuscripts.

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Contents

Part I
Supply Chain Sustainability

A Methodology for Green Supplier Selection in Food Industries

Narges Banaeian, Hossein Mobli, Izabela Ewa Nielsen and Mahmood Omid

Abstract Supplier selection process is a key operational function to develop sustainable partnerships and enhance the supply chain performance. This chapter aims to develop an applicable methodology for green supplier selection in food industry. The methodology consists of two phases of classification and ranking of criteria, and the supplier selection phase. In first phase 10 criteria of supplier selection with two dimensions (conventional and green) are identified. Then the criteria are examined and ranked by evaluation factors (frequency in references, adaptation with kind of product, easily understand and easily measurement). The financial, qualitative, service and environmental management system criteria are selected as high ranked criteria. In second phase, potential suppliers are evaluated by high ranked criteria. Group decision making using fuzzy and grey set theories helped to give better results in green supplier selection. At the end of this study in order to demonstrate effectiveness of the proposed methodology, it is applied for a case of edible oil industry for packaging material supplier selection. The results of this study will support the company to establish the methodology to rank and select the best green suppliers within a set of criteria.

Keywords Packaging material supplier · Green purchase · Multi criteria decision making · Fuzzy grey relational analysis

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1 Introduction

Supplier selection is the process which companies identify, evaluate and contract with suppliers (Beil 2010). Competitive international business circumstances made many companies to focus on supply chain management and supplier selection. Once a supplier becomes part of a well-managed and established supply chain, the relationship between the buyer and supplier will have a viable effect on the competitiveness of the entire supply chain. Also most of the companies have been spending considerable amount of their revenues on purchasing, therefore supplier selection process has become one of the most important issues for establishing an effective supply chain management system (Singh et al. 2012).

Formerly companies made decisions just on price, but after study in the supplier selection area started in 1960s, another criteria became determinant. The suppliers selection is a complex decision making problem, which should include both quantitative, and qualitative criteria, as well as global criteria to account effectively for suppliers performance (Ho et al. 2010). Some researchers agreed that a combination of factors should fit not only the technical requirements, but also the company's strategy (Cheraghi et al. 2004).

Traditional supplier selection models focus on supplier's economic and technical efficiency while ignoring the ecological efficiency of the supplier. Nowadays organizations should aim towards spreading environmental awareness amongst the suppliers, along with offering incentives to them to become environment-friendly. Organizations are now demanding that their suppliers reduce their environmental impacts while doing so themselves (Kumar et al. 2014).

Packaging industry plays a vital role in terms of protection, storage and hygienic handling of a product and it plays a key role in the marketing mix. A distinctive, unmistakable and eye-catching appearance is a signal at the point-of-sale to which all customers respond positively. During the packaging material supplier (PMS) selection process, many factors need to be analyzed. A food manufacturer must evaluate potential packaging suppliers according to some of the following delicate characteristics when selecting a PMS (Levary 2007): availability of the technological base necessary to produce the packaging material; availability of the skilled labor force necessary to produce the packaging material; a requisite standard of quality program; technical support for maintaining the components; volume flexibility to manufacture different lot sizes; product flexibility to efficiently manufacture many different products; effectiveness in protecting the manufacturer's proprietary information; reliability of supplier and reliable suppliers supplying the manufacturer's supplier; reliable transportation companies serving the route between the supplier location and that of the manufacturer; low country risk; which includes political, natural or man-made disasters and currency convertibility risk; and risk of disruption to the manufacturer's production.

Food companies are closely monitored by their customers who want to be confident that the food being purchased is safe and environmental friendly. In this regard, they are usually asked to pass an independent audit to check good manufacturing, hygiene and environmental practice (Losito et al. 2011).

Environmentally-friendly (sustainable) packaging's materials help reduce global warming, carbon footprint and greenhouse gases. In addition, they divert tons of plastic and other non-degradable materials from our landfills. Sustainable packaging is a relatively new addition to the environmental considerations for packaging, so selection of green packaging supplier has a pivotal role in green supply chain of food production.

In this chapter a methodology for green supplier selection (GSS) in food industry is developed. Systematic integration of technique for order of preference by similarity to ideal solution (TOPSIS), analytic hierarchy process (AHP) and grey relational analysis (GRA) techniques is implemented. A case study on determination of criteria and ranking of potential packaging material suppliers in food company is illustrated.

2 Literature Review

Typically there are two kinds of supplier selection approaches: single sourcing and multiple sourcing (Ghodsypour and Obrien 1998). In the first kind of supplier selection, one supplier can satisfy all the buyer's requirements but in multiple sourcing company need to select a collection of selected suppliers and their allocations. Purchase manager makes a strategic plan for the number of suppliers according to the specifications of the company, product and market.

2.1 Decision Making Techniques in Supplier Selection

There are several different decision making techniques used mostly for supplier selection divided in three main group of multi-criteria decision making (MCDM), mathematical programming and artificial intelligence techniques as shown in Fig. 1 (Chai et al. 2013). Ranking results of MCDM and mathematical programming in multiple source approaches, are developed to determinate allocation of high ranked suppliers (Ghodsypour and Obrien 1998). Chai et al. (2013) indicated that the most frequently used technique in supplier selection is AHP followed by linear programming and TOPSIS. Recently combination between techniques is usually adopted to deal with the problem of supplier selection. Ho et al. (2010) and Govindan et al. (2013) divided decision making techniques used for supplier selection into individual approaches and integrated approaches critically. The use of appropriate techniques can bring effectiveness and efficiency to the selection process (Boer et al. 1998). Techniques are differing from several aspects of: supporting decision maker group, type of criteria, number of potential suppliers and criteria, criteria independence, uncertainty, agility in decision process and complexity in computations. To select techniques one must take into account the alignment of the particularities of the problem at hand with the characteristics of the techniques (Junior et al. 2014).

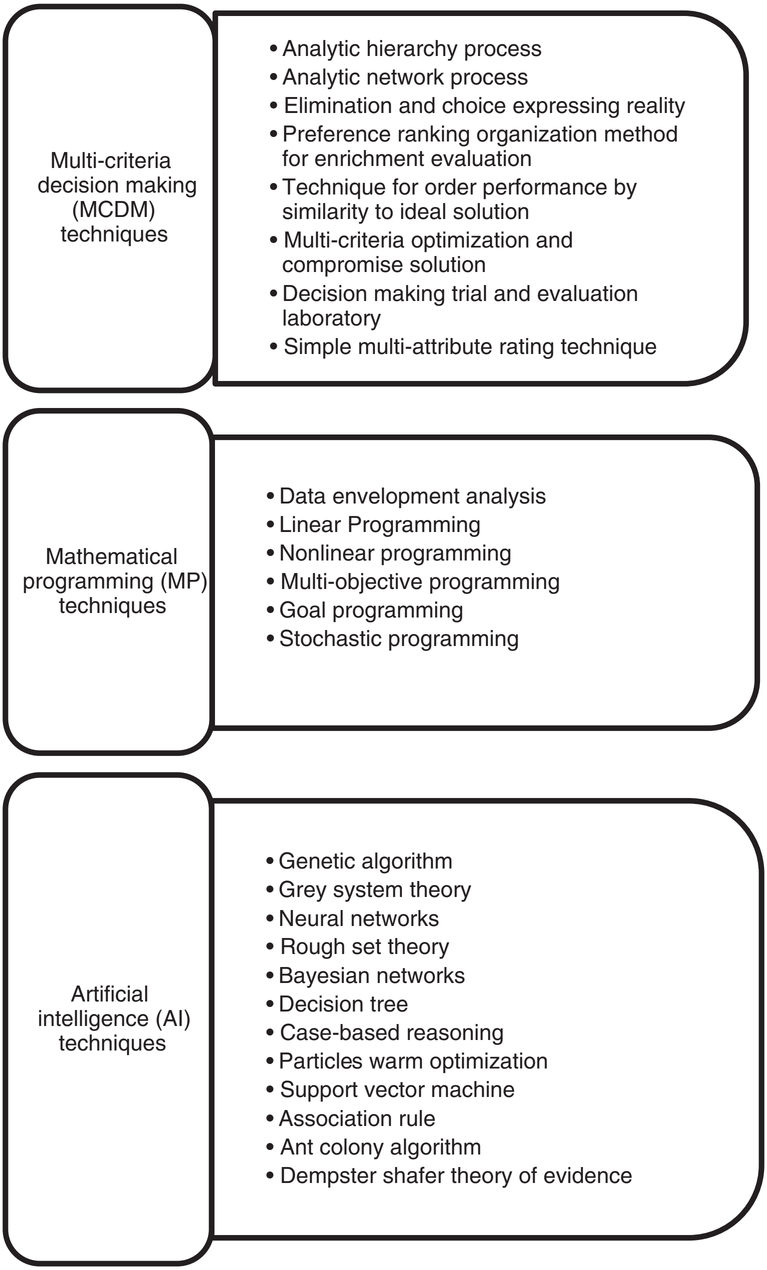

Fig. 1 The summary of used decision making techniques in supplier selection

2.2 Supplier Selection Criteria

Decision making on supplier selection is based on criteria, so definition and selection of criteria has an important role in the selection process. Traditionally, companies considered only the price when evaluating supplier performance. Relying on a single criterion makes the supplier selection process risky, therefore a multi criteria approach is recommended. Conventional supplier selection criteria generally intend to cover issues such as quality, capacity in terms of finance, services, and equipment, quantity, responsiveness, and others.

Today purchasing process has becomes more complicated as a result of increased environmental pressures; now many companies not only consider price, quality, delivery and etc. but also environmental issues and the measurement of their suppliers' environmental performance (Humphreys et al. 2006). Green supplier selection criteria arise from an organization inclination to respond to any existing trends in environmental issues related to business management and processes.

Quantitative environmental criteria articulated in economic terms and qualitative environmental criterion which focuses on more intangible (e.g. company image and reputation) have been used for supplier selection (Govindan et al. 2013). The major criteria considered in literature are environmental management system and quality (Grisi et al. 2010). Table 1 shows the most relevant criteria for conventional supplier selection and green supplier selection proposed in review paper.

Table 1 The most relevant criteria proposed in review paper

Approach	Duration	The most relevant criteria
Conventional supplier selection		
Weber et al. (1991)	1966–1990	Price, delivery, quality, production facilities and capacity
Dikson (1996)	1996	Quality, delivery, performance history, warranties and claim policies
Cheraghi et al. (2004)	1966–2001	Price, delivery, quality, production facilities and capacity
Ho et al. (2010)	2000–2008	Quality, delivery, price, manufacturing capability
Thiruchelvam and Tookey (2011)	1966–2010	Price, delivery, quality, production facilities and capacity
Green supplier selection		
Govindan et al. (2013)	1996–2011	Environmental management system, green image, design for environment, environmental improvement costs, green competencies
Nielsen et al. (2014)	1996–2013	Environmental management system, green image, environmental (green) competences, design for environment, environmental improvement costs

Collecting the relevant criteria help the decision maker to realize the effective items in both conventional and green supplier selection. Having the most relevant criteria makes decision making more precise and easier.

2.3 Supplier Selection in Packaging and Food Industries

Kumar et al. (2011) studied supplier selection process for food packaging, and combined closed loop supplier selection modeling framework and the total cost of ownership model in the selection of low-cost packaging material. Although they didn't note environmental criteria in packaging supplier selection but considered risk of disruption, volume and product flexibility and innovation as specific criteria for PMS selection. Also Magdalena (2012) studied green packaging supplier selection of food industry focusing on limited criteria and using combination of Taguchi loss function and fuzzy AHP techniques. He considered four criteria of quality, delivery, completeness and environmental management in terms of cost. Cost based models convert every criterion based solely on price which is sometimes impossible for qualitative criteria; the buyer-supplier relationships based solely on price criterion are no longer applicable.

Vachon and Klassen (2006) examined the impact of environment-related interactions in the supply chain of the Canadian and United States package printing industry on operational performance. The results indicate that green project partnership with customers in package industry was positively linked to quality, flexibility and environmental performance. The literature shows that there are few studies on supplier selection of packaging and food industries which most of them overlooked environmental and sustainability issues in supplier selection process. Therefore it is necessary to focus on GSS in food industry.

The area of criteria selection is not well investigated. There are some gaps and overlaps in considered criteria of the literature. Any changes in government policy, market development and customer preferences will change the criteria for supplier selection (Igrashi et al. 2013). It is necessary to develop methods which effectively link the issue of criteria selection and supplier selection. Previous studies insist on fixed and limited criteria for supplier selection, but the proposed methodology in this chapter is flexible and before starting supplier selection process allows the decision makers for candida ting, ranking and choosing criteria for supplier selection.

2.4 Method Selection for Green Supplier Selection

According to literature review, there are many methods for supplier selection but AHP, TOPSIS and GRA are the most relevant methods in supplier selection due to broad set of applications, intuitive and easy to use (Chai et al. 2013; Govindan et al. 2013).

Based on Saaty (1990) AHP has a built-in mechanism for input validation. Also AHP, known for its flexibility and ability to decompose a decision problem (Oztaysi 2014), is used to determine the weights of the evaluation factors and criteria then these weights are later used in TOPSIS and GRA respectively.

The main idea of TOPSIS is that the best alternatives should have farthest distance from the negative ideal solution and the shortest distance from the positive ideal solutions. TOPSIS method is agile and well suited to the problem of decision making in regard to changes and number of alternatives and criteria. Also TOPSIS can analyze both qualitative and quantitative criteria (Junior et al. 2014). Therefore in this chapter, criteria selection procedure is based on TOPSIS technique and required data are derived from purchase manager who is often experienced in supplier selection of food industries. Candidate criteria rank based on evaluation factor which is aligned with company policy and goals.

In decision making process of supplier selection, the decision makers try to gather as much information as possible through surveys, investigations, sampling, etc. To reach the aspired decision obtaining all the information is impossible; therefore decisions are usually made in uncertain process, i.e. without complete information. This is where GRA, finds application in solving MCDM problems (Oztaysi 2014; Zhang and Liu 2011). In comparison with conventional evaluation methods, the GRA possesses several advantages: calculations are simple, requires small samples, sample distribution is not needed as per probability theory, no confliction between subjective and objective data sets and it is effective in dealing with distributed statistics (Deng 1989; Wu 2002; Goyal and Grover 2012).

In many situations of real world, precise description is impossible; therefore approximations (or fuzziness) must be introduced. Fuzzy logic can transform uncertain human knowledge into a mathematical formula (Zadeh 1965). Combining fuzzy sets to decision making methods will lead to realistic results. Subjective judgment of decision maker has encouraged application of group decision making which uses an expert team to make final decision. Finally fuzzy GRA technique has been named for green supplier selection.

This chapter will support decision makers in developing methodology for nominating, order ranking and choosing effective criteria and then selecting green supplier. Criteria selection is based on evaluation factors which are weighted by AHP and using TOPSIS analysis high ranked criteria collected for GSS. Then high ranked criteria are weighted by AHP and suppliers ranked using fuzzy GRA.

3 Methodology

The methodology proposed in this chapter, support the decision maker to find criteria which is firstly adapted to company policy and then accomplish the supplier selection procedure.

This methodology has been developed in two main phases of criteria selection and supplier selection. The two-phase multi criteria methodology is as follows:

1. Identifying the regular conventional and green criteria for supplier selection from review papers, weighting the evaluation factors using AHP, and then determining the most suitable criteria based on expert opinions using TOPSIS.
2. Giving weights to the determinant criteria using AHP, examining potential suppliers and transforming linguistic variable (expert team opinion) to fuzzy numbers, evaluating and ranking the potential alternatives using GRA.

The proposed supplier selection process is shown in Fig. 2 and phases of supplier selection process are explained below in details.

This methodology can find company preferences systematically; rank all potential suppliers, and finally select correspondent supplier by five main steps (Fig. 3):

(a) Review company requirements and literature. Make a set of candidate criteria and determine evaluation factor for ranking criteria based on company preferences;
(b) Conduct pairwise comparisons of evaluation factors by expert team manager, and calculate evaluation factors weights using AHP technique;
(c) Score candidate criteria based on evaluation factors, construct decision matrix and rank candidate criteria using evaluation factors weights and TOPSIS technique;

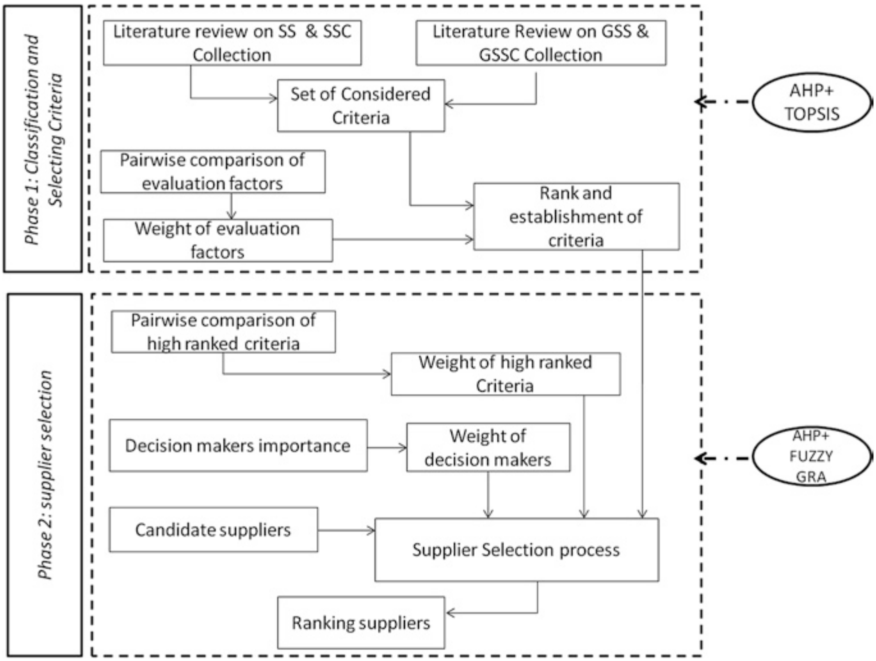

Fig. 2 Structural methodology for green supplier selection

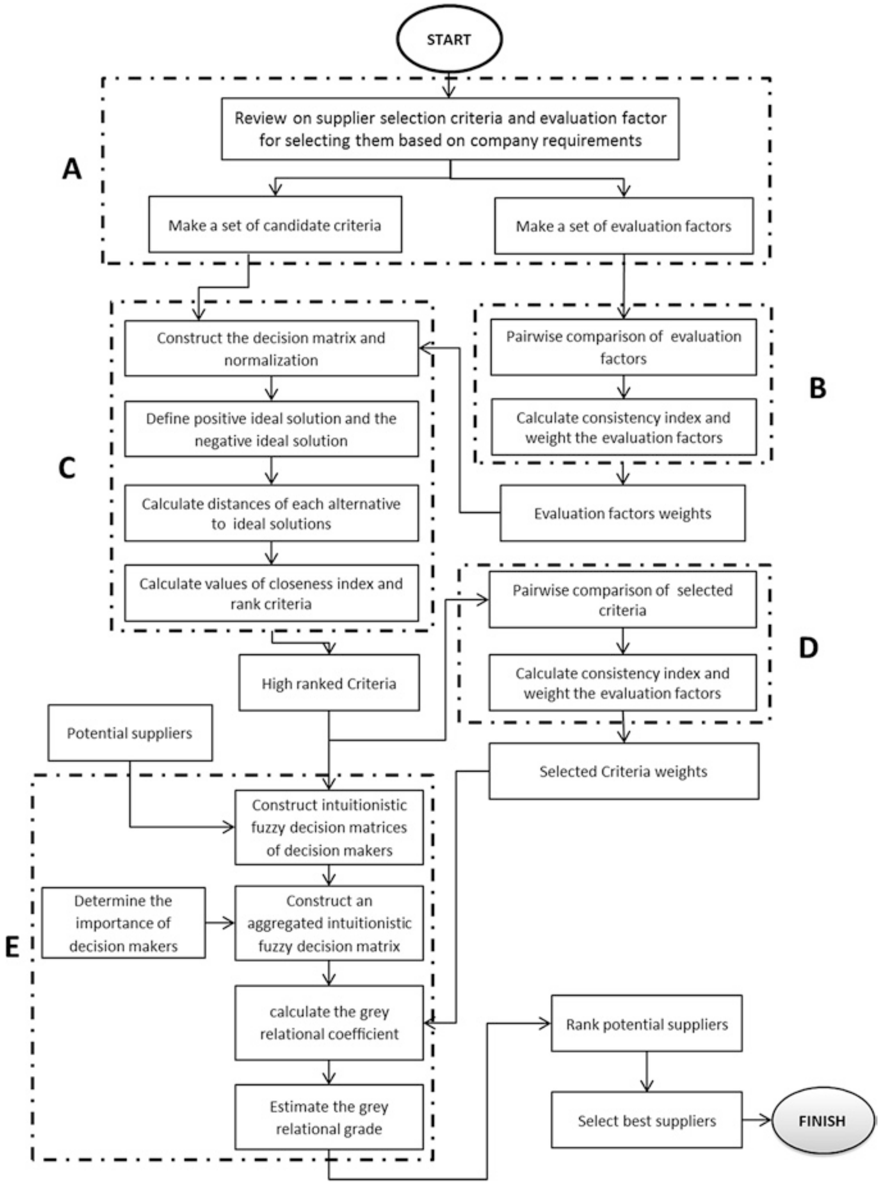

Fig. 3 Step by step procedure of green supplier selection

(d) Calculate high ranked criteria weights in similar way to evaluation factors weights;
(e) Find potential suppliers by initial screening. Score potential suppliers based on high ranked criteria, then rank potential suppliers using high ranked criteria weights and Fuzzy GRA technique.

The whole procedure is presented in food industry. In the next section, the methodology is fully illustrated step by step according to Fig. 3.

4 Numerical Case Study

To demonstrate the presented MCDM methodology, real survey from a case study (edible oil company) is given. This company is one of the well-known and biggest Iranian edible oil companies which has five huge manufacturing units for extracting and refining of edible oil and detergent accessories production.

The company packages productions in three forms of glass, Polyethylene terephthalate (PET) bottles, and steel sheet (tin). Glass bottle application is limited and uses only for some olive oil. This company desires to select from PMS of PET granule and tin.

For judgment about suppliers, it is difficult to obtain precise preferences of decision makers because of two reasons: (1) The decision data of human preferences are often vague, (2) As improvement of greening depends on environmental (planet), social (people) and economical (profit) aspects, decision makers may not be able to evaluate suppliers from all these aspects. While one decision maker might have economic expertise, another might have experience with environment-related issues. An expert team nominated from different position (purchase manager, purchase staff, environmental expert, and research and development staff), also the importance of each decision maker in expert team is considered.

The details of proposed methodology applied in the case study described in following sections from part A to E (see Fig. 3).

4.1 Part A

Criteria selection is based on evaluation factors. Evaluation factors determine and prioritize the characteristics which company expected from criteria. According to company preferences four evaluation factors of frequency in references, adaptation with kind of product, easily understanding and easily measurement selected to examine candidate criteria.

Several factors may affect a supplier's performance. The most relevant criteria from conventional supplier selection and green supplier selection review papers collected as set of candidate criteria (Table 1). According to conventional supplier selection papers qualitative, financial, service, and management and organization criteria are the most important criteria. Similarly from the green supplier selection papers environmental management system (EMS), green image, design for environment (DE), environmental improvement costs (EIC) and green competencies are the most important criteria.

4.2 Part B

Weights of four evaluation factors are calculated based on pairwise comparisons (by means of a nine points Likert scale) which represent the importance of evaluation factors. A questionnaire according to the format proposed by Humphreys et al. (2003), ought to be carried out to determine the weight of evaluation factors.

According to Saaty (1990) pairwise comparisons are classically carried out by asking the decision maker about the value of a criterion (C1) when compared to another criterion (C2) with respect to overall goal, then verbal judgments of the decision maker are transformed into numerical values (Oztaysi 2014). The verbal judgments of the decision makers are then transformed into numerical values using the scale presented in Table 2.

The pairwise comparisons of evaluation factors can be summarized in a square evaluation matrix A = (a_{ij}) where every element ($i, j = 1, 2, \ldots, n$) is the quotient of weights of the evaluation factors. After construction of square and reciprocal matrix (Eq. 1), the procedure of developing weights in AHP which is described in Saaty (1990) has been done.

$$\mathrm{A} = (a_{ij}) = \begin{pmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{pmatrix}; \ \mathrm{A} = \begin{bmatrix} 1 & \frac{1}{5} & \frac{1}{2} & \frac{1}{3} \\ 5 & 1 & 3 & 2 \\ 2 & \frac{1}{3} & 1 & \frac{1}{2} \\ 3 & \frac{1}{2} & 2 & 1 \end{bmatrix} \quad (1)$$

In the next point, matrix is normalized and the relative weights are calculated. The relative weights are given by the right eigenvector (w) corresponding to the largest eigenvalue ($\lambda_{\max}$), as:

$$A_w = \lambda_{\max}.w \quad (2)$$

If the pairwise comparisons are completely consistent, the matrix A has rank 1 and $\lambda_{\max} = n$. In this case, weights can be obtained by normalizing any of the rows or columns of A (Saaty 1990). It should be noted that the quality of the output of the AHP is related to the consistency of the pairwise comparison. Consistency index (CI) are calculated (Eq. 3) for pairwise comparison matrix and checked for consistency ratio (Eq. 4) using a random index (RI) presented in Table 3 (Saaty 1990).

Table 2 Verbal judgments and numerical rate

Verbal judgment of preference	Numerical rate
Equal importance	1
Weal importance of one over another	3
Essential or strong importance	5
Demonstrated importance	7
Absolute importance	9
Intermediate values between the two adjacent judgments	2, 4, 6, 8

Table 3 Random index

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 4 Evaluation factors weights using AHP

Evaluation factor	Frequency in references (F_1)	Adaptation with kind of product (F_2)	Easily understand (F_3)	Easily measurement (F_4)
weight	0.09	0.48	0.16	0.27

$$CI = \frac{\lambda \max - n}{n - 1} \quad (3)$$

$$CR = \frac{CI}{RI} \quad (4)$$

The number 0.1 is the accepted upper limit for CR. If the final consistency ratio exceeds this value, the evaluation procedure has to be repeated to improve consistency (here CR = 0.004). Table 4 represents a set of grades of evaluation factors importance obtained AHP.

Results showed that adaptation with kind of product is the most important factor for considering criteria in supplier selection process which often overlook.

4.3 Part C

Candidate criteria are ranked by TOPSIS technique using a nine point likert scale with 1 as lowest and 9 as highest. TOPSIS is a multiple criteria decision making method which is initially proposed by Hwang and Yoon (1981). The technique is based on the idea that the optimal solution should have the shortest distance from the positive ideal solution and the farthest from the negative ideal solution (Oztaysi 2014). A solution is determined as a positive ideal solution if it maximizes the benefit criteria or minimizes the cost criteria. On the other hand, the solution which maximizes the cost criteria or minimizes the benefit criteria is called the negative ideal solution (Wang and Elhag 2006).

Candidate criteria are scored based on four evaluation factors by purchase manager of company (Table 5) and composed decision matrix.

In the initial step of the technique, decision matrix ($i = alternatives, j = evaluation\ factors$) are constructed. After composing decision matrix, normalized decision

Table 5 Criteria scored based on four evaluation factors

Criteria	Evaluation factor			
	Frequency in references (F_1)	Adaptation with kind of product (F_2)	Easily understand (F_3)	Easily measurement (F_4)
Qualitative ($\boldsymbol{A_1}$)	9	9	9	7
Financial ($\boldsymbol{A_2}$)	7	7	9	9
Management and organization ($\boldsymbol{A_3}$)	6	8	6	4
Services ($\boldsymbol{A_4}$)	9	9	9	8
Production technology ($\boldsymbol{A_5}$)	6	6	7	6
EMS ($\boldsymbol{A_6}$)	9	9	8	7
Green image ($\boldsymbol{A_7}$)	6	7	6	5
DE ($\boldsymbol{A_8}$)	4	6	6	5
EIC ($\boldsymbol{A_9}$)	4	6	8	9
Green competencies ($\boldsymbol{A_{10}}$)	5	7	7	6

matrix (N_D) will be formed by using Eq. 5 then the normalized value is multiplied in criteria weight derived from AHP analysis and weighted normalized matrix will be composed.

$$n_{ij} = \frac{r_{ij}}{\sqrt{\sum_i r_{ij}^2}} \tag{5}$$

Decision matrix normalized by using Eq. 5 and formed normalized matrix of N_D. For example the normalized value for n_{11} can be represented as:

$$n_{11} = \frac{9}{\sqrt{9^2 + 7^2 + 6^2 + 9^2 + 6^2 + 9^2 + 6^2 + 4^2 + 4^2 + 5^2}} = 0.42 \tag{6}$$

Evaluation factors weights (Table 4) transformed to a diagonal matrix and multiple to normalized matrix (N_D) and composed weighted normalized matrix of V.

$$N_D = \begin{bmatrix} 0.42 & 0.37 & 0.37 & 0.32 \\ 0.32 & 0.29 & 0.37 & 0.41 \\ 0.28 & 0.33 & 0.24 & 0.18 \\ 0.42 & 0.37 & 0.37 & 0.37 \\ 0.28 & 0.25 & 0.29 & 0.27 \\ 0.42 & 0.37 & 0.33 & 0.32 \\ 0.28 & 0.29 & 0.24 & 0.23 \\ 0.18 & 0.25 & 0.24 & 0.23 \\ 0.18 & 0.25 & 0.33 & 0.41 \\ 0.23 & 0.29 & 0.29 & 0.27 \end{bmatrix} \quad \mathrm{V} = \begin{bmatrix} 0.03 & 0.18 & 0.05 & 0.08 \\ 0.02 & 0.14 & 0.05 & 0.11 \\ 0.02 & 0.16 & 0.03 & 0.05 \\ 0.03 & 0.18 & 0.05 & 0.10 \\ 0.02 & 0.12 & 0.04 & 0.07 \\ 0.03 & 0.18 & 0.05 & 0.08 \\ 0.02 & 0.14 & 0.03 & 0.06 \\ 0.01 & 0.12 & 0.03 & 0.06 \\ 0.01 & 0.12 & 0.05 & 0.11 \\ 0.02 & 0.14 & 0.04 & 0.07 \end{bmatrix} \tag{7}$$

As stated previously, in TOPSIS technique, best alternatives have shortest distance from the positive ideal solution and the longest distance from the negative ideal solution calculated by closeness index (CI). The positive ideal solution (A^+) is determined by selecting the largest normalized and weighted score for each criterion. Similarly, the negative ideal solution (A^-) is determined by selecting the least normalized and weighted score of each criterion (Roy 2004). So based on definition, the positive ideal solution and the negative ideal solution are:

$$A^+ = [0.037, 0.182, 0.059, 0.113] \tag{8}$$

$$A^- = [0.016, 0.121, 0.039, 0.050] \tag{9}$$

The distances of each alternative to the positive ideal solution R^+ and negative ideal solution R^- calculated.

$$R_i^+ = \sqrt{\sum_{j=1}^{n} (\vartheta_{ij} - \vartheta_j^+)^2} \quad \textit{for the alternative } i, i = 1, 2, \ldots, m \tag{10}$$

$$R_i^- = \sqrt{\sum_{j=1}^{n} (\vartheta_{ij} - \vartheta_j^-)^2} \quad \textit{for the alternative } i, i = 1, 2, \ldots, m \tag{11}$$

where ϑ_i^+ is the positive ideal, ϑ_i^- is the negative ideal for the evaluation factor j.

Using these calculated values closeness index (CI) for each alternative is computed using Eq. (12):

$$\textit{Closeness index } (CI) = \frac{(R)^-}{(R)^+ + (R)^-} \textit{for the alternative } i \tag{12}$$

The closeness index (CI) can get values between 0 and 1 and the alternative which has the highest CI is selected as the best alternative (Oztaysi 2014).

The distances of each alternative to the positive ideal solution (R^+) and negative ideal solution (R^-) and closeness index (CI) are calculated preference order ranked as shown in Table 5. Also the ranking in Table 6 shows that qualitative, service, EMS and financial criteria are the high ranked and most important criteria for this case study.

4.4 Part D

Company decided to use four high ranked criteria (service, qualitative, EMS and financial criteria) for supplier selection, because more than four criteria make the process too complicated and less may decrease certainty of the decision. Description of high ranked criteria is in Table 7.

Table 6 Distances of each alternative to the positive and negative ideal solution closeness index and ranking of criteria

Criteria	R^+	R^-	CI	Rank
Qualitative	0.025	0.077	0.754	2
Financial	0.041	0.070	0.628	4
Management and organization	0.070	0.041	0.371	6
Services	0.012	0.084	0.869	1
Production technology	0.073	0.027	0.270	8
EMS	0.025	0.075	0.744	3
Green image	0.068	0.025	0.268	9
DE	0.084	0.012	0.130	10
EIC	0.064	0.064	0.498	5
Green competencies	0.059	0.033	0.358	7

Table 7 Description of high ranked criteria

Criteria	Description
Service	On time delivery, after sales service and production capacity
Qualitative	Quality of material, labor and operation
Financial	Proposed price, capital and financial power of company
EMS	Environmental prerequisite, planning and certificates

High ranked criteria interfere in supplier selection process which may not be assumed to be equal importance. Weight of high ranked criteria calculated in a similar way to section B (Eqs. 1–4) from the paired comparison between the criteria. After pairwise comparison, evaluation matrix constructed (Eq. 13) and weights computed using AHP method.

$$A = \begin{bmatrix} 1 & \frac{1}{6} & \frac{1}{4} & \frac{1}{3} \\ 6 & 1 & \frac{1}{3} & 3 \\ 4 & 3 & 1 & 5 \\ 3 & \frac{1}{3} & \frac{1}{5} & 1 \end{bmatrix} \tag{13}$$

In this research *W* represents a set of grades of four high ranked criteria importance (Table 8).

4.5 Part E

After initial screening, some candidates (i.e. potential alternatives for PMS) are selected by experts but the names are not given and abbreviated in a_1, a_2 and a_3 for steel sheet suppliers and b_1, b_2 and b_3 for PET granule suppliers.

Table 8 Criteria weight using AHP

w	Financial (w_1)	Services (w_2)	Qualitative (w_3)	EMS (w_4)
Value	0.07	0.28	0.53	0.12

Potential suppliers are ranked based on high ranked criteria using fuzzy GRA technique. Fuzzy set theory (Zadeh 1965) has been extensively used for modeling decision making processes based on imprecise and vague information such as judgment of decision makers. Also Grey System Theory (GST) is a mathematical method that is applied to imprecise information in the form of interval values and developed by Deng (1989).

General description in concept of intuitionistic fuzzy set (IFS) has been explained in following. If X be a fixed set, an IFSA in X is given by Atanassov (1986) as follows:

$$A = \{(x, \mu_A(x), \nu_A(x))|x \in X\} \tag{14}$$

where the functions $\mu_A(x) : X \to [0, 1],\ x \in X \to \mu_A(x) \in [0, 1]$ and $\nu_A(x) : X \to [0, 1],\ x \in X \to \nu_A(x) \in [0, 1]$ satisfy the condition $0 \le \mu_A(x) + \nu_A(x) \le 1$ for all $x \in X$.

The numbers $\mu_A(x)$ and $\nu_A(x)$ define the degree of membership and non-membership for the element $x \in X$ to the set A, respectively.

Ratings of potential alternatives with respect to selected criteria could be expressed using linguistic variables presented in Table 9, then linguistic variables can convert to intuitionistic fuzzy numbers (IFN) (Junior et al. 2014; Zhang and Liu 2011).

Afterward the intuitionistic fuzzy decision matrices of each decision maker for selection of two kind suppliers a (steel sheet) and b (PET granule) constructed, and the linguistic evaluation converted into IFNs. Finally the intuitionistic fuzzy decision matrices (R) of each decision maker for each supplier formed. For example matrix R_{a2}(3 × 4; three potential suppliers of steel sheet and four high ranked criteria) is related to opinion of second decision maker (d_2) for supplier a:

$$R_{a2} = \begin{bmatrix} (0.85,\ 0.1,\ 0.05) & (0.65,\ 0.25,\ 0.1) & (0.85,\ 0.1,\ 0.05) & (0.65,\ 0.25,\ 0.1) \\ (0.35,\ 0.55,\ 0.1) & (0.25,\ 0.65,\ 0.1) & (0.05,\ 0.95,\ 0) & (0.65,\ 0.25,\ 0.1) \\ (0.5,\ 0.4,\ 0.1) & (0.95,\ 0.05,\ 0) & (0.85,\ 0.1,\ 0.05) & (0.65,\ 0.25,\ 0.1) \end{bmatrix} \tag{15}$$

Table 9 Conversion between linguistic variables and IFNs

Number	Linguistic variables (Importance)	IFNs
1	Extreme low (EL)	(0.05, 0.95, 0.00)
2	Very low (VL)	(0.15, 0.80, 0.05)
3	Low (L)	(0.25, 0.65, 0.10)
4	Medium low (ML)	(0.35, 0.55, 0.10)
5	Medium (M)	(0.50, 0.40, 0.10)
6	Medium high (MH)	(0.65, 0.25, 0.10)
7	High (H)	(0.75, 0.15, 0.10)
8	Very high (VH)	(0.85, 0.10, 0.05)
9	Extreme high (EH)	(0.95, 0.05, 0.00)

The importance of decision makers in the group decision making process are shown in Table 10. These linguistic variables used can be converted into IFNs (Zhang and Liu 2011) and weight of decision makers are calculated using Eq. (16).

$$\lambda_k = \frac{(\lambda_k + \mu_k(\frac{\mu_k}{\mu_{k+v_k}}))}{\sum_{k=1}^{t}(\mu_k + \pi_k(\frac{\mu_k}{\mu_{k+v_k}}))} \quad (16)$$

where $\sum_{k=1}^{t} \lambda_k = 1$ ($k = number\ of\ decision\ makers$).

In group decision making process, all the individual decision opinions need to be fused into a group opinion to construct an aggregated intuitionistic fuzzy decision matrix. In order to do that, the IFWA operator given by Xu (2007) is utilized:

$$\begin{aligned} r_{ij} &= \mathrm{IFWA}_\lambda\left(r_{ij}^{(1)}, r_{ij}^{(2)}, \ldots, r_{ij}^{(t)}\right) = \lambda_1 r_{ij}^{(1)} \oplus \lambda_2 r_{ij}^{(2)} \oplus \cdots \oplus \lambda_t r_{ij}^{(t)} \\ &= 1 - \prod_{k=1}^{t}\left(1 - \mu_{ij}^{(k)}\right)^{\lambda_k}, \prod_{k=1}^{t}\left(\left(\nu_{ij}^{(k)}\right)^{\lambda_k}\right), \prod_{k=1}^{t}(1 - \mu_{ij}^{(k)})^{\lambda_k} - \prod_{k=1}^{t}((\nu_{ij}^{(k)})^{\lambda_k}) \end{aligned} \quad (17)$$

Therefore according to Eq. 17 all the intuitionistic fuzzy decision matrices $(R_{a1}, \ldots, R_{a5})$ aggregated into a complex intuitionistic fuzzy decision matrix R_a.

$$R_a = \begin{bmatrix} (0.15,\ 0.11,\ 0.04) & (0.21,\ 0.15,\ 05) & (0.22,\ 0.16,\ 0.06) & (0.33,\ 0.24,\ 0.09) \\ (0.58,\ 0.48,\ 0.1) & (0.65,\ 0.55,\ 0.1) & (0.72,\ 0.65,\ 0.07) & (0.53,\ 0.43,\ 0.1) \\ (0.39,\ 0.31,\ 0.07) & (0.34,\ 0.28,\ 0.05) & (0.23,\ 0.19,\ 0.04) & (0.38,\ 0.31,\ 0.07) \end{bmatrix} \quad (18)$$

Next point is forming of reference sequence which is the optimal sequence of the criteria values. In the intuitionistic fuzzy decision matrix, the maximum value $\alpha^+ = (1, 0, 0)$ can be used as the reference value. That, in this case the reference sequence r_0 is:

$$r_0 = (r_{0j})_{1\times n} = \left[\alpha^+ \alpha^+ \ldots \alpha^+\right]\ (n = number\ of\ criteria) \quad (19)$$

Equation (19) is used in order to calculate the distance δ_{ij} between r_{ij} and r_{0j} (Table 11). Distance measure between two IFNs is defined as follows:

Let $\alpha_1 = (\mu_{\alpha 1}, \nu_{\alpha 1}, \pi_{\alpha 1})$ and $\alpha_2 = (\mu_{\alpha 2}, \nu_{\alpha 2}, \pi_{\alpha 2})$ be two IFNs, then

$$d(\propto_1, \propto_2) = \frac{1}{2}(\mu_{\alpha 1} - \mu_{\alpha 2} + \nu_{\alpha 1} - \nu_{\alpha 2} + \pi_{\alpha 1} - \pi_{\alpha 2}) \quad (20)$$

Table 10 The importance of decision makers

Acronym	Decision maker type	Linguistic variables	λ
d_1	Environmental expert	Important	0.22
d_2	Purchase manager	Very important	0.26
d_3	Research and development staff	Important	0.22
d_4	Purchase staff	Medium	0.15
d_5	Purchase staff	Medium	0.15

Table 11 Decision matrices (The distance δ_{ij} for suppliers)

Suppliers		Criteria			
		C1	C2	C3	C4
(a) Steel sheet	δ_{a_1j}	0.16	0.21	0.22	0.34
	δ_{a_2j}	0.58	0.65	0.73	0.53
	δ_{a_3j}	0.39	0.34	0.24	0.38
(b) PET granule	δ_{b_1j}	0.12	0.15	0.10	0.19
	δ_{b_2j}	0.47	0.57	0.41	0.44
	δ_{b_3j}	0.62	0.55	0.59	0.51

By comparing δ_{ij} and obtaining the biggest value $\delta_{\max}$ and the smallest value $\delta_{\min}$, the grey relational coefficient (ξ_{ij}) can be calculated by formula (Zhang and Liu 2011):

$$\xi_{ij} = \frac{\delta_{\min} + \rho\delta_{\max}}{\delta_{ij} + \rho\delta_{\max}} \quad i \in M,\ j \in N \tag{21}$$

Grey relation coefficient matrix (Ξ_a) for steel sheet suppliers is:

$$\Xi_a = \begin{bmatrix} 1 & 0.91 & 0.88 & 0.74 \\ 0.55 & 0.51 & 0.47 & 0.57 \\ 0.68 & 0.73 & 0.86 & 0.69 \end{bmatrix} \tag{22}$$

Grey relational grades are calculated by substituting grey relational coefficients and weights of high ranked criteria into Eq. (23) (Zhang and Liu 2011); shown in Table 12.

$$\gamma_i = \sum_{j=1}^{n} w_j \xi_{ij} \quad i \in M \tag{23}$$

w_j is calculated using AHP in section D (Table 8).

The greater the value of grey relational grade (γ), the better the alternative is. Alternatives are ranked according to descending order of grey relational grade:

$$\textit{potential supplier for steel sheet} \quad \gamma_{a_1} > \gamma_{a_3} > \gamma_{a_2} \tag{24}$$

$$\textit{potential supplier for PET granule} \quad \gamma_{b_1} > \gamma_{b_2} > \gamma_{b_3} \tag{25}$$

Thus the most appropriate PMS candidates are a_1 for steel sheet and b_1 for PET granule.

Table 12 Grey relational grade for suppliers

Suppliers	γ_1	γ_2	γ_3
Steel sheet (a)	0.88	0.50	0.79
PET granule (b)	0.94	0.47	0.40

The results of this methodology helped purchase manager to know packaging partner better and pick the right ones, those who are well matched with company business objectives and requirements. Suppliers a_1 for steel sheet and b_1 for PET granule are the best business partner. Collaborating with proposed suppliers will lead to several advantages such as more financial benefits, suitable services and quality. Also both proposed suppliers have environmental certificates such as ISO14000. According to location of company in residential region and government insistence on decreasing environmental issues, contracting with green suppliers will conform to company policies and provide less environmental impacts.

5 Conclusions

Definition and selection of criteria has an important role in supplier selection process. Ideally, a purchaser should be able to understand the strategic processes, recognize the strategic implications of environmental aspects and finally translate these implications into meaningful criteria for GSS. To achieve this aim, the current research presents a systematic methodology to make criteria selection by defining objectives (based on company requirements and policies) and using TOPSIS technique for criteria ranking. Criteria selection phase make the methodology flexible and can match with fluctuation in the company business objectives and requirements.

Supplier selection is a complex decision making problem that includes qualitative criteria and imprecise judgment of decision makers, so fuzzy sets and GST sets give better results in modeling decision making processes. Evaluation results for food industry show that the proposed methodology can provide reasonable outcomes with a smaller number of decision making units.

In this chapter, a methodology using the AHP-TOPSIS and AHP-fuzzy GRA, proposed for criteria selection and GSS. In order to demonstrate effectiveness of the methodology, it has been implemented in one of the food producer company and GSS process has been accomplished in steel sheet and PET granule suppliers.

Future researches can consider other environmental criteria (like Carbon footprint, greenhouse gas (GHG) emissions, life cycle assessment (LCA) of products and etc.) which currently have been focused on. These kinds of environmental subjects will provide more practical results in GSS, provided that suppliers trace its environmental footprint accurately.

Furthermore in future research the presented methodology will be implemented in a decision support system (DSS) to support purchase managers in selecting green suppliers according to the company's specific policies.

References

Atanassov KT (1986) Intuitionistic fuzzy sets. Fuzzy Sets Syst 20(1):87–96
Beil D (2010) Supplier selection. Encyclopedia of operations research and management science, Wiley, New York
Boer LD, Wegen LVD, Telgen J (1998) Outranking methods in support of supplier selection. Eur J Purch Supply Manage 4:109–118
Chai J, Liu JNK, Ngai EWT (2013) Application of decision-making techniques in supplier selection: a systematic review of literature. Expert Syst Appl 40:3872–3885
Cheraghi SH, Dadashzadeh M, Subramanian M (2004) Critical success factors for supplier selection: an update. J Appl Bus Res 20(2):91–108
Deng J (1989) Introduction to grey system theory. J Grey Syst 1(1):1–24
Dikson GW (1996) An analysis of vendor selection: systems and decisions. J Purchasing 1(2):5–17
Ghodsypour SH, Obrien C (1998) A decision support system for supplier selection using an integrated analytical hierarchy process and linear programming. Int J Prod Econ 56–57:199–212
Govindan K, Rajendran S, Sarkis J, Murugesan P (2013) Multi criteria decision making approaches for green supplier evaluation and selection: a literature review. J Clean Prod 1:1–18
Goyal S, Grover S (2012) Applying fuzzy grey relational analysis for ranking the advanced manufacturing systems. Grey Syst Theory Appl 2(2):284–298
Grisi RM, Guerra L, Naviglio G (2010) Supplier performance evaluation for green supply chain management. Bus Perform Meas Manage Part 4:149–163
Ho W, Xu X, Dey PK (2010) Multi-criteria decision making approaches for supplier evaluation and selection: a literature review. Eur J Oper Res 202(1):16–24
Humphreys PK, Wong YK, Chan FTS (2003) Integrating environmental criteria into the supplier selection process. J Mater Process Technol 138(1–3):349–356
Humphreys P, McCloskey A, Mclvor R, Maguire L, Glackin C (2006) Employing dynamic fuzzy membership functions to assess environmental performance in the supplier selection process. Int J Prod Res 44(12):2379–2419
Hwang CL, Yoon KP (1981) Multiple attribute decision making methods and applications. Springer, New York
Igrashi M, Boer L, Fet AM (2013) What is required for greener supplier selection? A literature review and conceptual model development. J Purchasing Supply Manage 19(4):247–263
Junior FRL, Osirob L, Carpinettia LCR (2014) A comparison between fuzzy AHP and fuzzy TOPSIS methods to supplier selection. Appl Soft Comput 21:194–209
Kumar S, Hong QS, Haggerty LN (2011) A global supplier selection process for food packaging. J Manufact Technol Manage 22(2):241–260
Kumar A, Jain V, Kumar S (2014) A comprehensive environment friendly approach for supplier selection. Omega 42:109–123
Levary RR (2007) Ranking foreign suppliers based on supply risk. Supply Chain Manage Int J 12(6):392–394
Losito P, Visciano P, Genualdo M, Cardone G (2011) Food supplier qualification by an Italian large-scale-distributor: auditing system and non-conformances. Food Control 22:2047–2051
Magdalena R (2012) Supplier selection for food industry: a combination of Taguchi loss function and fuzzy analytical hierarchy process. Asian J Technol Manage V 5(1):13–22
Nielsen IE, Banaeian N, Mobli H, Omid M (2014) Green supplier selection criteria: from a literature review to a flexible framework for determination of suitable criteria. In: Golinska P (ed) Eco production book series: logistic operations, supply chain management and sustainability. Springer, Switzerland, pp 79–100
Oztaysi B (2014) A decision model for information technology selection using AHP integrated TOPSIS-grey: the case of content management systems. Knowledge-based systems. http://dx.doi.org/10.1016/j.knosys.2014.02.010

Roy B (2004) Paradigms and challenges. In: Greco S, Figueira J, Ehrgott M (eds) Multiple criteria decision analysis: state of the art surveys. Springer, Berlin

Saaty TL (1990) How to make a decision: the analytic hierarchy process. Eur J Oper Res 48:9–26

Singh R, Rajput H, Chaturvedi V, Vimal J (2012) Supplier selection by technique of order preference by similarity to ideal solution (TOPSIS) method for automotive industry. Int J Adv Technol Eng Res (IJATER) 2(2):157–160

Thiruchelvam S, Tookey JE (2011) Evolving trends of supplier selection criteria and methods. Int J Automot Mech Eng (IJAME) 4:437–454

Vachon S, Klassen RD (2006) Green project partnership in the supply chain: the case of package printing industry. J Clean Prod 14(6):661–671

Wang YM, Elhag TMS (2006) Fuzzy TOPSIS method based on alpha level sets with an application to bridge risk assessment. Expert Syst Appl 31(2):309–319

Weber C, Current J, Benton W (1991) Vendor selection criteria and methods. Eur J Oper Res 50:2–18

Wu HH (2002) A comparative study of using grey relational analysis in multiple attribute decision making problems. Qual Eng 15(2):209–217

Xu ZS (2007) Intuitionistic fuzzy aggregation operators. IEEE Trans Fuzzy Syst 15(6):1179–1187

Zadeh LA (1965) Fuzzysets. Inf Control 8:338–353

Zhang SF, Liu SY (2011) A GRA-based intuitionistic fuzzy multi-criteria group decision making method for personnel selection. Expert Syst Appl 38:11401–11405

A Solution Approach for Agricultural Service Center Location Problem Using TOPSIS, DEA and SAW Techniques

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Abstract In this research, agricultural service centers have been introduced as a strategic decision to improve efficiency of agricultural supply chain. Since the location problems in agriculture exhibit several features, such as their large scope and size, and demonstrate increased levels of complexity, so the main aim of this study is developing an integrated Multi-Attribute Decision Making (MADM) approach considering all aspects of the Agricultural Service Center Location Problem (ASCLP) including: customers, service suppliers, and also technical suitability of candidate location. In this regard two main MADM approaches are developed. The first approach was the combination of Simple Additive Weighting (SAW), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and Data Envelopment Analysis (DEA). The second approach is developed to improve the solutions for some cases which the first approach was unable to reach to the non-dominated solutions. Before completing the MADM approaches, initially a Delphi fuzzy-analytical hierarchy process survey has been completed to extract the objectives and attributes of ASCLP and their local weight, which is published in previous work by the authors. The main contribution of current chapter is to consider more comprehensively the attributes in solving a service facility location problem such as: distances to demand points and also suppliers, cultivated area of demand points, population of demand points, number of cultivated crops, and the ration of irrigated cultivated lands to dried cultivated lands. The developed approach was able to use all mentioned decision methods, simultaneously. In the second approach, the developed attributes are used, two scores

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(maxi-min and maxi-max) for each candidate location is computed and non-dominated solutions are identified. To prove the capability of the selected attributes one case study is addressed. The results reveal that the chosen attributes to a very large degree can lead to the non-dominated solutions.

Keywords Supply chain · Agriculture · Service · Location · Decision making

1 Introduction

Agriculture is the only main sector which uses the land surface as an essential input into its production function. This wide geographical dispersion of agricultural commodities has an important economic consequence; transportation becomes essential to leave the outputs from the farm for consumption by others or if inputs are to be used on the farm to increase output (Timmer et al. 1983).

In supply chain design, locating and sizing facilities to serve customers is a critical part which presents a number of challenges. Customers are sensitive to the total cost of interacting with a firm's service, including time and access cost, in addition to price (Pangburn and Stavrulaki 2005). Lucas and Chhajed (2004) use a number of distinguishing features to identify location problems in agriculture. They believe that many agricultural location studies took place in developing countries, and most of these studies were initiated upon request of a government agency, because in developing areas, agriculture is a key sector: it provides food, stimulates foreign exchange earnings, and generates a large share of a country's total employment. The location problems in agriculture exhibit several features, such as their large scope and size, variation in time of different operations in agriculture in different areas, yield and quality variation of a given commodity due to inter-regional disparities in climate, or the consideration of multiple and often conflicting objectives such as: maximize a profit function, minimize cost; distance or time; number of facilities, government expectations from agricultural sector and its policies and, thus, demonstrate increased levels of complexity (Lucas and Chhajed 2004).

1.1 Agricultural Services

Several services can be given to the whole of agricultural supply chain. Some services are for farms, specifically. In the following section four types including: input supply, mechanization services, advisory services and financial services are discussed.

The majority of farm input supply companies are concentrated in urban areas or rural zones with large concentrations of commercial farmers. Therefore millions of poor farmers in rural areas without large commercial farmers do not have access to affordable agricultural inputs such as improved seeds, chemical fertilizers and other agro chemicals needed to help them raise their farm productivity

(Dorward and Chirwa 2011). So the location of agricultural input suppliers must be close to the farms to accelerate the input supply for them.

Agricultural mechanization includes the use of tools, implements and machines for agricultural land development, crop production, harvesting, and preparation for storage, storage, and on-farm processing. The manufacture, distribution, repair, maintenance, management and utilization of agricultural tools, implements and machines is covered under this discipline with regard as to how to supply mechanization inputs to the farmer in an efficient and effective manner. (Lak and Almasi 2011). This service type needs to be near to the farms, because of high transportation cost for agricultural machinery from service provider to customer's farm.

The basic indicators for success of a demand-driven advisory service system in agriculture are: farmers have access to agricultural advisory services, farmers use the advisory services, farmers have increased income from agricultural production, and finally greater choice and competition among agricultural advisers. The particular objective of supporting agricultural advisory services to the farms is to improve the agricultural income and productivity consequently (Chipeta 2006).

The limited access to financial resources may lead to several problems in agricultural production such as: disturb the time of farming operations (input supply, planting, trading and etc.), decrease the input quality and etc. So increase the access to financial services including loan and insurance can improve the productivity in agriculture.

Agricultural facilities may have different topological structures. Bojic et al. (2013) suggest an allocation model to solve biomass power plant locations. Their model was created from nodes and arcs (network structure). The nodes represent primary storages and potential power plant locations. The arcs represent the existing transport connections between the nodes. An example of discrete topological structure is Thompson et al. (2013) which use Geographical Information System (GIS) analysis to create and map a data layer of polygons that indicate all of the potential locations where, based on suitability criteria, anaerobic digester system can be installed.

Location analysis in planning for regional development can provide a framework for investigating service accessibility problems, analyzing previous locational decisions and generating alternatives to suggest more efficient service systems (Farrow et al. 2011). Many studies have used this concept for public health facilities (Teixeira and Antunes 2006), but few studies have been done in solving problems of input firms in the agricultural context (Farrow et al. 2011). Poor physical accessibility to both private and public sector retailers increases costs for farmers. So it is necessary to pinpoint underserved areas and identify optimal sites for locating new agro-dealers (Farrow et al. 2011).

1.2 Multi-attribute Decision Making in Location Problem

The distinguishing feature of the MADM problems is that there are usually a limited number of predetermined alternatives. These alternatives satisfy each objective in a specified level. There are many techniques, which are used to solve the

MADM problems. The most relevant techniques are: dominant, maxi-min, maxi-max, conjunctive method, disjunctive methods, lexicographic method, elimination by aspects, permutation method, Simple Additive Weighting (SAW), hierarchical additive weighting, Elimination and Choice Expressing Reality (ELECTRE), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Linear programming Techniques for Multidimensional Analysis of Preference (LINMAP) and etc. (Hwang and Yoon 1981). Some other MADM methods have been successfully used in various location problems in literatures such as Analytic Network Process (ANP), Analytic Hierarchy Process (AHP), Multi-Attribute Utility Theory (MAUT), and Stochastic Multi-criteria Acceptability Analysis (SMAA) (Aras et al. 2004; Higgs 2006; Tuzkaya et al. 2008).

1.3 Agricultural Service Center Location Problem

Improving efficiency is the key parameter of any system to be sustainable and successful. A strategy has been developed by Iranian agricultural ministry to create a network of agricultural service firms. In this study a new framework for specifying the service center location is developed. Agricultural services have different characteristics in comparison with other public services such as health, police or etc. These characteristics make their location selection procedure somehow different. Some assumptions have been considered in current location problems regarding customers (see Table 1). There are three types of customers in this location problem, which their characteristics explained in following section:

Customer type A: The number of farms is very large, and is hard to consider all of them; so this study will aggregate the all demand of each village in the center of that village. Also the demand weight of all farms will be sum up as demand of village point (these aggregated points will be called as demand point in this study). Any demand point has different type of service requirements and may need several services in several times. Candidate locations and demand points are the same (both are the village points). For transport any product of each demand point, it's enough to reach the demand point and the destination is not important in this location problem.

Customer type B and C: they want to access the services on their location. There may be customers of these types or not.

The layout of location problem of agricultural service centers (ASC) can be seen in Fig. 1. Since there are several services, more distance functions should be considered.

Initially a Delphi fuzzy-AHP survey has been done to extract the objectives and attributes of the ASCLP. Subsequently using Fuzzy Analytic Hierarchy Process (FAHP) the local weight of location attributes for the location problem is computed (Zangeneh et al. 2014). The main aim of current study is developing a multi-attribute decision making approach to consider all aspects of the ASCLP for customer type A (the most popular customer of ASC). The ideal solution for

Table 1 Services description

Characteristics	Service type						
	Pre-production	Production			Post production		
	Input supply	Mechanization	Consulting for farms	Financial	Consulting	Inspection	Business
Times for each season	Single	Multiple	Multiple	Single	Multiple	Single	Multiple
Customer for each service	A, B, C	A	A	A	B, C	B, C	A, B, C
Location of service demand	On farm	On farm	On service center	On service center	On site	On site	On site
Capacity	Unlimited	Limited	Unlimited	Limited	Unlimited	Unlimited	Limited
Demand weight	Weighted	Weighted	Un-weighted	Weighted	Un-weighted	Un-weighted	Weighted
Time criticality	Yes	Yes	No	Yes	No	No	Yes

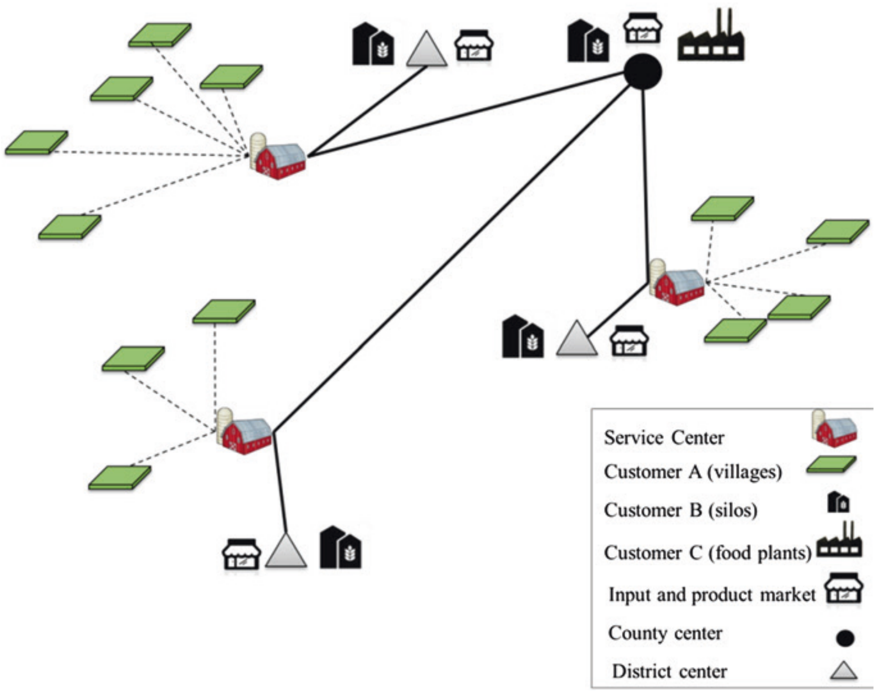


Fig. 1 Layout of the studied service network

this location problem should satisfy the main objectives of this research including: maximize service quality, service speed, and service centers profit and minimize service cost simultaneously.

2 The Method

In this chapter the concept of MADM method is applied to get best candidate locations for agricultural service centers in rural regions. The general procedure to develop the integrated MADM approach has been shown in Fig. 2.

At first the main objective of establishing ASC defined using Delphi method (Zangeneh et al. 2014). Then, based on the ASC objectives and inherent characteristics of agricultural services, the location problem of ASC defined. There are two main methods to solve the ASC location problem, but the solution space determines the appropriate method. In this study discrete solution space considered, so MADM method will be applied. In continuous solution space, if isn't possible to gain the required data for whole of the solution space, a substitute way is to reduce the solution space to a discrete one and then apply the MADM methodology.

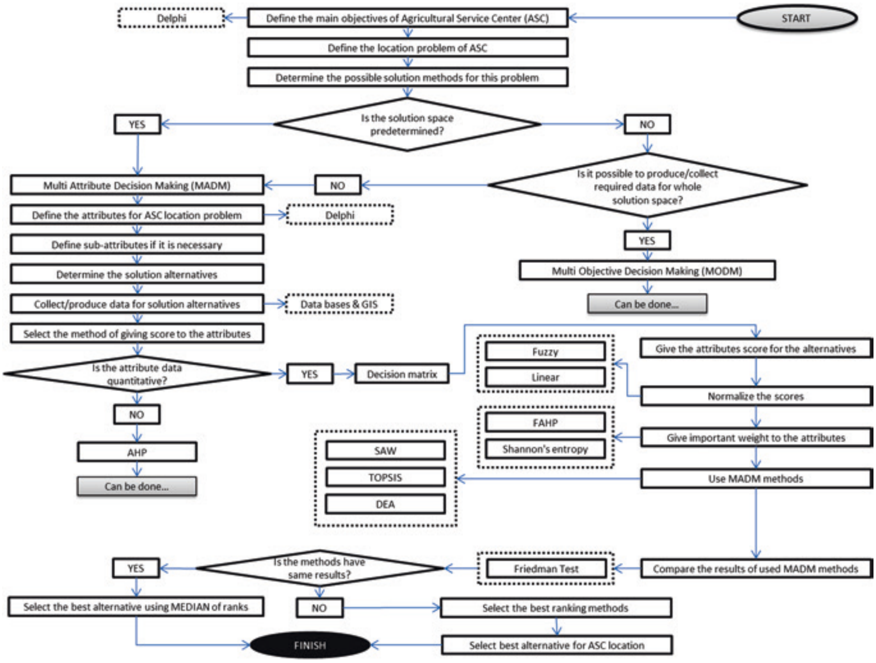


Fig. 2 The procedure of MADM method

First action in MADM is specifying attributes and also sub-attributes if it is necessary. In this phase, Delphi method can be used to help. The sub-attribute definition is to facilitate the data gathering. The data must be gathered or generated from databases, surveys and Geographical Information System (GIS) and etc. Next step is the giving score to the attributes for each alternative (candidate location). In this step, according to attribute data type, quantitative or qualitative, decision matrix method or AHP can be selected. In the current study, because of several technical reasons, village points are proposed as candidate location in each region. Quantitative date more than qualitative data will lead to reliable judgment about candidate locations. So in this study qualitative data is preferred and decision matrix method is selected for giving score to the attributes of candidate locations.

Some decision methods such as SAW and TOPSIS use the additive values of attributes to analysis. Since the type of data is different for all attributes, data normalization is required. Some other ranking methods, such as DEA, are not sensitive to the unit of data, but in this study normalized data is used for all analysis. In this research fuzzy and linear normalization methods are used. The data order in the linear normalization method is retained, while in the fuzzy normalization method the order is disturbed. Totally in this chapter seven MADM methods are applied and because of the linear normalization method ability, in this research linear method is used in five methods.

2.1 Linear Normalization Method

Simple linear normalization method is used. For both positive and negative attributes separate formulations have been used. Equations 1 and 2 have been used for positive and negative attributes, respectively (Shakouri et al. 2014):

$$Z_{ij} = \frac{a_{ij}}{\max(a_{ij})} \tag{1}$$

$$Z_{ij} = \frac{\frac{1}{a_{ij}}}{\max(\frac{1}{a_{ij}})} \tag{2}$$

2.2 Fuzzy Normalization Method

The fuzzy normalization formula for positive attributes and negative attributes are describes in Eqs. 3 and 4, respectively:

$$z_{ij} = \frac{a_{ij} - \min\ a_{ij}}{\max\ a_{ij} - \min\ a_{ij}} \tag{3}$$

$$z_{ij} = \frac{\max\ a_{ij} - a_{ij}}{\max\ a_{ij} - \min\ a_{ij}} \tag{4}$$

Usually the relative importance of attributes is different, so a weighting method for attributes must be applied. In this study, two relevant methods has been used; FAHP and Shannon's entropy.

2.3 Fuzzy-AHP

The procedure of standard FAHP has been fully described in Zangeneh et al. (2014).

2.4 Shannon's Entropy

The original Shannon's entropy comes with the concept of information theory, where it is used to measure uncertainty expressed by distribution of p_i, and find how much storage is needed to capture all uncertain information. The calculations can be expressed in a series of formulas that are expressed below (Shakouri et al. 2014):

$$E_j = -k \sum_{i=1}^{n} \left[P_{ij} \times \ln\left(P_{ij}\right)\right] \quad \forall j \tag{5}$$

where, each P_{ij} is calculated as an estimate of the probability distribution for the attributes by:

$$P_{ij} = \frac{z_{ij}}{\sum_{i=1}^{n} z_{ij}} \quad \forall i, j \tag{6}$$

And k is a constant coefficient equal to:

$$k = \frac{1}{\ln(n)} \tag{7}$$

Uncertainty or degree of deviation of the data for index j, namely d_j, states how much information each of the criterion indexed by j contains for decision making, i.e. how much information it is. This value is obtained simple as:

$$d_j = 1 - E_j \quad \forall j \tag{8}$$

Then, the weight of each criterion is calculated by:

$$w_j = \frac{d_j}{\sum_{i=1}^{n} d_j} \quad \forall j \tag{9}$$

Next step is MADM method development. In this chapter, totally seven MADM method applied to find best location for ASC. In this section, six MADM methods are described. The methods are different combination of SAW, TOPSIS and DEA. The characteristics of these methods are illustrated in Fig. 3.

2.5 TOPSIS Technique

TOPSIS is a multiple criteria decision making method which is initially developed by Hwang and Yoon (1981). The technique is based on the idea that the

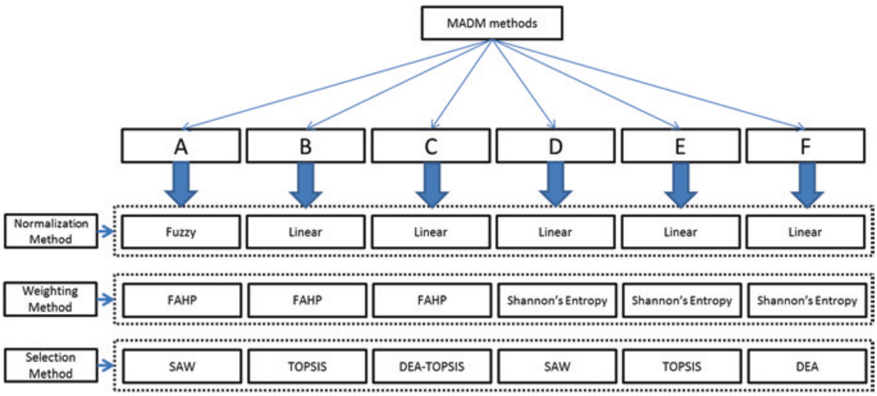


Fig. 3 The characteristics of integrated MADM methods

optimal solution should have the shortest distance from the positive ideal solution and the farthest from the negative ideal solution (Oztaysi 2014). In current research, the maximum value of each attribute is considered as positive ideal solution and the minimum value as negative ideal solution. This values is mentioned for positive attributes where higher value of them are preferred for the location of ASC, e.g. population of candidate location, while for negative attributes is vice versa. To determine these values, the decision matrix is formed and normalized by using the linear method. Then the positive ideal solution (A^{+}) and negative ideal solution (A^{-}) is determined as described in Roy (2004).

After calculating the ideal solutions, the distances of each alternative to the A^{+} and A^{-} calculated as R^{+} and R^{-}, respectively (see Eqs. 10 and 11) (Oztaysi 2014):

$$R_j^{+} = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^{+})^2} \quad i = 1, 2, \ldots, J \tag{10}$$

$$R_j^{-} = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^{-})^2} \quad i = 1, 2, \ldots, J \tag{11}$$

where; v_j^{+} is the positive ideal and v_j^{-} is the negative ideal for the criteria j.

Using these calculated values closeness index (C.I.) for each alternative is computed using Eq. 12 (Roy 2004):

$$C.I. = \frac{(R^{-})}{\left(R^{+}\right) + (R^{-})} \tag{12}$$

The closeness index can get values between 0 and 1 and the alternative which has the highest *C.I.* is selected as the best alternative (Oztaysi 2014).

2.6 DEA Technique

DEA first introduced by Charnes, Cooper, and Rhodes (CCR) (Charnes et al. 1978). The original CCR model was applicable only to technologies characterized by constant returns to scale (CRS) globally. Banker et al. (1984) divide the overall efficiency into technical and scale efficiencies. Technical efficiency is defined as the Decision Making Unit (DMU's) ability to achieve maximum output from given inputs. Using standard notations, the efficiency can be written as Eq. 13 (Charnes et al. 1978):

$$Efficiency = \frac{u_1 y_1^{j*} + u_2 y_2^{j*} + \cdots + u_N y_N^{j*}}{v_1 x_1^{j*} + v_2 x_2^{j*} + \cdots + v_M x_M^{j*}} \tag{13}$$

where, $u_1, u_2, \ldots$ are the weight given to output n $(n = 1, 2, \ldots, N)$; $y_1^{j*}, y_2^{j*}, \ldots, y_N^{j*}$ are the amount of output n of Decision Making Unit (DMU) j^*; $v_1, v_2, \ldots$ are the weight given to input m $(m = 1, 2, \ldots, M)$; $x_1^{j*}, x_2^{j*}, \ldots, x_M^{j*}$ are the amount of input m to DMU j^*; and j^* is the DMU under consideration. The efficiency is usually constrained to be between zero and one. A unit can be made efficient either by reducing the input levels and getting the same output (input orientation) or by increasing the output level with the same input level (output orientation). The input oriented analysis is becoming more common in DEA applications because profitability depends on the efficiency of the operations.

In this study the DEA technique is used for some integrated decision making approaches. Candidate locations in each region (district) considered as DMUs. The attributes divided to two groups; negative attributes as input group and positive attributes as output in DEA method. The model of CCR-input oriented used to rank DMUs based on their efficiency scores. Then the efficient DMUs will be selected to use in TOPSIS. A summary of DEA approach has been shown in Fig. 4.

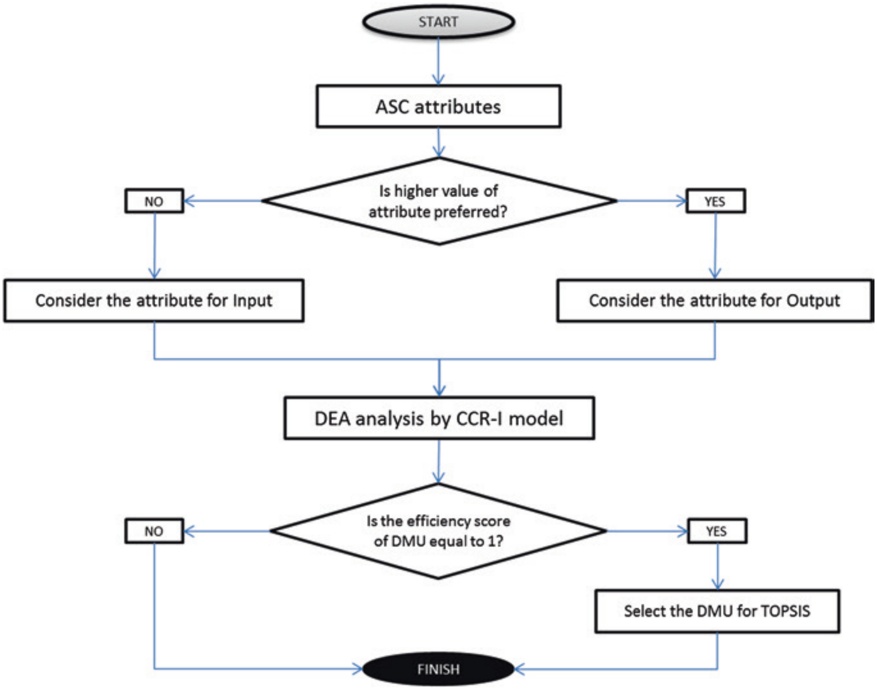


Fig. 4 DEA procedure used in this chapter

2.7 Simple Additive Weighting (SAW) Technique

Simple Additive Weighting (SAW) method is one of the most popular and most widely used methods because of its simplicity (Shakouri et al. 2014). It assumes additive aggregation of decision outcomes, which is controlled by weights expressing the importance of attributes. SAW uses all attribute values of an alternative and uses the regular arithmetical operations of multiplications and summations.

Usually the results of MADM methods are different, so their results should be compared and best rank for alternatives selected. Friedman test can be applied to compare different related samples. If the results of Friedman test showed that there is no meaningful difference between rankings, so to use the benefits of all developed MADM methods, the median of all ranking for each alternative can be used. Otherwise the best ranking method should be selected.

2.8 New MADM Technique

Since the mentioned MADM methods might be able to lead to best solution, another MADM methodology developed for them. In this technique first a hierarchical model is developed to create decision attributes for ASCLP. The summary of proposed MADM method has been shown in Fig. 5.

To find the priority of the ASC location selection attributes, a FAHP survey was designed and performed. The local weights of relative importance are computed to the attributes against the objectives; and also the global weights, which are the relative importance attributes against the goal. To derive the global weight of each attribute, its local weight was multiplied by the local weight of each corresponding objectives (Zangeneh et al. 2014).

To select best candidate location for ASCs, some sub-attribute for each location attribute were defined which can easily be measured. The Eq. 14 can be used for calculating the value of each attribute for each candidate location:

$$\chi_{ij} = \sum_{k=1}^{p} \tilde{C}_k \quad \forall i,j \tag{14}$$

where, k is the index of sub-attribute, and $\tilde{C}_k$ is the normalized value of sub-attribute k.

Since the unit of the sub-attributes is different, to sum and use them in formulations they are converted them to a normal range between one and zero before calculation of decision parameters using the Eq. 15:

$$\tilde{C}_k = \frac{C_k - \min\ C_k}{\max\ C_k - \min\ C_k} \quad \forall i,j \tag{15}$$

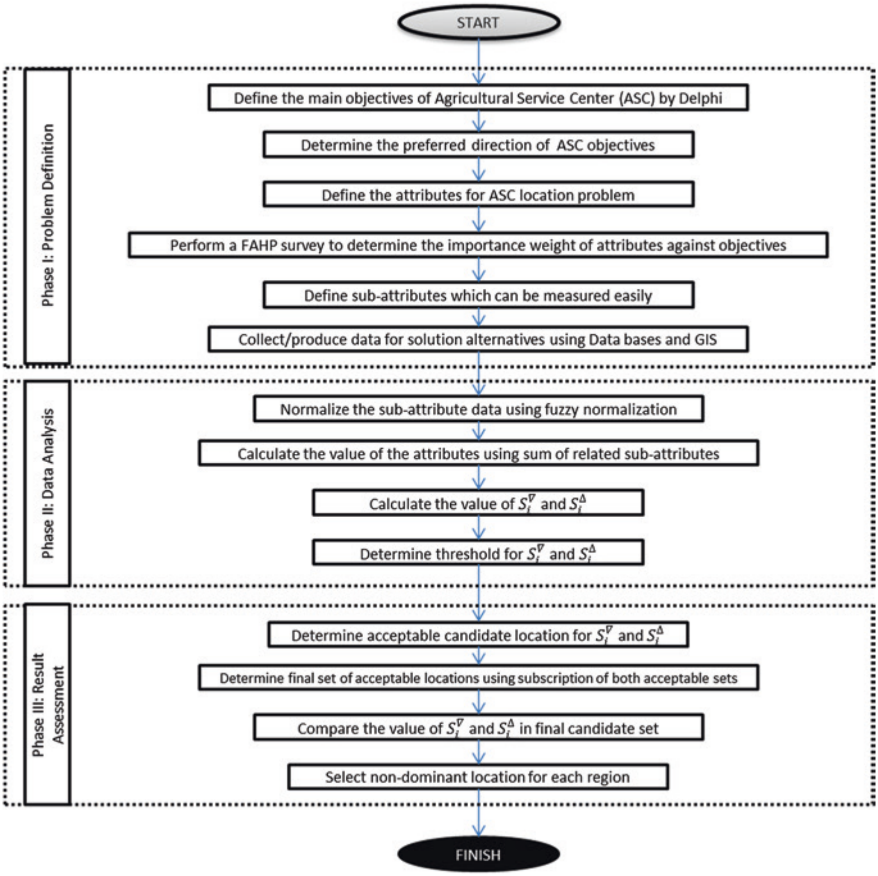


Fig. 5 The summary of developed MADM approach

There are two type of attributes viewpoint of their preferred values, i.e. there are two optimization directions: lower values of are preferred for some attributes, e.g. distances, while higher values is outrank for the ASCLP to select such candidate location for establishing ASC on it, e.g. the total cultivated area. To address two separate formulations for maxi-min and maxi-max attributes are defined (see Eqs. 16 and 17). These equations will be used to compute the suitability of candidate locations for service center establishment.

$$S_i^{\nabla} = \sum_{i=1}^{n} \gamma_j \left[\chi_{ij}\right] \quad (j = 1, 3, 4) \tag{16}$$

$$S_i^{\Delta} = \sum_{i=1}^{n} \gamma_j \left[\chi_{ij}\right] \quad (j = 2, 5) \tag{17}$$

where:

i The index of candidate locations and demand points.
j The index of attributes of service center location problem.
S_i^{∇} The final score of candidate location i for attributes which lower values of them are preferred (maxi-min).
S_i^{Δ} The final score of candidate location i for attributes which greater values of them are preferred (maxi-max).
γ_j The important weight of attribute j obtained from FAHP.
χ_{ij} The value of attribute j for candidate location i.

After calculating the final scores of each candidate location, they will be ranked based on their score values. Then candidate locations which their score of maxi-min score (S_i^{∇}) is lower than a threshold ($\alpha\%$ of the selected range which identified by decision maker) and also for maxi-max score (S_i^{Δ}) which is bigger than a threshold ($\beta\%$ of the selected range which identified by decision maker) will selected and categorized in two set of A_ρ and B_ρ for each region of study (see Eqs. 18 and 19).

$$A_\rho = \left\{ i | S_i^{\nabla} \le \alpha\% \text{ of the selected range} \right\} \tag{18}$$

$$B_\rho = \left\{ i | S_i^{\Delta} \ge \beta\% \text{ of the selected range} \right\} \tag{19}$$

At last step of this approach, we will select locations which satisfy both selection constraints described before. Since we are going to select at least one location for each region to open a service center, locations will be selected from the set adhering to the subscription set of A_ρ and B_ρ (see Eq. 20):

$$Y_\rho = A_\rho \cap B_\rho \tag{20}$$

where:

ρ The index of region $\rho = (1, \ldots, 7)$.
A_ρ The set of candidate locations which has been selected the using minimization selection criteria.
B_ρ The set of candidate locations which has been selected the using maximization selection criteria.
Y_ρ The final selected locations for region ρ.

After finding the set of Y_ρ, the best location must be proposed, because more than one location may satisfy the selection conditions. In classic location models a distance function is always used to select the best location (Franco et al. 2008). However, in this case due to the characteristics of agricultural services other attributes in addition to distance function are adopted. These further attributes enables to also consider the technical aspects of potential locations.

To prove the capability of the proposed sub-attributes and the developed multi-attribute decision making process, one case study has been conducted in a region of Iran. The studied region is Razan, a county located on the north of

Hamadan province of Iran. The Hamadan province has 1.2 % of the total area of the country and is located in the west of Iran, within 36° 40′ latitude and 48° 31′ longitude. The total area of this province is 1,494,400 ha, and the farming area is 660,000 ha, with a share of 44.16 % (Zangeneh et al. 2010). The county is subdivided into three regions: the Central region, Sardrood region, and Qorveh-e Darjazin region. Also each region divided to some districts and totally there is seven districts in the studied county.

3 Results and Discussion

At first based on the main objectives of development of ASC policy and by consulting agricultural experts using Delphi method, four objectives were made for ASCLP which are shown in Fig. 6. It is a fair comparison that the objectives constructed here are the main objectives of agricultural supply chain. To attain these objectives, candidate locations must be selected based on their attributes which are in accordance with the objectives as described in the following:

1. Maximize service quality: by minimizing the distance of service centers to the gas stations, spare parts, repair, machinery customer service center, input markets, crop markets, county center and province center.
2. Minimize service cost: by minimizing the distance of service centers to other villages, by minimizing the distance of service centers to the gas stations, spare parts, repair, machinery customer service center, input markets, crop markets, county center and province center.
3. Maximize service speed: by minimizing the distance of service centers to other villages.
4. Maximize service center profit: by maximizing cultivated area, population, number of cultivated crops, and the ration of irrigated cultivated lands to dried cultivated lands.

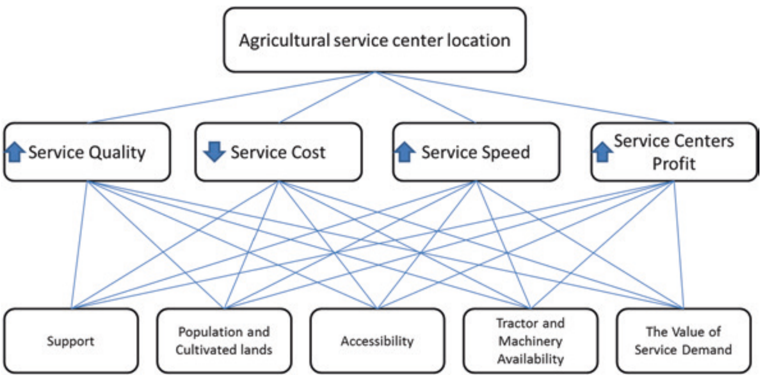


Fig. 6 Analytic hierarchy process model for location selection attributes

The sub-attribute which can be easily measured is defined (Table 2).

After defining the sub-attributes, related data has been generated/collected and then normalized. The normalized data for a district of studied region (Boqrati) is shown in Table 3.

The result of FAHP survey for importance weight of objectives and attributes of ASCLP are shown in Table 4 (Zangeneh et al. 2014).

Using the FAHP weights, the weighted score of attributes for each candidate location has been calculated (Table 5). Also Shannon's entropy is calculated for all regions and used for several MADM methods. The results of Shannon's entropy for the Boqrati district have been showed in same table.

After calculating the weighted data, six MADM methods applied which their results have been shown in Table 6 for Boqrati district. The ranking of alternatives in other districts has been identified similar to Boqrati district (see Appendix 1). The rankings of best alternatives for all districts are illustrated in Table 7.

Table 2 The attribute and sub-attribute used for ASCLP

Attribute	Sub-attribute	
Easy support χ_1	Distance to center of county (maxi-min): C_{11}	Distance to center of district (maxi-min): C_{12}
Proximity to more population and cultivated lands χ_2	The number of families (maxi-max): C_{21}	Total cultivated area (maxi-max): C_{22}
Easy access χ_3	Total distance to other villages (maxi-min): C_{31}	
Proximity to less tractor and machinery availability χ_4	Number of tractors (maxi-min): C_{41}	The value of mechanization efficiency (maxi-min): C_{42}
Proximity to more service demand χ_5	The number of crop type cultivated (maxi-max): C_{51}	The ratio of irrigated cultivated land to dried cultivated land (maxi-max): C_{52}

Table 3 The normalized sub-attribute data for Boqrati district

Candidate locations	Sub-attributes								
	C_{11}	C_{12}	C_{21}	C_{22}	C_{31}	C_{41}	C_{42}	C_{51}	C_{52}
Urte-qamish	0.000	0.022	0.270	0.252	0.031	0.298	0.595	0.500	0.102
Baba-nazar	0.255	1.000	1.000	1.000	0.446	0.000	0.000	0.667	0.053
Tape-dibi	0.262	0.733	0.273	0.235	0.465	0.536	0.158	0.500	0.145
Chahar-bolaq	0.021	0.000	0.264	0.069	0.000	0.286	0.840	0.500	0.092
Churmagh	0.341	0.314	0.591	0.443	0.370	0.393	0.000	1.000	1.000
Qeinarje	0.342	0.476	0.853	0.488	0.420	0.083	0.575	0.667	0.033
Qaderkhalaj	0.387	0.167	0.389	0.313	0.289	0.405	0.234	1.000	0.832
Qarakand	0.047	0.297	0.251	0.406	0.220	0.488	0.000	1.000	0.185
Qalejuq-zamani	0.440	0.110	0.155	0.125	0.222	0.905	0.000	0.333	0.000
Qale-zandlij	0.122	0.592	0.138	0.304	0.372	0.690	0.306	0.333	0.000
Gunduz	0.148	0.616	0.519	0.592	0.401	0.274	0.337	0.667	0.029
Mazrae-deimur	0.398	0.182	0.084	0.222	0.294	0.821	0.000	1.000	0.272
Yarmche-baq	0.158	0.551	0.202	0.157	0.323	0.714	0.581	0.333	0.000

Table 4 The local weight of location attributes which calculated by FAHP

Attribute	Importance weight ω_i
Support χ_1	0.212
Population and cultivated lands χ_2	0.202
Accessibility χ_3	0.201
Tractor and machinery availability χ_4	0.194
The value of service demand χ_5	0.189

Table 5 The FAHP and Shannon's entropy weighted attribute data for Boqrati district

Candidate locations	Attributes									
	χ_1^a	χ_1^b	χ_2^a	χ_2^b	χ_3^a	χ_3^b	χ_4^a	χ_4^b	χ_5^a	χ_5^b
Urte-qamish	0.005	0.005	0.105	0.119	0.006	0.006	0.173	0.134	0.114	0.122
Baba-nazar	0.266	0.290	0.404	0.457	0.090	0.083	0.000	0.000	0.136	0.146
Tape-dibi	0.211	0.230	0.103	0.116	0.093	0.087	0.135	0.104	0.122	0.131
Chahar-bolaq	0.004	0.005	0.067	0.076	0.000	0.000	0.218	0.169	0.112	0.120
Churmagh	0.139	0.152	0.209	0.236	0.074	0.069	0.076	0.059	0.378	0.406
Qeinarje	0.174	0.189	0.271	0.307	0.084	0.078	0.128	0.099	0.132	0.142
Qaderkhalaj	0.118	0.128	0.142	0.160	0.058	0.054	0.124	0.096	0.346	0.372
Qarakand	0.073	0.080	0.133	0.150	0.044	0.041	0.095	0.073	0.224	0.241
Qalejuq-zamani	0.117	0.127	0.057	0.064	0.045	0.041	0.176	0.136	0.063	0.068
Qale-zandlij	0.151	0.165	0.089	0.101	0.075	0.069	0.193	0.150	0.063	0.068
Gunduz	0.162	0.177	0.224	0.254	0.081	0.075	0.118	0.092	0.131	0.141
Mazrae-deimur	0.123	0.134	0.062	0.070	0.059	0.055	0.159	0.123	0.240	0.258
Yarmche-baq	0.150	0.164	0.073	0.082	0.065	0.060	0.251	0.195	0.063	0.068

[a]The results of FAHP method
[b]The results of Shannon's entropy method

As can be seen in the ranking results, the ranks of candidate locations seem relatively different in all MADM methods. So the Friedman test was applied to test this hypothesis that is the results of different ranking approached are same? Table 8 has been shown the Friedman test for all MADM methods. As can be seen in the results, the Friedman tests indicate that no meaningful differences are between the MADM methods. To use the benefits of all integrated MADM methods, the median all of rankings of each candidate location has been used to determine the final ranking of each candidate location for ASC.

The high ranked locations (first to third candidates) for locating ASC on them for Boqrati district is illustrated on map in Fig. 7. The related maps of other districts can be seen in Appendix 2.

Table 6 The ranking results of six MADM approaches for Boqrati district

Candidate location	MADM ranking methods						Median of rankings
	A	B	C	D	E	F	
Urte-qamish	13	6	8	12	6	12	10
Baba-nazar	2	2	3	1	2	2	2
Tape-dibi	7	11	–	6	11	6	7
Chahar-bolaq	12	8	–	13	8	13	12
Churmagh	1	1	1	2	1	1	1
Qeinarje	3	5	6	3	5	5	5
Qaderkhalaj	4	3	–	4	3	3	3
Qarakand	10	4	2	8	4	8	6
Qalejuq-zamani	11	10	7	11	10	11	10.5
Qale-zandlij	9	12	–	10	12	9	10
Gunduz	5	7	5	5	7	7	6
Mazrae-deimur	6	9	4	7	9	4	6.5
Yarmche-baq	8	13	–	9	13	10	10

Table 7 The median of best alternative rankings for all studied districts

District	Best location	MADM Ranking methods						Median of rankings
		A	B	C	D	E	F	
Boqrati	Churmagh	1	1	1	2	1	1	1
Darjazin-Olia	Karafs	13	1	1	1	1	18	1
Darjazin-Sofla	Darjazin	1	6	5	1	3	1	2
Kharaqan	Dorniyan	4	1	1	5	1	2	1.5
Razan	Hariyan	20	2	1	1	1	1	1
Sardrood-Olia	Mola-bodaq	1	1	1	1	6	1	1
Sardrood-Sofla	Tulki-tape	8	1	1	1	1	2	1

Table 8 Friedman test results

District	N	Chi-square	df	Asymp. sig.
Boqrati	13	0.135	4	0.998^{ns}
Darjazin-Olia	22	1.448	4	0.836^{ns}
Darjazin-Sofla	14	0.202	4	0.995^{ns}
Kharaqan	15	0.191	4	0.996^{ns}
Razan	21	2.663	4	0.616^{ns}
Sardrood-Olia	11	0.262	4	0.992^{ns}
Sardrood-Sofla	14	1.297	4	0.862^{ns}

^{ns}Not significant

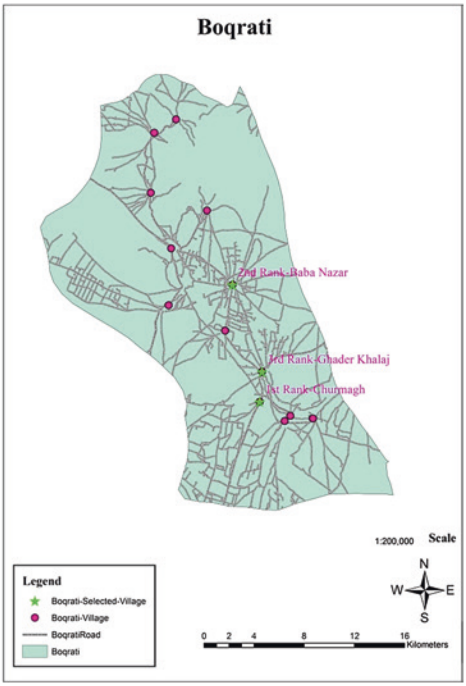


Fig. 7 The position of solutions on the map of Boqrati

The first rank candidate location of some districts is not acceptable; such as Kharaqan, Razan and Sardrood-Sofla (see Appendix 2). So the new MADM approach used for these districts and the results are more acceptable.

3.1 Results of New MADM Approach

The values of all attributes have been calculated using their related sub-attributes for each candidate location in each region. Then by multiplying attributes and their related weights, which has been estimated using FAHP, the value of final maxi-min and maxi-max scores calculated for them. To clarify the computations, the attribute and final score of Boqrati region has been shown in Table 9.

The calculations of final scores for other regions have been done similar to the Boqrati region.

Using the defined set conditions, candidate location which satisfies the selection condition in each region has been selected and the results are illustrated in Table 10.

As can be seen in last column of Table 10, more than one candidate location satisfies the selection condition. So in this phase the aim is to select the best one for each region. In other words the non-dominated solution for this decision problem should be found. The final score of the selected candidate location in districts

Table 9 The results of attributes in district of Boqrati

Candidate location	χ_1	χ_2	χ_3	χ_4	χ_5	S_i^{∇}	S_i^{Δ}
Chaharbolaq (1)	0.243	0.040	0.066	0.133	0.065	0.441	0.104
Urteghamish (2)	0.307	0.081	0.059	0.187	0.067	0.553	0.147
Yaremchebaq (3)	0.095	0.045	0.007	0.101	0.000	0.203	0.045
Qeinarje (4)	0.224	0.261	0.000	0.237	0.101	0.462	0.361
Gunduz (5)	0.294	0.210	0.008	0.252	0.100	0.553	0.310
Ghalezandlij (6)	0.251	0.063	0.102	0.169	0.000	0.523	0.063
Ghaderkhalaj (7)	0.193	0.120	0.041	0.247	0.346	0.481	0.466
Tapedibi (8)	0.159	0.078	0.009	0.237	0.075	0.405	0.153
Ghalejughzamani (9)	0.293	0.028	0.201	0.194	0.000	0.688	0.028
Mazraedeimur (10)	0.277	0.033	0.170	0.212	0.241	0.659	0.274
Churmagh (11)	0.289	0.193	0.138	0.304	0.378	0.730	0.571
Babanazar (12)	0.016	0.404	0.105	0.388	0.105	0.510	0.509
Gharakand (13)	0.303	0.110	0.172	0.283	0.224	0.758	0.334

Table 10 The set of selected locations in each region

Region	A_ρ	B_ρ	Y_ρ
Boqrati	1, 3, 4, 7, 8, 12	4, 5, 7, 11, 12, 13	4, 7, 12
Darjazin-Olia	2, 3, 4, 6, 7, 8, 10, 12, 13, 14, 15	3, 4, 6, 8, 9, 10, 14, 15	3, 4, 6, 8, 10, 14, 15
Darjazin-Sofla	2, 3, 4, 5, 6, 9, 10	1, 5, 6, 9, 10, 12, 14	5, 6, 10
Kharaqan	2, 3, 4, 5, 6, 8, 10	2, 7, 8, 9, 11, 12, 15	2, 8
Razan	2, 3, 4, 5, 7, 8, 9, 10, 14, 17	1, 5, 6, 7, 10, 13, 15, 17, 20, 21	5, 7, 10, 17
Sardrood-Olia	1, 2, 3, 6, 7	2, 4, 6, 9, 11	2, 6
Sardrood-Sofla	2, 3, 5, 6, 7, 8, 10	1, 2, 4, 5, 6, 13, 14	2, 5, 6

$\alpha = 50\ \%$, $\beta = 50\ \%$

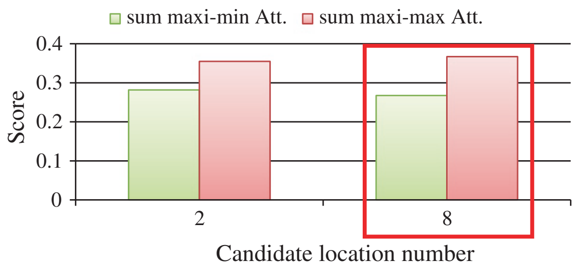


Fig. 8 The chart of selected locations of Kharaqan

which their solutions were not acceptable by first approach has been shown in Figs. 8, 9 and 10, respectively. Usually in location decisions, distance and transportation play a very important role. So the role of maxi-min attributes, which contain different distance functions are highlighted, in selecting the best solutions.

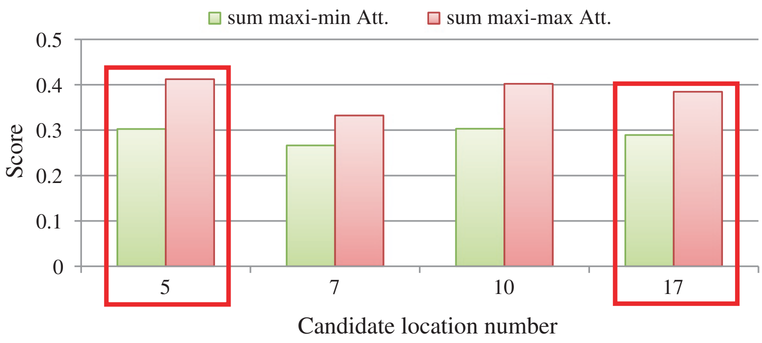


Fig. 9 The chart of selected locations of Razan

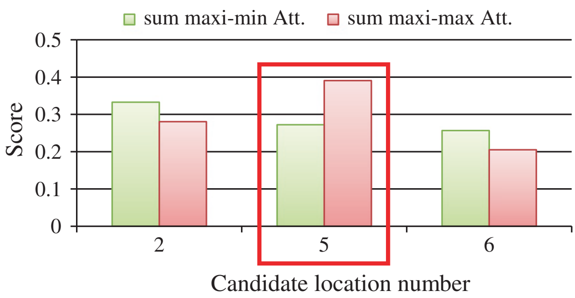


Fig. 10 The chart of selected locations of Sardrood-Sofla

As can be seen in these figures, in some regions, e.g. Boqrati, there is no unique non-dominated solution. In the Boqrati region, S_4^{∇} is lower than S_7^{∇} while S_7^{Δ} is higher than S_4^{Δ}. In this situation no one solution can dominate the other one. In such cases all non-dominated solutions are proposed and this is the main disadvantage of proposed approach, while it has several advantages such as simplicity of calculations, the ability to consider inherent specification of agricultural activities. The attributes considered in this research can improve the success of locating and activity of ASCs. The non-dominated solutions for Kharaqan, Razan and Sardrood-Sofla have been illustrated by red rectangular in Figs. 8, 9 and 10. The results of other districts can be seen in Appendix 3.

The position of selected solutions of Boqrati, Kharaqan, Razan and Sardrood-Sofla have been shown in Figs. 11 and 12 to clarify the power of proposed multi attribute decision making approach.

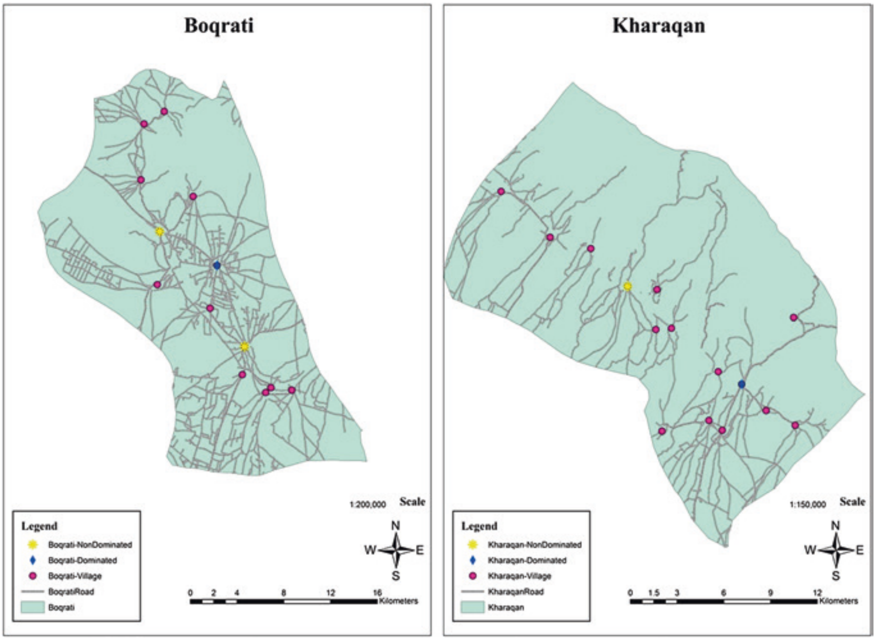


Fig. 11 The position of solutions on the map of regions Boqrati and Kharaqan districts

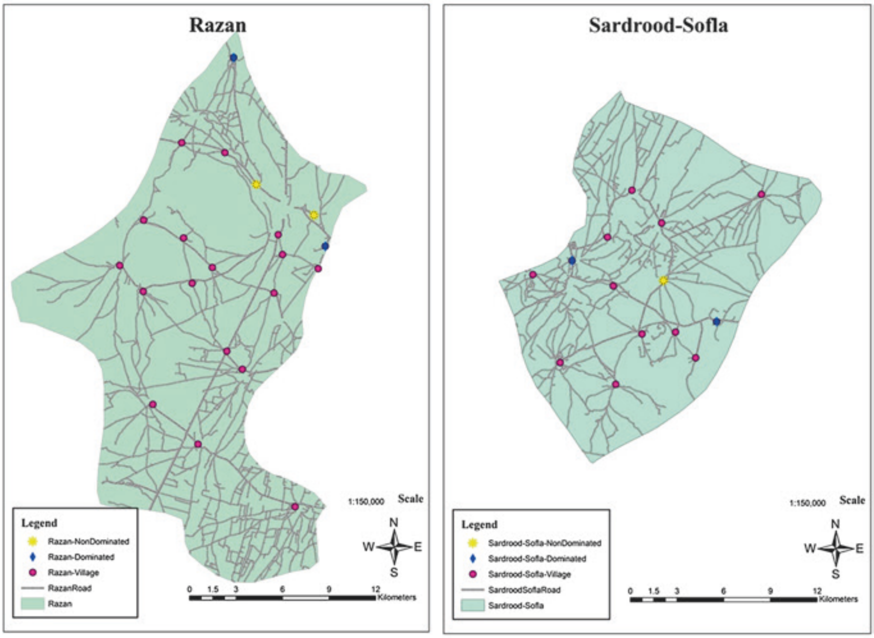


Fig. 12 The position of solutions on the map of regions Razan and Sardrood-Sofla districts

In Darjazin-Olia, the non-dominated locations are not in the center of the region, similar to the Boqrati region. This has happened because of attributes which are added to this location problem; i.e. distance to district and county centers. Since the service center needs to be supported by some suppliers for some inputs, they are should be near to these centers. For example the market of agricultural inputs, fuel stations, spare parts, and also the market of agricultural products are always placed in county and district centers.

Like what was described for Darjazin-Oila, similar results can be seen in the Razan district. In this region, the proximity to center of the county plays the main role in the location of the service center.

4 Conclusion

In this chapter which constitutes part of large project, several fast and intelligible approaches to solve an important agricultural facility location problem are developed. All aspects of agricultural service location problem have been considered, i.e. from the viewpoint of customers, service suppliers, and also technical suitability of candidate location for locating the service center on them. Some multi criteria decision making methods used to find optimum location for ASC. These methods enable strategic managers to taking to account sustainability items for location selection decisions in the subject of agricultural services. In classic location models just distance and demand weight be mentioned, but in developed approach moreover other items included. The proposed approach can be used in other regions and also other service location problems with some modifications. If the results of ranking methods be different or not median of ranking results which introduced in this chapter can lead to a near to optimum solution, because each method has its different way to find rankings. The main limitation of proposed approach is the non-dominated solutions which occurred in some case studies. In this case further research is required to overcome this.

Acknowledgments The financial support provided by University of Tehran is duly acknowledged. Thanks and appreciations of authors also go to colleagues in developing the research and people who have willingly helped us with their abilities.

Appendix 1: The Ranking Result of MADM Approaches

See Tables 11, 12, 13, 14, 15 and 16.

Table 11 The ranking results of six MADM approaches for Darjazin-Olia district

Candidate location	MADM ranking methods						Median of rankings
	A	B	C	D	E	F	
Pelikan	15	12	–	11	11	7	11
Pirbag	7	3	–	22	8	22	8
Tamuzan	8	13	–	14	18	8	13
Javarsajin	4	9	5	9	12	2	7
Rakin	9	16	–	8	19	5	9
Sonqorabad	16	2	2	6	4	9	5
Sangeran-kuh	21	18	6	17	20	17	17.5
Suzan	3	11	–	2	2	1	2
Shanjur	12	21	–	10	17	14	14
Shavand	6	4	–	4	3	12	4
Ein-abad	10	17	–	3	5	3	5
Qaraqie	19	22	–	16	22	19	19
Kaj	1	5	4	7	6	6	5.5
Karafs	13	1	1	1	1	18	1
Gol-tape	20	15	3	15	15	11	15
Mazrae-sarem	18	6	–	12	10	10	10
Manuchehr	14	7	–	18	9	20	14
Misinq	11	10	–	20	13	16	13
Nakin	17	20	–	13	21	13	17
Valashajard	5	14	–	19	14	15	14
Vasmaq	2	8	–	5	7	4	5
Yengeje-karafs	22	19	–	21	16	21	21

Table 12 The ranking results of six MADM approaches for Darjazin-Sofla district

Candidate location	MADM ranking methods						Median of rankings
	A	B	C	D	E	F	
Ahmad-abad	12	13	–	11	14	8	12
Behkandan	7	3	1	7	5	7	6
Poshtejin	4	7	–	6	8	2	6
Hakan	11	1	3	5	1	13	4
Darjazin	1	6	5	1	3	1	2
Razin	13	11	–	12	11	12	12
Zakan	14	5	6	14	9	14	11.5
Sayan	8	2	2	8	4	10	6
Salilak	10	10	–	13	10	11	10
Aman	3	12	–	4	7	5	5
Kamandan	9	14	–	9	13	6	9
Nezam-abad	2	9	–	3	6	4	4
Nudeh	6	8	–	10	12	3	8
Neer	5	4	4	2	2	9	4

Table 13 The ranking results of six MADM approaches for Kharaqan district

Candidate location	MADM ranking methods						Median of rankings
	A	B	C	D	E	F	
Amir-abad	2	4	–	6	5	8	5
Aqche-kharabe	10	8	–	11	7	9	9
Aqchai	12	15	–	9	13	10	12
Badkuh	11	9	–	14	10	14	11
Jaryanloo	13	3	3	8	2	4	3.5
Khalaj	9	13	–	12	15	12	12
Dorniyan	4	1	1	5	1	2	1.5
Sarijloo	14	5	2	3	4	1	3.5
Surtejin	3	11	–	4	12	7	7
Karvaneh	6	12	–	7	11	6	7
Garmak	15	7	–	15	8	13	13
Gavanloo	5	2	–	13	3	15	5
Lale-dan	8	6	–	1	6	3	6
Mahnian	1	10	–	2	9	5	5
Vahandeh	7	14	–	10	14	11	11

Table 14 The ranking results of six MADM approaches for Razan district

Candidate location	MADM ranking methods						Median of rankings
	A	B	C	D	E	F	
Amiriyeh	9	13	–	10	14	5	10
Abbarik	13	5	–	5	4	9	5
Aqkand	17	14	–	19	15	18	17
Tazeh-kand	15	20	–	16	19	14	16
Tekye	8	16	–	12	17	8	12
Jamishloo	18	7	–	7	6	11	7
Khomigan	5	11	–	11	9	12	11
Sirab	7	8	–	15	10	13	10
Qazyatan	19	9	–	21	12	20	19
Qolamali	12	17	–	14	16	10	14
Farsejin	2	10	–	3	7	4	4
Qater-olan	21	15	–	20	20	19	20
Kahard	6	1	–	4	2	15	4
Mad-abad	10	19	–	18	18	16	18
Navar	1	4	2	2	3	2	2
Nianj	16	18	–	9	13	7	13
Hariyan	20	2	1	1	1	1	1
Varqestan	4	3	–	13	5	21	5
Varvazin	14	21	–	17	21	17	17
Vafs	11	6	3	8	8	6	7
Yenge-qaleh	3	12	–	6	11	3	6

Table 15 The ranking results of six MADM approaches for Sardrood-Olia district

Candidate location	MADM Ranking methods						Median of rankings
	A	B	C	D	E	F	
Ojaq	7	9	–	9	1	10	9
Arpa-dareh	8	6	–	8	2	9	8
Aqche-kharabeh	11	11	3	6	8	8	8
Takht	4	4	–	4	5	4	4
Chopoqloo	9	10	–	7	11	5	9
Khorvandeh	2	2	–	5	4	6	4
Qarebolaq	5	8	–	2	10	2	5
Kahriz-boqazi	3	3	–	11	9	11	9
Gavsavar	6	5	–	3	3	3	3
Mola-bodaq	1	1	1	1	6	1	1
Mansoor-abad	10	7	2	10	7	7	7

Table 16 The ranking results of six MADM approaches for Sardrood-Sofla district

Candidate location	MADM Ranking methods						Median of rankings
	A	B	C	D	E	F	
Payandeh	6	12	–	9	11	10	10
Pilejin	10	7	–	11	8	11	10
Tulki-tape	8	1	1	1	1	2	1
Jafar-abad	12	11	5	8	9	9	9
Chal-boqa	7	9	–	7	7	8	7
Chayan	4	4	6	4	4	4	4
Khanjar-abad	1	5	–	5	5	5	5
Serleh	13	8	–	10	10	6	10
Soltan-abad	2	2	2	3	2	3	2
Qayesh	3	3	3	2	3	1	3
Qeraylar	14	10	–	14	12	13	13
Qozlijeh	9	14	–	12	14	12	12
Qale-shater-bali	5	6	–	6	6	7	6
Viar	11	13	–	13	13	14	13

Appendix 2: The Position of High Ranked Solutions for All Regions by Six MADM Methods

See Figs. 13, 14, 15 and 16.

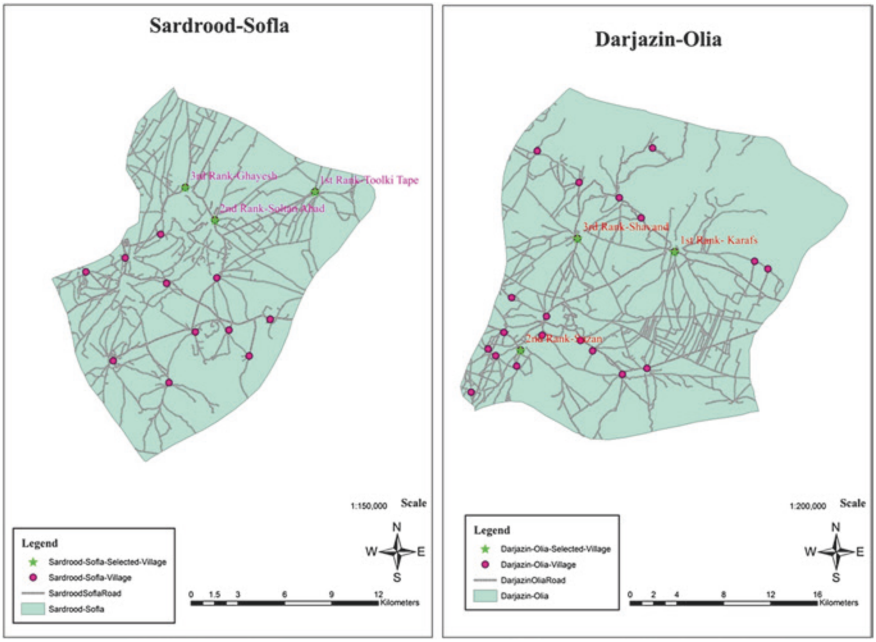


Fig. 13 The position of solutions on the map of Sardrood-Sofla and Darjazin-Olia districts

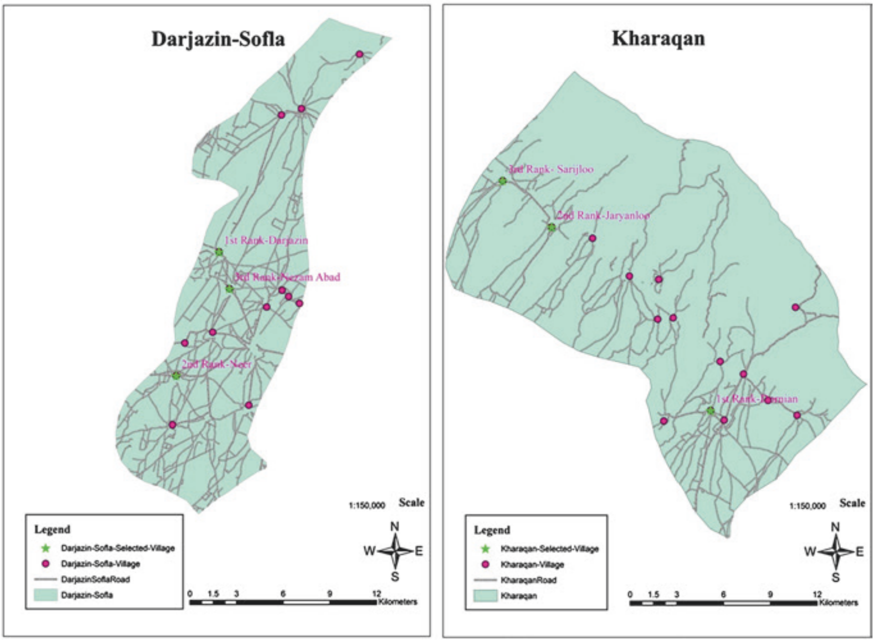


Fig. 14 The position of solutions on the map of Darjazin-Sofla and Kharaqan districts

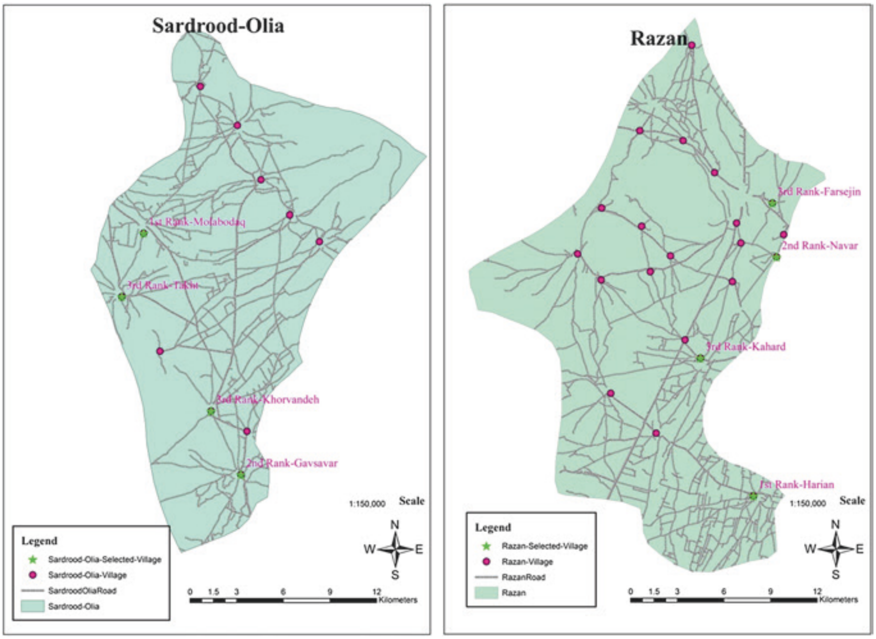
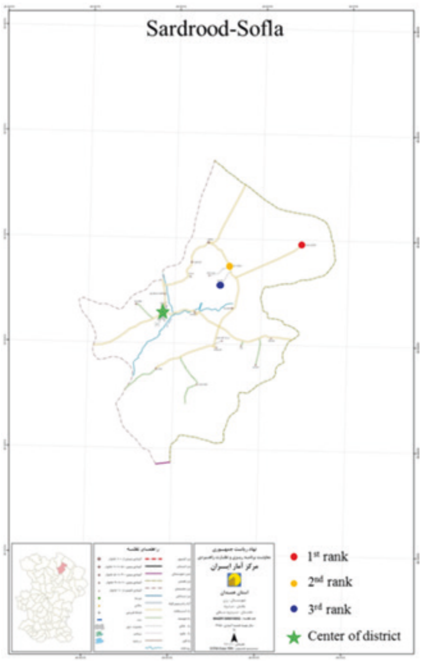


Fig. 15 The position of solutions on the map of Razan and Sardrood-Olia districts

Fig. 16 The position of solutions on the map of Sardrood-Sofla district



Appendix 3: The Final Location Selection Charts by New MADM Method

See Figs. 17, 18, 19 and 20.

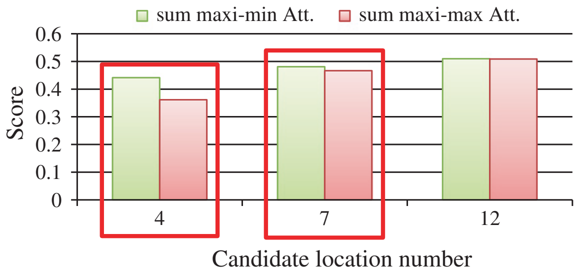


Fig. 17 The chart of selected locations of Boqrati

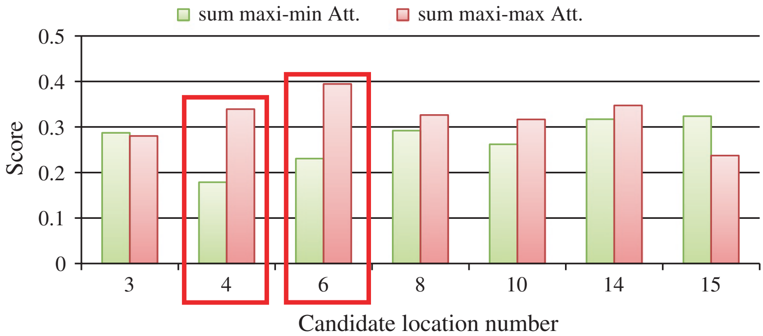


Fig. 18 The chart of selected locations of Darjazin-Olia

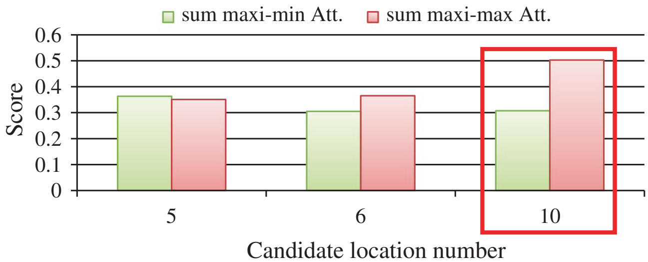


Fig. 19 The chart of selected locations of Darjazin-Sofla

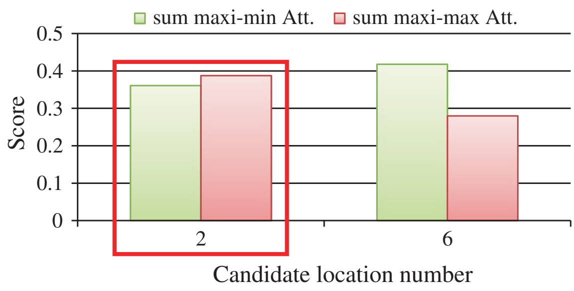


Fig. 20 The chart of selected locations of Sardrood-Olia

Appendix 4: The Position of Solutions on the Map of Three Districts by New MADM Approach

See Figs. 21 and 22.

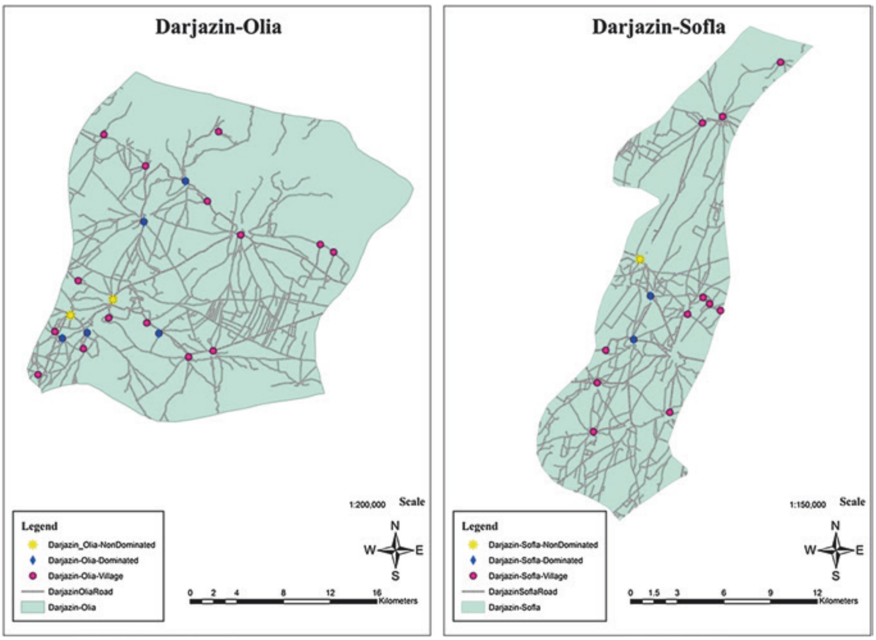


Fig. 21 The position of solutions on the map of regions Darjazin-Olia and Darjazin-Olia districts

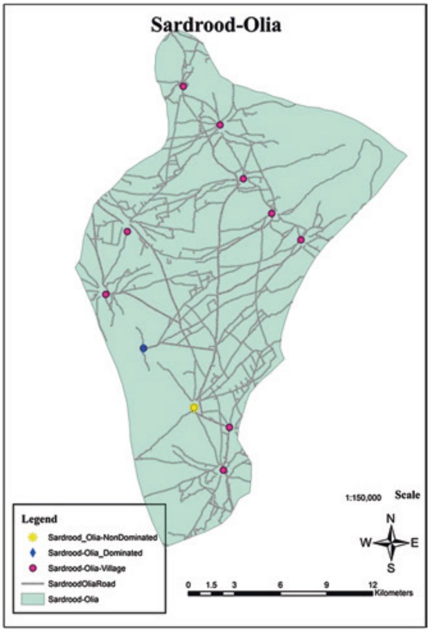


Fig. 22 The position of solutions on the map of regions Sardrood-Olia district

References

Aras H, Erdogmus S, Koc E (2004) Multi-criteria selection for a wind observation station location using analytical hierarchy process. Renew Energy 29:1383–1392

Banker RD, Charnes A, Cooper WW (1984) Some models for estimating technical and scale inefficiencies in data envelopment analysis. Manage Sci 30:1078–1092

Bojic S, Datkov D, Brcanov D, Georgijevic M, Martinov M (2013) Location allocation of solid biomass power plants: Case study of Vojvodina. Renew Sustain Energy Rev 26:769–775

Charnes A, Cooper WW, Rhodes E (1978) Measuring the efficiency of decision making units. Eur J Oper Res 2:429–444

Chipeta S (2006) Demand driven agricultural advisory services. Neuchatel Group, Denmark

Dorward A, Chirwa E (2011) The Malawi agricultural input subsidy programme: 2005/06 to 2008/09. Int J Agric Sustain 9:232–247

Farrow A, Risinamhodzi K, Zingore S, Delve RJ (2011) Spatially targeting the distribution of agricultral input stockists in Malawi. Agric Syst 104:694–702

Franco CV, Rodriguez-Chia AM, Miranda IE (2008) The single facility location problem with average-distances. Top 16:164–194

Higgs G (2006) Integrating multi-criteria techniques with geographical information systems in waste facility location to enhance public transportation. Waste Manage Res 24:105–117

Hwang CL, Yoon KP (1981) Multiple attribute decision making methods and aplications. Springer, New York

Lak MB, Almasi M (2011) An analytical review of parameters and indices affecting decision making in agricultural mechanization. Aust J Agric Eng 2:140–146

Lucas M, Chhajed D (2004) Applications of location analysis in agriculture: a survey. J Oper Res Soc 55:561–578
Oztaysi B (2014) A decision model for information technology selection using AHP integrated TOPSIS-Grey: the case of content management systems. Knowl Based Syst. doi:10.1016/j.knosys.2014.02.010
Pangburn MS, Stavrulaki E (2005) Service facility location and design with pricing and waiting-time considerations. In: Supply chain optimization. Applied optimization, vol 98. Springer, US, pp 209–241
Roy B (2004) Multiple criteria decision analysis: state of the art surveys. Springer, New York
Shakouri H, Nabaee M, Aliakbarisani S (2014) Aquantitative discussion on the assessment of power supply technologies: DEA (data envelopment analysis) and SAW (simple additive weighting) as complementary methos for the "Grammar". Energy 64:640–647
Teixeira J, Antunes AP (2006) A hierarchical location model for public facility planning. Eur J Oper Res 185:92–104
Thompson E, Wang Q, Li M (2013) Anaerobic digester systems (ADS) for multiple dairy farms: a GIS analysis for optimal site selection. Energy Policy 61:114–124
Timmer CP, Falcon WP, Pearson SR (1983) Food policy analysis. The Johns Hopkins University Press, Baltimore and London
Tuzkaya G, Onut S, Tuzkaya UR, Gulsun B (2008) An analytic network process approach for locating undesirable facilities: an example from Istanbul, Turkey. J Environ Manage 88:970–983
Zangeneh M, Akram A, Nielsen P, Keyhani A (2014) Introducing strategy for locating agricultural mechanization service centers using covering, Multicriteria and Allocation Models. PhD Thesis, Univeristy of Tehran, Tehran
Zangeneh M, Omid M, Akram A (2010) A comparative study on energy use and cost analysis of potato production under different farming technologies in Hamadan province of Iran. Energy 35:2927–2933

Supply Chain Sustainability—Drivers, Inhibitors, Solutions

Mariusz Szuster

Abstract This chapter describes the process of change of attitude towards sustainability and its consequences for manufacturing and logistics industries. It was recognized that sustainable production strategies are dependent upon policies, regulations and green demand. This chapter summarizes environmental initiatives used by manufacturers and logistics service providers. The target was the identification of initiatives realized in this field. Part of the chapter contains terms connected with sustainability, supply chains and others. The literature review was intended to show the theoretical background, to define several terms, and describe details of potential effects of solutions and practices. There is also description of policy and regulation initiatives, description of green production and green supply chain, the environmental impacts of different industries and transport, and also identification of main sources of pollution. There are also many examples showing impacts of regulations on industry. Environmental and sustainable operations realized in supply chains demonstrate a high level of complexity. Final part of the chapter presents a set of practices connected with environmental decision making. They match the broad range of processes and operations realized in manufacturing and logistics industries.

Keywords Sustainability · Green supply chains · Green manufacturing · Environmental regulations · Sustainable practices · Logistics

1 Sustainable Supply Chains at the Background of Contemporary Society

Sustainable supply chains became an area of a huge interest of researchers and practitioners. It concerns mainly members of supply chains; manufacturers, their suppliers, distributors, logistics service providers, trade companies, and

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other organizations. It concerns also investors, stakeholders, customers, consumers and policy makers. Sustainability can be defined as the strategic, transparent integration and achievement of an organization's social, environmental and economic goals in the systemic coordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its supply chain (Carter and Easton 2011). Sustainability is a complex concept containing various meanings across different fields, businesses and industries. Sustainability refers to the integration of environmental, social and economic responsibilities of the business. World Commission on Environment and Development (known also as the Brundtland Commission) defined sustainability as the necessity to meet the needs of the present without comprising the ability of future generations to meet their own needs (World Commission on Environment and Development 1987). Sustainability in production and logistics contexts is ranging from operational to strategic solutions and ideas, such as:

- environmental performance and green production (reduction of quantity of waste and pollution),
- eco-efficiency,
- green operations and logistics management,
- green supply chain management and reverse logistics, in the context of global, regional or local networks and routes of materials flows,
- eco-design and sustainable new product development.

Environmental performance is generally defined as the impact of a firm on the natural environment (Klassen and Whybark 1999). It can be obtained by lower gas emissions or waste effluence, as well as the resignation from hazardous or toxic materials. Taking into consideration the growing green-consciousness, improving environmental performance is often treated as an effective tool which helps companies to gain positive image.

Idea of green production of goods or services consists of (Doran and Ryan 2012; Nunes and Bennett 2010):

- reduced material use per unit of output,
- replaced materials with less polluting or less hazardous substitutes,
- recycled waste and materials,
- reduced soil, water, or air pollution,
- reduced noise,
- reduced environmental burdens on the final disposal,
- reduced need for landfills,
- reuse of valuable components of an end-of-life product,
- elimination of unnecessary processes,
- reduction of excessive and burdensome pollution and waste.

Objective of green manufacturing is also to enhance environmental performance during construction and operation of an industrial plant considering sustainability of the production site, water and energy efficiency, resource and material use, environmental management issues, innovation and design process (Nunes and

Bennett 2010). The main profit should be the reduction in maintenance costs, resulted from lower amount of waste, reduced costs of utilization and lower burden of taxation imposed on the polluters. It may be also the result of energy and water savings. The other objective of green manufacturing is to convert raw materials into usable products in the way which will be most friendly to environment. Theories and studies on the management of sustainability in manufacturing companies, varying from high-level general management strategies to more detailed methods for addressing specific problems (Alblas et al. 2014). Generally green manufacturing means a better economic environmental, social and economic performance through reduction of waste. It is also connected with higher efficiency.

Eco-efficiency combines the environmental and economic dimensions of sustainability (Helminen 2000). Schmidheiny and Zorraquin (1996) defined eco-efficiency as: a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and corporate change maximize the value added while minimizing resource consumption, waste and pollution. Eco-efficiency is also defined as the reduction of resource intensity consumption and minimization of environmental impacts of production and products or services (Dias-Sardinha and Reijnders 2001).

Green operations based on the use of environmental practices help to avoid usage methods which are harmful for environment. Gupta and Sharma (1996) defined environmental operations management as the integration of environmental management principles with the decision-making process. Green operations practices can be considered as those practices that contribute to the enhancement of environmental performance in companies' operations.

Green logistics can give a strategic role in improving the competitiveness and eco-efficient performances of a company. Moreover, environmental performances are still needed in logistics practice (Jumadi and Zailani 2010). Still there is little discussion covering performance and environmental issues related to the practical applications of eco-efficient initiatives in the logistics industry (Venus 2010). Some logistics service providers have created a "green line" of environmentally friendly services. Most companies operating in the logistics industry are willing to invest in order to become eco-efficient, but customers are not willing to pay a premium price for more eco-efficient logistics services (Zailani et al. 2011). This is a reason of very little attention which has been given to eco-efficiency in the context of the logistics industry (Lieb and Lieb 2010).

Sarkis (2001) has proposed the concept of green supply chain through the use of environmental tools such as design of processes, products and structure for environment, total quality environmental management, in-bound, out-bound and reverse logistics. It concerns practices for production planning, supply chain management, production, and finally after-sales operations. Consequently environmental management is evolving from pollution control to pollution prevention and finally to the subsequent implementation of systematic product and process management tools. Instead of having to spend money clearing up its waste, money is saved because the materials that go into the production are used more efficiently and they are required in less amount. If a firm wants to produce a green product, usually it needs more specific raw materials or packaging materials. If firms' suppliers also adopt a green perspective then it is possible to lead to strong interdependent relationships within a supply chain, what would be environmentally and economically enhancing. Accordingly to this idea, well developed systems encompass materials sourcing, manufacturing, final disposal and after sales cooperation. Green supply chain incorporates environmental criteria, concerns purchasing decisions and long-term relationships with suppliers. Such an attitude may bring transfer of environmental technology and consequently waste and cost reduction in the whole structure of supply chain. For the forward and backward flows in the supply chains, different skills are necessary. Reverse logistics is commonly considered as a part of green supply chain management. It contains planning, implementation and control backward flows of materials mainly after use of finished goods. The interaction between production, use and disposal of products brings also greater complexity and difficulties in taking environmental decisions.

Consequently sustainability concerns also strategic decisions like product and process design. Eco-design or design for environment consider the product's lifecycle in order to offer more environmentally friendly products and use environmentally sound processes, enhancing reusability, recyclability and remanufacturing possibilities, and reduction of the use of hazardous substances (Nunes and Bennett 2010). Eco-design is concerned with strategic issues. It is argued that environmental considerations must be identified at the very early stage of product development (Ölundh and Tingström 2008). Eco-design must have a clear direction and environmental targets.

Sustainable new product and process development. Typical new product development process relies on creation, market research, product design, detail engineering and environmental influence evaluation. This process may be recognized as suitable when sustainability scope and targets are clear. In such a state each project begins with defining a clear scope and a set of sustainability targets. They provide the boundaries of the project and direction for designers and engineers (Alblas et al. 2014). Targets provide also guidance and direction to design sustainable products or services. Sustainability issues are then respected in the whole process and the environmental impacts of products are known in detail (Alblas et al. 2014).

There are many methods and tools for sustainable product design. The well-known method for a sustainable product design is life-cycle assessment (LCA). It is a technique to assess the environmental impacts associated with all stages of a product's life from raw material extraction through material processing, manufacture, distribution, use, repair and maintenance, to eventual disposal or recycling (Matos and Hall 2007). The effectiveness of this method is debated in the literature. For instance, it is criticized for limited effectiveness in early product design (Sousa and Wallace 2006). This is the result of the use of imprecise, sometimes predictive or wishful input data based on expectations (sometimes on the wishes) about future technologies and their efficiency. This is generally connected with a huge rate of technological and organizational changes observed in industry, transport and logistics.

2 Industrial Sources of Waste and Pollution

Industrial growth gives local and regional positive effects. It is connected with new jobs creation, higher employment rate and increasing welfare. Other factors of economic contribution of industry and transport concern more intensive trade (especially international) of goods and services, spin-off effect and others. Positive economic contribution of transport relies on higher mobility of people (workers and consumers) and goods. The economic growth and development bring not only profits but also environmental degradation, especially when adequate regulations and other instruments destined to minimize the negative impact are not implemented. The main environmental aspects and impacts concern the activities of the industry, transport and logistics sector. Negative impact has local, regional or even global scope. Each manufacturing process gives:

- emissions of harmful substances (e.g., during a car's production, the main negative environmental impacts result from solid waste generation, emission of voltaic organic compounds) (Nunes and Bennett 2010),
- energy, water and material consumption,
- depletion of natural resources and pollution.

There are also serious environmental concerns about the production and final disposal of many products; cars, white goods, electronics etc. In addition, if there is irresponsible final disposal and inadequate management of landfill sites, end-of-life products may contaminate the soil and water. Processes realized in many industries and their products are significant sources of environmental impacts. For the automotive industry, the major global impacts result after production from vehicle use (Mildenberger and Khare 2000). The use of the automobiles consumes a significant amount of fossil fuels, and therefore is an important source of pollution. The harmful substances in the car's exhaust emissions include carbon dioxide, carbon monoxide, sulphur and nitrogen oxides, particulate material, ozone, aldehyde compounds and hydrocarbon particles (Nunes and Bennett 2010). Logistics and transport have also a significant impact on the environment. The logistics industry may pollute the natural environment. The logistics services often lead to several negative impacts on the natural environment, including air pollutants, gas emissions, hazardous waste disposal, solid waste disposal, fuel consumption, and also pollution of sea and air, traffic congestion, worse quality of water in seas and oceans (Rossi et al. 2013). Transport and logistics needs well developed infrastructure—roads, highways, parking, bridges, ring roads, which also need land. In recent years, the transportation sector has accounted for 27 % of the world's total energy consumption and 33.7 % of the greenhouse gas emissions (Tie and Tan 2013). China and Taiwan are currently the example of countries suffering from heavy environmental burdens due to serious air pollution from vehicle and industrial exhaust.

In spite of efficiency gains, in most industrial countries total energy consumption is increasing. Moreover, in practice, efficiency gains and current incentives often work against environment (Wackernagel and Rees 1996). Direct and indirect effects of the

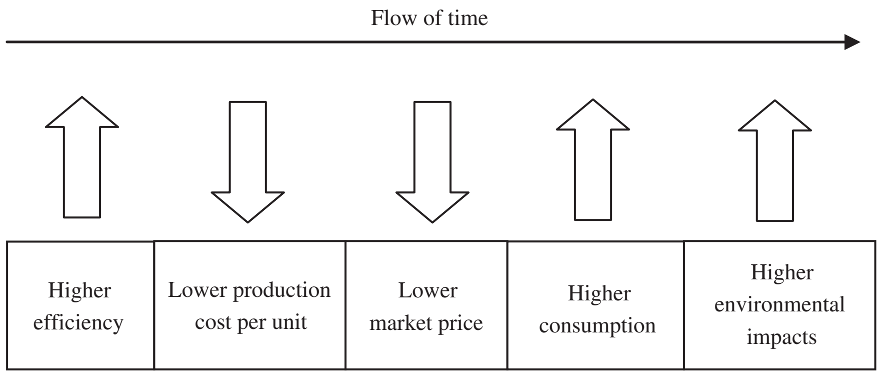

Fig. 1 The increase in overall environmental impact of efficiency gains (Wackernagel and Rees 1996)

increasing efficiency are shown in Fig. 1. Due to this conception, higher efficiency leads to increasing consumption, which increases the overall use of resources.

Because of that, environmental concerns must go beyond mere efficiency gains. All these arguments lead to more active attitude of establishment in question of sustainability.

3 Socio-political Aspects of Sustainability—Attitude of Contemporary Society and Policy Makers

While most business practices concern private profits, environmental protection is strongly recognized as a public good (Orsato 2006). There is an inter-dependence between the economic, the social and ecological sphere. The economy belongs to a society, which itself belongs to the natural environment. The balance between them may allow on sustainable growth and welfare. The inter-dependence between the environment, society and economy makes each sphere has an evident impact on the others. For example, the environment may harm the economy and society through natural disasters, while society may harm the environment realizing destructive investments, like rivers' regulations in Russia or China. Economic activity may also damage the environment with industrial pollution, may lead to depletion of natural resources. Sustainability is therefore the need to respect the three "Ps"—planet, people and profit (Kleindorfer et al. 2005). The conditions for a sustainable society have been defined by Daly (1990) and Meadows et al. (1992). They described rules for a sustainable society:

1. Society's rates of use of renewable resources do not exceed their rates of regeneration.
2. Society's rates of use of non-renewable resources do not exceed the rate at which sustainable renewable resources are developed.
3. Society's rates of pollutant emission do not exceed the assimilative capacity of the environment.

Citizens of many countries and regions face with a number of environmental challenges such as global warming, hurricanes, droughts, declining natural resources and pollution of natural environment. The question is what role the environmental regulation should play in this field. Sustainability has become a sphere of great interest, especially in case of energy intensive industries—heavy, metal, power industries, and also transport and logistics. It is a reason of increasing pressure for the adoption of environmentally friendly processes and green products promotion. If firms don't want to engage in eco-innovation then there is a need for environmental policies and regulation. There are arguments that correctly designed government regulations and institutional arrangements may stimulate sustainable development (Halila and Rundquist 2011). This opinion is now commonly accepted in the policymaking circles of many developed countries. Hence, governments formulate environmental regulations, directly or indirectly establish limits on emissions and to control the material and energy outputs of society to the environment (Ramanathan et al. 2010). Even in China policy makers have started to notice the importance of problems connected with sustainability. The result was an increased environmental pressure on Chinese manufacturers (Zhu et al. 2007). The question is how stringent regulation must be to be effective and how liberal regulation must be to avoid resistance and opposition?

3.1 Different Attitudes of Policymakers

Consequently there are seen big differences in the world. As an example, there is a large gap in regard to stringency of fuel-efficiency standards in Europe and Japan on the one hand and the USA on the other. The stringent regulation is defined as the regulation requiring meaningful environmental improvements, being costly or inducing significant technological change (Ashford 2005). The EU and Japanese policy instruments seem to be more stringent and more efficient than the USA approach (CAFE) (Leitner et al. 2010). Transport process is one of the major sources of environmental problems. Taking it into consideration, the European Commission states that its aim is to "disconnect mobility from its adverse effects" (Rossi et al. 2013). The so-called voluntary agreements are an important element of the EU's strategy to reduce CO_2 emissions from passenger vehicles, energy producers, building sector (energy saving construction, targeted in the perspective of 2020) and to generally improve fuel efficiency.

The next option is so-called "smart regulation" for industry which should stay competitive. It idea aims to make more effective and efficient use of public resources by using a greater variety of regulatory instruments, from taxes and emissions trading to corporate environmental disclosure and public participation rights (Leitner et al. 2010). Such an approach attempts to create incentives and procedures that induce entities to act in certain ways.

Standardization and benchmarking are also possible competitive regulatory tools. In contrast to traditional sustainable regulations, the involvement of mixed instruments partly adopted from their sensibility to market observations joined with the process of designing sustainable regulation appears to be a suitable approach. Authors of regulation should take into account current and future directions of technology changes. The special case is a change in environmental policy where politics clearly exceeds the given technological possibilities. The example may be Top Runner approach which has been established in Japan in 1999 and aims to reduce energy use in the commercial (for example in car industry), private as well as transport sector (Leitner et al. 2010). The most energy-efficient products and systems are awarded annually. Among the product groups (e.g., passenger cars), the most energy-efficient product (the "Top Runner") becomes the basis of the standard in three–12 years time, then the standards are used in the program of law and tax scheme proposition. Top Runner focus on the quick diffusion of new technologies and incremental innovations (Leitner et al. 2010). This is an interesting example of good cooperation between innovators and authors of eco-regulations and standards.

3.2 Expected Impact of Eco-Regulations

Most of the environmental regulations dedicated to the industrial sector have direct impact on the operations and performance of firms. Generally, there are many contrary views being expressed in the debate about the positive or negative impact of environmental regulations on the competitiveness of particular industry (Triebswetter and Wackerbauer 2008). In policy circles, the thesis of a positive relationship between environmental regulations and competitiveness became very popular in the nineties but is still controversial, primarily because of the complexity of attributing regulation and the largely ambiguous empirical evidence (Leitner et al. 2010). Many authors have found a positive relationship between environmental regulations and improved performance. There are many examples of positive effects. Zhu et al. (2007) have studied operations strategies (in the form of green supply chain practices) and performance of Chinese manufacturers in response to environmental and institutional pressures. They have found that increased environmental pressure on Chinese manufacturers improved performance of firms.

Khanna et al. (2009) argue that the mere anticipation of stringent environmental regulations is often enough to induce innovation and to have positive influence on industrial performance. In many cases the anticipation of rigid policies may entice firms to become more innovative in order to gain a competitive advantage by establishing industry standards and creating potential barriers to entry for competitors.

Maxwell et al. (2000) argue that firms are more likely to eco-innovate in anticipation of regulatory changes in cases where the threat of government regulation is high, the marginal cost of eco-innovation is low, and most importantly, the perceived marginal value by consumers for such environmental improvements is high.

The environmental regulations prompt firms to look for ways of "lean manufacturing", which lead to implementation of economical methods of production.

Christmann (2000) argues that if a firm takes action to control pollution and other environmental problems ahead of time, then the firm may be able to lower the future cost of compliance. If companies can innovate as the regulation evolves, they can also use the existing regulation to obtain a competitive advantage. In such situation companies innovate to raise resource productivity so that regulation becomes not an obstacle but a driver for innovation. Higher environmental standards mean greater protection for the environment, and will also encourage innovative practices that reduce costs and lead to new products development, making firms more internationally competitive (Ramanathan et al. 2010).

Bonato and Schmutzler (2000) derived strategic effects (spillover) explaining why environmental regulation could spur cost-reducing innovations that would not have been carried out without given regulation.

Product offsets occur when environmental regulation influences manufacturers which produce not just less pollution but also creates better performing products, safer products or lower cost products. Process offsets leads not only to reduced pollution but also higher resource productivity, materials savings, better utilization of by-products or lower energy consumption (Smith and Crotty 2008).

Berman and Bui (2001) have found that stricter regulations in the USA petroleum refining industry tend to increase abatement costs, but also increase productivity. Salama (2005) has found strong positive relationships between corporate financial performance and corporate environmental performance for top performing companies in Great Britain.

Sanchez and McKinley (1998) have studied the moderating roles of organizational characteristics on the relationships between environmental regulation and product innovation in USA firms (Sanchez and McKinley 1998). They have found that the relationships between regulatory impact and product innovation were moderated by age of the plants, with the extent of impact increasing with age. Regulatory impact had a positive impact on product innovation for older plants and had a negative impact for younger plants.

Bansal and Clelland (2004) have used regression analysis to study the influence of corporate environmental legitimacy on risk. Using relevant stock market data from highly polluting firms in the USA, they have found that firms with higher corporate environmental legitimacy have experienced lower unsystematic risk.

Manufacturing firms that can align these requirements into new green products and processes are better able to meet customer demands, thereby outperforming competitors in the market through first-mover advantages (Reinhardt 1998).

Regulation can stimulate innovation. There is even more evidence of regulation spurring radical innovation than of market-based instruments doing so (Leitner et al. 2010). However, the statement "regulation will lead to innovation" is ambivalent since any response pattern to new standards can be labeled innovative (Leitner et al. 2010).

These examples show that it is possible to adhere to regulation while at the same time improve economic performance. But opinions about effectiveness of environmental regulations are also neutral or negative. Triebswetter and Wackerbauer (2008) have studied the impact of integrated environmental product innovation on company competitiveness using qualitative analysis of case studies in selected firms in Munich in Germany. Their analysis have shown that environmental regulations of waste water, packaging waste and clean air have not resulted in an improvement in the economic performance in the German manufacturing industry but at the same time have not damaged the economic performance. On the other hand there are many examples of other numerous negative consequences of strict regulations.

3.3 Negative Consequences of Strict Regulations

Firms might have experienced a negative influence of regulations on their economic performance. The opponents prove that environmental regulations are harmful to the competitiveness. The traditional, neoclassical cost-based approach suggests that private costs induced through strict environmental regulations reduce competitiveness and productivity. A negative effect on productivity and competitiveness leads to increased expenses and therefore induces boundaries for businesses (Palmer et al. 1995). The traditional view argues that the costs incurred by a firm as a result of strict environmental regulations, reduces its competitiveness and productivity, because resources are diverted away from productive investments (Doran and Ryan 2012). The introduction of environmental regulation raises costs and results in a negative outcome for businesses. Thus regulations interfere also with the performance of firms. Higher costs of industry limits competitive advantage of domestic firms in international markets (free of such regulation). It leads to a decrease in the international competitiveness of a firm or industry when compared with those from other countries where regulations are not very stringent (Ramanathan et al. 2010).

Environmental regulations usually require significant level of capital, especially in case of pollution-intensive industries. Environmental regulation is treated as an instrument which forces companies to internalize external costs they would normally impose to society. According to the traditional view, although environmental regulations may be necessary and desirable from a social perspective, they force polluting firms to internalize costs that they would not have previously considered. This rise in costs is then reflected in a worsening of financial performance (Ramanathan et al. 2010). There are many examples showing a negative relationship between environmental regulations and companies' performance, showing that companies have viewed sustainability initiatives as driving additional costs (Abbasi and Nilsson 2012).

Rassier and Earnhart (2010) have found that eco-regulation increases costs and hence reduces the profitability of publicly held firms operating within the chemical manufacturing industries.

Similarly Brännlund and Lundgren (2010) have found evidence that eco-regulation, in the form of a CO_2 tax, reduced the profitability of most Swedish firms, especially those in energy intensive industries.

In the USA, Dean and Brown (1995) have found that environmental regulations discourage entry of new firms in several industrial sectors, reducing the competitiveness of the whole branch.

Filbeck and Gorman (2004) have looked at 24 USA electrical utilities firms and have found that regulatory compliance tends to lead to lower financial returns.

Gray and Shadbegian (2003) have found that greater abatement efforts tend to reduce productivity.

Triebswetter and Hitchens (2005) have found that in the German manufacturing industry the cost of environmental compliance relative to turnover incurred by the firms is likely to be a negative function of the productivity level.

Problems concern also non-financial aspects. Many years after the introduction of the ISO 14000 series for environmental management systems, many companies still face the challenge of strict sustainability demands (Nunes and Bennett 2010). New technologies developed as an alternative to growing environmental problems often have to face a regulation which is not suited to their diffusion, as this regulation was developed in the framework of existing in the past "traditional" technologies (Leitner et al. 2010). Consequently the environmental regulations can reduce innovation efforts. The deterministic nature of regulation limits strategic choice of possible investment projects and does not leave enough scope for firms to innovate. Many managers, mainly from heavy industry, conceive regulation as interference of their common activity. This depends on the operational approach that if the staff has to comply with lots of regulations they are less likely to spend time innovating and that they are likely to move their plants away from regions with more regulations. In effect worries about declining competitiveness of the European industry compared to their American and Asian competitors lead policy makers to reduce the regulatory burden on industry (Leitner et al. 2010). The other option is looking for such solutions which give positive effects without reduction of competitiveness.

3.4 Conditions of Positive Effect of Regulations

The management guru Porter has argued that environmental regulations can positively influence performance. It was argued that properly designed environmental regulations, coupled with a proactive attitude of managers to environmental management, would yield innovation that allowed the regulations to be met, and should encourage dynamic change and greater efficiency in the use of resources (Porter 1991). A competitive advantage might be achieved in terms of strict environmental regulation, which diffuses internationally later on. If there has been a development of technologies in response to strict environmental standards, manufacturers might be able to compete in the demanding markets. There is evidence that this can happen in highly regulated but innovating industries, such as airplane production (Leitner et al. 2010).

Innovations (also eco-innovation) may contribute to competitive advantage. Improving environmental performance may help to gain first-mover advantage and providing market leadership. Thus, a majority of evidence seems to conclude that, for most measures of performance, environmental regulation does in fact have a positive impact. It should be noted that the evidence is not 100 % conclusive (Ramanathan et al. 2010). The question which environmental policy instrument really has a positive effect on performance and innovation should be adopted remains inconclusive (Leitner et al. 2010).

Regulation and policy instruments are innovation friendly when they fulfill certain criteria (Leitner et al. 2010):

- regulations should provide both an normative and informative content, they should help to translate the environmental demand into specific rules or give an issue exact guidelines to polluters and eco-innovators as to what is expected,
- they must create the maximum opportunity to innovation, leaving the approach to innovation to industry,
- the regulatory process should leave as little room as possible for uncertainty at every stage,
- new regulations can't surprise managers,
- new regulations can't be changed shortly before they are introduced,
- regulations should be predictable, stable and realistic,
- regulation should not locking in any particular technology,
- the innovation process must be strongly linked with actions aiming to change regulations to obtain a "match" with new technology.

3.5 Other External and Internal Drivers of Eco-Investments

There are external and internal drivers of eco-investments. External drivers of eco-investments and other green supply chain practices can be classified into a few major groups:

- regulations,
- government support (e.g., grants),
- consumers and customers pressure (positive PR),
- suppliers,
- competitors pressure.

These are the primary drivers of increasingly managing sustainability. Environmental innovations may be divided into policy (first two points) and technology-induced (through contacts with external entities). For many researchers eco-regulation is the primary driver of eco-innovation. Regulation is the most important stimulus for innovation with other incentives such as cost reductions, effects of supply chain pressure and influence of campaigning being also crucial in some circumstances (Green 2005). Horbach (2008) has investigated the determinants of environmental innovation in Germany, and has found that environmental regulation was an important driver. Kammerer (2009) identified environmental regulations as the most important driver of eco-innovation as it can change the level and nature of competition between firms.

First-generation environmental regulation relied on "command and control" model. succeeding government grants can be also viewed as a potential alternative approach to encouraging eco-innovation. They can be used to fund and support a myriad of green activities such as the removal of harmful substances, incentivizing early consumer adoption of new eco-friendly goods (by sharing the costs of producing green houses and cars) or by funding research and development projects (Doran and Ryan 2012). For example in 2010, the Irish Government committed 660 million to sustainable energy programs (Doran and Ryan 2012). Firms which receive grants are more likely to introduce eco-innovation (5.96 %), however, the responsiveness of firms to this incentive is less than regulation (16.87 %) (Doran and Ryan 2012). The availability of government grants appears to be the least important (experienced by only less than 6 % of firms) while existing regulation, customer perceptions and voluntary agreements appear to be the most frequently experienced (Doran and Ryan 2012).

But grants or regulations (existing or expected) are not always needed to foster eco-innovation. Environmental technology innovation often diffuses without political impact. External linkages are also important drivers of eco-innovation. In many cases consumer demand for environmentally friendly products, interest group pressures, social corporate responsibility and public procurement requirements are enough to induce firms to develop, adapt and use more environmentally friendly products, process and management systems (Horbach 2008). Community may exert pressure, for example by causing negative publicity, on firms to improve certain aspects of activity. Pressure from environmental interest groups, seem to compel organizations to take appropriate actions and manage their sustainability. The adoption of eco-efficient standards became to be a requirement for companies to be selected by customers and included in their supply chains (Seuring and Müller 2008).

Furthermore, it is important to highlight the role of sustainable consumption for overall sustainability and customer demand for sustainable goods and services. The adoption of eco-efficient standards seems to be a basic requirement of a growing group of customers. Market demand was found to have significant impact on green product innovation and green process innovation (Lin et al. 2014). Significant relationships were found between green product innovation and market share and reputation. Green process innovation also was found to have significantly positive impact on both market share and reputation (Lin et al. 2014). The next largest effect is a customer's perception. The demand for eco-innovation products is largely driven by the way in which consumers perceive the eco-innovation. Firms which believe customers expect environmentally friendly products are 43 % more likely to eco-innovate (Kammerer 2009).

Some authors revealed a growing education on sustainability among the consumers (Hitchcock 2012; Svensson and Wagner 2012). Khanna et al. argue that the pressure on firms to eco-innovate is strongest in product markets which are close to final consumers. In these markets consumers are often willing to pay premiums for environmentally friendly products and therefore firms often voluntarily eco-innovate (Khanna et al. 2009). Such eco-innovations allow firms to produce higher quality environmental friendly products while simultaneously differentiating themselves from their competitors. Van Hoek (2002) adds how important is to consider if there is a market willing to pay for the green product and other business issues. Green-conscious customers demand innovative green products, and have demonstrated a willingness to pay higher prices for green products (Chen et al. 2008). Manget et al. (2009) found that consumers in Canada, France, Germany, Italy, Japan, Spain, the UK and the USA are willing to pay five to ten percent more for green goods. But Kammerer has found that consumers are only willing to pay for eco-innovation if the associated products deliver quantifiable added value. He contends that while consumers will readily pay extra for environmental friendly baby food and clothes, they are not always willing to pay extra for green electricity as the added value is difficult to measure (Kammerer 2009). Oltra and Saint Jean (2009) pointed out the considerable demand for products capable of meeting environmental criteria, demands for decreased fuel consumption, and lower prices.

However, customers' attitudes do not always appear to be clear. Concerns about the environment and future generations are still not included in customers' utility function so that the decision making process will not lead them towards a more environmentally friendly purchase, unless there are no differences in the final price (Rossi et al. 2013). Rehfeld et al. (2007) disputed the existence of a strong stimulus for eco-innovation from the demand side, citing the fact that green products are still expensive and not all customers are willing to trade off product quality or features for green attributes.

Whereas customers can create a sustainability pressure, suppliers can give incentives for eco-innovations. Suppliers can develop more sustainable ways of mining materials or producing parts and thereby offer an opportunity to improve product sustainability. Unfortunately, suppliers can offer the same solutions to competitors. Supply-side drivers are also important in case of eco-innovation. The successful implementation of new and more sustainable product designs heavily depends on suppliers' willingness to cooperate in sustainability improvements, and, most likely, to implement changes as well (Alblas et al. 2014). Geffen and Rothenberg (2000) found evidence that whilst the networking activities of firms (horizontal linkages) is an important driver of eco-innovation, a strong relationship with suppliers (backward linkage) is particularly key. Industries with highly integrated supply chains are often able to reduce costs and, as a result, remain globally competitive while simultaneously reducing their energy use and carbon footprint (Doran and Ryan 2012). In Ireland Roper et al. checked how firms engage in collaboration with customers, suppliers, competitors, universities and public research institutes in the development of new innovations.

The linkages to suppliers had a significant positive effect on the probability of eco-innovation (Roper et al. 2008). Cooperation with suppliers can increase the likelihood of engaging in both product and process innovation (Doran and Ryan 2012). The remaining external factors have been found to have no significant impact on the likelihood of eco-innovation.

Competitors' successful sustainable products may force a firm to change its practices in order to stay in the competition. If a competitor stay behind in sustainable products development process, this may give the firm an opportunity to acquire a competitive advantage (Alblas et al. 2014). If a competitor fails it will be a sign that he committed some mistakes or chose wrong direction of development.

Manufacturers are also internally triggered to boost sustainability. By improving the sustainability of products and operations, manufacturers assume they can cut costs, improve quality, acquire a green and social image, through which a competitive advantage can be sustained or gained (Forsman 2013).

The performance of internal R&D may also act to develop internal resources and the absorptive capacity of the firm which can be leveraged for the introduction of new eco-innovations (Cohen and Levinthal 1990).

Firms which build organizational capabilities in areas such as pollution control, green sourcing, green product design and efficient energy use are most likely to eco-innovate. Many argue that the more innovative company and the more knowledge it has accumulated, the higher its capacity to apply these factors to environmental innovation (Kemp and Foxon 2007).

Internal drivers include also awareness of shareholders, their open-minded attitude for new ideas, and middle management involvement. Many firms have realized the importance of sustainable development and the dangers of a deteriorating global environment (Tseng et al. 2009). This is particularly true in the vehicle manufacturing industry (Hoffmann 2007).

4 Sustainable Strategies in Supply Chains

There is a growing pressure worldwide to deliver products and services which are environmentally friendly. It may lead to the redesign of products and production processes so as to reduce waste and pollution which is a side effect of manufacturing process. Green et al. (2012) assumed that environmental sustainability must be adopted as a strategic imperative, incorporated as a key part of the organization's mission. The incorporation of eco-efficiency strategy into the mission refers to the development of eco-efficient processes, products and services, performance measurement encompasses the methods and indicators for eco-efficiency to assess the environmental performance and to cascade the environmental strategy within the supply chain (Rossi et al. 2013). Over recent decades, manufacturing organizations have shown a growing interest in managing the sustainability of their operations, supply chain, and products (Alblas et al. 2014). With increasing concern about environmental issues from customers, suppliers, the public and governments around the world, firms have been developing a number of environmentally friendly products (Tseng et al. 2013). Increasing attention to environmental concerns has forced firms to develop new green products and manufacturing processes to satisfy rigorous environmental regulations and overcome competitors through differentiation strategies (Lin et al. 2014). Firms promote green innovation in the manufacturing making environmentally friendly products and reducing environmental damage. Many firms developed flexible, energy-efficient manufacturing strategies. Sustainability within a supply chain means a systematic view and control of the environmental impacts of a company's products, services, processes and operations, sourcing of materials, manufacturing processes, logistics, delivery and disposal of end-of-life product. In some cases, firms have simply reacted to the environmental regulations while there are also several firms that have taken a more proactive role in reducing pollution due to their production and logistics processes. For many companies the opportunity to improve economic and also environmental performances results from collaboration through along the whole supply chain. Sometimes it is necessary to reconfigure the supply chain pulling the collaboration within this structure through common standards and procedures. Some manufacturers formulate environmental plans, which are useful in case of analyzing the suppliers, manufacturing and logistics capabilities needed to achieve eco-efficiency in supply chains (firms in the service sector also LSP are less likely to do it (Rossi et al. 2013). A company may publish environmental strategy showing who is responsible for environmental issues within the organization, and to what level the environmental policy is embedded in the organization (Rossi et al. 2013). In the transportation sector and logistics industry techniques for saving energy and reducing air pollution and CO_2 emissions have become important issue and principal challenges (Hui 2010). Additionally a significant factor increasing sustainability in the supply chains became third-party logistics providers' performance. They focus on improving resource utilization (e.g., cars and warehouses) and making processes more eco-efficient.

4.1 Benefits and Consequences of Sustainable Strategies

Green innovation can help firms to increase productivity, enhance corporate reputation, develop new markets, and achieve first-mover competitive advantages. In the automobile industry, in response to progressively stricter regulations, automobile manufacturers have developed innovations for the internal combustion engine, which have increased energy efficiency and reduced emissions of greenhouse and other toxic gases (Orsato and Wells 2007). This may be supported by the case of the Toyota Prius Hybrid, which has become a status symbol and an example for green-labeling product strategies (Bonini and Oppenheim 2004). Hybrid vehicle technology in Taiwan appears to be a promising solution to meet environmental regulations and customer demand (Fontaras and Samaras 2007).

Examples of further environmental innovation include the "design for disassembly initiative" of BMW, 3 M company's Pollution Prevention Pays principle, Chevron's Save Money and Reduce Toxics (SMART) program (Ramanathan et al. 2010).

Another example is sustainable innovation process for the "Mirra" chair. The American-based furniture company Herman Miller developed a tailored "design for the environment" (DfE), a product assessment tool that measures the extent to which a product meets environmental standards and expectations, paying special attention to: material toxicity, ease of disassembly, recyclability (Rossi et al. 2006). DfE was applied to the innovation process for a new ergonomic chair called the "Mirra". The 180 components of the Mirra were analyzed and rated according to how damaging they were to humans and the environment (Rossi et al. 2006). It was a huge challenge to find fully non-toxic materials and to gain the support of numerous suppliers. During the innovation process, Herman Miller also organized some 200 face-to-face meetings with suppliers to explain what it was trying to achieve with the DfE process and the Mirra (Rossi et al. 2006). Finally, changes were made to chemicals and components. But designers were unable to achieve 100 % in all three categories (Rossi et al. 2006).

Another example is the jump from coal to renewable energy in China and India. In China the lack of financing for developing a local wind-turbine manufacturing industry has been overcome with favorable government policies (Watson and Sauter 2011).

Toyota has a wide range of product and process-based initiatives. Starting with "green building" practices in August 2006, Toyota built the first Leadership in Energy and Environmental Design (LEED) certified automotive dealer facility in the USA. This facility uses 20 % less energy and 35 % less water than conventional object. These energy conservation measures have led to reduced costs and other benefits for the dealer (Nunes and Bennett 2010).

Toyota has extended its partnership with Panasonic to develop lithium batteries to replace nickel cadmium ones in its hybrid vehicles. Lithium batteries, which are currently used in laptop computers and mobile telephones, are much lighter, have a longer life and greater storage capacity. In order to use eco-friendly parts in production, Toyota is evaluating new materials from renewable resources such as eco-plastics, natural fibre and recycled plastics (Nunes and Bennett 2010).

More environmental supply chains are created by Toyota's environmental requirements for suppliers of parts or materials (Greener Supplier Guidelines and Green Purchasing Guidelines) and also by better logistics systems to reduce emissions in urban areas, avoid traffic jams, etc. Toyota has also moved shipments from truck to rail and reduced the number of miles trucks run empty between shipments (Nunes and Bennett 2010).

Other green supply chain initiatives related to supplier collaboration and logistics include improved packing and reusable metal shipping containers rather than disposable cardboard and wood pallets (Nunes and Bennett 2010).

To reduce the environmental impact from its production sites and processes, Toyota has adopted initiatives such purchasing of green (wind-generated) power

(Nunes and Bennett 2010). Reduction initiatives relate to water and energy, materials and toxic substances. The main source of environmental impact in production is usually the paint-shop, so one of the main improvements was achieved when Toyota converted its topcoat paints to a water-borne type. Reverse logistics initiatives have also promoted the collection and recycling of end-of-life parts, working with dealers and parts distributors (Nunes and Bennett 2010).

Such actions may be supported by the company's eco-design targets for dismantling and recycling. Ensuring that the final disposal and eco-efficient backward flow of end-of-life products are taken responsibly became a focus of LSPs. Sometimes it lead to focus on reverse logistics as a driver for LSP selection (Wolf and Seuring 2010).

4.2 Logistics Service Providers and the Sustainability

It is widely known that the transportation process has a great impact on supply chain sustainability. There are many opportunities for LSPs to improve their approach to eco-efficiency. The main focus of LSPs in terms of sustainability points directly towards their operations connected with transport route optimization, drive to economize, packaging, recycling looking for recyclable and reusable materials. Lieb and Lieb (2010) explain the extent to which large logistics service providers have committed themselves to environmental sustainability objectives. In pursuing sustainability goals, many of the LSP have closely worked with customers, transportation companies, trade associations, non-governmental organizations, and government agencies.

Fields of technological innovation in logistics contain such solutions like:

- usage of new means of transport, in context both quantitative (e.g., size of containerships) and qualitative (higher standards and security),
- other solutions in the field of transport, connected for example with the flow of information that helps to reduce a number of empty runs,
- solutions promoting quite new ways of transport like usage of drones for goods transport,
- new eco-efficient methods of reloading, warehousing, storage.

The other example is a case of TNT company (LSP) which introduced new interesting solution, based on portable agency. It consists of specialized semitrailer which performs as a sorting installation and portable warehouse, which may fit 11 containers with packages. It also consists of 3 three cycles. They are used to transport packages (taken from semitrailer) to receivers. This solution has been implemented in Brussels and appeared to be very useful in a congested city. It was financed by European Union, within the program Straightsol, supporting such environmental friendly initiatives (Mobilny oddział kurierski 2014).

4.3 Inhibitors of Sustainability

Despite market demand for green products like vehicles with higher fuel-consumption-efficiency, lower air pollution, failure to implement green innovation practices or invest in environmental management prevented the expected improvement in environmental investments. There are several reasons of such complications. Reducing the weight of cars is one of the techniques to reduce fuel consumption during use. This is usually done by substituting plastics, aluminium and composites for steel in cars. However, this technique makes disassembly more difficult, and therefore negatively affects the recycling of end-of-life vehicles (van Hoek 2002).

Companies tend to assume an internal rather than a supply chain perspective while planning to implement environmental initiatives (Vachon and Klassen 2006). In many cases sustainable solutions are still limited to the single member of supply chain. Improvements to existing technologies and reductions in resource inputs, materials and wastes, referred to only single facility or entity. Even when a completely new "clean" technology is introduced, it often results in a single change of environmental performance such as CO_2 emissions or lower water consumption but the change within supply chain is slight. Such a situation may be met when a manufacturer uses just-in-time practice which improve environmental performance in a particular facility, forcing its suppliers to more frequent deliveries. Such solution leads to increase of the energy usage in logistics, because of more frequent deliveries.

Interviews with chosen managers and workers from different manufacturing sectors and logistics industry show that companies still face huge difficulties in managing sustainability. The negative factors related to external and internal inhibitors remain still an obstacle. There are many examples of them:

- cost implications, when cost is much higher than expected before launching the new eco-innovation processes, projects, products and services,
- for many firms (especially in logistics industry) new issues (like new eco-efficient cars) are simply too costly,
- insufficient resources—especially small firms are not likely to have needed equipment,
- ambiguous law and regulations,
- a misperception of what should be done,
- lack of guidelines on how to implement environmental initiatives,
- unclear or too restrict regulations,
- fragmented and complex regulations,
- lack of support from governmental institutions in terms of regulations,
- insufficient communication with standard-setting agencies,
- incomplete information from regulation institutions,
- lack of flexibility of regulatory institutions,
- too restrictive inspections,

- inadequate knowledge and skills of personnel (own or partners in supply chain), (many managers are still inexperienced in dealing with environmental issues),
- lack of synchronization between suppliers and manufacturers,
- the complexity of communication and coordination efforts in supply chains, what increases in case of fragmented supply chains,
- low ability to control activity within the whole supply chain,
- poor commitment with members of supply chain and controlling
- poor suppliers', carriers', forwarders' and logistics service providers' performance,
- a focal firm may have limited bargaining power and can face huge resistance,
- green innovation involves high market uncertainty and risk,
- market demand often varies due to disturbances that may occur as a result of changes of attitude of consumers,
- specific for particular branch barriers,
- internal organizational inertia,
- control problems,
- poor internal and external attention of workers and managers to the environmental topics,
- organizations have limited attention and consequently ignoring some innovation opportunities.

Problems with unclear regulations seem to be very important. The calculation of CO_2 emissions is very complex because a global standard is still missing and there are differences not only among different countries, but also among companies within the same country (Rossi et al. 2013). Due to attention regarding the environment regulation among LSPs, there is a lack of suitable guidelines on how to implement initiatives. An example may be a company which is a member of a round table on CO_2 emissions calculation, organized by the Freight Transport Association-UK (FTA) which had serious problems with this question (Rossi et al. 2013). Unofficially many representatives of this industry confirm it.

Often there are many more important targets at the moment. The environmental initiatives must compete against other prospective targets in an organization like sales campaigns, distribution expansion, new supplier's evaluation process etc. Moreover sustainable initiatives not always return a profit for an individual entity.

5 Conclusion

Sustainable initiatives are very popular in contemporary society. Policymakers in many countries joined to this trend, setting many regulations. They are to force manufacturers and other companies to look for new more environmental friendly solutions. They may concern way of manufacturing, raw materials choice and deliveries, eco-design of products or processes, logistics solutions. Effects of regulations are disputable. Researchers found both positive and negative effects. Sometimes it depends on stringency of regulations, sometimes on good cooperation within supply chain. What is really important, many firms prove that apart of regulations and other drivers there are still many serious (sometimes "invisible") inhibitors which often are really troublesome.

References

Abbasi M, Nilsson F (2012) Themes and challenges in making supply chains environmentally sustainable. Supply Chain Manage Int J 17(1):517–530

Alblas A, Peters K, Wortmann J (2014) Fuzzy sustainability incentives in new product development. An empirical exploration of sustainability challenges in manufacturing companies. Int J Operations Prod Manage 34(4):513–545

Ashford NA (2005) Government and environmental innovation in Europe and North America. In: Weber M, Hemmelskamp J (eds) Towards environmental innovation systems. Springer, Berlin, pp 159–174

Bansal P, Clelland I (2004) Talking trash: legitimacy, impression management, and unsystematic risk in the context of natural environment. Acad Manag J 47(1):599–615

Berman E, Bui LTM (2001) Environmental regulation and productivity: evidence from oil refineries. Rev Econ Stat 83:498–510

Bonato D, Schmutzler A (2000) When do firms benefit from environmental regulations? a simple microeconomic approach to the porter controversy. Schweizerische Zeitschrift für Volkswirtschaft und Statistik 136(4):513–530

Bonini SMJ, Oppenheim JM (2008) Helping green products grow. McKinsey Quarterly, October, pp 1–8

Brännlund R, Lundgren T (2010) Environmental policy and profitability: evidence from Swedish industry. Env Econ Policy Studies 12(1–2):59–78

Carter CR, Easton PL (2011) Sustainable supply chain management: evolution and future directions. Int J Phys Distrib Logistics Manage 31(1):46–62

Chen LY, Hwa MY, Lee YC, Yu TY, Wu CT (2008) Particle size distribution of exhaust stream from in-use motorcycles. J Env Eng Manage 18(6):397–402

Christmann P (2000) Effects of 'best practices' of environmental management on cost advantage: the role of complementary assets. Acad Manag J 43(4):663–680

Cohen W, Levinthal D (1990) Absorptive capacity: a new perspective on learning and innovation. Adm Sci Q 35(1):128–152

Daly H (1990) Toward some operational principles of sustainable development. Ecol Econ 2:1–6

Dean TJ, Brown RL (1995) Pollution regulation as a barrier to new firm entry: initial evidence and implications for future research. Acad Manag J 38:288–303

Dias-Sardinha I, Reijnders L (2001) Environmental performance evaluation and sustainability performance evaluation of organizations: an evolutionary framework. Eco-Manage Auditing 8:71–79

Doran J, Ryan G (2012) Regulation and firm perception, eco-innovation and firm performance. Eur J Innov Manage 15(4):421–441

Filbeck G, Gorman RF (2004) The relationship between the environmental and financial performance of public utilities. Environ Res Econ 29(2):137–157

Fontaras G, Samaras Z (2007) A quantitative analysis of the European automakers' voluntary commitment to reduce CO2 emissions from new passenger cars based on independent experimental data. Energy Policy 35(4):2239–2248

Forsman H (2013) Environmental innovations as a source of competitive advantage or vice versa? Bus Strategy Environ 22(5):306–320

Geffen C, Rothenberg S (2000) Suppliers and environmental innovation—the automotive paint process. Int J Oper Prod Manage 20(2):166–186

Gray WB, Shadbegian RJ (2003) Plan vintage, technology and environmental regulation. J Environ Econ Manage 46:384–402
Green KW, Zelbst PJ, Meacham J, Bhadauria VS (2012) Green supply chain management practices: impact on performance. Supply Chain Manage Int J 17(3):290–305
Green K (2005) Towards environmental innovation—a policy synthesis. In: Weber M, Hemmelskamp J (eds) Towards environmental innovation systems. Springer, Berlin, pp 319–323
Gupta M, Sharma K (1996) Environmental operations management: an opportunity for improvement. Prod Inventory Manage J 37(3):41–43
Halila F, Rundquist J (2011) The development and market success of eco-innovations: a comparative study of eco-innovations and other innovations in Sweden. Eur J Innov Manage 14(3):278–302
Helminen RR (2000) Developing tangible measures for eco-efficiency: the case study of the Finnish and Swedish pulp and paper industry. Bus Strategy Environ 9(3):196–210
Hitchcock T (2012) Low carbon and green supply chains: the legal drivers and commercial pressures. Supply Chain Manage an Int J 17(1):99–100
Hoffmann E (2007) Consumer integration in sustainable product development. J Prod Innov Manage 16(5):332–338
Horbach J (2008) Determinants of environmental innovation—new evidence from German panel data sources. Res Policy 37(1):163–173
Hui S (2010) Multi-objective optimization for hydraulic hybrid vehicle based on adaptive simulated annealing genetic algorithm. Eng Appl Artif Intell 23(1):27–33
Jumadi H, Zailani S (2010) Integrating green innovations in logistics services towards logistics service sustainability: a conceptual paper. Env Res J 4(4):261–271
Kammerer D (2009) The effects of customer benefit and regulation on environmental product innovation: empirical evidence from appliance manufacturers in Germany. Ecol Econ 68(8–9):2285–2295
Kemp R and Foxon T (2007) Eco-innovation from an innovation dynamics perspective, measuring eco-innovation.eu sixth framework programme, vol. 6. Mannheim, Deliverable 1 of MEI project (D1), p 25
Khanna M, Deltas G, Harrington DR (2009) Adoption of pollution prevention techniques: the role of management systems and regulatory pressures. Env Res Econ 44(1):85–106
Klassen RD, Whybark DC (1999) The impact of environmental technologies on manufacturing performance. Acad Manage J 42(5):599–615
Kleindorfer PR, Singhal K, van Wassenhove LN (2005) Sustainable operations management. Prod Oper Manage 14(4):482–492
Leitner A, Wehrmeyer W, France Ch (2010) The impact of regulation and policy on radical eco-innovation. The need for a new understanding Manage Res Review 33(11):1022–1041
Lieb KJ, Lieb RC (2010) Environmental sustainability in the third-party logistics (3PL) industry. Int J Phys Distrib Logistics Manage 40(7):524–533
Lin RJ, Chen RH, Huang FH (2014) Green innovation in the automobile industry. Ind Manage Data Syst 114(6):886–903
Manget J, Roche C, Münnich F (2009) For real, not just for show. MIT Sloan Manage Rev
Matos S, Hall J (2007) Integrating sustainable development in the supply chain: the case of life cycle assessment in oil and gas and agricultural biotechnology. J Operations Manage 25(6):1083–1102
Maxwell WJ, Lyon T, Hackett S (2000) Self-regulation and social welfare: the political economy of corporate environmentalism. J Law Econ 43(2):583–617
Meadows DH, Meadows DL, Randers J (1992) Beyond the limits. Chelsea Green Publishing, White River Junction, VT
Mildenberger U, Khare A (2000) Planning for an environment-friendly car. Technovation 20:205–214
Mobilny oddział kurierski—@: http://logistyka.infor.pl/uslugi-kurierskie/wiadomosci/673562,mobilny-oddzial-kurierski.html. Accessed 10 Aug 2014

Nunes B, Bennett D (2010) Green operations initiatives in the automotive industry. An environmental reports analysis and benchmarking study, Benchmarking. Int J 17(3):396–420
Oltra V, Saint Jean M (2009) Sectoral systems of environmental innovation: an application to the French automotive industry. Technol Forecast Soc Chang 76(4):567–583
Ölundh Sandström G, Tingström J (2008) Management of radical innovation and environmental challenges development of the DryQ capacitor at ABB. Eur J Innov Manage 11(2):182–198
Orsato RJ (2006) Competitive environmental strategies: when does it pay to be green? Calif Manage Rev 48(2):127–143
Orsato RJ, Wells P (2007) U-turn: the rise and demise of the automobile industry. J Clean Prod 15(11/12):994–1006
Palmer K, Oates W, Portney P (1995) Tightening environmental standards: the benefit-cost or the no-cost paradigm? J Econ Perspect 9:119–132
Porter ME (1991) America's green strategy. Sci Am 264(4):168
Ramanathan R, Black A, Nath P, Muyldermans L (2010) Impact of environmental regulations on innovation and performance in the UK industrial sector. Manag Decis 48(10):1493–1513
Rassier DG, Earnhart D (2010) The effect of clean water regulation on profitability: testing the Porter hypothesis. Land Econ 86(2):329–344
Rehfeld KM, Rennings K, Ziegler A (2007) Integrated product policy and environmental product innovations—an empirical analysis. Ecol Econ 61(1):91–100
Reinhardt FL (1998) Environmental product differentiation: implications for corporate strategy. Calif Manage Rev 40(4):43–73
Roper S, Du J, Love J (2008) Modeling the innovation value chain. Res Policy 37(6–7):961–977
Rossi S, Colicchia C, Cozzolino A, Christopher M (2013) The logistics service providers in eco-efficiency innovation: an empirical study. Supply Chain Manage: Int J 18(6):583–603
Rossi M, Charon S, Wing G, Ewell J (2006) Design for the next generation: incorporating cradle-to-cradle design into Herman Miller products. J Ind Ecol 10(4):193–210
Salama A (2005) A note on the impact of environmental performance on financial performance. Struct Change Econ Dynamics 16:413–421
Sanchez CM, McKinley W (1998) Environmental regulatory influence and product innovation: the contingency effects of organizational characteristics. J Eng Technol Manage 15(4):257–278
Sarkis J (2001) Greener manufacturing and operations: from design to delivery and back. Greenleaf, Sheffield
Schmidheiny S, Zorraquin FJL (1996) Financing change, the financial community, eco-efficiency, and sustainable development. MIT Press, Cambridge
Seuring S, Müller M (2008) From a literature review to a conceptual framework for sustainable supply chain management. J Clean Prod 16(15):1699–1710
Smith M, Crotty J (2008) Environmental regulation and innovation driving ecological design in the UK automotive industry. Bus Strategy Environ 17(6):341–349
Sousa I, Wallace D (2006) Product classification to support approximate life-cycle assessment of design concepts. Technol Forecast Soc Chang 73:228–249
Svensson G, Wagner B (2012) Implementation of a sustainable business cycle: the case of a Swedish dairy producer. Supply Chain Manage Int J 17(1):93–95
Tie SF, Tan CW (2013) A review of energy sources and energy management system in electric vehicles. Renew Sustain Energy Rev 20(4):82–102
Triebswetter U, Hitchens D (2005) The impact of environmental regulation on competitiveness in the German manufacturing industry: a comparison with other countries of the European Union. J Clean Prod 13(7):733–745
Triebswetter U, Wackerbauer J (2008) Integrated environmental product innovation and its impact on company competitiveness in the region of Munich. J Clean Prod 16:1484–1493
Tseng ML, Divinagracia L, Divinaracia R (2009) Evaluating firm's sustainable production indicators in uncertainty. Comput Ind Eng 57(4):1393–1403
Tseng ML, Wang R, Chiu ASF, Geng Y, Lin YH (2013) Improving performance of green innovation practices in uncertainty. J Clean Prod 40:71–82

Vachon S, Klassen RD (2006) Extending green practices across the supply chain: the impact of upstream and downstream integration. Int J Operations Prod Manage 26(7):795–821

van Hoek RI (2002) Case studies of greening the automotive supply chain through technology and operations. Int J Technol Manage 23(1–3):89–112

Venus LY (2010) Green management practices and firm performance: a case of container terminal operations. Resour Conserv Recycl 55(6):559–566

Wackernagel M, Rees W (1996) Our ecological footprint: reducing human impact on the earth. New Society, Philadelphia

Watson J, Sauter R (2011) Sustainable innovation through leapfrogging: a review of the evidence. Int J Technol Globalisation 5(3/4):170–187

Wolf C, Seuring S (2010) Environmental impacts as buying criteria for third party logistical services. Int J Phys Distribution Logistics Manage 40(1):84–102

World Commission on Environment and Development (1987) Our common future. Oxford University Press, Oxford

Zailani S, Amran A, Jumadi H (2011) Green innovation adoption among logistic service providers in Malaysia: an exploratory study on the managers' perceptions. Int Bus Manage 5(3):104–113

Zhu Q, Sarkis J, Lai K (2007) Green supply chain management: pressures, practices and performance within the Chinese automobile industry. J Clean Prod 15:1041–1052

Logistic Sector as a Support Segment for Sustainable Supply Chains

Arkadiusz Kawa and Anna Maryniak

Abstract The aim of this chapter is to draw attention to the growing importance of supply chain sustainability (SCS) and to present practical solutions in this field on the example of the logistics industry. In the research, literature review, surveys and case studies have been used. The results of the analyses have led to the conclusion that an increasing number of researchers have become interested in the subject of SCS in the last few years. On the basis of the survey, it has been stated that education is particularly important in minimizing the negative impact on the environment, formulating professional announcements about CSR and strategic and operational issues of sustainable logistics. In addition, it has been found out that from among stakeholders of closer and more distant environment of businesses entities of the logistics industry are attributed great importance in the development of sustainable supply chains, equivalent to other entities directly involved in the supply chain. The examples of practical CSR projects prove that logistics service providers strongly affecting other entities outside the industry focus on this topic. The aim of this chapter is to draw attention to the growing importance of supply chain sustainability (SCS) and to present practical solutions in this field on the example of the logistics industry. In the research, literature review, surveys and case studies have been used. The results of the analyses have led to the conclusion that an increasing number of researchers have become interested in the subject of SCS in the last few years. On the basis of the survey, it has been stated that education is particularly important in minimizing the negative impact on the environment, formulating professional announcements about CSR and strategic and operational issues of sustainable logistics. In addition, it has been found out that from among stakeholders of closer and more distant environment of businesses entities of the logistics industry are attributed great importance in the development

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of sustainable supply chains, equivalent to other entities directly involved in the supply chain. The examples of practical CSR projects prove that logistics service providers strongly affecting other entities outside the industry focus on this topic.

Keywords Logistics industry · Logistics service providers · CSR projects · Supply chain sustainability

1 Introduction

Milton Friedman, the elder statesman of "Chicago School" economics, has argued that social initiatives are "fundamentally subversive", because they undermine the profit-seeking purpose of public companies The State of Corporate Citizenship in the US (2005, p. 2). On the basis of the ongoing series of surveys conducted in the United States, it can be claimed that the most business leaders have charted a different course than Friedman. The attitudes and actions of businesses—regardless of size, sector, or region—show that businesses play a wide-ranging role in our society and should participate in corporate social responsibility actions.

The issue of Corporate Social Responsibility (CSR), expands currently in theory and practice on partner's, customer's, supplier's, logistic operator's and trade agent's behaviors in a supply chain. It is thus, justified to consider CSR in terms of vertical and horizontal integrated Caroll's (1979, 1991) pyramids, representing each stakeholder.[1]

Globalization and internationalization of practices and global trends in supply chain management (Next-Generation Supply Chains 2013; Outlook on the Logistics & Supply Chain Industry 2013) point that logistic sector can play a crucial role as an integrator and diffusor of socially responsible actions.

2 Conceptual Framework of a Sustainable Supply Chain

In order to identify issues discussed within the framework of sustainability supply chain concept and to evaluate the increase of the interest in this science discipline the literature review have been conducted. As a source of the research Web of Science data base was chosen, including Science Citation Index Expanded (SCI-EXPANDED)—1945–present; Social Sciences Citation Index (SSCI)—1956–present; Arts & Humanities Citation Index (A&HCI)—1975–present; Conference Proceedings Citation

[1] The United Nations Global Compact (2010, p. 7) refers to supply chain sustainability (SSC) and defines this as "the management of environmental, social and economic impacts and the encouragement of good governance practices, throughout the lifecycles of goods and services. The objective of supply chain sustainability is to create, protect and grow long-term environmental, social and economic value for all stakeholders involved in bringing products and serves to markets".

Table 1 The output of authors writing about SSC

Field: authors	Record count	% of 416
Seuring S	14	3.365
Sarkis J	10	2.404
Guillen-Gosalbez G	6	1.442
Pagell M	6	1.442
Jimenez L	5	1.202
Wu ZH	5	1.202
Carter CR	4	0.962
Chaabane A	4	0.962
Cruz JM	4	0.962
Govindan K	4	0.962
Kumar S	4	0.962
Mele FD	4	0.962
Searcy C	4	0.962
Beske P	3	0.721
Buyukozkan G	3	0.721
Dehghanian F	3	0.721
Gold S	3	0.721
Gunther HO	3	0.721
Hall J	3	0.721
Klassen RD	3	0.721
Koh SCL	3	0.721
Manzardo A	3	0.721
Matos S	3	0.721
Paquet M	3	0.721
Ramudhin A	3	0.721
Ren JZ	3	0.721
Scipioni A	3	0.721
Toniolo S	3	0.721
Vermeulen WJV	3	0.721

Index-Science (CPCI-S)—1990–present; Conference Proceedings Citation Index-Social Science & Humanities (CPCI-SSH)—1990–present. Using the search query: Sustainability Supply Chain, Socially Responsibility Supply Chain, Responsibility Supply Chain, over 400 records have been found.[2]

Whilst the conducted research has produced the conclusion that a very few scientists in global scale specialize in sustainability supply chain issues and the most authors have only just a few titles (Table 1) in their literary output, the analysis

[2] The research had some limitations, because of the time when it was conducted. It doesn't present complete data from 2014, but only data until April. Moreover, it is recommended that the research should be complemented with other bibliometric research methods. In this connection, the presentation of data should be treated as an analysis illustration, which from other research perspectives will seem to be different, but generally similar.

of the given releases of the several titles indicate clearly that the interest in SSC issues has increased.

The review of issues discussed by the given authors leads to the conclusion that the subject matter of SSC is exceptionally complex[3] and it is problematic to maintain a comprehensive scientific discourse in this matter. Therefore, establishing a framework supporting SSC implementation is extremely difficult. Moreover, the attempts of setting the framework for SSC (Carter and Jennings 2004; Carter and Rogers 2008; Jayaratne et al. 2011; Maloni and Brown 2006; Morali and Searcy 2013; Seuring and Müller 2008; Svensson 2007; Zhu et al. 2007; Zsidisin and Siferd 2001) don't provide a finite set of rules explaining socially responsible actions in a supply chain, and each subsequent proposal of the framework only shows other perspectives for possible analyses.

Taking the above into consideration, it is advisable to develop specific business models on the basis of general guidelines found in the literature, which integrate the issues of sustainable development typical of the given sector.

As a starting point of the future analyses the following research scheme can be used (Fig. 1).

As presented clearly by the given scheme, the logistic sector is naturally predisposed in an exceptional way to the diffusion of knowledge about socially responsible actions in the entire supply chain and therefore, it can play a significant role in underpinning SSC.

3 Challenges and Directions of Development of the Logistics Industry in the Context of Corporate Social Responsibility

The transport, forwarding and logistics industry and, in particular, its entities—logistics companies—constitute an important element of present-day supply chains, but also the economy. In terms of its direct contribution to the economy, logistics services account for around 9 % of global GDP (2013). In the European Union alone, the logistics sector generated revenues of €1 trillion in 2009, or around 10 % of European GDP (Klaus and Kille 2008/2009).

In spite of its maturity, this sector is still being shaped and its structures are being established. There are many companies specialized in one field of logistics activity, such as warehouse businesses, transport companies (http://www.commdev.org/files/1339_file_Logistics.pdf), customs agencies. Logistics operators also emerge that integrate processes related with transport, storage, distribution and that serve whole supply chains.

[3] Due to the text width, individual topics and years of publications assigned to the specific authors have not been distinguished in the tables.

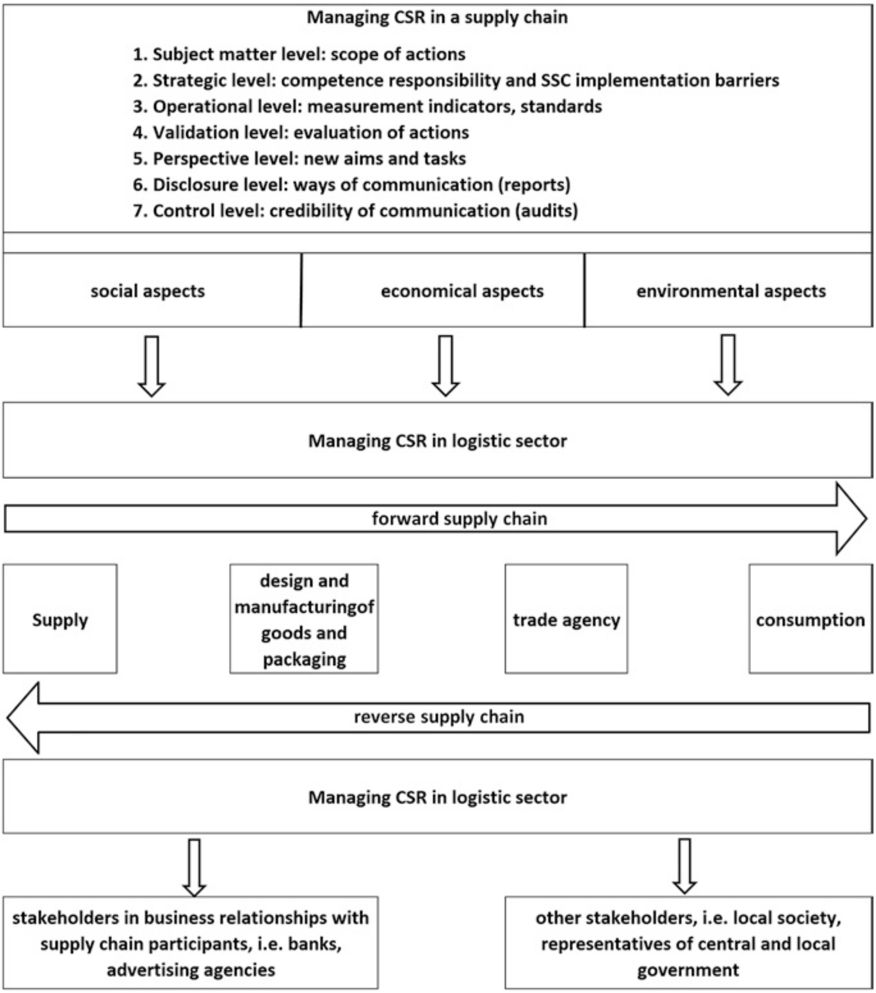

Fig. 1 Research scheme concerning sustainable supply chain

Strategies of logistics enterprises derive from changes taking place on the market of production factors and consumer products. This is connected with the secondary character of the demand for transport and storage services. In their strategies, companies must, then, allow for certain trends occurring on the market. These are mainly: changes in attitudes of productive and commercial companies towards storage, manifested in the pursuit of stock reduction, the so-called mass customization production (individualized mass production allowing to offer highly diverse products), growing popularity of electronic commerce, internationalization and globalization of enterprise activity manifested in an increasing exchange of goods and greater and greater popularity and importance of corporate social responsibility (Jeszka and Kawa 2005).

What influences the strategies of logistics operators and, thus, CSR are mainly relations with customers. These are the customers who determine new directions of development for the sector through new needs and expectations. They affect strategic decisions, e.g. those concerning the choice of the field of logistics activity to be developed: faster road transport or more ecological railway transport. Relations with one key client often determine further development of an enterprise and its strategic plans. For instance, a contract for logistics service of a selected client may force the logistics operator to use railway transport.

An example is the Unilever company, one of the world's biggest manufacturers of consumer products. Unilever has set a target to reduce carbon emissions in the distribution of their products. The company outsources transport and uses the services of logistics operators. Environmental considerations are an integral part of all distribution offers and their competence in reducing carbon emissions and striving for innovation in this area are an important asset. Moreover, Unilever requires all its logistics service providers to have an effective carbon management program. For example, Unilever UK introduced a 10-point checklist for greener transport of food in transport contracts in the UK. All logistics service providers must meet the requirements included in the checklist (Delivering tomorrow 2010).

The greatest challenge for the logistics industry is excessive CO_2 emission. The research of the Panel on Climate Change shows that transport (including freight and personal transport) is equal to 13.1 % of global greenhouse gas (GHG) emissions. According to the World Economic Forum, the logistics industry generates around 2,800 megatons of GHG emissions per year, which accounts for around 5.5 % of global GHG emissions. Road freight is responsible for approximately 60 % of total emissions from the logistics and transport sector, with over 1,500 megatons of CO2-equivalent emissions. Air freight is still the most carbon-intensive transportation mode in emissions per ton kilometer, even if new generation aircraft are expected to burn up to 20 % less fuel. The most carbon-efficient transportation modes are rail and ocean. In turn, logistics buildings produce about 300 megatons of CO_2, of which about 80 % is due to lighting (Delivering Tomorrow 2010) (Fig. 2).

The logistics industry is continuously growing, so its energy consumption and GHG emissions will be increasing. That is why it needs to improve its energy efficiency and develop alternatives to fossil fuels, otherwise it will find itself ever more vulnerable to the uncertainty of oil supplies, as well as the increasing prices of fossil fuels (Delivering Tomorrow 2010).

Logistics companies have been acting for years so as to contribute to natural environment protection. Part of these activities is their own initiative, some are required by their customers, and yet others originate in legal regulations and willingness to save. Due to rising costs of fuel, companies try to fill vehicles optimally, purchase a modern fleet, conduct eco-driving training courses. In addition, according to CSR rules, logistics operators take care of good relations with their stakeholders, particularly with their suppliers, clients, employees and the local community.

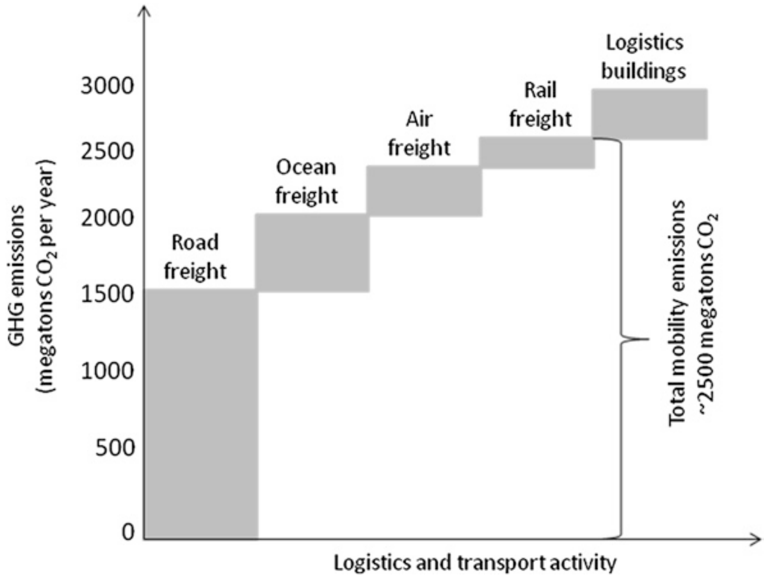

Fig. 2 GHG emissions of logistics activities. *Source* Delivering tomorrow. Towards sustainable logistics. How business innovation and green demand drive a carbon-efficient industry, 2010, Deutsche Post AG, Bonn

4 Creating Socially Responsible Actions with the Support of Logistic Sector Companies

On the basis of literature analysis as well as taking into consideration the above mentioned trends in the sector under discussion it can be assumed that there is a lot of areas (Logistics and Transport Companies 2002) where logistic companies may perform socially responsible actions and that there is a lot of issues requiring future research. For example, with reference to logistic companies, the issues under research include: CSR disclosures (Tong and Moussa 2012), descriptions of best practices for the sake of internal and external stakeholders as well as supported supply chain elements (Larsson et al. 2012), analysis of factors influencing the development of socially responsible actions (Lin and Ho 2010), identification of the level of interest in socially responsible actions among logistic service ordering parties (Lieb and Lieb 2010), level of knowledge about green logistics among logistic companies (Krzywda 2012), innovative initiatives within ecological effectiveness (Rossi et al. 2013), effectiveness of ecological driving in cargo transport (Chaari and Ballot 2012), relationships between Logistics Service Providers (LSPs) and shippers in understanding the needs of providing “green services” (Martinsen and Björklund 2012), review of logistic services in terms of sustainable development challenges (Gammelgaard et al. 2012), roles of logistic operators in developing sustainable supply chains in the view of ordering parties (Prockl and Gammelgaard 2012).

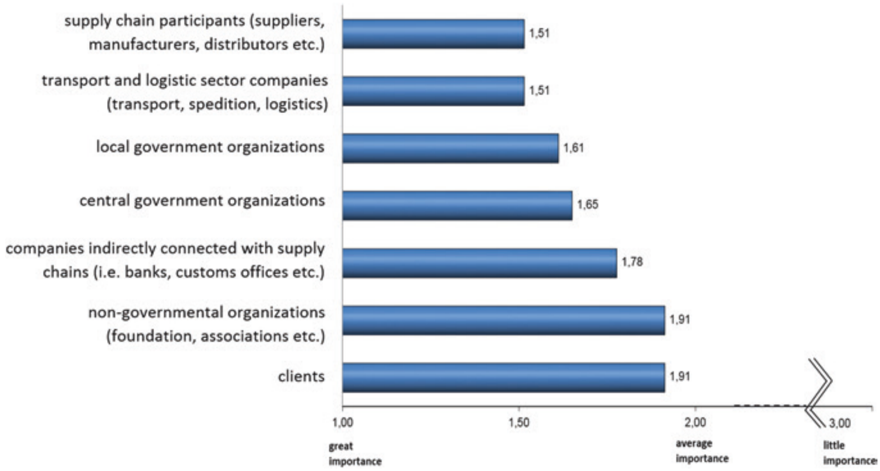

Fig. 3 The role of stakeholders in supporting SSC

On the basis of the research conducted among Polish market companies it can be assumed that logistic sector plays a great role in developing sustainable supply chains (Fig. 3). Therefore, every CSR action of logistic companies may stand for an endless source of inspiration and knowledge for other horizontally integrated companies. According to respondents, companies directly connected with supply chains, such as suppliers, manufacturers, trade agents and logistic sector companies, have the greatest influence on supporting SSC development. Furthermore, central and local government organizations, companies indirectly connected with supply chains, non-governmental organizations and clients have been listed. The fact that each stakeholder has been assigned at least an average role in SSC development is significant. Thus, it can be concluded that respondents notice the opportunities of SSC support both in macro- and micro environment of companies.

Moreover, among the urgent questions requiring education on SSC, the sustainable logistic service has been recognized as one of the greatest priority (Fig. 4).

Summing up, the logistic sector, which is taking over the logistic support of companies to an ever increasing extent (2014 Third-Party Logistics Study 2014), can not only take over the role of a supply chain co-ordinator in a natural way, but also the role of a co-ordinator and an initiator of SSC actions. It is all the more justified, in the context of putting in the first place (in terms of sustainable development) the environmental needs. As it has been earlier stressed, the logistic sector has its significant role in generating CO_2.

5 Examples of Sustainability Actions in Logistic Sector

Actions concerning both strategic and operational issues can be enumerated among many actions undertaken by logistic sector companies for the sake of sustainability supply chains (Table 2).

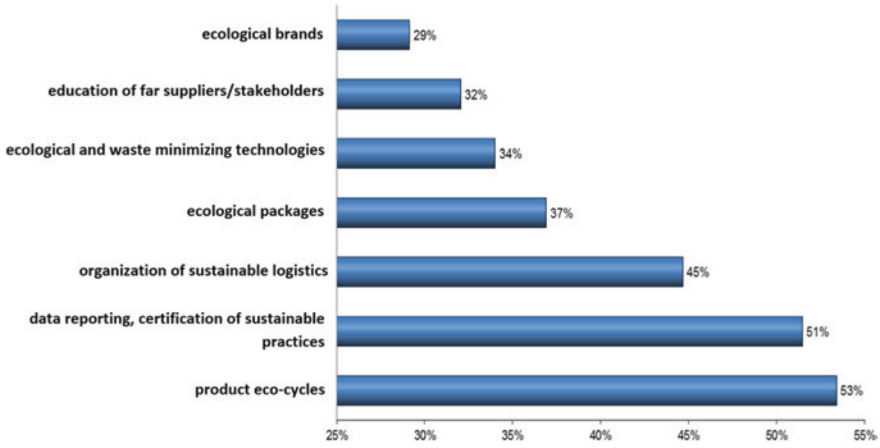

Fig. 4 The most common CSR issues among supply chain participants

Table 2 Examples of socially responsible actions undertaken by logistic sector companies

Strategy building through communication with the community	Research of local communities (local residents, workers, neighboring companies' representatives, local authorities and NGOs, social workers, academic institutions, journalists) in order to learn about their expectations and opinions about company's troublesome activities and to develop CSR strategies accordingly. The research conducted by, among others, Shenker (Michałowska and Przybysz 2012)
Management instruments	Using Ecodesk internet tool which enables all organizations to publish and exchange information about CSR activities in one place. After creating a profile, the database also allows calculating the carbon footprint on a company's level, but also for all organizations in the delivery chain (Gruszecka-Tiesluk 2013)
Warehouse infrastructure	Building or leasing certified buildings with Leadership in Energy and Environmental Design (LEED) or Building Research Establishment Environmental Assessment Methodology (BREEAM) system
	An example of such an initiative is the G.Blue Planet Chatterley Valley logistic centre in England which got the highest mark awarded in the BREEM system as the first in Europe and in the world. One of the many solutions implemented there are kinetic plates installed on the access roads leading to the warehouse. Under pressure electric energy is produced and stored Radomska-Deutsch (2010)

(continued)

Table 2 (continued)

Warehouse equipment	Using Lean Lift warehouse shelves with Ecodrive system (product made by Hanel company) which guarantee working time savings, reduction of storage space, and most importantly reduction of energy costs. They operate based on a frequency converter with an integrated recycling unit which uses the energy of a downward moving extractor and converts it back into electrical energy, which is supplied to the electrical grid. Depending on the extractor type and the load, up to 40 % of the energy needed to move upwards is channeled back to the electrical grid Knehr (2013)
Transport	Delivery consolidation and investing in electric delivery cars, which are a real alternative to vehicles with diesel engines. The Freight Electric Vehicles in Urban Europe (FREVUE) programme (financed by the European Commission's FP7 Programme) has been dealing with promotion of solutions of this kind among logistic operators. UPS and TNT Express are among the companies involved in this project (Taefi et al. 2014)

Source Own work based on Gruszecka-Tieśluk (2013), Knehr (2013), Michałowska and Przybysz (2012), Radomska-Deutsch (2010), Taefi et al. (2014)

Table 3 Examples of CSR reports in logistics industry

Company's name	CSR report name	Website
DB Schenker	DB sustainability report	deutschebahn.com/en/sustainability/sustainability_report/
UPS	Committed to more	sustainability.ups.com/committed-to-more/
DHL	The and makes the difference	dhl.com/crreport
TNT	Annual report	tntplanetme.com
Nipppon Express	CSR report	nipponexpress.com/about/csr/pdf/2011env-report.pdf
Vos Logistics	Eco-safe logistics	voslogistics.com/download.asp?id=200

Due to the ongoing consolidation of the logistics industry, as well as the strong dependence of weaker entities on outsourcing, the industry leaders should be particularly important in the development of CSR activities.

In recent years, more and more frequent CSR activity and socially responsible attitudes can be noticed among logistics companies. The scope of their activities is very different—from one-off actions, through support for specific programs, to long-term, integrated projects. Logistics services providers also increasingly present their CSR activities in the form of reports available on the Internet (Table 3).

One of the examples of companies which report all their CSR activities is DB Schenker. It is a leading logistics service provider, promoting socially responsible actions within the company itself and the supply chains it is part of. It offers comprehensive service in the area of logistics, land, air and sea transport as well as warehousing. It conducts dedicated projects for enterprises from different branches, e.g. the electric, car, FMCG and chemical industries. DB Schenker manages global supply chains for producers, exporters and importers of leading brands (http://www.dbschenker.com).

The company pays a lot of attention to sustainable development and behaves in accordance with the principles of responsible business. DB Schenker is guided by long-term values and appreciates customer satisfaction, honesty and reliability, professionalism, trust, co-operation, improvement and development. The enterprise focuses on good relations with its partners, undertakes a range of pro-social and pro-ecological activities, supports the development of science and entrepreneurship.

DB Schenker in Poland has won the first place in the Ranking of Responsible Companies in the category called "Transport, Trade, Services" for three consecutive years. The strategy of sustainable development is based on the European Foundation for Quality Management (EFQM) model applied by the company and on management through building the Lean culture. The strategy assumes harmonious development within three areas concerning economy, society and environment. One of the key challenges is creating an attitude of co-responsibility among employees and suppliers.

DB Schenker has systematically been undertaking CSR activity. An example of this is the ECO2 PHANT program aimed at reducing carbon dioxide emission and noise level by 20 % by the year 2020. The program is divided into a few smaller projects (Social Report, DB Schenker, http://dbschenker-csr.pl/en/):

- DB Optimizer—created for customers who get individually prepared best logistics solutions and for whom the supply chain is specially adjusted, at simultaneous CO_2 emission reduction,
- Eco-calculator—a tool allowing to accurately calculate (after having obtained all the detailed data: the route, transport type and consignment weight) the amount of energy generated and the emission of carbon dioxide, nitric oxide, hydrocarbons, sulfur dioxide and particulates for a single transport type as well as for multiple transport types used for one consignment,
- Emission report—a tool which provides information about environmental pollution emitted during transport. The customer can individually determine the type consignment, set the date, type of transport and direction (the generated report concerns all logistics operations carried out in Europe by DB Schenker). Data on fuel and energy consumption in kWh are also given,
- Eco Plus—rail transport with the use of renewable energy, thanks to which 100 % reduction of carbon dioxide emission may be achieved. At the customer's request, renewable energy is fed into the German rail electricity grid, in the amount needed to transport the given goods for the customer,
- Eco Warehouse—ecological warehousing, in facilities equipped with state-of-the-art environment-friendly infrastructure (possible reduction of 125 t of CO_2 for annual warehousing on a surface of 10,000 m^2),

- Eco Charter—air transport by fuel-efficient planes,
- Eco SCHENKERskybridge—a combination of air and sea transport,
- Eco OceanLine—sea transport with the use of ships moving at economical speed,
- Eco Neutral—related to any kind of transport aimed at minimising CO_2 emission for every type of shipment.

DB Schenker's strategy concerning corporate social responsibility was adopted in 2010. It includes all stakeholders (employers, clients, carriers and couriers, local community and students). A range of activities is performed for each of the groups (Social Report, DB Schenker, http://dbschenker-csr.pl/en/):

- **Clients**—are the most important stakeholders. The offer is targeted at large and medium-sized production and commercial enterprises, for which the highest standards of service quality are proposed. Achieving benefits and satisfaction by both sides is the key factor for the enterprise. Constant dialogue is held as part of sustainable development, in order to get feedback as well as ideas for more efficient solutions. With this aim in mind, satisfaction surveys, regular meetings and events for clients are organized, telephone and e-mail contact and a website are maintained.
- **Carriers and couriers**—relations with suppliers based on partnership are one of the main aims of Schenker's attitude towards this category of stakeholders. The company attaches great importance to the quality of transport services. It has developed internal regulations, such as supplier selection and verification, driver training, evaluation and improvement of carriers, which ensure the right choice of business partners. The company places a lot of emphasis on constant communication with carriers and couriers, conducting surveys of their satisfaction and organizing regular meetings with them.
- **Local community**—the company takes care of good contacts and co-operates with representatives of the local communities from the vicinity of its terminals and warehouses. It has been carrying out a project called "DB Schenker as a preferred neighbor", which consists in examining opinions of the people living in the neighborhood of the company's branches, since 2010. Thanks to this, the company gains information helpful in planning CSR activities. It performs actions which improve the functioning of different facilities and the quality of their services. It educates children and youth, refurbishes buildings and playgrounds.
- **Employees**—the company takes care of its employees and tries to create favorable working conditions for them. A policy of "compliance" functions in the company, whose main assumption is to act according to legal regulations. This is an essential basis for building a workplace of the highest standards. As part of the health-promoting program, DB Schenker's employees are offered co-financed health care and recreational and sport activities. Building the Lean culture, the company focuses on all workers being committed to the organization's improvement and elimination of waste. With the use of an electronic platform every employee and courier can propose ideas for improving work processes and methods. The ideas may concern both local and general issues.
- **Students and universities**—DB Schenker supports development of students and their professional skills. The company's workers share their knowledge of

the logistics industry, company management or social responsibility. The most common forms of co-operation are: conducting classes for students, organizing study visits for students in the company's branches, active participation in conferences. DB Schenker also organizes the Sales Consulting Trainee Programme, which is addressed to university graduates. Trainees may participate in the development of DB Schenker's service portfolio, implementing sales projects on their own. The company organizes summer trainings for final-year students, too. The best and most committed ones stand a chance for permanent employment.

Taking into consideration DB Schenker's activities described above, one can definitely say that it realizes the assumptions of CSR in the company as well as in co-operation with other entities. DB Schenker and other logistics companies play a very important role in the supply chain. Third party logistics http://www.capgemini.com/resource-file-access/resource/pdf/3pl_study_report_web_version.pdf coordinate logistics operations between enterprises and, thus, can realize the idea of SSC. In addition, Schenker takes a number of actions which are intended to encourage the other participants in the supply chain to follow suit.

6 Conclusions

Actions concerning both strategic and operational issues can be enumerated among many actions undertaken by logistic sector companies for the sake of sustainability supply chains (Table 2).

Currently, SSC is a critical factor in strategic management, which is a part of business models. In every year, the role of SSC is more and more significant, because logistic companies, as elements supporting logistic chains, contribute greatly in this. The field under research, concerning the logistic sector, is at an initial stage of development. The undertaken research consists mainly of the analyses of the chosen case studies, report analyses and, to a lesser extent, of surveys. Particularly, there is a lack of comprehensive approaches.

The conducted analyses produce the following conclusions:

- sustainable actions are one of the key trends in the logistic sector,
- so far, when analyzing logistic companies, the main attention has been given to CSR without considering the whole context of supply chains,
- supply chain participants expect the support from logistic companies in terms of developing horizontally integrated socially responsible actions,
- logistic sector has many opportunities and possibilities in using the wide range of tools in developing SSC.

It seems that an overview of the organization in terms of socially responsible actions, especially from the wider perspective of logistic ordering parties, can be a source generating additional values and at the same time creating competitive advantages. The implementation of sustainable development principles on the level of business leads to the analysis of intangible values (not only in the form of services) or connected areas, but also to the overview of capital located in each stakeholder surrounding the company. The existing evidence for a positive relationship between SSC and market value of companies is an incentive to further research in this area.

The given examples of ecological, social and environmental solutions in logistic sector can stand for a valuable source of knowledge and an inspiration for the further comprehensive development of sustainability supply chains. The analyses have a lot of implications for science and practice. The multi-dimensional and diversified character of managing SSC by logistic companies creates a lot of challenges and great possibilities in terms of knowledge diffusion to each chain element.

Summing up, it is advisable in the future to undertake comprehensive research, which aims at evaluation of SSC components in the context of a branch, a sector and geography. It is particularly advisable to extend analyses regarding the confirmation of the hypothesis about the positive influence of SSC development in transport and logistic sector on individual chain elements as well as the hypothesis about the significance of transport and logistic industry for the integration of socially responsible actions of horizontally integrated companies.

References

2014 Third-Party Logistics Study (2014) The state of logistics outsourcing. Results and findings of the 18th annual study

Carroll A (1979) A three-dimensional conceptual model of corporate performance. Acad Manag Rev 4(4):497–505

Carroll A (1991) The pyramid of corporate social responsibility: toward the moral management of organization organizational stakeholders. Bus Horiz 34(4):39–48

Carter C, Jennings M (2004) The role of purchasing in corporate social responsibility: a structural equation analysis. J Bus Logistics 25(1):145–186

Carter C, Rogers D (2008) A framework of sustainable supply chain management: moving toward new theory. Int J Phys Distrib Logistics Manage 38(5):360–387

Chaari H, Ballot E (2012) Fuel consumption assessment in delivery tours to develop eco driving behaviour. In: The European transport conference 2012, Glasgow: Royaume-Union 2012. http://abstracts.aetransport.org/conference/index/id/18

Delivering tomorrow (2010) Towards sustainable logistics. How business innovation and green demand drive a carbon-efficient industry. Deutsche Post AG, Bonn

Gammelgaard B, Prockl G, Thordardottir K, Kinra A (2012) Service innovation and sustainability in the danish logistics sector: results from a survey. In: Töyli J, Johansson L, Lorentz H, Ojala L, Laari S (eds) Proceedings of the 24th annual nordic logics research network conference: NOFOMA 2012. Turku School of Economics and Business Administration, Turku, pp 172–180

Global Logistics Market Hits Bottom, Could Rise to $4 Trillion by 2013 [Online], http://logisticstoday.com/global_markets/global-logistics-hit-bottom-could-rise-0419

Gruszecka-Tieśluk A (2013) Zrównoważony łańcuch dostaw: trendy i innowacje, Analiza matematyczna, Nr 3, s.1–9

Jayaratne P, Styger L, Perera N (2011) Sustainable supply chain management: using the Sri Lankan tea industry as a pilot study. In: 25th annual Australia New Zealand Academy of Management Conference (ANZAM) 2011. ANZAM, New Zealand, pp 1–22

Jeszka AM, Kawa A (2005) Branża usług logistycznych. In: Ciesielski M (ed) Rynek usług logistycznych, Difin, Warsaw

Klaus P, Kille C (2008/2009) The top 100 of logistics. DVV Media Group, Hamburg
Knehr G (2013) Inteligentne systemy magazynowe, Magazyn przemysłowy, Nr 6(128), s.68–70
Krzywda J (2012) Oni mają zielone pojęcie. Koncepcja "zielonej logistyki" oczami niemieckich przedsiębiorców branży logistyczno-spedycyjnej, Logistyka, Nr 3, s.1215–1221
Larsson A, Muyingo R, Serebrennikov D, Ahmed S, Mark-Herbert C (2012) Sustainable business development—a case study of the international logistics industry. In: Ghenai CH (ed) Sustainable development—education, business and management—architecture and building construction—agriculture and food security. InTech, Rijeka- Shanghai, pp 41–60
Lieb K, Lieb R (2010) Environmental sustainability in the third-party logistics (3PL) industry. Int J Phys Distrib Logistics Manage 40(7):524–533
Lin CY, Ho YH (2010) Determinants of green practice adoption for logistics companies in china. J Bus Ethics 98(1):67–83
Logistics and Transport Companies (2002) Expectations and opportunities at the leading edge of corporate social responsibility. International Business Leaders Forum. IBLF
Maloni M, Brown M (2006) Corporate social responsibility in the supply chain: an application in the food industry. J Bus Ethics 68(1):35–52
Martinsen U, Björklund M (2012) Matches and gaps in the green logistics market. Int J Phys Distrib Logistics Manage 42(6):562–583
Michałowska M, Przybysz M (2012) Dla kogo w logistyce? Logistyka a Jakość, Nr 2., s.25–29
Morali O, Searcy C (2013) A review of sustainable supply chain management practices in Canada. J Bus Ethics 117(3):635–658
Next-Generation Supply Chains (2013) Efficient, fast and tailored. Global Supply Chain Survey 2013, PwC. http://www.pwc.com/en_UA/ua/services/consulting/assets/global-supply-chain-survey-2013-eng.pdf
Outlook on the Logistics & Supply Chain Industry 2013 (2013) Global agenda council on logistics and supply chain systems 2012–2014. World Economic Forum, Geneva
Prockl G, Gammelgaard B (2012) Sustainability and the logistics service industry: red thread from a workshop. Institut for Produktion og Erhvervsøkonomi, CBS, Frederiksberg
Radomska-Deutsch E (2010) Nowoczesny magazyn: zrównoważony znaczy zielony, Logistyka, Nr 4., s.26–29
Rossi S, Colicchia C, Cozzolino A, Christopher M (2013) The logistics service providers in eco-efficiency innovation: an empirical study. Supply Chain Manage Int J 18(6):583–603
Seuring S, Müller M (2008) From a literature review to a conceptual framework for sustainable supply chain management. J Clean Prod 16(15):1699–1710
Svensson G (2007) Aspects of sustainable supply chain management (SSCM): conceptual framework and empirical example. Supply Chain Manage Int J 12(4):262–266
Taefi T et al (2014) A comparative analysis of european examples of schemes for freight electric vehicles. A systematic case study approach with examples from Denmark, Germany, The Netherlands, Sweden and the UK. In: 4th international conference on dynamics in logistics (LDIC 2014), Bremen, Germany, 10–14 Feb 2014
Tong M, Moussa T (2012) How logistics firms deal with and report on CSR expectations. Jönköping University, Jönköping
The State of Corporate Citizenship in the US (2005) Business perspectives in 2005. The Center for Corporate Citizenship at Boston College, Boston
United Nations Global Compact (2010) Supply chain sustainability. A practical guide for continuous improvement. UN Global Compact Office. http://globalcompact.oit.duke.edu/globalcompact/sites/default/files/BSR%20supply%20chain%20sustainability.PDF
Zhu Q, Sarkis J, Lai K (2007) Green supply chain management: pressures, practices and performance within the Chinese automobile industry. J Clean Prod 15(11):1041–1052
Zsidisin G, Siferd S (2001) Environmental purchasing: a framework for theory development. Eur J Purchasing Supply Manage 7(1):61–73

CSR in Supply Chains of Brewing Industry

Arkadiusz Kawa and Iwona Łuczyk

Abstract The European brewing sector engages in Corporate Social Responsibility (CSR) activity on various aspects. More and more importance is being attached at breweries to responsible use of resources in the production process. All large beer-producing concerns currently employ experts in environment protection. Their job is to analyse the impact of production on the natural environment. At present, special attention is paid to: responsible sourcing, sustainable packaging, reverse logistics, minimising water and wastewater use as well as energy and gas emission. They inform about their progress in this field in CSR reports. It not only helps to emphasise the ethical aspect of the company's operation and authenticate its mission in the clients' eyes, but also facilitates cost optimisation—reduction of water consumption or recycling are economically profitable. The aim of this chapter is to show the way in which the CSR conception is put into practice by Polish brewing enterprises and how it influences their functioning on the example of the two largest beer producers in Poland.

Keywords Brewing industry · CSR · Supply chain sustainability

1 Introduction

In the era of progressive globalisation, growing production and consumption scale as well as environment degradation, a number of social, environmental and economic problems appear. This requires a change in the management's attitude towards their enterprise's operation and acceptance of responsibility not only for

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shareholders and employees, but also for the society, environment or suppliers. Companies must start neutralising the negative effects of their operation and supporting the principle of sustainable development. This paradigm is realised in economic practice by the concept of corporate social responsibility (CSR). ISO 26000 defines CSR as “an organisation’s social responsibility and commitment to including social and environmental aspects in the decision-making process and acceptance of responsibility for the effect of the decisions and activity on the society and environment” (Gadomska-Dzięcioł et al. 2012).

It may seem that the conception of corporate social responsibility is another short-lived fashion for a specific manner of management, similar to the conception of total quality management (TQM) or knowledge management. Many managers still approach this subject with distrust, treating CSR activity only as an additional cost and a waste of time. Their scepticism may also be justified by saying that they fear changes which implementation of environmental management systems carries. It should, though, be noticed that economic, social and ecological responsibility stops being “good practice” and becomes a necessity. The authors of “Green growth, green development” (Henzelman et al. 2011), however, claim that “similarly to the previous changes, the green revolution will sweep away from the market those companies, or even whole industry branches, which will miss or ignore signs thereof (…). The present revolution does not have to influence the competitiveness of enterprises negatively. They can use it as a springboard to get to the first league, providing they take active part in transforming the industry and establishing new rules of the game”.

The conception of socially responsible business is effectively supported by the United Nations Global Compact initiative inaugurated in 2000 by the UN Secretary-General Kofi Annan. The UN Global Compact is a “leadership platform for the development, implementation and disclosure of responsible and sustainable corporate policies and practices” (UN Global Compact 2010).

By means of a wide spectrum of activities, co-operation with the private sector, non-governmental organisations, scientific institutions and other stakeholders, the UN Global Compact propagates and supports implementation of ten UNGC principles, which have been divided into four areas: human rights, labour, environment and anti-corruption. With nearly 12,000 corporate participants in 145 countries, the UN Global Compact is currently the world’s largest corporate sustainability initiative. The UN Global Compact is not a regulatory instrument, but rather a voluntary initiative that relies on public accountability, transparency and disclosure to complement regulation and to provide a space for innovation and collective action (UN Global Compact 2010). The Global Compact initiative is a response to the rapid globalisation processes, whose negative effects include, among others, deepening disproportions and unsustainable development.

Entrepreneurs aware of the current conditioning actively participate in the development of business policies based on environmental aspects. A particularly high level of ecological awareness and a desire to reduce the negative impact on the environment are demonstrated by the European brewing sector. The largest European beer producers, also operating on the Polish market, the SABMiller group (which includes Kompania Piwowarska) and the Heineken Group (the main shareholder of Grupa Żywiec), have committed themselves to applying the United Nations Global Compact (UNGC) principles. Taking part in the UN Global Compact project, the breweries seek solutions to strategic economic problems, create sustainable growth processes on an international scale and neutralise the negative effects of beer production processes. They contribute to the development of the conception of socially responsible business in this way.

The aim of the study is to show the way in which the CSR conception is put into practice by Polish brewing enterprises and how it influences their functioning. The beer market in Europe and Poland has been described. Next, the operation and results of the two largest beer producers in Poland, i.e. Kompania Piwowarska and Grupa Żywiec, have been analysed in terms of the most important sources of increasing sustainable development: responsible sourcing, sustainable packaging, reverse logistics, water and wastewater, energy and gas emission. These data were received from CSR reports published annually by both Kompania Piwowarska and Grupa Żywiec. They are prepared in accordance with the new GRI G4 guidelines in the 'Core' version. In the case of Kompania Piwowarska, the Sustainability Assessment Matrix (SAM) programme was used to draw up the report, which means that within individual areas it is partly identical to the GRI guidelines and, additionally, adjusted to the nature of the operation. The report is also verified by the consultancy PwC, in accordance with the International Standard on Assurance Engagements 3000 (ISAE 3000). The report of Grupa Żywiec, in turn, is prepared by PwC and is the only social responsibility report referring to the Global Reporting Initiative (GRI) guidelines as well as to measuring the social and economic influence of the organisation in the whole brewing industry in Poland. Writing CSR reports by beer producers facilitates development and a comparison with others, as well as an exchange of the so-called good practices and effective methods of solving different production, social or environmental problems not only in Poland, but also on the international arena. Companies making such analyses not only respond to their stakeholders' expectations more adequately, but also, seeing the whole picture of the social and economic impact, plan and operate more effectively (2012).

2 Brewing Industry in Europe and Poland

2.1 European Brewing Sector

The European Union is one of the most important beer-producing regions in the world. This beverage, known to Europeans for a few 100 years, plays a significant role in every country and constitutes an inseparable element of culture and consumption. The European Economic and Social Committee emphasises the continuous development of the brewing sector and its ability to adjust as well as resistance to fluctuations of economic conditions. The operation of this sector is compatible with the aims of the "Europe 2020" strategy in its priority areas: employment, eco-development, innovation, education and social inclusion. The European Union meets a quarter of the world demand for this product (Jirovec and Calleja 2013). It has just recently been overtaken by China in terms of production volume, but still ranks higher than the United States, Russia, Brazil and Mexico. In 2011, in Europe more than 380 million hectolitres of beer were brewed and sold all over the world (Berkhout et al. 2013).

The European brewing sector is extremely varied. It is not only home to the world's largest brewing companies, such as ABInbev, Carlsberg, Heineken and SABMiller but also to numerous small and mid-sized, independent breweries. The number of breweries in the European Union increases every year. In 2013 there were 4,460 of them. Germany has the most breweries within the EU, with a number of 1,339. Other EU Member States with over 100 breweries are: the United Kingdom (1,113), France (503), Italy (425), the Czech Republic (213), Austria (171), Belgium (165), the Netherlands (165), Denmark (150), Poland (132) and Spain (132). The total beer sales in 2010 reached EUR 106 billion, which corresponded to 0.42 % of GNP of the European Union. It is estimated that over 63 % of the European beer production is purchased through the off-trade channel, that is, in supermarkets and other retail outlets. The remaining 37 % falls on the on-trade channel in the hotel and gastronomy sector, that is, in bars, pubs and restaurants (see Fig. 1) (Berkhout et al. 2013).

Since 2007 a fall in beer consumption has been noticed in Europe, which has a direct influence on brewery operation. After many years of expansion on the EU market, beer production has significantly decreased—from 420 million hectolitres in 2007 to 377 million hectolitres in 2011. The change of economic and legal conditions expected in the next few years and an increase in beer export outside the

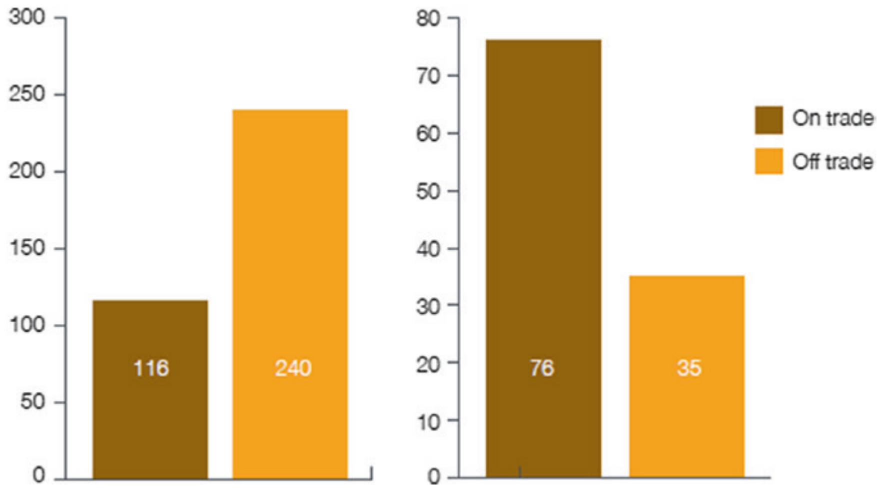

Fig. 1 Beer consumption in the European Union in millions of hectolitres (*left*) and billions of Euro (*right*) in 2012 (adopted from Berkhout et al. 2013)

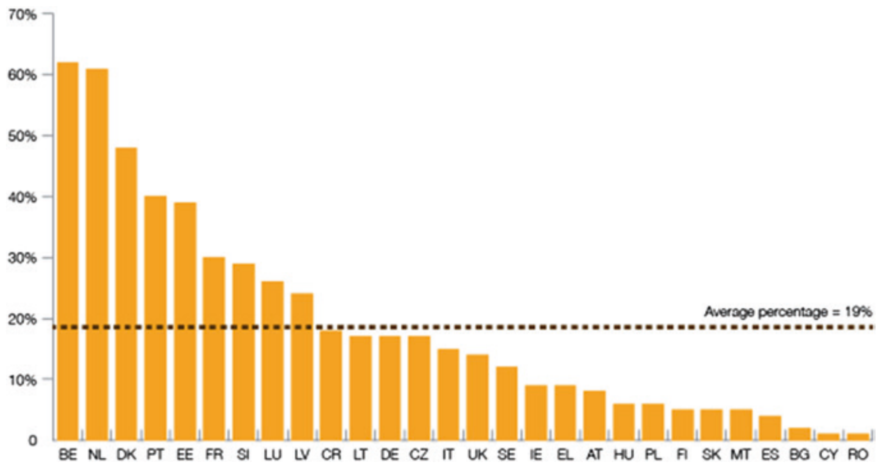

Fig. 2 Exports (intra-EU/extra-EU) in 2012 as a percentage of total production per EU Member State (adopted from Berkhout et al. 2013)

European Union could contribute to a revival in the brewing sector (Jirovec and Calleja 2013).

Most European beer production is sold on the internal market of the European Union, but export to other regions of the world has continuously been rising since 2000 (so far, this growth has amounted to 30 %). The greatest export receivers include: the United States, Canada, Angola, China, Switzerland, Taiwan, Russia and Australia. Moreover, European breweries are also large investors on all continents and participate in various initiatives of co-operation with local breweries and distributors. In 2012, beer export from Belgium, the Netherlands, and Denmark was particularly important (see Fig. 2). The percentage of the total national beer production exported from these Member States was relatively high, ranging from 48 to 62 %, and can also be accounted for by the presence of large multinational brewing companies. In absolute terms, Germany (15.7 million hectolitres), the Netherlands (14.7 million hectolitres) and Belgium (11.7 million hectolitres) were the largest European Union beer exporters (Berkhout et al. 2013).

In 2012 47 million hectolitres of beer produced in the European Union were imported. The largest importers were: Luxembourg, Estonia, France, Italy, and Malta, with 32–60 % of total beer consumption comprising imported beer (see Fig. 3). In absolute terms, the United Kingdom (8.8 million hectolitres), France (7.4 million hectolitres), Germany (7.3 million hectolitres) and Italy (6.2 million hectolitres) were the most important importers (Berkhout et al. 2013).

In the last 15 years the European beer market has undergone diverse changes resulting from technological progress, investments in development, mergers and establishment of new enterprises, as well as changing consumer attitudes. An increase in the number of smaller breweries has been noticed in all countries of the European Union. This contributes to a wider range of products being offered to consumers. It is also a favourable phenomenon from the viewpoint of sustainable

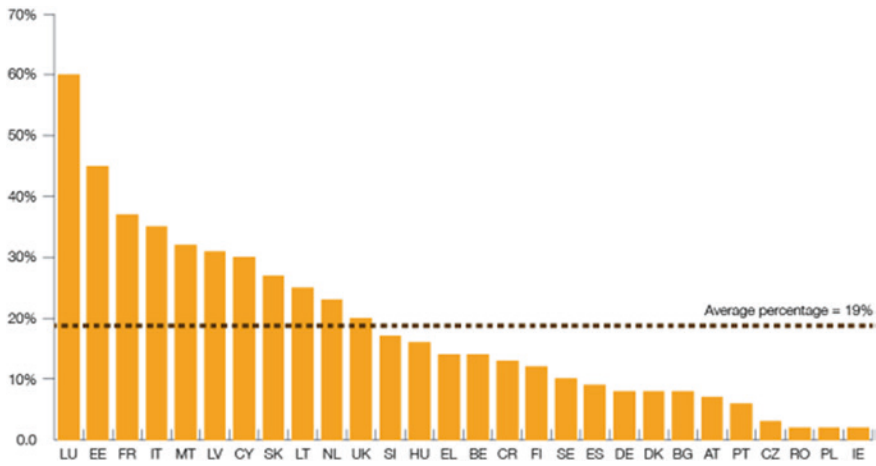

Fig. 3 Imports (intra-EU/extra-EU) in 2012 as a percentage of total consumption per EU Member State (adopted from Berkhout et al. 2013)

development because, as a rule, it indirectly contributes to development of regional tourism and a shorter production and consumption cycle, which has a positive influence on the environment (Jirovec and Calleja 2013).

The growing number of breweries and product innovations has also led to emergence of new products bringing benefits to consumers, the society and environment. Opportunities for breweries of all sizes have appeared thanks to diversification towards low alcohol and non-alcoholic beer, which has led to a rise in sales. Availability of ecological beer is increasing all the time, too (Jirovec and Calleja 2013).

2.2 *Polish Brewing Industry*

Thanks to fast privatisation of the leading breweries with the participation of foreign investors, the brewing sector in Poland quickly achieved world class in terms of technology. Between 1993 and 2002 beer production in Poland doubled (Lichota 2012), whereas between 2000 and 2011 alcohol consumption in Poland increased by 30 %, half of which was beer. In 2011 beer consumption per capita amounted to almost 94 l. As a result, the domestic beer market is currently the fifth biggest one in Europe, right after Germany, Britain, Russia and Spain (Okrzesik 2003).

Approximately 80 % of beer produced in Poland is made at breweries belonging to the three foreign concerns: SABMiller (Kompania Piwowarska), Heineken (Grupa Żywiec) and Carlsberg. Such a large degree of market concentration does not exist in any other European country. However, regional beer made at contract breweries (beer is brewed on the basis of their own formulas in the leased part of a large brewery's production line) or craft breweries (tiny production plants where small amounts of beer are produced) is enjoying growing popularity (2014).

Table 1 Beer consumption in Poland (adopted from Beer statistics 2012)

	2008	2009	2010	2011	2012	2008–2012
Total consumption in hectoliters	35,861,000	34,384,000	34,484,000	36,236,000	38,142,000	+6.4 %
Total consumer spending (in million Euro)	5,996	5,434	5,202	5,340	5,342	−10.9 %
Consumption of beer per capita (in litres)	94	91	91	95	98	+4.3 %
Beer consumption on-trade (hospitality)	20 %	15 %	15 %	13.5 %	10 %	−10 %
Beer consumption off-trade (retail)	80 %	85 %	85 %	86.5 %	90 %	+10 %

Beer production and sales are strongly dependent on seasonality. That is why breweries are forced to keep considerable production surpluses because they would not be able to cope with the increased demand during the summer season from May until August for technological reasons (Okrzesik 2003) (Table 1).

In Poland there are over 100 breweries, most of which are small breweries of local importance. As a result of numerous takeovers and mergers, three main brewing groups can be distinguished, i.e. Kompania Piwowarska, Grupa Żywiec and Carlsberg, which are united in the Union of Brewing Industry Employers—Polish Breweries (2014).

The leader of the domestic brewing industry is Kompania Piwowarska, whose owner is one of the largest beer producers in the world—the SABMiller concern. In the financial year 2013 the sales volume of Kompania Piwowarska amounted to 14.5 million hectolitres, which translated into a 38.2 % market share for the Group. It currently includes breweries in Białystok, Poznań and Tychy. The Group mainly owes its positive results to three brands that remain undisputed market leaders, i.e. Tyskie, Żubr and Lech (Kompania Piwowarska Sustainable Development 2013).

The vice leader of the Polish beer market is Grupa Żywiec with a market share of about 30 %. The shareholder of Grupa Żywiec is the Dutch brewing concern Heineken. In the first half of 2013 the capital group Żywiec sold 5.3 million hectolitres of beer, compared to 5.7 million hectolitres the year before. The most important brands of the Group are Żywiec, Warka and Tatra. Special beers such as wheat Paulaner and Warka Radler also enjoy great popularity. At present, Grupa Żywiec includes breweries in Żywiec, Leżajsk, Warka, Elbląg and Cieszyn (2013).

The third biggest company in the brewing industry is Carlsberg Polska with an approximately 14 % share in the Polish beer market and annual production exceeding 4 million hectolitres. The company was initially called Carlsberg Okocim S.A. After the takeover of all the shares by the Dutch concern Carlsberg in 2004 the name of the enterprise was changed into Carlsberg Polska S.A. The most popular brands of the Group are Carlsberg, Harnaś, Okocim, Karmi, Kasztelan, Bosman and Piast. Three breweries are part of the Carlsberg Polska Group, namely Okocim Brewery, Kasztelan Brewery and Bosman Brewery (Carlsberg Polska 2014).

In 2013 annual beer production in Poland increased by 0.7 % in relation to 2012 and amounted to 39.56 million hectolitres. Beer consumption, in turn, decreased in Poland in 2013 by 2 % to 37.2 million hectolitres, which resulted from the economic situation in the country and unfavourable weather conditions as well as quite a high basis from the previous year when the Euro 2012 championship took place, driving beer sales. According to data from the Central Statistical Office Główny Urząd Statystyczny, (GUS), in January 2014 annual beer production in Poland declined by 1.1 % compared to the same period of the previous year and was 2.79 million hectolitres (2014).

The falling sales on the domestic market is partly compensated by export. The year 2013 ended in a rise in export for the brewing sector. According to data from GUS, beer export increased by over 360,000 hl (16.7 %) in comparison with the previous year, reaching a level of more than 2.5 million hectolitres. These data provide a basis for forecasting a continually growing share of export in the total beer sales in 2014.

Beer sales at the current level of 37 million hectolitres proves market stabilisation. The expected improvement of consumer attitudes and continuous introduction of beer novelties may contribute to a small increase in sales. What might also improve sales in forthcoming years is a wider and wider range of special beers: non-pasteurised and flavoured ones (shandies and radlers), which are offered to consumers by all breweries in Poland. This reflects the tastes of the present enthusiasts of the beverage, who are characterised by openness to novelties, a search for new flavours and experiences. The trend for increasing demand for new flavours can be noticed by both corporate producers and small local breweries. The sales results from 2013 suggest that it is exactly this segment in which beer producers see a potential chance for the growth of the market which is perceived as already saturated (a statistical Pole drinks about 96 l of beer per year) (2014).

3 Case Studies

3.1 Responsible Sourcing

At the level of enterprise management, responsible supply chain management (RSCM) represents the conception of corporate social responsibility. The aim of a sustainable supply chain is to create, protect and strengthen environmental, social and economic values for all the parties engaged in supplying products and services to the market. The brewing sector may contribute to expansion of the conception of sustainable development by co-operating with its suppliers and demanding similar involvement in environment protection aspects from them (UN Global Compact 2010).

3.1.1 Kompania Piwowarska

Kompania Piwowarska purchases from local suppliers, thanks to which new workplaces are created in the region, in addition to new opportunities for employees and their families as well as the local community. Furthermore, it contributes to taxes coming into local budgets and an improvement in healthcare and education quality. The company encourages suppliers and clients to treat their operation responsibly, especially in the field of ethical and ecological practices. Responsible and effective operation of partners in the supply chain brings them all such benefits as high product quality, cost reduction and competitiveness. All of these actions contribute to joint effort in aid of sustainable development.

Moreover, Kompania Piwowarska creates a sustainable supply chain due to its participation in the Ethical Trading Initiative (ETI) organisation. It is an alliance of companies, non-governmental organisations and trade unions that promotes responsible actions and behaviours of companies in the whole value chain, which can significantly contribute to better working conditions and life of employees who make different kinds of products. ETI has prepared an essential code of ethical conduct called ETI Base Code. The standard is currently popularised worldwide for audits at enterprises. Follow-up audits are performed in accordance with the SEDEX methodology. It is a non-profit organisation uniting many different organisations to work on improving ethical standards. Post-audit reports are placed on an internet platform, thus allowing every company to check if a given supplier realises actions in aid of sustainable development or not (Kompania Piwowarska Sustainable Development 2013).

3.1.2 Grupa Żywiec

In order to build a sustainable supply chain and support its partners, Grupa Żywiec has created a Supplier Code of Grupa Żywiec which defines important actions in the field of sustainable supply. According to the Code, a supplier's task is to "build and maintain relations based on honesty, trust, respect for human rights, observance of the law, respect for the environment and business practice consistent with the principles of sustainable development and the Social Responsibility Policy". All suppliers with whom contracts are signed as a result of a tendering procedure as well as those who raise doubts about the respect for the standards adopted by the company need to sign a declaration of being familiar with the Supplier Code and willing to obey the rules contained in it. Nearly 1,400 suppliers of the Group signed the document in 2012.

3.2 Reverse Logistics

In the modern economy there are few plants that may be called wasteless, which usually results from technological constraints. However, enterprises of high environmental awareness are trying to approach the assumptions of wasteless production. In order to do this, they are trying to increase material durability, select appropriate raw materials and optimise their use, and re-use the same materials. If it is not likely to avoid waste production, all possible effort should be made to recycle it.

Breweries are complex units, where processes of beer production are accompanied by both management-related processes and secondary processes, without which the enterprises would not be able to realise the primary processes. The secondary processes taking place at breweries include, among others, reverse logistics. Appropriate use of a brewery's capacity and effective action taken by its management in the face of changes resulting, for instance, from amendments to the "Waste Disposal Act" may decide on efficiency of the activity in this area. Breweries are specific organisations in that respect as two types of activity may be distinguished within reverse logistics (see Fig. 4), namely:

- activity connected with recycling individual packaging used to package and distribute beer,
- and activity connected with management of waste understood as "all substances or objects whose holders dispose of, intend to do so or are obliged to dispose of" (Lisiecka-Biełanowicz et al. 2014).

All around the world, breweries generate relatively large amounts of waste. An appropriate approach to waste management, however, makes it possible to treat the waste produced as by-products because a lot of this waste is valuable for farmers, recycling plants and other companies. Waste minimisation and finding alternative ways to use it are key methods of environment protection. Waste management is

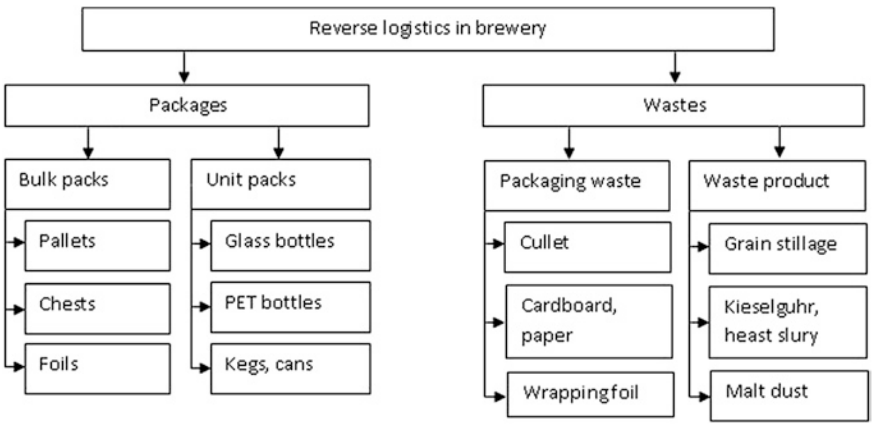

Fig. 4 Types of reverse logistics in a brewery

becoming a crucial issue, while traditional methods, i.e. storage, have a negative impact on the environment.

3.2.1 Kompania Piwowarska

As part of waste management optimisation, Kompania Piwowarska concentrates on three aspects: separating post-production waste intended for recycling, limiting the amount of waste taken to landfills, managing waste as harmlessly for the environment as possible. All waste from the production process, such as brewer's grains or waste yeast, are practically 100 % re-usable in farming, the pharmaceutical and cosmetic industries. Other waste, such as glass, metals, paper, cardboard, foil or wood, are segregated and passed on to specialist companies in order to be recycled. To reduce the volume of waste, breweries have introduced, for example, can crushers and pressing containers for other waste. Temporary landfill and segregation sites are prepared in such a way that safety is ensured and no waste can permeate into the soil (Kompania Piwowarska Sustainable Development 2013).

3.2.2 Grupa Żywiec

The brewery in Elbląg, belonging to Grupa Żywiec, has shown initiative to regulate the management of the waste produced at the brewery, in accordance with the country's and concern's policy on ecology. The 3R (Reduce, Reuse, Recycle) rule has been applied at the brewery. The main aim of the programme is to reduce the cost of non-segregated waste storage.

As a result of this initiative, the cost of non-segregated waste storage at the city landfill has been significantly minimised, waste treatment principles defining how to handle it ensuring people's life and health protection as well as environment protection have been introduced, in addition to principles of waste recycling and neutralisation.

Employees are trained in the obligation to segregate waste, which is aimed at increasing awareness and establishing good practices when handling waste. Employees of all external companies, subcontractors at the brewery's premises have also been trained in the ISO requirements, particularly those concerning dangerous waste handling.

The non-segregated waste production rate for the year 2010 was the following:

- for the brewery in Elbląg: 0.025 kg/hl (kilogram per hectolitre of beer produced)
- for Grupa Żywiec: 0.035 kg/hl

The amount of waste to be recycled is also controlled:

- 99.92 % of waste produced at breweries of Grupa Żywiec is subjected to recycling.
- 0.08 % of non-segregated waste produced at breweries of Grupa Żywiec is stored at the city landfill. At the brewery in Elbląg the rate is 0.01 %.

The initiative has resulted in limiting the increase in the costs of storing waste at the city landfill (Grupa Kapitałowa Żywiec S.A. 2012).

3.3 Sustainable Packing

Packaging is essential to the brewing sector, because it provides safe and fresh delivery of beer to consumers. In recent years there has been a move to reduce the amount of materials in packaging, i.e. light-weighting, for example by minimising the amount of glass used in glass bottles. There is a balance between reducing the weight of packaging/recycled content to reduce environmental impact and ensuring product safety and minimal waste due to breakages. Figure 5 shows that there is a variation in packaging materials and volumes in the EU. This is a reflection on consumer preference, culture, climate and the geographical area where the beer is being consumed. All materials which are used are recyclable and some are reusable. The materials most commonly used are steel, glass, aluminium and plastic polyethylene terephthalate (PET). Every country has a different approach to packaging for serving beer. However, the challenges each country faces are still largely the same in minimising the environmental impact of packaging. The main focus areas are in using reusable packaging, recycling, light weighting and increasing the proportion of recycled materials in newly made packaging (Donoghue et al. 2012).

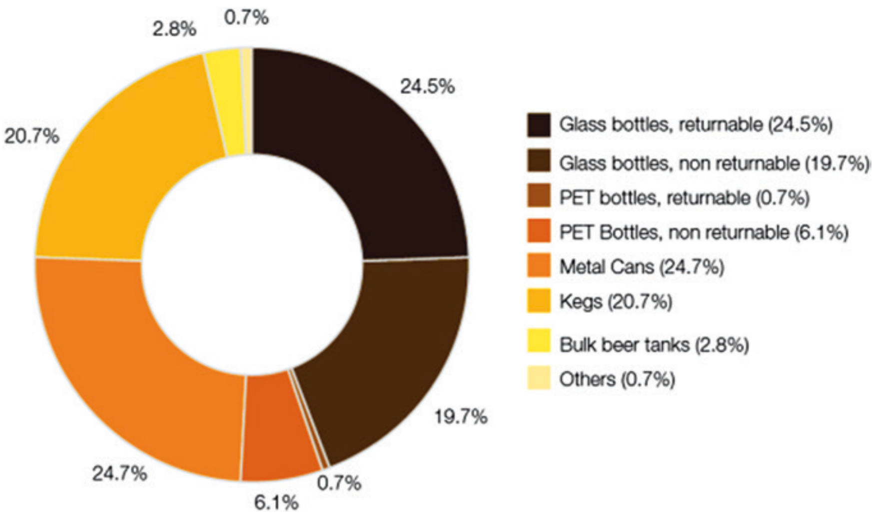

Fig. 5 Packaging used by European breweries (adopted from Berkhout et al. 2013)

3.3.1 Kompania Piwowarska

In order to ensure constant availability of returnable packaging for production, Kompania Piwowarska is continuously increasing effectiveness of gathering it from the market. The vehicles that come back to a distribution centre or a brewery after having delivered beer to a client should always do so with returnable packaging, regardless of the amount of the packaging available at the address of the delivery.

The company also tries to educate the market in the field of sorting packaging. Leaflets and posters that inform which bottles are returnable and in which crates they should be returned have been prepared for retail shops. When sorting quality is raised, production capacity on bottle lines is increased—and it is the packaging that is the most desired and, at the same time, most difficult element in the season because of reverse logistics (Kompania Piwowarska Sustainable Development 2013).

3.3.2 Grupa Żywiec

In 2010, in co-operation with one of the key packaging suppliers, Grupa Żywiec realised a project whose aim was to reduce the thickness of the metal sheet used to produce plain cans for Grupa Żywiec. The decrease in the metal sheet thickness from 260 to 245 μ translated into a decrease in the weight of the cans and made it possible to reduce the amount of the material used. The weight reduction by as little as 0.3 g enabled to decrease CO_2 emission by 1,310 kg and cut the amount of energy used by nearly 1.33 % for every million of new/lighter cans. In 2012 Grupa Żywiec bought 924,963,560 cans, which meant CO_2 emission savings at the level of 1,211 t (Grupa Kapitałowa Żywiec S.A. 2012).

3.4 Energy and Greenhouse Gases

Economic development causes an increasing demand for energy worldwide. It is satisfied to a large extent by burning fossil fuels such as coal, oil or gas. When burning fuels, huge amounts of carbon dioxide (CO_2), which, apart from other greenhouse gases such as methane, contributes to global warming and climate changes, are released into the atmosphere. Energy consumption and carbon dioxide emission have already ceased to be the subject of scientific theories only. Governments in the whole world are starting to exert pressure to introduce appropriate solutions by tax tools and fees for emission. In 2010, the average specific energy consumption of breweries was 116.8 MJ/hl (calculated on a LCV basis). This represents a decrease of 3.8 % since 2008 (see Fig. 6) (Donoghue et al. 2012).

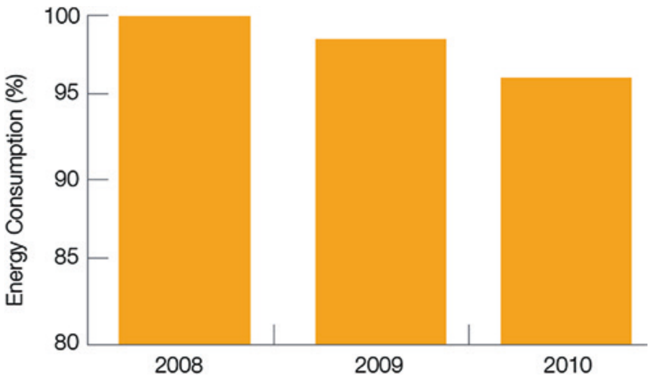

Fig. 6 Specific energy consumption of breweries in UE (adopted from Berkhout et al. 2013)

3.4.1 Kompania Piwowarska

At all breweries of Kompania Piwowarska, electric and thermal energy consumption is continuously monitored, which allows to identify the efficiency of the production processes. Additionally, at the breweries in Tychy and Poznań constant monitoring of fuel consumption in the boiler rooms is carried out, which, in turn, enables to regularly estimate the size of CO_2 emission to the atmosphere. At the same time, work connected with improvements in the technological processes and modernisation of the existing systems never stops at all the premises.

These actions have led to a significant reduction in the energy intensity indicators in recent years. The consumption rate of the thermal energy produced per a unit of beer made at the brewery in Poznań has gradually fallen from the value achieved in 2013 which was equal to 57.68 MJ of energy per hectolitre of beer. In the case of the electric energy consumption, the global rate for the entire Kompania Piwowarska was 5.84 kWh/hl of beer. The reference indicator of electric energy intensity determined in Best Available Technology (BAT) for the brewing sector ranges from 8 to 12 per hectolitre of beer. Therefore, the rate accomplished by Kompania Piwowarska suggests a high degree of commitment to limiting energy consumption in the production processes.

The use of renewable energy sources is mainly conditioned by technical limitations and availability of the “clean” fuels. The technical conditions of the brewery in Tychy allow to use renewable energy in the form of biogas produced at the premises of the factory’s sewage treatment plant. Biogas, due to its composition, is burnt together with natural gas. Application of this innovative solution brings both economical and environmental benefits. Wanting to decrease the environmental burden, in 2006 Kompania Piwowarska eliminated the boiler room burning coal that was exploited at the brewery in Poznań and replaced it with a modern gas and oil boiler room. Thanks to the conversion of coal into gas and oil, a considerable reduction in the emission of, among others, carbon compounds

Table 2 Electric energy consumption in Kompania Piwowarska (adopted from Kompania Piwowarska Sustainable Development Report 2013)

Budget year (hl)	2011	2012	2013
Production output (hl)	14,364,997	13,646,374	14,740,165
Electricity consumption (kWh)	87,579,223	80,687,663	86,118,109
Indicator (kWh/hl)	6.1	5.91	5.84
Consumption of heat from non-renewable sources (GJ)	88,4049	81,3127	823,277
Consumption of heat from renewable sources (GJ)	56,597	43,265	50,036
Indicator (kwh/hl)	64.12	66.31	60.94

into the atmosphere was achieved. The boiler room is also additionally powered with biogas produced at the sewage pre-treatment plant. In 2013, the amount of heat used by the breweries in Poznań and Tychy from the so-called own sources produced from gas, oil or biogas was 760,412 GJ. Besides, the truck fleet which carries out Kompania Piwowarska's distribution processes is subjected to actions aimed at converting to fuels of low carbon compounds content. The result is replacing 20–30 % of the consumed diesel oil with natural gas (LPG). This technology makes it possible to reduce emission of particulate matter (Kompania Piwowarska Sustainable Development 2013) (see Table 2).

3.4.2 Grupa Żywiec

Grupa Żywiec is also trying to rationally use energy at individual breweries and technological processes. The company is trying to achieve one of the environmental objectives that it sets itself, connected with the necessity to reduce CO_2 emission, in two ways: by reducing the total energy consumption and increasing application of energy from renewable sources. In 2012, Grupa was successful in improving the renewable sources share in the thermal energy consumption (see Table 3). Simultaneously, the total thermal and electric energy use at Grupa Żywiec rose to 1,313,715,021 MJ (i.e. by 1.1 %), which was, however, mostly connected with an increase in production. The breweries in Elbląg and Warka

Table 3 Direct and indirect energy consumption in Grupa Żywiec in 2012 by energy sources (adopted from Plzenský Prazdroj Sustainable Development Report 2013)

	2011	2012
Purchase of electric energy (in kWh)	68,390,026	69,889,418
Purchase of heat (in MJ)	694,389,978	684,710,260
Sale of heat (in MJ)	12,978,396	13,222,373
Consumption of natural gas (in Nm^3)	10,972,982	10,691,016
Consumption of biogas (in Nm^3)	1,904,952	1,896,218
Consumption of oil (in kg)	55,215	54,337
Consumption of LPG (in kg)	549,123	485,502
Consumption of diesel oil (in kg)	15,942	10,693

noted a fall of the total energy consumption by 7.3 and 2.2 %, respectively. At present, the breweries in Elbląg and Żywiec enjoy the lowest energy consumption per 1 hl of beer. It amounts to 104 and 112 MJ/hl, respectively. The use of thermal energy at the breweries in Żywiec, Warka and Elbląg was also reduced. The results achieved in this area are connected, for example, with the following:

- the change of the type of beer produced at the brewery in Żywiec, which now requires lower thermal energy consumption (by 0.3 MJ/hl),
- the implementation of actions in the field of optimisation of processes in the brewhouse (Żywiec brewery), on the line of washing bottles (lowering the washing temperature from 84 to 80 °C),
- the optimisation of solutions in the field of heat recovery at the brewery in Żywiec,
- the replacement of selected technologies in the boiler room and water treatment plant in the boiler room at the brewery in Warka (Corporate Social Responsibility Report of Grupa Kapitałowa Żywiec S.A. for 2012).

3.5 Water and Wastewater

Brewing beer is a process requiring enormous quantities of water, which constitutes as many as 92 % of the beer volume. It is also used in production for cleaning, in steam production, cooling water and in heat exchangers for temperature control. A shortage of water poses, then, a potential threat not only to certain fields of brewery operation, but also to the communities among which they operate. One of the priorities for breweries is to increase beer production and, at the same time, reduce water consumption. The specific water consumption dropped by 4.5 % between 2008 and 2010. The specific water consumption, according to national production data, varied from 2.5 to 6.4 hl/hl with an average of 4.2 hl/hl in 2010 (Donoghue et al. 2012).

Water use in technological processes is inseparably connected with wastewater production. Breweries aware of the dangers resulting from uncontrolled movement of polluted water supervise the circulation of the wastewater produced and strive for reduction thereof. In 2010, every litre of beer produced in the EU translated into 2.7 l of wastewater on average, which constituted a 5.9 % fall in relation to the year 2008 (see Fig. 7) (Donoghue et al. 2012).

3.5.1 Kompania Piwowarska

As part of the co-operation between Water Futures and WWF and GIZ (a German international agency for development), SABMiller participates in developing new conceptions of water management. SABMiller engages in co-operation in aid of watershed protection on a global scale, and Kompania Piwowarska successfully

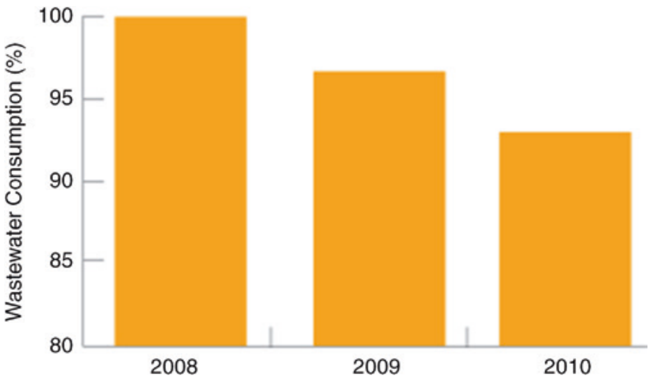

Fig. 7 Wastewater production by Breweries in Europe (adopted from Berkhout et al. 2013)

realises the priority of decreasing the amount of water used for beer production with a simultaneous increase in production. At every brewery of Kompania, water consumption calculated for a unit of the beer produced is monitored. The observations are carefully analysed and, on that basis, new solutions are introduced thanks to which the values keep decreasing. In 2013 the water consumption indicator for the whole company was 2.96 hl of water per a hectolitre of the beer produced (data for 2013). By contrast, 10 years ago the indicator was 4.6 hl per a hectolitre of beer. Water is supplied to individual breweries of Kompania Piwowarska from its own intake stations (underground water) or from the city water supply. In order to adjust its parameters to the beer production requirements, it is subjected to treatment processes (Table 4).

All three plants of Kompania are successful in reducing the amount of wastewater produced. In the last few years each of the breweries has managed to decrease the quantity of wastewater by a few dozen per cent. In Białystok, the amount of the wastewater generated has fallen by as many as 51 % in 7 years. The wastewater treatment principle is obeyed by every brewery before it releases it to the environment. When the existing infrastructure allows to do so, the treatment process is carried out at the brewery's premises. The one in Tychy has a modern wastewater pre-treatment plant at its disposal. It is based on anaerobic methods of treatment with granules. As a result of anaerobic fermentation, biogas is made, stored and, then, used as fuel of standard value to heat boilers. Wastewater from the other breweries is directly sent to the municipal treatment plants.

Table 4 Water consumption in Kompania Piwowarska (adopted from Kompania Piwowarska Sustainable Development Report 2013)

	2011	2012	2013
Total water consumption	46,134,680 hl	41,045,198 hl	43,595,926
Municipal water supply	33,056,450 hl	28,990,628 hl	29,840,036 hl
Water drawn from own wells	13,078,230	12,054,570 hl	13,755,890 hl

Kompania Piwowarska is striving for a decrease in the amount of the wastewater produced by partial re-use of water. It is possible thanks to the following (Kompania Piwowarska Sustainable Development 2013):

- using water from the brew kettle condensate to pre-rinse whirlpools,
- using water from the final rinsing at the clean in place for external rinsing,
- using the excess water from the bottle wash to wash empty crates,
- feeding conveyor sprinklers with water returning from can and bottle washes,
- using cascade water for foam fractionators.

3.5.2 Grupa Żywiec

The Heineken Group, which owns breweries in 70 countries worldwide, is also trying to increase effectiveness of using this material in production. The corporation has committed itself to lowering the water consumption rate to 3.7 l per 1 l of the beer produced before 2020. It will mean a 25 % reduction in comparison with the result achieved in 2008. In 2012 the average water consumption at 165 breweries of the Heineken group was decreased to 4.2 l per 1 l of beer.

The breweries of Grupa Żywiec which are part of the Heineken concern have for many years consistently been cutting the consumption of water used in beer production and currently belong to the most ecological and efficient ones in the world. Grupa's breweries in Żywiec, Warka, Elbląg, Leżajsk and Cieszyn use, on average, 2.9 l of water to produce 1 l of beer. In terms of water consumption, as many as 4 out of 5 breweries of Grupa Żywiec are in the top ten most ecological ones among 165 plants of the Heineken Group. An effective way of limiting water consumption applied by the Group has been implementing semi-dry and dry lubrication systems on the lines where beer is poured into bottles at the breweries in Leżajsk and Warka. Trials conducted at the Leżajsk production brewery have shown a decrease in the amount of water and wastewater on this production segment by 70 and 85 % in Warka in contrast with the traditional method. These systems are among the most advanced ones in the world (Corporate Social Responsibility Report of Grupa Kapitałowa Żywiec S.A. for 2012) (Table 5).

In 2012 the total amount of wastewater produced at the breweries of Grupa Żywiec constituted 60 % of the water used. Wastewater from the plants in Żywiec and Warka is partially deprived of pollution in the pre-treatment plants operating at the breweries before it gets to the municipal treatment plant. Due to increasing beer production, wastewater emission rose at all breweries apart from the one in Warka where the wastewater quantity fell by 2.8 % in relation to 2011. The plant

Table 5 Consumption of water in individual breweries of Grupa Żywiec (in m^3) (adopted from Corporate Social Responsibility Report of Grupa Kapitałowa Żywiec S.A. 2012)

	Cieszyn		Elbląg		Leżajsk		Warka		Żywiec	
Year	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Water consumption	21,040	21,621	701,458	701,082	375,776	446,417	838,791	845,968	1306,660	1374,866

in Żywiec maintained the 2012 value at a level close to the previous year, whereas at the other breweries the amount of the emitted wastewater grew (Corporate Social Responsibility Report of Grupa Kapitałowa Żywiec S.A. for 2012).

4 Conclusions

The European brewing industry undertakes actions in response to a range of objectives connected with energy efficiency, limiting carbon dioxide emission and water consumption as well as changes in packaging ways. This is an element of the policy realised by the European Union in aid of sustainable development. Investments made in co-operation with scientific institutions lead to a decrease in natural resources consumption, reduction of the amount of waste produced and consistent recovery of secondary raw materials created during beer production processes (Jirovec and Calleja 2013).

Breweries in the whole world, including the two largest beer producers in Poland, i.e. Kompania Piwowarska and Grupa Żywiec, demonstrate commitment to natural environment protection. The brewing sector has been working on guidelines concerning the Best Available Techniques (BAT), which emphasise the role of sustainable management and which may serve as a point of reference for engagement in achieving environment protection aims (Jirovec and Calleja 2013). The brewing sector in Spain has produced a comprehensive document of Best Available Techniques (BATs). The brewing sector and the Ministry of Environment combined their expertise to design the most accurate and up-to-date BATs possible. In addition to providing guidance on best techniques, the document also makes the point that sustainable management is important to be included in any economic growth plan and should be a factor in any decisions going forward. Further benefits of BAT documents are that they can be used as common reference resources to make realistic commitments to environmental targets in the future (Donoghue et al. 2012).

Supply chain management in a sustainable way is a great challenge for brewing enterprises. A trend towards replacing the classical supply chain with a value chain is currently being observed. The latter make it possible for breweries not only to reduce business and image-related risk, but also to improve the quality of products and build stable relationships with stakeholders. Breweries that want to develop a responsible supply chain system have numerous tools at their disposal. Apart from the Supplier Codes of Conduct, used, among others, by Grupa Żywiec, there are also many platforms and IT tools which index potential suppliers (Corporate Social Responsibility Report of Grupa Kapitałowa Żywiec S.A. for 2012). Kompania Piwowarska uses the SEDEX platform, which enables to gather and report information from suppliers, which is divided into four categories: work standards, health and safety, environment, and business ethics (Kompania Piwowarska Sustainable Development 2013). Another IT solution allowing to manage a responsible supply chain within which a brewery produces and delivers its products is the CSRware's Sustainability Supply Chain. This programme makes it possible to benchmark individual suppliers. In addition, it evaluates suppliers on the basis of various indicators and allows to create one's own supplier ranking (Zrównoważony łańcuch dostaw: trendy i innowacje 2013).

The beer industry is the only one in which unit packaging is used. Packaging management in such a way that the greatest recycling degree is ensured constitutes one of the largest challenges for breweries. The two biggest beer producers in Poland conduct numerous campaigns and programmes aimed for ensuring the best packaging return system possible. The present system, however, is not sufficiently supported by the law, so a bottle makes, on average, 8–10 cycles. This type of returnable packaging, though, is prepared for a larger number of cycles, even more than 20 times. The deposit and return of beverage packaging system applied in Denmark seems a comprehensible solution. The initiative undertaken in 2002 by retailers and producers in agreement with the Danish Environmental Protection Agency was the first enterprise of this type and aimed for unifying the system of packaging return. Its main assumption was and is for one entity to be responsible for collecting and segregating packaging and paying deposits on a domestic scale. This entity operates as an external non-profit organisation which assures shops that they will obtain the due funds for sorting and returning packaging (Kacprzyk 2010). The costs of the whole system are reduced by installing machines enabling to return both returnable glass bottles and disposable packaging which is then recycled in retail outlets. As a result, the packaging does not re-circulate, which would have disastrous consequences for the environment. As a rule, the system is supposed to be self-sufficient; accordingly, producers and importers are obliged to cover part of the operational costs (Kacprzyk 2010).

Some valuable by-products are made during the brewing process from the raw materials used for beer production. They are appreciated and used in other industrial processes or as raw materials for specific aims or products, such as pharmaceuticals, healthy food, renewable energy sources, industrial application, feed for animals and farming products, cosmetics or spa products. The importance and value of the brewing by-products has persuaded breweries to sign long-term contracts concerning deliveries with traders and end-users. The production waste reuse indicator is close to 100 % both at Kompania Piwowarska and Grupa Żywiec's breweries. Similar results are achieved by many European brewing concerns. For example, the brewery Plzenský Prazdroj from the Czech Republic has collaborated with a local university to create a tool for making the best use of its secondary products. It is currently being used for the Plzeský Prazdroj brewery and, if successful, will provide a blueprint for other breweries. About 98.6 % of waste is used in a secondary way. Prazdroj has sought ways to further reduce the volume of waste that cannot be re-used with partners and suppliers of Plzenský. Plzeňský Prazdroj is a member of the EKO-KOM association, which deals with the issue of packaging recycling and re-use in line with the applicable Czech legislation (Plzenský Prazdroj Sustainable Development Report 2013).

In recent years, the European brewing sector has been trying to reduce water and energy consumption for beer production. As a result, water and energy consumption has been decreased by 4.5 and 3.8 % per 1 hl of beer produced, respectively. It is estimated that CO_2 emission has also been limited by 7.1 %. Proper water and energy management by suppliers and breweries is necessary to guarantee the sustainable character of beer production. Kompania Piwowarska and Grupa Żywiec use, on average, 2.9 hl of water per 1 l of beer. The energy consumption rate per 1 hl of beer is, however, more varied—57.68 MJ for Kompania Piwowarska and 104 MJ for Grupa Żywiec. Beer producers in the whole Europe seek new solutions to improve these results all the time. Some enterprises not only reduce energy consumption, but also use energy from renewable sources. For example, the Clemens Härle brewery from Leutkirch produces all of its beer using 100 % of renewable energy. It has been the first brewery in Germany that has made all its beer with the use of green energy. Achieving this level of environmental performance has taken over 15 years. The first step was producing a document detailing a lifecycle assessment of the brewery, which could then be used to formulate a plan to move towards the ambitious goal. The largest investment the brewery has made was installation of a combustion plant which uses wood chips to provide all the brewery's heat. What is more, they have installed photovoltaic panels on the plant, which makes up to 12 % of the electricity needed. The remaining electricity required is purchased from renewable sources, including water, sun and wind. In total, the brewery has removed 900 t of CO_2 emission per year (Donoghue et al. 2012).

Enterprises of the European brewing industry are dependent on the quantity and quality of natural resources to a huge extent. This sector is, however, an example of great ecological awareness. Breweries all over Europe, including those in Poland, especially Kompania Piwowarska and Grupa Żywiec, continue working on decreasing their negative impact on the environment. Thanks to numerous investments in new technology and co-operation with all stakeholders, they protect the environment and contribute to development of the conception of social responsibility.

References

Beer statistics 2012 edition (2012) The Brewers of Europe

Berkhout B, Bertling L, Bleeker Y, Wit W, Kruis G, Stokkel R, Theuws R (2013) The contribution made by beer to the European Economy. A report commissioned by the Brewers of Europe and conducted by Regio Plan Policy Research and EY

Carlsberg Polska (2014) wzrost szybszy niż rynek. http://www.Carlsbergpolska.pl/media/najnowsze/pages/carsbergpolska_wzrosyszybszynizrynek.aspx. Accessed 25 Aug 2014

Corporate Social Responsibility Report of Grupa Kapitałowa Żywiec S.A. for 2012

Donoghue C, Jackson G, Koop JH, Heuven AJM (2012) The environmental performance of the European Brewing sector

Gadomska-Dzięcioł P, Stankiewicz J, Pezda M (2012) Komunikacja działań CSR w Polsce. http://effectivepr.pl/Image/pdf/komunikacja-dzialan-CSR.pdf. Accessed 25 Aug 2014

Henzelman T, Schaible St, Stoever M, Meditz H (2011) Geneza zielonej rewolucji ekonomicznej i spodziewane korzyści [in] Zielony wzrost, zielony zysk, Kluwer Wolters, Warszawa

Informacja prasowa Związku Pracodawców Przemysłu Piwowarskiego w Polsce (2014) Piwowarzy: rok 2014 zapowiedzią stabilizacji sprzedaży. http://www.browary-polskie.pl/artykulPlik/file_150.pdf. Accessed 25 Aug 2014
Jirovec L, Calleja E (2013) Opinion of the European economic and social committee on incentivising the growth potential of the European beer industry
Kacprzyk M (2010) Duński system depozytu i zwrotu opakowań napojów. http://copenhagen.trade.gov.pl/pl/analizy-rynkowe/article/detail,3378,Dunski_system_depozytu_i_zwrotu_opakowan_napojow.html. Accessed 06 June 2014
Kompania Piwowarska Sustainable Development Report 2013, (2014). http://www.kp.pl/documents/article/KP_raport_SD_2013.pdf. Accessed 25 Aug 14
Lichota J (2012) Beer statistics 2012 edition. The Brewers of Europe
Lisiecka-Biełanowicz M, Dusza J, Wawrzyniak J (2014) Odpady opakowaniowe w modelach gospodarowania odpadami niemedycznymi w szpitalach, Opakowanie, nr 3
Obszary zrównoważonego rozwoju w przedsiębiorstwie (2012). http://ksb.uek.krakow.pl/klub-ksb-alumni-mba/wyklady-goscinne/artykul/zobacz/obszary-zrownowazonego-rozwoju-w-przedsiebiorstwie.html. Accessed 25 Aug 2014
Okrzesik J (2003) Branża browarnicza, Boss Gospodarka, nr 7, s. 83–92
Plzenský Prazdroj Sustainable Development Report 2013. http://www.prazdroj.cz/data/web/spolecenska-odpovednost-2013/PP-SD-report-21x21-AJ-VERZE.pdf. Accessed 25 Aug 14
Produkcja piwa w Polsce lekko spadła w styczniu (2014). http://www.portalspozywczy.pl/alkohole-uzywki/wiadomosci/gus-produkcja-piwa-lekko-spadla-w-styczniu,97844.html. dostęp: 06 June 2014
Rynek piwa—analiza Equinox Polska (2013). http://gieldaspozywcza.pl/Wiadomo%C5%9Bci/Rynek-piwa-analiza-Equinox-Polska-60220.html. Accessed 25 Aug 2014
Skórski R (2012) Niszowe piwo podbija rynek. http://pierwszymilion.forbes.pl/niszowe-piwo-podbija-rynek,artykuly,31602,1,1.html. Accessed 25 Aug 2014
UN Global Compact Management Model (2010) Delloite
Zachęcające wyniki KP pomimo trudnych warunków rynkowych (2013). http://www.kp.pl/wyniki/wyniki-kp/. Accessed 25 Aug 2014
Zrównoważony łańcuch dostaw: trendy i innowacje (2013) Forum Odpowiedzialnego Biznesu
Żywiec sprzedał mniej piwa (2013). http://www.parkiet.com/artykul/1335499.html. Accessed 25 Aug 2014

Part II
Technologies for Transportation and Sustainability

Smart Cities—A Vision of the Future or the Present?

Anna Brdulak

Abstract This chapter aims to look more closely at the subject of smart cities in view of sustainable development. The discussion about the concept of smart cities is becoming particularly important from the perspective of dynamic urban processes. Authorities of growing metropolises handle not only greater space that must be managed but also all consequences resulting from the phenomenon such as slums or traffic congestions. That is why, they more often resort to modern technologies which facilitate and improve the quality of inhabitants' life. At the same time they try to get citizens involved into issues concerning building the social capital. The chapter discusses examples of technological improvements applied in selected cities aspiring to be called a smart city.

Keywords Smart city · Sustainable development · City development · Urbanization · New technologies

1 Introduction

The concept of sustainable development is gaining more importance at times of the economic slowdown. That is why, it is worthwhile looking at its assumptions. A definition of sustainable development provided in the report of the World Commission on Environment and Development in 1987 also called G.H. Brundtland's report by the Norwegian Prime Minister in charge of the Commission is considered one of the first ones. According to this definition sustainable development basically aims to meet development aspirations of the current generation to enable next generations to realize the same ambitions (Borys 1999). The basis for sustainable development is constituted by internal and

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inter-generation equality. It is essential to ensure this equality for societies to acquire an ability of sustainable development (Turner et al. 1994).

The above definition indicated the necessity of economic and social development of the population taking into account not only the environment but also current problems such as increasing social discrepancies in the possessed income, violating human rights, no access to education, insufficient health protection systems or a growing urbanization ratio and expansion of cities. It additionally includes postulates concerning the rational usage of natural resources. Thus development cannot be encouraged at the cost of other people or the natural environment. It should be harmonious and keep a balance in various areas it relates to.

In Poland the definition of sustainable development directly refers to previously quoted definitions also to the interpretation included in the Law on Environment Protection from 2001. Apart from equality issues overriding social goals of the sustainable development concept comprise prosperity and broadly understood social safety. Social and economic developments as well as maintaining ecological functions are to secure achievement of these social goals (Łojewski 2007). It is of key importance to take into account development of transport infrastructure connected to an increasing number of cars.

The idea of sustainable development is becoming especially valid in view of the crisis that took place in 2008. It naturally resulted in the necessity of detailed analysis and introducing relevant changes to the previous business model used by the majority of enterprises. Changes mean a broader look on completion of basic goals of an organization in the long-term as well as paying particular attention to stakeholders being near the company and elaborating programmes targeted at environment protection or helping local communities.

The economic and financial crisis has reviewed opinions of not only organizations but also made governments change the way they think. A lot of countries and organizations focused on internal problems with generating costs and minimising time of particular processes. Shortening cycles leading to savings in logistics costs, improving the level of customer service or the speed of satisfying expectations of the society living and moving faster and faster constitute only some of noticeable market phenomena (Brdulak 2012).

In addition we may observe a growth in wealth of the society which translates into a bigger number of cars owned by households. Unfortunately, appropriate infrastructural changes preventing the congestion do not go with it. In Allianz Global Wealth Report (Brandmeir et al. 2013) the authors characterise the trend in detail indicating societies with growing wealth. Inhabitants of analysed countries[1] are divided into three groups according to the wealth level. The middle class comprises people owning assets worth between EUR4,900 to EUR29,200, people with assets worth less than EUR4,900 belong to a low wealth class however the richest group consists of people having net financial assets of over EUR29,200.

[1] The Allianz Global Wealth Report is based on data from 52 countries. This group of countries covers around 90 % of global GDP and 69 % of the global population.

Bearing in mind the above it is worthwhile emphasising that the crisis has contributed to the growth in the group with low income in developed countries whereas in poorer countries it has led to expansion of the group with a medium level of wealth. Only in 2012 the number of people with medium income increased by almost 140 million and the biggest growth was recorded in China. In total in 2012 there were about 860 million people with a medium level of net financial assets.

Moreover according to the report within recent 12 years, since the beginning of 21st century the percentage of people from the middle wealth category on the global scale doubled in emerging countries of Eastern Europe and Latin America. However in Asia, except for Japan, it grew ten times. These processes result in changing the structure of people form the middle wealth category. In 2000 almost 60 % of its members came from North America and Western Europe and nowadays every second person comes from Asia. The percentage of the middle class dropped from 60 to 30 % in developed countries. According to forecasts of report analysts this trend will maintain.

With the expansion of the medium wealth category the importance of retail (including e-commerce), real estate trade or other services e.g. beauty and hairdressing services grows. Needs and expectations of the society are becoming more and more sophisticated. Consumers gain access to a wide range of goods improving the quality of life. There are more opportunities to travel.

The above phenomenon is accompanied by a deepening social stratification which is a serious problem as it may constitute a barrier in creating smart cities. Attention to this was drawn by a columnist of Market Watch, an internet supplement to "The Wall Street Journal", R. Nutting. He indicates that *the share of income earned by* 1 % *of the wealthiest in total income of the Americans is the highest since 1927 and exceeds* 20 %. Discrepancies in earnings and wealth are growing. This phenomenon does not only concern the United States where 1 % of the richest people own 34.1 % of the assets but also Switzerland—34.8 %, or Sweden—24 % (Gadomski 2014). The data from Global Wealth Data Book Credit Suisse Research Institute from 2013 shows that even in Denmark 39.5 % households own assets of less than 10,000 dollars whereas 5.7 % of households have a budget which is greater than a million dollars.

Taking into account an increasing urbanization ratio, polarization of the society may hinder aspirations for building the social capital also based on creation of the civic society, a social dialogue leading to compromises as well as responsible decision making (2014). It may negatively affect the application of the concept of smart cities where these values play a key role and the basis is constituted by counteraction by many entities from various areas.

In the context of described phenomena the idea of sustainable development mentioned previously is gaining more importance promoting the balance between economics, the environment and the social area which includes striving for harmony between work and private life. Time is becoming a very precious commodity desired not only as an element of building a competitive position of entities but also as a synonym to a better quality more peaceful life (Brdulak and Brdulak 2014).

This chapter aims to present problems arising from the growth in importance of cities in the context of dynamically occurring urbanization processes. The initial concept of smart cities will be extended by examples of smart cities functioning now and trying to combine a traditional urban infrastructure with technological innovations. The summary will formulate recommendations for further research in view of arising problems.

2 Urbanization Problems and the Process of Creating Smart Cities

Cities play an essential role in the life of the majority of the society having importance to global social and economic development. According to data of the UN over a half of the world population lives in cities and in 2050 this percentage will increase by over 70 % (Fig. 1). Almost the entire urban growth will be noticed above all in emerging economies.

Leipzig Charter on Sustainable European Cities from May 2007 includes a description of the role of cities. It indicates unique cultural and architectural values cities have as well as strong mechanisms of social integration and exceptional possibilities of economic development. Cities constitute knowledge centers and sources of growth and innovation. However attention must be paid to demographic

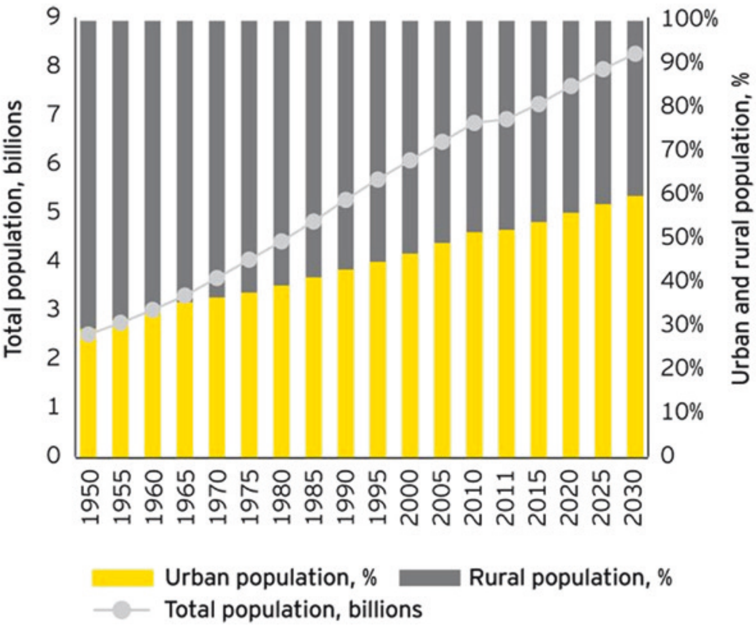

Fig. 1 The number of rural and urban population over the years 1950–2030 (2013)

problems such as social inequality, social exclusion of some groups, the lack of cheap and appropriate flats and ecological problems (Leipzig Charter 2007).

Increasing income discrepancies, a deepening gap between the poor and the rich lead in some communities to concentration of inequality with regard to a poor level of education, a high unemployment rate, bad housing conditions and limited access or no access to some services such as information technologies, telecommunication, health care or communication. The problem also concerns the richest cities where social and spatial segregation take place. Due to low income or the marginality nature (the elderly, the disabled) some people find it difficult to buy a flat they can afford. A growing number of "society outcasts" in many cities and their suburbs may result in arising sub-cultures with hostile attitude to the rest of the society (EU 2011). A particular attention must be drawn to actions preventing those growing gaps.

Various reports inform about a growing role of cities and development of urban logistics that follows it. According to 2013 report findings of Frost & Sullivan within next 10 year expenses for urban logistics will increase twofold reaching a global level of USD 5,980 billion (Frost & Sullivan 2013). Four trends have the strongest impact on these forecasts:

- urbanization,
- contact and convergence,
- model bricks and clicks (traditional and internet commerce),
- multimodal transport (high speed railway).

Transport and distribution will probably be the most cost consuming.

It is estimated that by 2025 the world will have about 25 megacities with the minimum number of population of 8 million and the GDP at the level of USD 250 million. Migrations are stronger and stronger and according to forecasts in 10 years three out of four people will live in an urban area (value estimated for 2025). Twenty biggest megacities are presented in Fig. 2.

Fig. 2 Top 20 megacities in 2025 (2013)

The urbanization growth will result from other phenomenon—the so-called arising smart cities or cities of the future. According to A. Caragliu from Milan University of Technology a smart city may be defined as the one where investments in the human and social capital and traditional (transport) and modern (based on telecommunication and information technologies) infrastructure power sustainable economic growth and build a high quality of life together with wise human resources management through participatory governance (Caragliu et al. 2014) (Fig. 3). One of the main conditions for development of smart cities is cooperation of self-government bodies with a wide range of entities from their environment affecting the way the city operates. These are all types of social organizations, social initiatives or activists.

According to Frost & Sullivan analysts, development of cities of the future involves new technologies used for development of urban logistics. Cities are differentiated from each other by a different structure of spatial development, infrastructural solutions or the location. That is why each city has a possibility of adjusting services offered by logistic companies to its needs and expectations which reduces the risk occurring at the stage of goods distribution.

The concept of smart cities assumes involving inhabitants thanks to an easier access to information and arranging dialogues and social consultations to enable inhabitants put forward their ideas or notify problems. In this context it is important that all people living in the metropolis have a wide access to the internet.

The nature of future cities makes inhabitants become main designers of solutions whereas the administration will support the completion of projects.

An interesting vision was presented in 2010 by Tim O'Reilly, founder of O'Reilly Media, a supporter of a free access to software and means of communication. According to him the government as a collection of public units functions on the basis of an open platform. This platform creates an appropriate environment

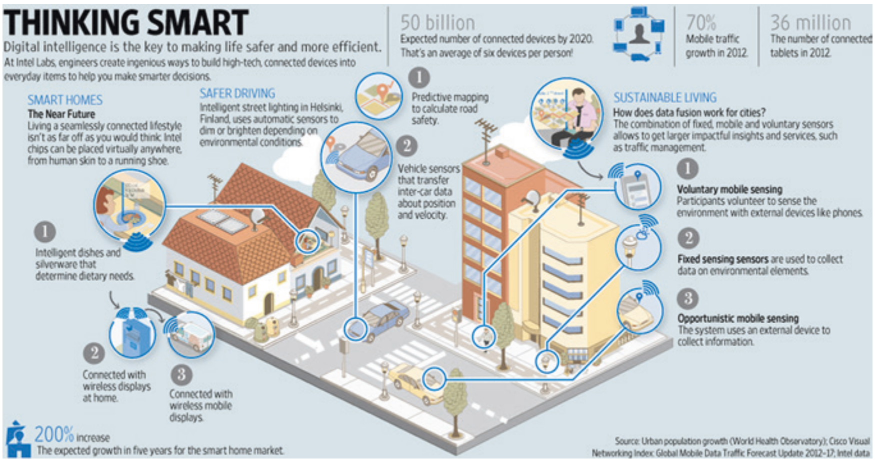

Fig. 3 Sample technological solutions in cities (2012–2017)

for activities of other entities enabling them to provide citizens and businesses with innovative services. So O'Reilly expects the government to secure "raw material" meaning statistics, public data and appropriate institutional conditions such as procedures, principles allowing the second and the third sector to create their own e-services or will create them together with public administration units. Thus the responsibility for providing e-services will be shifted from the government to their recipients and the services will be more adjusted to the actual needs.

Smart management concerns various issues. They are related to an optimal usage of energy with a contributing efficient public transport system aiming to complete assumptions of the low-emission economy.

A rapid development of technologies will also concern a banking sector. Living faster and faster consumers have a wider access to information; they will expect changes to the way they pay for goods. It is confirmed by EY experts who claim that in 2030 when it comes to offered services the basic value will be constituted by accessibility and the speed of delivering information.

The results of carried out research indicate that nowadays an access to payment facilities regardless of a place and time is of more importance. Consumers expect that they will be able to pay in real time and barriers in international payments will be lifted. At the same time they value increased security and protection of privacy. Unfortunately these expectations often contradict development of technologies.

It is estimated that by 2035 a future city dweller will own more than 5 compatible devices which will secure contact with suppliers through various channels. Thanks to that ordering goods from any place and any time will not be difficult. Bearing in mind the above, logistic processes must function efficiently and on the larger scale in order to enable completion of impulse orders with immediate lead time. That is why logistics will make use of modern technological solutions which will change their nature from re-active into pro-active. Thus there should be a smooth information flow between entities involved in logistic processes on every stage of the supply chain.

Switching into retail online will change a traditional model of retail. This will result from the fact that most sellers will decide to accept a multi-channel distribution called bricks and clicks. Such enterprises carry out activities online as well as have physical representations rendering the same or a slightly narrower range of services.

It is most probable that by 2025 about 20 % retail sale will be done on the internet. In leading markets with higher expenses per person such as USA or UK, the share will amount to about 25 %. It is anticipated that by 2025 the total retail sale online will account for 19 % of the total retail sale.

The change of consumers' expectations wanting to have access to products in the store to verify their selected parameters and on the other hand to have an online access where prices of products may be more favorable made retail sellers offer more innovative and verified forms of delivering goods. Multimodal transport and possibilities of fast delivery play a key role here.

In case of express dispatches delivered on the same or next day, a good option is presented by high speed rail. Expenditure on these projects will amount to over USD

800 billion in the nearest decade. Some of them are to join continents. The growth in the share of rail transport will not only speed up the process of sending goods enabling logistic companies to introduce a fast delivery of parcels. This will relive the road infrastructure which constitutes the next step towards handling the problem of congestions and a negative impact of means of transport on the natural environment.

3 Smart Cities—Examples of Practical Solutions

The notion of a smart city cannot relate to every city regardless of its location, the size and the character. A smart city means development urban space offering a high quality life thanks to elements of sustainable development being implemented and distinguishable from other cities, solutions in the field of ecology, services offered by public institutions, the policy of local governments implemented in the urban area or technology. The combination of above elements into one common system is a condition to create a smart city which is unique due to a variety of its elements.

It is estimated that by 2020 the industry involved in creating smart cities will be worth over USD 400 billon globally (Lindert-Wentzell 2014). It results from the fact that a growing popularity of smart cities is accompanied by solutions enhancing effectiveness of managing urban space. All over the world urban authorities incur huge expenditure for technologies of sending, managing and analyzing data to support creation of innovative services improving the quality of inhabitants' life.

This denotes good development perspectives for ICT companies (Information and Communication Technologies, ICT). According to the elaboration of Frost & Sullivan The Role of ICT in Building smart Cities—Infrastructure in the process of creating smart cities a major development opportunity is given to enterprises specializing in providing smart energy solutions and providers of intelligent transportation systems (ITS) (2014).

In the above context a city may be called smart when it meets three basic criteria:

- ICT infrastructure should be flexible and should develop together with changes to the digital economy and not merely respond to current needs,
- an urban system should be fully integrated with an individual citizen and easily accessible,
- the role of urban authorities is to provide tools for creating solutions and to disseminate among inhabitants knowledge about digital development of cities and provide access to digital devices (Wojtas 2013).
- In terms of solutions introduced in the public transport Budapest may be called a smart city as compared to other European cities of similar size and the level of development.

According to analyses of a Hungarian website portfolio.hu (2014) Budapest has the most dense public transport system. It is twice bigger than in Vienna or Prague. Data from the Real Estate Developer Forum shows that Budapest has more stations than any other surveyed cities. Statistics confirm it. There are 9 various types of stops per 1 m^2 in the capital of Hungary which makes changes convenient regardless of the place. It is not more than a few hundred meters from one tram stop to a bus stop.

Budapest has the biggest network of day and night buses and trams. To compare in Vienna there are 98 stops, in Prague 134, in Warsaw 170 whereas in Budapest 219. The city distinguishes itself by a big number of tram lines. It has 31 of them whereas Bratislava 8 and Belgrade 10. In terms of the range of tram lines of 157 km, Budapest takes the seventh place in the world after Melbourne, St. Petersburg, Berlin, Moscow, Amsterdam and Vienna. On the other hand the layout of lines is not that effective as in Vienna or Zagreb where tram are connected to other means of transport creating an essential element of a coherent changing system.

However considering the number of stations of four operating underground lines (52), the capital of Hungary is among cities such as Bucharest-51 or Prgue-57. Vienna has more of them—104 whereas Warsaw less than a half—21 station.

For the purposes of optimal planning the route, the city provided inhabitants with a special application which can also be used offline. It is enough to download timetables and routes of particular means of transport and chose an appropriate line to get information about the most convenient road.

The application is equipped with an interesting feature of your favorite routes. It enables the user to save his/her favorite or the most frequently used routes. It helps to search connections faster and get information about any possible hindrances.

Budapest public transport is an example of cooperation between city authorities and inhabitants. A big number of various means of transport from the underground, trolleybuses, buses or to trams operating frequently and covering a wide range as well as improvements such as digital applications enable public transport to be a real alternative to the car.

Actions undertaken by city representatives with regard to the public infrastructure are in line with the concept of sustainable development where the society should aspire to neutralize or counteract a negative impact on the natural environment. The above case concerns improvement of the quality of inhabitants' lives as well as solving the problem of congestion and polluting public space.

Seoul the capital of South Korea is an interesting example of creating a smart city. It is necessary for inhabitants to have a mobile device e.g. a smartphone in order to access digital services. For these purposes city authorities joined two trends into one system. The wealthy Seoul inhabitants more often change their telephones and they have a possibility of to reduce their tax by USD 50–100 per each device they give to the less wealthy. This way older devices are not thrown away which decreases the amount of electronic waste and systematically increases the number of people owning mobile devices. Additionally Seoul offers its inhabitants full access to the broadband Internet inter alia in offices, means of urban communication or in parks (Hwang et al. 2013).

It is also worthwhile mentioning u-Seoul Safety System designed for people with small children, people taking care of the elderly or people suffering memory lapses. These people are equipped with a transmitter giving their current location. Each transmitter has the so-called safety zone being part of the city where the person may freely move. If the transmitter's owner leaves the safety zone, the device will inform minders, the police, the fire station or the supervisors of the system. Additionally it may inform children about approaching the danger zone as well as call for help be means of one button either in the device or selected places in the entire city. The buttons are compatible with the overall system u-Seoul Safety. In 2013 the above solution was used by 50,000 inhabitants. The transmitter is also available for less wealthy people. They may buy it for 2 % of the price and in particular cases people may get it for free.

The above solutions constitute only selected examples of long, digital experience of Seoul. The way people work in offices is an example of flexibility of a city and adjusting the infrastructure to real needs of the society. They may work in one of ten co-working centers depending on the place they live. Their working time is registered as usual by means of a magnetic card and they have to be available on the chat online all the time. Such a solution is more and more popular being appreciated by the workers themselves.

Virtual stores are also worth mentioning. Seoul inhabitants may do shopping while waiting on a bus or tram stop or going through a subway. It is enough to scan a bar code of a product from a poster and send an order and a courier will deliver the purchases to the indicated address.

The option of viral shopping has been available in Poland since 6 November 2013 only for Warsaw inhabitants for the time being. The first "shop window" offering groceries appeared in the Centrum underground station. Since June this year virtual stores in the form of delivery vans may be met in Warsaw also in the streets.

Seul and solutions applied there constitute an outstanding example. In Europe the idea of Smart City, apart from Budapest, Amsterdam and Malaga began to introduce. Asian countries and New York are other followers.

A Centralized Command Centre in Rio de Janeiro built by IBM is an example of systems used by a Smart City. Thanks to available technologies employees may monitor the entire city, anticipate dangers resulting from weather changes and manage risk effectively. Pavegen is becoming more famous. Thanks to the pressure generated by pedestrians on pavements electric energy is produced (Haslemayer 2014).

There are numerous examples like that. It is worthwhile observing technological development of smart cities to define what directions this concept is evolving and answer the question whether we will be ready and whether we want to live in a safer and more convenient but more controlled world.

4 Conclusions

A dynamic urbanization process occurring in the world poses new challenges to the authorities. The problem arises with an inappropriate infrastructure which has to secure inhabitants with appropriate amount of water, energy or guarantee their mobility. A city should "grow" together with increasing needs of citizens. On one hand it is to secure safety on the other it should enable its inhabitants to live a comfortable life and be friendly.

Development cannot be prevented. We should think what directions it will go to have a positive impact on the three areas the concept of sustainable development concerns—the environment, the economy and the society. The analysis of solutions introduced by cities may raise a fear that costs of implementations and investments will exceed budget possibilities of a particular metropolis. It seems that in order to solve this problem, city authorities more often expand a network of roads, build housing estates or business parks and use modern technologies. Their elaboration and the purchase are tied up with higher costs however later usage is cheaper, more ecological and effective as compared to traditional solutions. Nowadays cities have smart ITS systems allowing traffic lights to adjust to the current traffic, monitoring which increases safety of inhabitants and locates current break-downs, pavements releasing energy, systems designed for particular groups e.g. minders of children or the elderly following movements of these people in a specific safety zone and many other solutions being elaborated and implanted to adjust to the concept of smart city. Cities want to be smart and succeed more often.

It is worthwhile to ask a question whether also Polish Cities want to be smart? It would undoubtedly give a great opportunity to not only manage a metropolis more efficiently but also to build the social capital through involving inhabitants into those issues. The social dialogue would lead to more conscious changes in the urban space and improvements in life of all social groups both the elderly and the disabled.

Innovations may be more real thanks to the possibility of using resources of the European Union. Nowadays development of smart cities in Poland is curbed by fragmentary implementation of projects leading to a poor coordination between particular sectors and a limited cooperation between entities (2014). As long as there is not a compatible platform of information management, the authorities will not be able to manage the city effectively and inhabitants will come across various hindrances such as the lack of information about break-downs and detours of trams or buses, the lack of one ticket for all means of transport, the lack of appropriate transport infrastructure, solutions for users of cycling paths or long commuting time to get to the office caused by traffic jams.

Development of smart cities is very dynamic. All over the world metropolises arise based on modern technologies. In view of the above it would be interesting to know to what extent modern solutions reduce exclusion of particular social groups (e.g. parents with small kids, the elderly, the disabled) to what extent implemented systems are compatible with each other and removing one problem does not entail another.

This situation can be illustrated by selected low-floor lines of public transport in Wroclaw in Poland. They indeed give physically impaired people a possibility of travelling however the fact that the lines operate selectively deprives them of reaching a destination as they are not able to use one low-floor vehicle. These current problems to say nothing of the urban infrastructure such as traffic lights, the quality or the height of pavements preventing not only the elderly or the disabled but also parents with prams and small children from moving freely. The potential of using modern solutions in this area is huge. Beforehand real users' needs have to be examined by having a dialogue with the authorities.

Development of smart cities is inevitable. One may actively take part in their creation to make them friendly, safe places improving the quality of life. That is why we have to think about real problems of citizens so that instead of creation of a smart city we would not create a smart prison where every movement is monitored and decision are made somewhere at the top.

References

Art. 3 of the Law on Environment protection dated 27 April 2001. J Laws, No. 62 item 627 (2001)
Available: www.odpowiedzialnybiznes.pl/hasla-encyklopedii/agenda-21/ (Online), 10.07.2014
Available: www.dailynewshungary.com/budapest-public-transport-in-european-context 08 2014 (Online), 10.07.2014
Borys T (1999) Indicators of eco-development, economy and environment. Publishing House, Białystok, p 64
Brandmeir K, Grimm M, Heise M, Holzhausen A (2013) Allianz global wealth report 2013. Allianz SE, Public Policy & Economic Research, Munich, pp 54 and further
Brdulak H (2012) Logistics in difficult times—an opportunity or a risk? Changes to global supply chains. In: Brdulak H (ed) Logistics of the future. Polish Economic Publishing House, Warsaw, pp 13 and further
Brdulak A, Brdulak H (2014) In search of lost time. The dilemmas of contemporary city dwellers. Examples of Polish solutions, Celje, Slovenia
Building the bank of 2030 and beyond. The themes that will shape it. EYGM Limited (2013)
Caragliu A, Del Bo C, Nijkamp P (2014) Smart cities in Europe. ftp://zappa.ubvu.vu.nl/20090048.pdf, 06.08.2014
Cities of the future, challenges, visions, perspectives. EU report, the European union, pp VI–VII (2011)
Gadomski W (2014) Machines do not fords. Gazeta Wyborcza 2–3 Aug 2014 pp 22–23
Haslemayer S (2014) Interviewee Big Brother or Big Society? Sascha Haslemayer's statement in conversation wih Wojciech Kacperski (Interview), 08.08.2014
Hwang J-S, Young OG, Choe H (2013) Smart Cities Seoul: a case study ITU-T technology watch report, Seoul, Feb 2013, p 8
Investments in development of smart cities in Poland as an opportunity for ICT solutions providers, Frost & Sullivan. Warszawa (2014)
Investments in development of smart cities in Poland as an opportunity for ICT solutions providers, Warsaw, 10 July 2014. www.frost.com/prod/servlet/press-release.pag?docid=291405357. Frost & Sullivan, 05.08.2014
Leipzig charter on sustainable European Cities (approved on an informal meeting of ministers concerning development of cities and territorial coherence in Leipzig 24–25 May 2007)
Lindert-Wentzell A (2014) Getting smart with urban living. Business in focus 24 June 2014, pp 92–97
Łojewski S (2007) Economics of resources and environment, Bydgoszcz. Publishing House of Kujawsko-Pomorska Higher School, Bydgoszcz, p 176
Turner RK, Pearce D, Bateman I (1994) Environmental economics. An elementary introduction. Harvester Wheatsheaf, New York
Urbanization, connection, convergence, bricks and clicks and a high speed rail will shape the logistic industry in next years. Frost & Sullivan (2013)
Urbanization trends in 2020: mega cities and smart cities built on a vision of sustainability. Frost & Sullivan (2013)
Urban population growth (World Health Observatory), Cisco Visual Networking Index, Global Data Traffic Forecast Update 2012–2017, Intel data
Wojtas S (2013) Smart-Inhabitants of cities of the future, the daily interactive. About the Influence of new media on the world, 18 Mar 2013

Reducing Truck Emissions in Import Operations at Container Terminal—A Case Study in a Singaporean Port

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Abstract Emissions from idle truck engines are a main source of pollution from transportation, and emission reduction from idle truck engines at container terminal has for this reason become a priority. At the import yard of a container terminal, an incoming truck has to wait for its turn to be loaded with containers which are then to be delivered to a customer. Reducing waiting time of trucks means that truck emissions are decreased as well as the competition of port increases. In this study, the emission from idle truck engines at the import yard is considered. The goal of this study is to develop a methodology for reducing emissions generated by trucks idling at import yards. The proposed method includes a mathematical model for minimizing truck emissions. In the model, total truck waiting time in the yard is estimated using discrete event simulation. To solve this model, a genetic algorithm is proposed. A case study in a Singaporean port is used for conducting experiments. The experiment result shows that the manager of a container terminal should control truck arrivals based on the stacking of import containers in order to reduce the truck idling time and thereby the truck emissions in the import yard.

Keywords Container terminal · Truck emission · Simulation-based GA · Arrival management

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1 Introduction

The acceleration in the growth rate of the world economy and the consequently increasing global trade have led to a growing demand for transporting goods over the last decades. The increase in global trade has also been accompanied by an increase in the use of containers as a safe and inexpensive mode of transport for goods. Asariotis et al. (2010) in Review of Maritime Transport (2010) reports that the container flows among Asia—US—Europe continuously increased from 1995 to 2010. In 1995, the total container flow was 15 million TEUs and a more than threefold increase, 50 million TEUs, was seen in 2010. In a report from Drewry Shipping Consultants, Ltd. (2010), the global container trade was estimated to be continuously growing and reach the volume of 200 million TEUs in 2015.

Recently, green shipping has received more and more attentions, as traditional shipping produces large CO_2 emissions. Consequently, there is increasing pressure on governments and industries to come up with (more) climate-friendly strategies (Geerlings and Duins 2011). Many international agreements have been signed for the reduction of CO_2 emissions such as the Kyoto Protocol. Transport systems have significant impacts on climate change as they account for between 20 and 25 % of world energy consumption and CO_2 emission (Moriarty and Honnery 2008). However, it is predicted that the growth of containers flowing from Asia will accelerate, and that the number of container handlings will rise from 11 million per year in 2008 to 33 million per year in 2033 (Geerlings and Duins 2011). This growth will account for a significant increase in the contribution of CO_2 emissions caused by container handling (Geerlings and Duins 2011). It is reported that the operations of container terminal contribute not only CO_2 (and thereby adding to climate change) but also other emissions such as NO_x, SO_x, and particulate matter which affect human health. This is particular critical as container terminals are often located close to population centers. Several studies have been conducted on air pollution at seaports such as Danish seaports (Saxe and Larsen 2004), Port of Los Angeles (Starcrest Consulting Group 2011), Port of Piraeus (Tzannatos 2010) and Belgian ports (Meyer et al. 2008) and they unanimously indicate that the emissions could induce health problems to people living or working near the ports. Some researches have been studied on optimizing the supply chain networks. Bocewicz et al. (2012) addressed the cyclic scheduling for supply chain network. Sitek and Wikarek (2013) proposed an hybrid approach for modeling and solving constrained problems that is recommended for decision-making problems in the supply chain.

At container terminals, the emissions come primarily from vessels, harbor crafts, container handling equipment, rail, and heavy-duty vehicles. Pachakis et al. (2008) investigate emissions at a port and find that heavy duty vehicles (including trucks) are the second largest polluter after the vessels themselves. Further, for CO-emissions heavy duty vehicles are in fact the worst polluters of all (Pachakis et al. 2008). This could indicate efforts should focus on controlling the source of emissions such as using cleaner fuel, upgrading engines, or using alternative power sources. However, this is a very costly and time consuming approach. An alternative tool for emission reduction is to reduce idling and queuing times. Lazic (2004) reveals that approximately 70 % of the emission at a container terminal comes from trucks. They also reports that this is because of their waiting time to be processed and running engines for air conditioning and heating. Therefore, reducing idling and queuing time of trucks can significantly reduce the emissions at container terminals. This has received significant attention, as these truck emissions probably have more harmful impact—relative to the emitted amounts—when emitted near local communities (Saxe and Larsen 2004). There have been a number of studies and industry reports on truck emission reduction efforts at seaports. Some of these studies focus on the impact of engine technologies on emission factors, e.g. Truck Stop Electrification (Zietsman et al. 2009); while other studies focus on different mechanisms to coordinate terminal and truck operations, for example Terminal Appointment System (TAS), tariff/toll pricing policies and Vessel-Dependent Time Windows (VDTWs) for truck entries and operational and capacity improvements (Karafa 2012).

Usually the yard of a container terminal can be divided into two areas: an area for stacking export containers which will be loaded to vessels heading for another container terminal, and an area for stacking import containers which will be loaded to trucks and delivered to the consignees. To transport containers inland, trucks are usually used for transporting containers into or out of the container terminal. Shipping companies or 3rd party logistic companies (from now referred to as shipping company for short) are in charge of this inland transportation. In order to cooperate with the container terminal manager, they register the time for delivery or picking up the import containers via TAS that is a web-based system. Usually, there is no change after the shipping company makes the registration. Based on the registrations, the manager of container terminal will arrange the container handling equipment to load/unload container when trucks arrive. Import containers are unloaded from vessels and stacked at the import yard. The officer of container terminal will inform the shipping company about picking up containers. Export containers are unloaded from trucks and stacked at the export yard. Stacking export container is more complicated than stacking import container. The reason is that vessels are berthed as short time as possible at the container terminal due to high berthing cost. Export containers should be stacked in the right order so that they fit with the stowage plan and can be loaded onto the vessel in a short period time. There have been many studies on how to optimize the export container stacking. The decision on export container stacking is made before vessels arrive. However, the arrival rate of trucks in a given period of time in a day varies. E.g. collected data studied from port of Los Angeles (POLA) (Chen et al., accepted) and other container terminals shows that the arrival rate is high from 8 to 9 a.m. and from 6 to 7 p.m. while shipping company can register any period from 0 a.m. to 23 p.m. for picking up containers. This means that the shipping companies prefer to deliver or pick up containers at the beginning or at the end of a working day. Waiting time of trucks may be lengthened due to the number of handling operations of yard cranes. For example, if a truck arrives to pick up a container at the bottom of a stack, the yard crane has to move all the upper containers so that it can reach the required container, which means longer waiting time of that truck and subsequent trucks already queued because of unnecessary container movements. On the other hand, at the export yard, the export container should be stacked following the stowage plan and it also takes time to move containers if the arrival pattern does not match the plan.

The waiting time of trucks can be shortened if the truck arrival pattern is matched with the stacking plans for import and export containers. However, with the current operation of TAS, it is very hard for the container terminal manager to keep the arrival pattern under control. The approach proposed in this study is that the TAS will offer available periods of time for pick-up of containers for each shipping company. Different shipping companies will have different available periods based on the plans for stacking containers. It is a challenge to identify the optimal arrival patterns via TAS. This optimization will minimize the emissions of idle truck engine with the consideration of the inconvenience onto the shipping company which may have due to the limited number of periods for pick-up of containers.

This study will propose a methodology for minimizing idle engine emission by controlling arrival pattern via TAS. First, a mathematical model is formulated to find the appropriate periods for delivery or pick up of containers for each shipping company. Then, a discrete event simulation model is used to estimate the total waiting time and emission. A simulation-based genetic algorithm is proposed to solve the problem. Genetic algorithm (GA) is used to find the feasible solutions for the mathematical model while simulation is used to estimate the quality of the solutions obtained from GA. Based on a case study in a Singaporean port, numerical experiments are conducted in order to show the relationship between emission reduction and the number of available periods for delivery or picking up containers.

2 Literature Review

There is a rich literature in the area of truck emissions at a seaport. In this section focus is on studies related to truck idling emissions, truck turn time estimation and truck arrival pattern optimization. Truck idling and emissions are receiving increased attention, as idling engines operate very inefficiently (about 3 % energy efficiency compared to 40 % when operating on the highway) and suffer greater wear and tear (Brodrick et al. 2002). Although heavy-duty diesel vehicles produce low levels of hydrocarbons (HCs) and carbon monoxide (CO), when compared to gasoline engines, they produce relatively high amounts of NOx and PM. The latter two emissions are widely considered as the two most serious air pollution threats (Brodrick et al. 2002). Idling emissions differ by trip duration, season, geographic location, and trucking operation, making it difficult to quantify emission volumes produced. Some studies address emission factors of specific truck types or specific locations. For example, the Environmental Protection Agency's MOBILE model provides emission factors dependent on several parameters, including speed, fuel type, vehicle age, and ambient temperature (Utts et al. 2000); while engine idling emission factors in POLA are provided by Starcrest Consulting Group (2011).

Truck turn time is defined as the duration from the arrival of a truck at the terminal gate to the moment of exit. Existing studies identify three modeling approaches to estimate truck turn time and its components: (a) simulation models (Huynh et al. 2004; Huynh 2009), (b) regression models (Huynh et al. 2004; Goodchild and Mohan 2008), and (c) queuing models (Guan and Liu 2009; Chen et al. 2011a, b).

Huynh et al. (2004) develop a discrete event simulation model of a container terminal, representing the precise movements of trucks and yard cranes. The simulation model is used to find the number of yard cranes needed to achieve a desired truck turn time. Huynh (2009) developed a simulation model to evaluate performance of various rules for truck arrival management. Both simulation models are powerful tools to present detailed operations of trucks and terminal equipment and can be used to test different operation scenarios. On the other hand, simulation models require long computational times, as a large number of replications are needed to reduce sampling variance and provide reliable results. This is a major barrier for integrating a simulation model into an optimization process. In this study, one of the contributions is to improve in this aspect by programming both the simulation model and the optimization model on the same platform, so at to improve the algorithm computational efficiency.

Huynh et al. (2004) applied regression analysis on the output of their simulation model for different scenarios of container terminal operations. A second order polynomial function was developed to predict truck turn times, with an adjusted R^2 of 0.7381, using the average truck number served by a crane as the predictor variable. Goodchild and Mohan (2008) discussed the prediction accuracy of the model by Huynh et al. (2004) and claimed that using averages rather than a single simulation replication reduces the variability and improves the fit of the regression model (i.e. high R^2 value). To support their claim, they developed a linear function of truck turn times using a single simulation replication data of truck arrivals. The R^2 of their model was only 0.1709. Therefore, regression models are not accurate enough to estimate truck turn times at terminals.

There are two types of queueing models used to estimate truck turn times: (a) conventional stationary queueing models, and (b) non-stationary queueing models. Guan and Liu (2009) analyzed truck queues at marine container terminal gates with a stationary $M/E_k/c$ queueing model. A limitation of stationary queueing models is they neglect the transient behavior and only analyze the steady state of a queue. This raises concerns about the applicability of simple stationary models (Green and Kolesar 1991). Typically, truck queues at marine container terminal gates are not in a steady state, as truck arrival and gate service rates vary over time. This indicates the need to use state-dependent queueing models, as they are more effective and robust tools to capture time-varying behavior of such queueing processes (Smith 2010). In a pioneering study by Green and Kolesar (1991), a point-wise stationary approximation (PSA) was proposed to model non-stationary queueing systems. Whitt (1991) further verified that the PSA model is asymptotically correct as the service and arrival rates increase with fixed instantaneous traffic intensity. Wang et al. (1996) proposed a point-wise stationary fluid flow approximation (PSFFA) by combining PSA and a fluid flow model to analyze single server non-stationary queueing models. In their study, PSFFA was proved to have better accuracy than PSA. However, PSFFA relies on invertible steady state functions and therefore is not capable to analyze most multi-server non-stationary queueing models. To address the issue of inverting complex queueing functions, Chen et al. (2011a) proposed an integration of the bisection method with PSFFA (labeled B-PSFFA) for the multi-server non-stationary $M(t)/E_k(t)/c(t)$ queue. B-PSFFA was used to analyze truck queues at marine container terminal gates and compared to results from the model by Guan and Liu (2009). Simulation results revealed that the stationary $M/E_k/c$ model is inaccurate, while the B-PSFFA approximation can be highly accurate.

PSA, PSFFA, and B-PSFFA only consider truck queues at terminal gates, and do not capture queues at the yard. To address both gate and yard truck queues simultaneously, Chen et al. (2011b) developed a two-layer queueing network, in which the gate system is treated as multiple independent non-stationary $M(t)/M(t)/1$ queues (each gate lane is an $M(t)/M(t)/1$ queue) and the yard system as multiple independent non-stationary $M(t)/G(t)/1$ queues (each yard zone is an $M(t)/G(t)/1$ queue). Truck flows from the gate to the yard are assumed to follow a Poisson distribution, taking advantage of the '*equivalence property*' of $M/M/1$ system where the departure process of an $M/M/1$ queueing system with infinite queueing capacity involves an Exponential distribution identical to the one of the arrival process (Larson and Odoni 1981). This two-layer queueing network can model truck queues at the gate and yard simultaneously. However, there are two limitations: (a) the assumption that the gate service times follow an Exponential distribution is not based on any empirical analysis; and (b) the assumption that a gate system comprises of multiple independent queueing systems does not comply with practice where a truck queue is served simultaneously by all gate lanes. Ideally a gate system should be modeled as a multi-server queueing system.

The second part of the literature review focuses on truck arrival pattern optimization studies. Huynh and Walton (2008) integrated a search heuristic with the simulation model developed by Huynh et al. (2004) to reduce average truck turn times to a target level specified by the terminal operator. This optimization model has the disadvantage of long computational times due to an embedded simulation model. Chen et al. (2011b) compared computation times of a simple simulation and a queueing model, and found that the simulation model is 122 times more (computationally) expensive than the queueing model. As previously discussed, Chen et al. (2011b) developed a queueing network to model truck queues at the gate and yard simultaneously. Furthermore, they integrated their queueing network into an optimization model to minimize the weighted sum of three components: (a) the quadratic deviation between the original arrival time and the shifted arrival time of each truck, (b) queue length at the gate, and (c) queue length at the yard. However, they did not describe how the weights of the three components can be estimated to achieve optimal results. Furthermore, the first component of the objective function may be difficult to calculate as, in practice, original truck arrival times are not known during the planning phase. Nevertheless, to the best of the authors' knowledge, Chen et al. (2011b) is the only existing study modeling and optimizing truck flows at a marine terminal using a non-stationary queueing network. Two other studies exist, by Guan and Liu (2009) and Chen et al. (2011a), that propose optimization models considering only truck flows at the gates. Guan and Liu (2009) developed an optimization model based on a stationary queueing model to minimize the total system cost, including gate operation cost and truck waiting cost at gate. The result was an evenly distributed truck arrival pattern, requiring too many trucks to change their arrival schedule. This results from the steady-state limitation of stationary queue models. Chen et al. (2011a) improved Guan and Liu's model (2009) with the B-PSFFA approximation of non-stationary $M(t)/E_k/c(t)$ queues. The objective of the new model was to minimize the quadratic number of shifted arrivals with the constraint of a maximum truck waiting time specified by a terminal operator. The result was a time-dependent pattern of truck appointments, different from the result of Guan and Liu (2009), requiring only a small number of trucks to change schedule. It is important to note that, all the above optimization models are single objective. In practice, truck arrival optimization often involves the trade-off between contradicting objectives, e.g. the number of shifted arrivals and truck queue length. Understanding the trade-off will help the terminal operator to better manage truck arrivals.

From the literature review, a gap can be identified: none of the existing models/methods is able to accurately estimate truck turn times for import operations in a computationally efficient fashion. In addition, the optimization models found in the current-state are single objective and do not consider trade-offs between emission reduction and shifted truck arrivals. In this study, we address this gap and develop a simulation-based model to estimate truck turn times at a container terminal more accurately. We further develop an optimization model to investigate the relationships between the objectives of truck arrival coordination at a container terminal (i.e. number of shifted arrivals and reduction of truck idling emissions).

3 Problem Definition

3.1 Problem Description

In this study, we consider a container stacking block at the import yard of a container terminal. The block size varies, depending on the size of the container terminal. Typically, a block has about 40–60 bays (block length), 8–12 rows (block width), and 5–6 tiers (block height) where the unit of each dimension is a container. This means that a block may contain more than 1,600 import containers. Trucks enter the container terminal through an entrance with multiple lanes. The process of picking up an import container is described in Fig. 1. In order to pass the gate of a port, the truck has to go through an entrance process. The gate system is considered as a multi-server non-stationary queuing system where inter-arrival times of trucks follow exponential distribution and the service times of gate follow Erlang distribution (Guan and Liu 2009). However, the truck inter-arrivals may follow different distributions in different terminals (Lam et al. 2007). Currently,

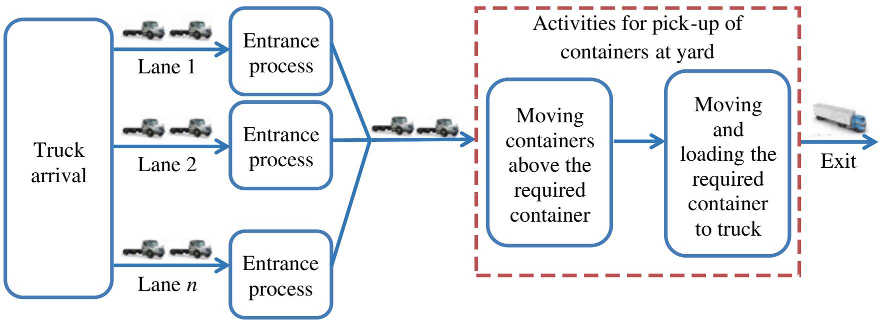


Fig. 1 Process for picking up import container at container terminal

many researchers have studied to apply an automatic system for entrance process with the aim to reduce processing time. This means that the service time can be a constant value. Nevertheless, changing in the distribution of truck inter arrivals and service time is handled because the proposed model can be implemented for any distribution as simulation is used to represent this system. After entrance the port, the truck will go to the stacking block and wait for picking import container. The import containers are already stacked before trucks coming to pick them, which means that the position of each container is known. It is assumed that a truck can carry only one container at a given point of time. Therefore, each container has its own available periods for pick up. The import yard system serves based on First Come First Serve principle. If the container to be picked up is located under other containers, the upper containers must be shuffled. Shuffling means that the upper containers must be moved to other positions (with in the block) in order that the required container can be picked up. The rule of shuffling containers at import yard is defined as follows: (1) containers will be moved to the lowest position, (2) if there are many possible places for moving, the containers are to be moved to the nearest position with inner position of higher priority. Shuffling should be avoided because this is an ineffective activity. Obviously, a methodology for optimizing the movement of containers, where the truck arrival pattern is given, can be proposed. However, this would be a study by itself and subject to further research. The time for moving containers is assumed to be linearly proportional with the distance of movement.

Due to scarce capacities in container terminals, usually trucks have to wait long time, generating big volume of idling emissions. In order to reduce truck idling time, it is necessary to control truck arrival times. In this study, we propose a method for this purpose: for each container the terminal operator provides a number of available pick-up periods to the shipping company (or the trucker); the trucker is free to select any one of the available periods for pick-up. It is assumed that the probability distribution of a trucker's selection over the available periods is known. Within the selected period, the arrival time of the truck is randomly distributed. Different arrival patterns will yield different sequences of yard crane operations even though the stacking of containers is given and the speed of moving a container is assumed to be constant. The result is that the total waiting time is also stochastic. A simulation model can be applied for these stochastic parameters and variables. To identify the optimal available periods for each container in order to minimize truck waiting time as well as the amount emissions is a combinatorial optimization with thousands of decision variables.

3.2 Mathematical Model

Before the model, here are the indices, the parameters, the variable and the derived variables.

Indices

i import container i, $i \in \{1, \ldots, I\}$
t period t, $t \in \{1, \ldots, T\}$
k emission factor k of idle truck engine, $k \in \{1,\ldots, K\}$

Parameters

e_k the quantity of emission factor k per hour (g/hr)
c the average handling capacity of yard crane (containers/hr)
m the minimum number of periods that available for picking up a container
λ_t arrival rate of truck in period t
μ average processing time at the gate of container terminal
v^{bay} gantry speed of yard crane when moves from bay to bay
v^{row} trolley speed of yard crane when moves from row to row
v^{tier} hoist speed of yard crane when moves from tier to tier

Variables

$$x_{it} = \begin{cases} 1, & \text{if container } i \text{ is available for being picked up in period } t \\ 0, & \text{otherwise} \end{cases}$$

Derived variables

X the set of variable x_{it}, $X = \{x_{it}\}$ $\forall i \in \{1, \ldots, I\}$ and $t \in \{1, \ldots, T\}$
$w^g(X)$ average waiting time of trucks at the gate of container terminal
$d_i^{bay}(X)$ total distance of moving containers above container i and moving container i to truck along the bay axis at the yard of container terminal
$d_i^{row}(X)$ total distance of moving containers above container i and moving container i to truck along the row axis at the yard of container terminal
$d_i^{tier}(X)$ total distance of moving containers above container i and moving container i to truck along the tier axis at the yard of container terminal

Model:

$$\text{Min} \sum_{k=1}^{K} e_k E(X)$$

where $E(X)$ is the average total waiting time of trucks picking up containers

$$E(X) = w^g(X) + \sum_{i=1}^{I} \left[d_i^{bay}(X)v^{bay} + d_i^{row}(X)v^{row} + d_i^{tier}(X)v^{tier} \right]$$

Subject to

$$\sum_{i=1}^{I} x_{it} \leq c \quad \forall t \in \{1, \ldots, T\} \tag{1}$$

$$\sum_{t=1}^{T} x_{it} \geq m \quad \forall i \in \{1, \ldots, I\} \tag{2}$$

$$x_{it} \in \{0, 1\} \tag{3}$$

The objective function is to minimize the total emissions from picking up containers at a block of import yard. The value of $E(X)$ is calculated by using a simulation model for the gate and import yard system, as described below. Constraint (1) assures that the total of containers picked up in a period cannot exceed the capacity of yard crane. Constraint (2) guarantees that the number of periods offered to shipping company cannot be less than a desired number decided by the container terminal. In a terminal without any arrival control, trucks can come at any time in a day, so this number of available periods (the variable m) will be 24 h. In this study, we would like to test what if the terminal operator provides half or one-third of such available periods to a specific container, whether and how much the truck waiting time and idling emissions can be reduced.

4 Solution Algorithm

In this section, we introduce the solution algorithm, including the genetic algorithm, the simulation model and the procedure of the overall solution algorithm.

4.1 Genetic Algorithm

The decision variables in the mathematical model described above are represented the available periods for picking up of import containers. There are thousands of containers in a block and each container has several available periods for being picked up. Hence, this is a combinatorial optimization of thousands of decision variables. Moreover, in order to evaluate a feasible solution, we have to estimate the total emissions which is proportional to the total waiting time of trucks.

However, truck arrivals is a stochastic process. Even though the truck arrival can be assumed as a Poison process as in queuing theory, it is not easy to calculate the total waiting time because the arrival pattern is random. Randomly selecting arrival period of a truck makes the randomly arrival pattern and this makes the waiting time of trucks at import container block also random. Thus a discrete event simulation calculation process should be included in order to calculate the average total waiting time of trucks. Because the mathematical model is a combinatorial optimization with a discrete event simulation calculation process, it cannot be solved with traditional mathematical approach. Therefore, one of possibility method to solve the above mathematical model could be genetic algorithms (GAs). GAs have the advantage of flexibility imposing no requirement for a problem to be formulated in a particular way, or that the objective function(s) is differentiable, continuous, linear, separable, or of any particular data-type. Thus, they can be applied to any problem (e.g. single or multi-objective, single or multi-level, linear or non-linear) for which there is a way to encode and compute the quality of a solution. GAs can be easily combined with exact solution algorithms (e.g. branch and bound), local search (i.e. memetic algorithms), and/or other (meta-) heuristics and guarantee local optimality of the solution or improve the convergence patterns (Golias et al. 2010). As an added advantage, GA can be easily combined with simulation that is used for estimate the quality of a solution provides by GA in this study. For an in-depth discussion of GAs and the theory behind we refer to Goldberg (1989) and Gen and Cheng (1999). The following section presents the structure of chromosome and how to calculate the fitness function.

The chromosome is coded as follows:

- Each chromosome include I substrings where I is the number of containers at the block.
- A substring represents for a container and includes T genes where T is the number of periods for picking up all containers at the block.
- Each gene of a substring represents a period and its value shows whether the corresponding container is available for pick up in that period or not.

Figure 2 is an example of a chromosome. In this example, Periods 1, 3, 4, and 5 is available for picking up container 1. This means that the value of variables relate to container 1 is as follows: $x_{11} = 1, x_{12} = 0, x_{13} = 1, x_{14} = 1, x_{15} = 1$.

In the maximization problem, the objective function value can be directly used for the fitness of a chromosome. However, the mathematical model in this study is a minimization model. Therefore, if the objective function value of a chromosome is higher, that chromosome shows less fitness. In this study, the following formula is used to calculate the fitness.

$$\text{Fitness}(m) = \frac{Z_{\max} - Z(m)}{\sum_{l=1}^{N} [Z_{\max} - Z(l)]} \quad Z_{\max} = \underset{l=1,\ldots,N}{\text{Max}} (Z(l)), N\text{: population size} \tag{4}$$

where Z(m) is the objective function value of chromosome m.

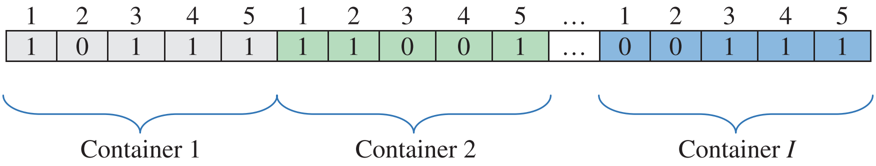


Fig. 2 Structure of a chromosome

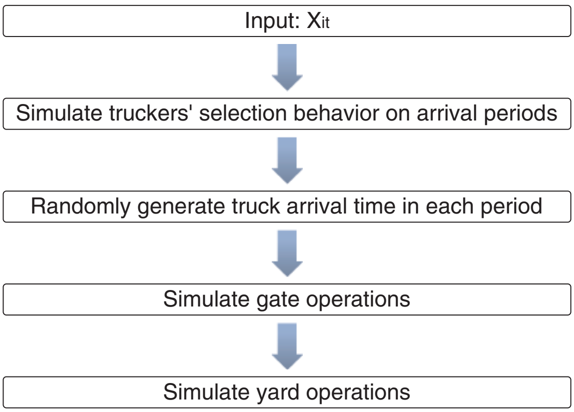
4.2 Simulation Model

Figure 3 shows the simulation process as following. In order to calculate the objective function, simulation is used to find $E(X)$, the average total waiting time of trucks picking up containers. As mentioned above, there is a probability for the selection of arrival time of trucks and the probability density function is given. Hence, for each container, the arrival time of the truck picking up that container is determined based on the given available periods and the probability density function of selection. If we use p_{it} to denote the selected period for picking up container i, it will satisfy the following constraints. These two equations ensure that a container will be picked only once and only during the available periods.

$$\sum_{t=1}^{T} p_{it} = 1 \quad \forall i \in \{1, \ldots, I\} \tag{5}$$

$$\sum_{t=1}^{T} p_{it} x_{it} = 1 \quad \forall i \in \{1, \ldots, I\} \tag{6}$$

Fig. 3 The process of the simulation model



After all arrival times have been determined, the arrival time of each truck is generated. In each period, every truck arrival is randomly generated based on the uniform distribution.

When a truck arrives at the entrance, it is assigned to the lane that has the shortest queue length. Then the time for entrance process for each truck is generated following an Erlang distribution.

The last process is the pick-up process at the block. The truck usually parks on the aisle along the block and next to the bay of the container to be picked up by the particular truck. Thus, the processing time for picking containers can be estimated as the summation of the total shuffling time of upper containers and the time moving the required container from its position to the truck. A heuristic algorithm is applied to shuffle the upper containers to other positions. The container on the top will be shuffled. Then, the second-top container is shuffled. This shuffling procedure is repeated until there is no container above the required container. For moving a container, the position which locates at the lower tier will have higher priority. If more than one position, we select the one that takes shortest time for moving containers. After picking up the container, the truck exits the container terminal immediately. In this simulation process, the truck waiting time at gate and in yard is recorded. The total waiting time is the summation of waiting times of all trucks. In this study, the simulation is executed on Visual basic language. Compared with using standard simulation software, it is more convenient and efficient to program GA and simulation in the same programming language.

4.3 Procedure of Solution Algorithm

The procedure of whole solution algorithm is shown as below

Step 0 Generate an initial population
Step 1 For each chromosome in the population

Step 1.1 For each substring of chromosome

Generate a random number between 0 and 1 to select the arrival period the truck corresponding to the container represented by this substring

Step 1.2 For each period

- Randomly generate the arrival pattern of truck in this period
- Randomly generate arrival time for each truck arriving in this period

Step 1.3 Simulate the gate and the yard system operations
Step 1.4 Calculate the total waiting time and record it
Step 1.5 Repeat from Step 1.2 to Step 1.4 for a sufficient number of times and then calculate the average total waiting time
Step 1.6 Calculate the objective function value of this chromosome

Step 2 Calculate the fitness function of each chromosome

Step 3 Update current best chromosome based on objective value
Step 4 Check stopping criteria of GA. If any stopping criterion is satisfied, go to Step 6; otherwise, go to Step 5
Step 5 Create new population by GA operators and go back to Step 1
Step 6 Record the current best chromosome and its corresponding objection value and stop.

The best solution found by this solution procedure is obtained by decoding the current best chromosome and the corresponding objection value is also yielded.

5 Case Study

Based on a case study in a container terminal in Singapore, several experiments are conducted to see the performance of the proposed methodology to reduce emissions of truck idling at container terminal. The emission factors are obtained from a seaport in the U.S. (Chen et al., accepted), shown in Table 1.

The container terminal in this case study has an entrance gate with eight lanes. The working time at this terminal is 24 h per day. However, Table 2 shows that the arrival rates from 10 p.m. to 5 a.m. are small. Therefore, the working time is considered 16 h per day in our experiments. The length of a period is 1 h. Typically, it takes about 3 days for picking up all containers at a block. Thus, the maximum number of available periods for a container is 48 periods. The service time at gate follows an Erlang distribution where the average service time is 45 s per truck and the degree is 4. The number of bays, number of rows, and number of tiers are varied from 40 to 60, from 8 to 12, and from 5 to 7, respectively. The yard crane gantry speed (movement from bay to bay) is 120 m/min. The yard crane trolleys (movement from row to row) and hoists (movement from tier to tier) move with a speed of 90 m/min and 90 m/min, respectively.

The experiment is conducted on a computer with 2.8 GHz i7-CPU and 8G RAM. Based on the collected data, we have 9 problem instances suggested from the manager of container terminal. These instances have the same yard crane moving speed but differ in the number of bays, the number of rows, and the number of tiers see Table 3 for some details.

Table 1 Emission factors of truck engine idling (g/hour)

CO_2	N_2O	CH_4	PM_{10}	$PM_{2.5}$	DPM	NO_X	SO_X	CO	HC
4,640	0.037	0.18	0.22	0.2	0.2	94.8	0.04	16.82	6.24

Table 2 Average arrival rates of per day (trucks per hour)

Time	00	01	02	03	04	05	06	07	08	09	10	11
Arrival rate	7.71	7.86	11.57	8.57	12.00	19.14	59.29	74.71	97.86	87.29	97.57	79.14
Time	12	13	14	15	16	17	18	19	20	21	22	23
Arrival rate	84.86	86.14	82.57	81.71	88.29	108.14	111.43	79.57	68.43	43.86	23.29	11.71

Table 3 Problem instances

Problem instance	Number of bays	Number of rows	Number of tiers
1	40	8	5
2	40	10	5
3	40	10	6
4	40	12	5
5	40	12	6
6	50	10	6
7	50	10	7
8	50	12	6
9	60	12	6

Through a pilot experiment, the GA parameters are as follows. The population size and maximum generation are 50 and 100, respectively. The crossover probability is 0.9 and uniform crossover is used. Mutation rate is 0.08 and bit-flip mutation is used. The GA procedure stops when maximum generation (maximum iteration for GA procedure) is reached or there is no change in the value of objective function in 20 consecutive iterations. Due to the stochastic results of simulation, we take ten runs for each problem instances. The number of available periods is 8. The average and standard deviation of each instance are presented in terms of the value of the objective function (the total emissions over truck idling time). Table 4 shows the result of these experiments. In each instance, the standard deviation is very small (less than 1 %) compared with the average value, which demonstrates the good and stable performance of the proposed algorithm.

In order to present the benefits of our study, some experiments, where different numbers of periods (the parameter m in the model) are available for picking up containers, are conducted. We consider two scenarios in which the number of available periods is 8 and 12. The results of these experiments are shown in Table 5 where a 48 h time period benchmark is also included. Note that the 8-available-period scenarios are presented in Table 4. The emission reduction can be seen by comparing these scenarios with the current situation which has 48 available periods. It can be seen that the proposed approach can reduce

Table 4 Experiment results of the problem instances

Problem instance	Average of objective value	Standard deviation of objective value	Problem instance	Average of objective value	Standard deviation of objective value
1	140,927	876.79	6	356,993	2,096.50
2	182,461	1,219.72	7	356,140	1,816.31
3	243,862	1,585.11	8	436,081	2,136.80
4	222,552	1,468.84	9	599,750	4,078.30
5	293,058	1,729.04			

Table 5 Comparisons among 8, 12, and 24 available periods

Problem instance	Number of available periods			Maximum percentage reduction compared to bench mark (%)
	8	12	48	
1	140,927	144,287	148,813	5.30
2	182,461	188,494	191,171	4.56
3	243,862	249,521	256,050	4.76
4	222,552	229,106	234,068	4.92
5	293,058	300,632	309,165	5.21
6	356,993	362,131	369,870	3.48
7	356,140	363,725	371,792	4.21
8	436,081	441,106	452,695	3.67
9	599,750	609,658	622,051	3.59

approximately 4 % of emissions. If the number of available periods decreases, more reduction of emissions is achieved. However, it is not convenient for shipping companies if number of available periods is much reduced because it will limit the selection of picking up period. In our opinion, 8 or 12 available periods is reasonable. Note that this is the percentage of reduction emissions for one block at a container terminal. Considering the activity of a terminal in a year, we can see that a huge reduction in emissions. This indicates that the truck emissions can be significantly reduced, if the terminal operator controls the truck arrival times by cutting one-fourth or one-sixth of the available container pick-up periods. In many container terminals, TAS system is mainly used for export containers due to the fact that it is more critical to reduce the time for loading container to vessel. Furthermore, TAS system is allowed 24 available periods in practical use. Therefore, implementing the proposed approach is more effective at ports that do not use TAS for import containers currently.

6 Summary

In this study, we considered import-related truck emission reduction at container terminal. A mathematical model which combines deterministic and stochastic factors is formulated. A solution algorithm is proposed to solve the problem in which a simulation-based GA is developed. Several experiments are conducted to show the performance of proposed algorithm. Throughout these experiments, it can be found that the emission from truck engine idling could be significantly reduced by providing appropriate service time for picking up containers. For example the emission is reduced about 4 % if the available periods are limited to either 8 or 12 h instead of 48 h.

The main contributions of this study are to propose a methodology to reduce the emission at container terminal by using TAS and to develop a mathematical model as well as solution algorithm. First, the TAS is currently used for export containers. This study proposes an approach to utilize the TAS for picking up import containers in order to reduce truck idling emission. Second, a mathematical model which combines deterministic and stochastic factor is developed for the proposed approach. Finally, the simulation-based GA is applied to solve the developed mathematical model.

This study can yield benefits to container terminal as well as shipping company. From this study, container terminal can obtain a method for fast and automatically generating available periods for pick-up container. The emissions coming from idle truck engines are reduced at the container terminal with the added benefit of reduced congestion of the terminal area. Moreover, the arrival rate at peak hour decrease and this will be easier for the container in resource planning for the yard operations. Shipping companies also get benefits from the presented methodology. It decreases the waiting time of trucks at the container terminal and thereby reduces the operation costs of shipping companies. In addition, the shipping company has a possibility to choose a convenient time to arrive at the container terminal. Last but not least, this study can improve the customer satisfaction for both container terminal and shipping company. The container terminal can reduce the working time of yard crane at a container block, reduce the time to pick up container of trucks, and have more flexible in scheduling their daily activities. The shipping company is more flexible in scheduling trucks for pick up containers and delivery to its customer. Moreover, reducing waiting time at container yard will help the shipping company to delivery containers to its customers earlier.

For further research, this study can be extended by considering emission reduction for both import and export containers. A truck that carries an export container has to wait at the entrance gate of terminal and at the export yard for unloading container. Moreover, an optimization model can be developed for the moving container at yard when truck arrival pattern is known. This is a challenge because there is a trade-off between the quality of the solution and the computation time.

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References

Bocewicz G, Wójcik R, Banaszak Z (2012) Cyclic scheduling for supply chain network. In: Corchado Rodríguez JM, Perez J, Golińska P, Giroux S, Corchuleo R (eds) Trends in practical applications of agents and multiagent systems, series: advances in intelligent and soft computing, vol 157. Springer, Berlin Heidelberg, pp 39–47

Brodrick C-J, Lipman TE, Farshchi M, Lutsey NP, Dwyer HA, Sperling D, Gouse III SW, Harris DB, King FG Jr (2002) Evaluation of fuel cell auxiliary power units for heavy-duty diesel trucks. Transp Res Part D 7(4):303–315

Chen G, Govindan K, Golias MM Reducing truck emissions at container terminals in a low carbon economy: proposal of a queueing-based bi-objective model for optimizing truck arrival pattern. Transp Res Part E: Logistics Transp Rev (accepted by)

Chen G, Govindan K, Yang ZZ (2011a) Designing terminal appointment system with integer programming and non-stationary queueing model. Technique report, University of Southern Denmark, Odense

Chen X, Zhou X, List GF (2011b) Using time-varying tolls to optimize truck arrivals at ports. Transp Res Part E: Logistics Transp Rev 47:965–982

Drewry Shipping Consultants, Ltd. (2010) http://seekingalpha.com/article/262778-2-charts-showing-the-global-economy-is-recovering

Geerlings H, Duins RV (2011) A new method for assessing CO_2-emissions from container terminals: a promising approach applied in Rotterdam. J Clean Prod 19:657–666

Gen M, Cheng R (1999) Genetic algorithms and engineering optimization, 1st edn. Wiley-Interscience, New York, USA

Goldberg DE (1989) Genetic algorithms in search, optimization and machine learning, 1st edn. Addison-Wesley Publishing Company, New York, USA

Golias M, Boilé M, Theofanis S, Efstathiou C (2010) The berth scheduling problem: maximizing berth productivity and minimizing fuel consumption and emissions production. Transp Res Rec: J Transp Res Board Mar Transp Port Oper 2166:20–27

Goodchild A, Mohan K (2008) The clean trucks program: evaluation of policy impacts on marine terminal operations. Marit Econ Logistics 10(4):393–408

Green L, Kolesar P (1991) The pointwise stationary approximation for queues with nonstationary arrivals. Manage Sci 37(1):84–97

Guan CQ, Liu RF (2009) Container terminal gate appointment system optimization. Marit Econ Logistics 11(4):378–398

Huynh NN (2009) Reducing truck turn time at maritime container terminals with appointment scheduling. Transp Res Rec: J Transp Res Board 3230:48–56

Huynh N, Walton CM (2008) Robust scheduling of truck arrivals at maritime container terminals. J Transp Eng 134(8):347–353

Huynh N, Walton CM, Davis J (2004) Finding the number of yard cranes needed to achieve desired truck turn time at marine container terminals. Transp Res Rec: J Transp Res Board 1873(1):99–108

Karafa J (2012) Simulating gate strategies at intermodal marine container terminals. MSc thesis, University of Memphis, Memphis

Lam SF, Park J, Pruitt C (2007) An accurate monitoring of truck waiting and flow times at a terminal in the Los Angeles/long beach ports—METRANS project AR 05-01. The METRANS Transportation Center, Long Beach

Larson RC, Odoni AR (1981) Urban operations research chap. 4. Prentice-Hall, New Jersey, pp 249–251

Lazic MB (2004) Container terminal operation emissions. West Coast region conference on marine port air quality impacts. Air and Waste Management Association, Seattle, Washington, USA

Meyer PD, Maes F, Volckaert A (2008) Emissions from international shipping in the Belgian part of the North Sea. Atmos Environ 42:196–206

Moriarty P, Honnery D (2008) Mitigating greenhouse: limited time, limited options. Energy Policy 36:1251–1256

Pachakis D, Fidell T, McNally J, Nye L (2008) Achieving emission reductions in container terminals through process change. Harbours, air quality and climate change (HAQCC 2008) conference, Rotterdam, Netherlands

Saxe H, Larsen T (2004) Air pollution from ships in three Danish ports. Atmos Environ 38:4057–4067

Sitek P, Wikarek J (2013) A Hybrid method for modeling and solving constrained search problems. In: Federated conference on computer science and information systems (FedCSIS). IEEE Press, Kraków, pp 385–392

Smith JM (2010) Robustness of state-dependent queues and material handling systems. Int J Prod Res 48:4631–4663

Starcrest Consulting Group, L (2011) The port of Los Angeles inventory of air emissions for calendar year 2010. Port of Los Angeles, Los Angeles
Tzannatos E (2010) Ship emissions and their externalities for the port of Piraeus. Atmos Environ 44:400–407
Asariotis R, Benamara H, Hoffmann J, Misovicova M, Núñez E, Premti A, Sitorus B, Valentine V, Viohl B (2010) Review of Maritime Transport 2010. United Nations Conference on Trade and Development (UNCTAD), UNCTAD/RMT/2010 United Nations Publication
Utts Jessica, Niemeier Debbie, Ring Laura (2000) Statistical methods for estimating speed correction factors with confidence intervals for mobile source emissions models. Transp Res Part D: Transp Environ 5:103–120
Wang W-P, Tipper D, Banerjee S (1996) A simple approximation for modeling nonstationary queues. In: Proceedings IEEE fifteenth annual joint conference of the IEEE computer societies (INFOCOM'96). Networking the next generation, vol 1, pp 255–262
Whitt W (1991) The pointwise stationary approximation for *Mt*/*Mt*/*s* queues is asymptotically correct as the rates increase. Manage Sci 37:307–314
Zietsman J, Farzaneh M, Schneider-IV WH, Lee JS, Bubbosh P (2009) Truck stop electrification as a strategy to reduce greenhouse gases, fuel consumption and pollutant emissions. Transportation research board annual meeting 2009. Transportation Research Board, Washington, DC

Energy Efficiency of Passenger Transport in Poznan Agglomeration in the Face of Peak Oil

Hubert Igliński

Abstract Economic growth and social development result in the growth of transport use. It is perfectly observed in developing countries with dynamic growth rates, such as China, where only in 2013, 20 million new cars were sold. What is more, the population of developing countries will have increased by almost two billion by 2050 and it will, too, increase the demand for transport, especially road and air transport. 95 % of transportation relies on oil refinement products. Its sources have not been exhausted, but are more and more limited. According to some experts, the world has reached or will soon reach peak oil and even a dynamic growth in the extraction from shale or other non-conventional sources will not increase the supply significantly. In the face of these challenges and the limited amount of its own oil, the EU postulates to speed up the process of sustainable transport development, which was expressed in, among others, in the White Paper of Transport of 2011. The aim of this chapter is to estimate the level of energy-intensity of passenger transport in Poznan agglomeration in public transport (tram and bus) and the dominating individual transport. It also indicates organisational and technological activities which would contribute to lowering energy intensity and increasing the sustainability of transport.

Keywords Energy-Intensity · Public transport · Sustainable transport · Peak oil · Supply of oil · Demand for oil

1 Introduction

The functioning and development of modern societies and economies are entirely dependent upon transport operation. Conveyance of the majority of goods and passengers is performed by means of mechanical modes of transport, which in more

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than 95 % of cases are fuelled by products of petroleum refining processes. This dependence caused the transportation sector to account for over the half of the use of petroleum supply in 2012 (2.14 billion tonnes). Apart from crude oil, the transportation industry used up around 110 million tonnes of other types of fuel, which consisted mainly of biofuel and synthetic fuels (BP 2014a). Even such high consumption of oil would not be alarming if there was no real and imminent threat of reaching a peak in the oil extraction, whose arrival is accelerated by increasing demand for transportation.

Road transport has a dominant share in this consumption. Its share in the transportation industry is growing dynamically, especially of individual vehicle ownership in passenger transport, which can be observed in all developing countries, including Poland. The results of this dominance are increasing environmental pollution, accidents and traffic congestion, all of which have become common problems in cities worldwide. Additionally, in the European Union, which has currently almost no petroleum resources and the production is able to satisfy only about 10 % of demand, solving these problems has become a challenge of top priority.

Therefore, it is essential to look for solutions which will enable to satisfy the need for mobility in societies at the same time being resource-efficient and remaining energy-saving, and will generate external costs that are as low as possible. The aim of this chapter is to analyze the level of energy intensity of individual passenger transport, with the use of passenger cars or public transport in Poznan agglomeration.

2 The Demand for Petroleum in the Transportation Industry

In 2012, 52.7 % of petroleum supply was used in the transportation sector. The remaining amount was used by the general industry (29.4 %), energy industry (6 %) and other sectors of the economy (11.9 %), including a considerable share of farming. Also, the consumption of petroleum in the transportation industry grew at the highest pace. Between 1990 and 2012 its consumption in the transportation industry rose to 44.7 %, whereas in the general industry and the remaining sectors it was 31.1 and 3.6 % respectively. In the energy industry, a fall by 17.4 % (BP 2014a) was observed. Even if calculated per capita, the worldwide consumption of petroleum in the transportation industry rose at the fastest pace, but obviously its dynamics was lower due to the constant growth in the number of the world population. In the examined period, the *per capita* growth was by 10 %, from 273 to more than 300 kg, ranging from around 80 kg in Africa to over 1,380 kg in North America (BP 2014a, b; UN 2013). In Poland the mean consumption in the transportation in 2012 was 460 kg (Eurostat 2013).

One of the key factors shaping the demand for transportation is the level of economic development calculated by means of gross domestic product (GDP per capita) and, more specifically, the level of disposable income by each citizen or household (Fig. 1).

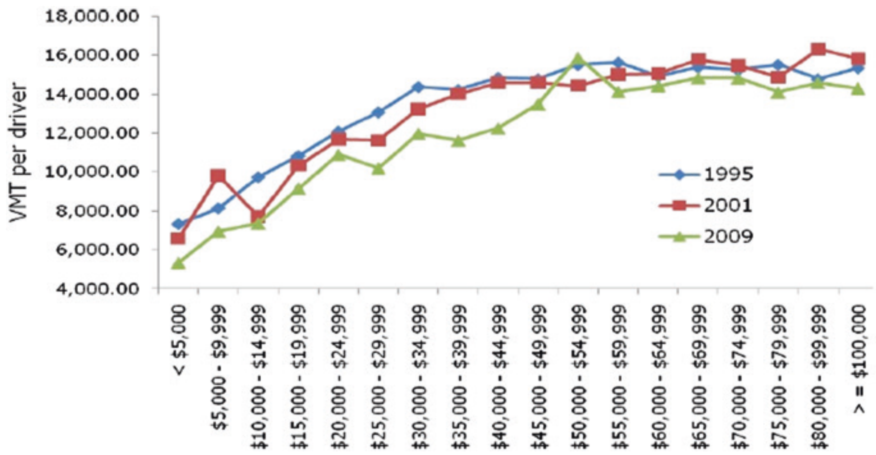

Fig. 1 Average annual vehicle miles per driver by total household income (ITF 2012)

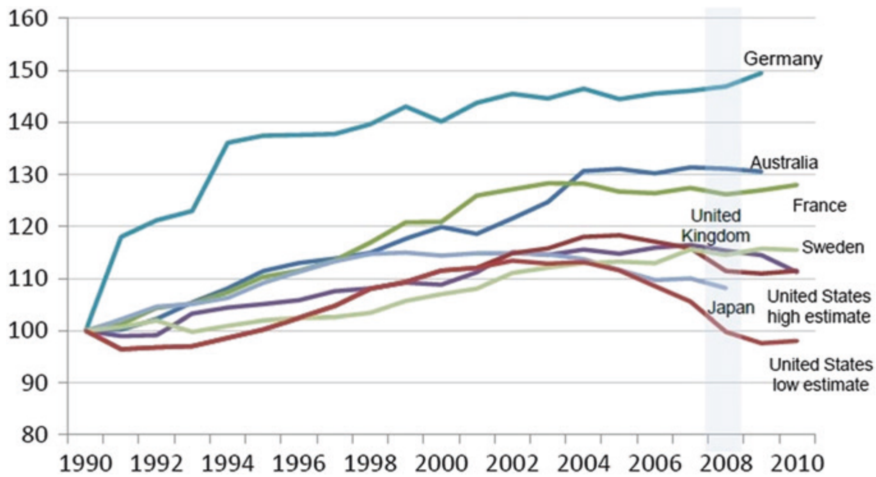

Fig. 2 Passenger-kilometres by private cars and light trucks, 1990–2009 (index 1990 = 100) (ITF 2012)

However, once a certain level is reached the demand is saturated and any further demand is only insignificant (Fig. 1). A similar interrelation is observed on a scale of whole countries. In the last years, the demand for transportation, especially in the vehicle transport satisfied by means of passenger cars and light trucks, has stabilized (Fig. 2). Another reason for the lessening demand for transportation in developed countries resulted from a range of other reasons, especially rising petrol prices, the economic crisis and a more and more uneven distribution of economic growth, the shrinking middle class, a growing level of urbanization, aging in society and growing digitalization.

Table 1 Motorization rate in selected countries, 2004–2011

Country	Years								
	2004	2005	2006	2007	2008	2009	2010	2011	2004 = 100
Japan	433	441	447	450	451	452	454	455	105.1
Germany	487	493	498	501	503	510	517	531	109.0
Great Britain	452	457	456	459	458	456	457	454	100.4
The Netherlands	430	435	442	451	459	461	466	471	109.5
Poland	314	323	351	383	422	432	452	470	149.7
Brazil	136	142	148	158	167	179	–	–	131.6
China	12	15	18	23	27	35	44	54	450.0
India	8	9	10	10	10	11	–	–	137.5
Russia	168	179	188	207	226	233	–	–	138.7
RSA	92	97	102	107	108	110	112	–	121.7

http://data.worldbank.org/indicator/IS.VEH.PCAR.P3/countries/PL-GR-AE-EU?display=default

In developed countries, gradual saturation has been observed in the number of passenger cars, whereas in developing countries, automotive industry rates are rising briskly (Table 1).

With the rising level of development, the growth rate of transport utilisation, in particular in passenger cars, will be decreasing, as indicated by the data above. Such a trend will also persist in Poland although deceleration in the level of demand for transportation is expected to occur in a few years. Expert forecasts indicate that in OECD countries the GDP per capita will have risen by an average of 85–110 % by the year 2050, whereas the demand for passenger transport will only have increased by between 10 and 50 %, and for cargo transport between 50 and 130 %.

At the same time it must be remembered that developed countries are inhabited by only 1 billion people and the vast majority of the remaining part of population would like to live their "American Dream" and improve their standard of living considerably. Their transportation needs will be on the increase as the majority of those people do not even own a bicycle and mostly travel on foot. In the most likely prognoses of UN experts, the population of developing countries will have risen from 5.9 (in 2000) to 8.3 billion people by 2050 (UN 2013).

Not only fulfilling one's dreams, but mostly fulfilling one's daily duties by the inhabitants of developing countries will translate into the expansion of scale of transport utilization. According to International Transport Forum (ITF 2012), passenger transport is forecast to increase from 140 to 260 % in these countries, and cargo transport from 150 to 450 % at the GDP per capita growth estimated at 220–270 %.

Catering for increased transport needs will go hand in hand with a considerable increase in the number of vehicles. Experts have calculated that the numbers of cars will have risen to around 2.8 billion by 2030, including 900 million motorbikes and motor scooters. In 2000, the total number of vehicles in the world was 840 and 250 million single-track vehicles (currently it is 1.5 billion including 1 billion passenger cars) (Sperling and Gordon 2009).

Analysts of Goldman Sachs forecast an even larger growth in the number of cars (Sachs 2009). According to them, it is only in BRIC countries that the number of cars in 2030 will reach 770 million and as many as 1.2 billion in 2040. That number was only 145 million in 2010. A similar process was observed in fast developing countries like Poland, where the number of registered passenger cars rose from 5.3 million in 1990 to 17.9 million in 2012 (GUS 2004, 2013).

In order to meet the demand for new cars, their production will have to increase from 81 million (including light trucks) in 2012 (KPMG 2013) to around 120 million in 2030 and as many as 170–180 million in 2050 (IEA 2009). Manufacturing an average car at the beginning of the 21st century necessitated 680 kg of steel, 230 kg of iron, 90 kg of plastic, 45 kg of rubber, 45 kg of aluminium and some other raw materials as well as 8–28 MW of energy (Dennis and Urry 2009). This will require a rise in the consumption of resources, including petroleum, and electric power in the course of their extraction, transportation and in the actual process of production and delivery of cars to a show room or to end customer.

A considerable rise in transport performance is also expected for other means of transport, in particular air transport. In 2012 a total of 3 billion passengers were carried and 51.4 million tonnes of cargo which was an increase of 48 and 33 % than in 2004 respectively. According to IATA estimations, in 2014, 3.3 billion people and 51.7 million tonnes of cargo will be carried by air. Until 217, this number will be rising at a yearly rate of 6.4 % for passenger transport and 4.5 % for cargo (IATA 2014). The demand for petroleum in aviation is tremendous. In 2012 airlines used 256 million tonnes of crude oil (IATA 2013).

Satisfying such considerable transportation needs will require the existing infrastructure to be expanded. Trillions of dollars will have to be spent on investments in infrastructure and hundreds of billions of dollars for their maintenance later. Each investment will require considerable energy consumption, most of which will derive from burning petroleum.

3 Petroleum Supply

A record-breaking amount of 4.2 billion tonnes (87.3 million barrels per day; b/d) of petroleum was produced in the world in 2013. Most of the oil was extracted from conventional sources (73 million b/d, 83.6 %). Natural gas liquids (NGL) are obtained in the process of natural gas extraction and processing (12.5 million b/d, 14.3 %) and from non-conventional sources: tight oil (shale oil)[1] and by deepwater drilling—from under seafloor, oil trapped in oil sands and kerogen (altogether 1.8 million b/d, 2.1 %—excluding shale oil)[2] (IEA 2014).

The mean amount of oil resources discovered in the course of the last five years was 12–13 billion barrels per year. This means the newly discovered sources

[1] Shale oil is considered to be an unconventional source of oil, even though IEA includes shale supply together with conventional sources, which is a surprising inconsistency.

[2] Biofuels have been purposefully excluded as they are considered to be a separate category. Their overall share is fairly insignificant, the world production of it in 2012 was 2.0 million b/d. Also, the so called processing gains (ca. 2.2 million b/d) have been excluded.

account for merely one third of the yearly oil consumption in that period, which is much less than at the beginning of the 1960s, when the amount of discovered oil deposits was 50–60 billion barrels per year (IEA 2013). Discovering gigantic oil deposits containing 500 million barrels (so called "elephants") belongs to a bygone era. One example of such an oil field is Ghawar in Saudi Arabia which spreads on the area of 280 km in length and 26 km in width and its ultimately recoverable resources (URR) values ranging from 66 to 150 billion barrels of oil. Another example is Cantarell Field in Mexico,[3] whose URR is estimated at 11–20 billion barrels (Aleklett 2012). Oil deposits discovered nowadays are ever smaller and contain 50 million oil barrels, whereas in the 1960s this amount was 230 million (IEA 2013). Non-abundant fields mean low returns to scale, so the generated cost of oil extraction is higher than in the case of big fields and leads to the reduction of *Energy Return on Energy Invested* (EROEI)[4] ratio.

In spite of employing advanced technologies, searching for new oil fields which are not so oil-abundant becomes more demanding and expensive. The total investments of $2.4 billion in the oil industry between 1994 and 2004 allowed to increase the extraction of oil by 12 million b/d. Similar expenditure between 2005 and 2010 only allowed to maintain the level of production (Heinberg 2013).

4 Peak Oil

In 1956, Marion King Hubbert, an American geophysicist, after thorough analyses of the levels of oil extraction in the USA, proposed a thesis that exploitation of non-renewable resources will cause their ultimate exhaustion in the foreseeable future. Hubbert estimated that for the USA the peak production will be reached between 1966 and 1972. His projections proved to be right as the peak oil was reached in the USA in 1970 (533.5 million tonnes).

The peak oil theory, in relation to conventional oil sources, is best exemplified for instance by the field located under the bed of the North Sea, which is exploited by Denmark, Norway and Great Britain. The extraction levels have been rapidly rising since the 1970s and peaked at the turn of the centuries, when it began falling systematically (Fig. 3). Great Britain was first to reach peak oil in 1999 with a 137.4 million tonnes yearly extraction rate. It had fallen by 70 % by 2013 to reach 40.6 million tonnes. It was followed by Norway, which reached peak oil of 162.5 million tonnes in 2001 and the fall by 50 % occurred by 2013. Similarly, in Denmark, where peak oil was reached in 2004 (at 19.1 million tonnes), the

[3] Discovered in 1976, the extraction started in 1979. Turned out to be the last greatest oil field discovered in the world.

[4] Another measure can be found in the literature, namely *Energy Return On Investments* (EROI), which includes all the investments made (including indirect investments) in order to extract oil.

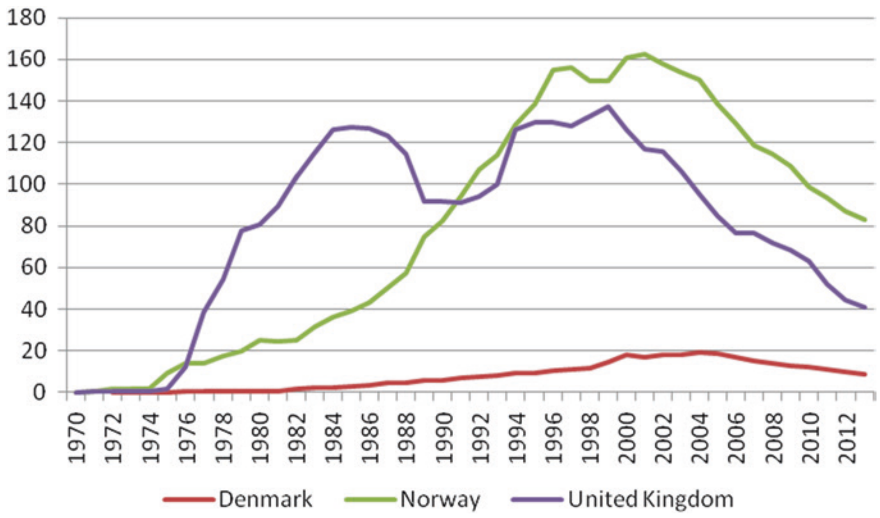

Fig. 3 Oil extraction (in mln t) from under the North Sea bed in 1970–2013 (BP 2014b)

extraction fell to 8.7 million tonnes. It must be noted that if those three countries wanted to keep the extraction level at the 2013 rate, their resources at hand would be used up within ten years. This state becomes a universal norm. Analysts estimate that peak oil has been reached in 55 out of 64 countries extracting conventional oil sources (Gilbert and Perl 2010).

The opponents of peak oil theory point out (Maugeri 2012; Yergin 2013) that its assumptions are wrong and, in fact, M.K. Hubbert was wrong determining peak oil for America. What is more, the resources of oil are not declining. There are still countries which constantly increase extraction (among others Canada, Brazil, Saudi Arabia, UAE, Qatar, Kazakhstan[5]) or, like the USA, are again increasing extraction. It appears that studying statistical data available does prove the opponents of the theory right, but only to a certain extent. The USA reached peak oil in 1970 (533.5 million tonnes) and the extraction started to decline, in spite of new oil fields being developed (Alaska, the Gulf of Mexico), to hit rock the bottom in 2008 (302.3 million tonnes), when the extraction level started to rise rapidly again to reach 446.2 million tonnes in 2013. It became possible only because of shale oil extraction and increasing deepwater oil drilling, whereas extraction from conventional sources is constantly deceasing.

Therefore, M.K. Hubbert was not mistaken about the conventional sources of oil. It was, in fact, impossible to extract from non-conventional sources in 1950s,

[5] Iraq has been constantly increasing oil extraction since 2005, although the case of Iraq is extremely difficult to examine in the context of *peak oil* as the country has been at war since the beginning of the conflict with Iran in 1980–1988, and a later embargo and occupation after the 2003 war.

when the theory was developed. Apart from that, they were partly unknown. The extraction of non-conventional sources does not refute the theory, either. What it does is shift its consequences in time a bit, but ultimately its result is inevitable.

5 Shale Oil and Other Non-conventional Sources of Oil

After huge surges in oil prices in the years 2008–2010, the price per barrel stabilized at the beginning of 2011 at a rate of around \$110 per barrel in the United States. The price oscillated around \$100 per barrel in 2013 and currently is \$97.6 (CNN 2014). Such high oil prices hinder the development of economy on the one hand as it was mostly due to very low oil prices that global economy was growing rapidly in the past decades. On the other hand, high oil prices allowed for exploration of new, previously unexplored sources, whose exploitation was previously unprofitable. Paradoxically, it is high prices in global markets that caused the US "oil fever". Exploitation of shale oil has been dynamically developing since 2008 (mainly from Permian Basin Shale, the Eagle Ford shale and the Bakken formation). The technique employed there is referred to as *fracking* (*hydraulic fracturing*). The employment of this technique (known previously but used only for conventional sources to improve the efficiency of extraction) brought the level of shale oil extraction to 4.5 million b/d in July, 2014 (EIA 2014).

The volume of extraction of shale oil is characterized by huge declining rate. In the first year of exploitation it is about 60 %, the second year 80–90 % of the maximum extraction level and in the third or fourth year it usually drops to less than 10 b/d, which makes the maintenance of the oil well unprofitable and it is often closed. The 2012 surveys estimated that in order to keep the exploitation level in the US, 6.2 thousand oil wells must be build yearly, for a price of \$35.8 billion (Hughes 2013). The current extraction rate is three times as high, so it is a quick math to perform to find out what costs must be incurred in the future in order to keep the current production level. Extraction growth in new wells is becoming lower, which indicates that it is close to a peak level.

Just as is the case in conventional sources, all the so-called sweet spots, the easily-accessible shale oil and oil sand sources, have been used. In the case of the Bakken formation in Montana, they have already been emptied and the extraction break-even level will be rising in more challenging locations (Heinberg 2013). Additionally, it is feared that hydraulic fracturing may have a damaging effect on health and the environment. Tremendous amount of water (ca. 12 barrels of water per each barrel extracted) needs to be heated and forced underground under pressure with various other chemicals. Additional 5 barrels for each barrel extracted are required during the necessary aboveground operations (Hughes 2013). With a growing deficit of pure, fresh water the benefits of this solution become disputable. Heating such amounts of water and pouring it deep underground itself involves high energy consumption. Another problem is handling and purifying water that is pumped out of the shafts before beginning to extract oil as, apart from the chemicals added to it, it contains radioactive elements, and among others benzene, toluene and xylene (Heinberg 2013).

Shale oil extraction requires a lot of deep drilling (the wells are longer due to their lower part running horizontally), which significantly raises the cost of extraction and lowers the level of EROEI. Although the level has not been studied in more depth, experts claim it becomes far lower than in the case of conventional sources. For Ghawar field in Saudi Arabia the EROEI ratio is at the level of 50, whereas for average sources in the world it is from 17 (Heinberg 2013) to almost 20 (Urry 2013). Therefore, extracting oil does not only require more energy input, but also becomes more expensive as the oil comes from more technically demanding oil fields.

A very low EROEI ratio of 3–5 (Hughes 2013) combined with damage to the natural environment due to deforestation, water contamination and polluting virgin ecosystems is typical of oil sand extraction, a process used on a large scale in Canada and in Venezuela.

Deep water drilling is associated with a hazard to the environment. The Deepwater Horizon explosion and then spill in 2010 is just one example. On these grounds, ecologists are sceptical of Brazil's plans to begin extracting oil from under the bed of the Atlantic Ocean. The Brazilian deposits are located much deeper than those in the Gulf of Mexico (that poses a huge technological challenge) and it is much further from the shore and higher costs will be involved to support the platforms and deliver the oil to the refinery, again lowering the EROEI ratio.

Exploiting underwater oil deposits in the Arctic and other non-conventional sources poses an even higher threat to the environment. In the Arctic, another problem arises. The melting ice cap would cause the rise in the sea level followed by unimaginable consequences that would be faced by hundreds of millions of people living near shorelines. Therefore, in author's view, it is best if those sources remain inaccessible.

A lot suggests that not only because of its low supply, but also unchanging demand and technological considerations, the price of oil will not decrease significantly. $60 per barrel of oil-sand oil seems to be the break-even point if it comes from previously exploited fields. For newly-exploited ones, $80 per barrel is cost-effective. In the case of new deepwater drilling, the cost-effectiveness is reached at $90 per barrel (Heinberg 2013). For shale, this value is $65–90 per barrel (Carlyle 2013).

6 EU Transport Policy in the Context of Oil and Sustainable Development

The European Union is in a predicament as its oil extraction totalled at a bit over 62 million tonnes in 2013 and it has been falling steadily for a decade now while the consumption is ten times higher and exceeds 600 million tonnes. Oil deliveries from Norway are some sort of support as Norway extracted only 83.2 million tonnes in 2013 and the Norwegian supplies of black gold are running low fast (BP 2014b).

Acquiring over 500 million tonnes of oil, the price of which fluctuated around $100 per barrel in 2013 requires an expenditure of $400 billion. Also some political risk needs to be taken into consideration. Every major political, military event or a terrorist incident in any place in the world or especially in an oil-extracting country cause the prices of oil to rise. One does not have to think back to the 1970s, the times of great oil crisis to understand the impact of such events. The successes of the Islamic State of Iraq and al-Sham in June 2013 brought about a 10 % increase in oil prices within just a few days. At the news of downing a Malaysian Boeing plane in July 2014 over Ukraine, the prices of oil rose by about 5 %. Today, the price is back to its earlier state, but these events prove how sensitive the oil market is. On the other hand, sometimes one is forced to acquire oil in countries alien to democracy or make rotten compromises. As many examples in the history show, oil, unlike many other resources, becomes a tool of autocratic rule in the hands of despots and juntas. Transporting oil by sea and by land is subject to terrorist attacks and piracy (French and Chambers 2010).

Burning oil by the transport industry is a reason for a whole range of unfavourable phenomena. Economists call these the external costs, which in transport include pollution, emission of carcinogenic solid particles, aromatic hydrocarbons and many other costs such as climate change, as burning oil means releasing enormous amounts of CO_2 and smaller but more harmful amounts of nitrous oxide (N_2O) and methane (CH_4) as well as noise, vibration and costs of accidents that are not covered by insurance, costs of congestion and others. It is estimated that combined external costs of transportation within the EU, Norway and Switzerland reached €500 billion in 2008 which accounts for 4 % of GDP of those countries (Delft 2011). According to a vast majority of experts, going along this path of development, which stands in contradiction to the assumptions of sustainable development (extremely resource-intensive and emitting a lot of greenhouse gases) will bring about extreme damage to the global ecosystem and in economy that is difficult to imagine and assess.

In the White Paper of transport of 2011, it was assumed that by 2050 a unified transportation system will have been developed. It will be competitive, it will support economic growth but will also be resource-efficient, and the emission of greenhouse gases will decrease by 60 % in comparison with 1990. Ten particular goals are supposed to be achieved for this to happen most important of which are as follows (COM 2011):

- total elimination of "conventionally-fuelled" cars from cities until 2050 (reduction by 50 % until 2030),
- introduction of low-carbon sustainable fuels in aviation (at least 40 % by 2050) and reduction of CO_2 in transport by sea by a minimum of 40 %,
- more reliance on rail transport for long distance cargo shipment,
- development and expansion of high-speed rail,
- reducing the number of road transport fatalities close to zero,
- final implementation of the rule "user/polluter pays", i.e. reduction external costs drastically.

The fact that in the European Union the majority of citizens (ca. 75 %) occupy cities, with the highest urbanization rate in the EU15 rather than in the new member states is a big advantage. That is because cities have always played a key role in the socioeconomic development, they are reservoirs of ideas and innovation. As well as that, they allow for more effective resource and energy use, especially cities with densely developed cities than rural areas or areas of urban sprawl. At the same time, they emit much less greenhouse gases or other types of pollution (Calthorpe 2013; Owen 2011). What is more, it is in medium-sized or large cities where effective public transportation systems can be created (Suzuki et al. 2013), bicycle paths can be built or various other solutions can be introduced, such as 30 kph zones, low-carbon emission zones—the German *Umwelt Zone*, no-entry zones in the city centre, parking policies, toll-entry to the city centre and others). All these solutions contribute to the lowering of vehicle ownership levels among inhabitants and the duration of time spent in the car.

7 Energy Intensity of Passenger Transport in Poznań Agglomeration

The urbanization level in Poland is only 60.6 % and is decreasing (GUS 2014b) as inhabitants of cities move out to the suburbs which are not too distant from the metropolitan area. This makes it difficult to provide these areas with efficient public transport service. Therefore, catering for most of transportation needs is via individual vehicle transport.

Poznan is, too, going through the process of suburbanization. The number of population fell from 582.2 thousand people in 2000 to 548 thousand in 2013. And the population in the Poznan district has increased from 260.5 thousand to 352.4 thousand (GUS 2014a). The processes of suburbanization create new, additional costs and phenomena which result in higher energy consumption. They can be classified as:

- economic
  - higher costs of infrastructure development,
  - growing congestion,
  - growing cost of individual transport (cost of petrol use and other supplies, the cost of time wasted etc.),
  - growing risk of real estate market speculation,
  - growing costs of providing urban transport,
  - metropolitan area becoming less competitive, lower quality of life for the inhabitants of this area;
- ecological
  - appropriation of farm and forest lands,
  - habitat fragmentation,

  - land degradation,
  - increased energy use (transportation, heating),
  - higher environmental pollution and greenhouse gas emission;

- social

  - disruption of social bonds,
  - social segregation,
  - conflicts between local and immigrant population.

Due to an increasing level of suburbanization and the resulting dispersion of starting and target locations it is essential to the transportation system in the whole agglomeration rather than just the city of Poznan. It is commonly assumed that Poznan agglomeration is made up of the city of Poznan and the surrounding district, consisting of 17 municipalities, 11 of them directly adjacent to the city, and 6 in the so called second Poznan ring.

Because of the statutory provisions resulting from the initiatives of the European Commission, the city of Poznan and Poznan district are obliged to execute the so-called transport plans. The authorities in both local self-government units rightly concluded and took the initiative of preparing a single, joint plan. The necessary condition to execute the transport plan was conducting a Comprehensive Traffic Survey [Kompleksowe Badanie Ruchu (KBR)] in 2013.

Individual journeys by car held the biggest share in the overall percentage of trips in Poznan agglomeration in 2013: 49.5 and 61.3 % in terms of transport performance (pkm) (Table 2) (KBR 2013).

The number of car journeys has not risen significantly, as it has been only by 9.2 % in comparison to previously conducted studies in 2000. However, the mean distance

Table 2 Transport performance in Poznan agglomeration (within one standard day) (KBR 2013)

Mode of transport	Journeys (thousand)	Share (%)	Transport performance (thousand pkm)	Average length (km)	Share (%)
Public transport	590.0	36.8	6,750.7	11.44	35.9
Trams			1,373.4	3.80	7.3
Municipal Transport Company (MPK) buses			1,343.0	3.56	7.1
Regional railway			947.4	22.67	5.0
Transregional railway			908.2	31.49	4.8
Remaining buses (in this region and transregional)			1,296.9	10.89	6.9
Pedestrian (accessing and leaving stops)			880.8	1.49	4.7
Passenger car	792.2	49.5	11,527.7	15.81	61.3
Bicycle	654.0	4.1	293.9	4.49	1.6
Pedestrian	152.3	9.5	219.5	1.44	1.2
Total	1,600.0	100	18,791.9	11.74	100

of a journey effected by road has risen considerably—from 7.22 km in the city of Poznan and 10.46 in Poznan district (KBR 2000) to 15.81 for the entire agglomeration (KBR 2013). The key influencing factor was progressing sprawling. The transport performance in individual transport has doubled, whereas in transit by a mere 17 %. Though it was, above all, caused by the expanded area that Zarząd Transportu Miejskiego (ZTM, Municipal Transport Authority) operated on. ZTM now provides service not only in the city of Poznan, but also in the neighbouring municipalities that constitute Poznan Agglomeration. Also, Poznan network of trams has grown.

If these trends continue, the transport system in Poznan agglomeration will become less and less balanced, and its energy-intensity and resource-intensity will grow. Therefore, as indicated in the introduction, the main aim is to survey the energy efficiency of passenger (bus, tram and passenger car[6]) transport in Poznan agglomeration.

In 2013, the trams transport performance in Poznan totalled at 370.8 million pkm, i.e. 1.73 million pkm within calculation day (one year = 270 calculation days). The total energy consumption by trams was 56.2 GWh. It means that the mean energy expenditure was 15.16 kWh/100 pkm (5.8 kWh/1 vehicle-kilometre) (MPK 2014). This value was achieved by an average occupancy of a vehicle of 38.3 passengers. Depending on the line, the average occupancy of a vehicle fluctuates between 15.3 (line 4) up to 74 (line 16) passengers, at the average capacity of a tram car of 153 passengers (BIT 2014). The trams utilized in Poznan have different carrying capacities and different energy consumption rates. However, the vast majority of lines are served by varied fleet. They are also driven by drivers with different driving styles (from cautious and fluid to "racing" drivers). So it can be assumed to be the only determining factor is demand and the energy-intensity of tram transport vary from about 8–38 kWh/100 pkm.

In Poznan area and in several neighbouring municipalities ZTM organizes service that is later provided by the Municipal Transport Company (MPK) and other carriers in the district. The total value of transport performance in vehicle-kilometres in 2013 for those carriers was 18 % of what MPK provided (BIT 2014). It is not only because of the volume of transport performance in comparison to other carriers, the structure of its fleet (ranging from small buses which are 8.6 m in length which can carry 51 passengers up to long, articulated buses, 18 m in length and capable of carrying 175 passengers), but also because of the range of its operation and the variety of areas covered by its service (from dense municipal areas with short distances between stops and low speed of traffic to suburban areas which are the exact opposite) that the author decided to examine only the energy efficiency of the MPK services, which can be treated as representative of the whole agglomeration.

MPK carried a total of 377 thousand passengers daily in 2013, that is 1.3 million pkm. The yearly transport performance value was 362.9 million pkm and consumed 9.9 million l of diesel (MPK 2014). The heating value of diesel is

[6] Unfortunately, for want of some more detailed data from railway companies, it was impossible to perform accurate analyses of the rail transport.

Table 3 The structure of passenger car fleet (in 1,000) in Poznan agglomeration in 2013 (Own research, based on KBR 2013; GUS 2014a)

Area	Engine displacement (cm^3)					
	Up to 1,399		1,400–1,999		Over 2,000	
	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel
Poznan	96.5	41.4	98.1	42.0	19.1	8.2
Poznan district	56.1	30.2	55.2	29.7	9.5	5.1

10.7 kWh/l, so within a year the consumption was 106 GWh. The mean energy expenditure for buses was 29.22 kWh/100 pkm (5.84 kWh/vehicle-km). This value was achieved at the bus occupancy of 20 passengers, whereas the average capacity of buses is 125 (standing and seating capacity).

It might seem that due to such excess supply of space in buses, the capacity of the utilized vehicles should be lowered. However, the demand is varied and occupancy at traffic rush hours is so high that a lower bus capacity would lead to the necessity of increasing the frequency of operation and introducing additional vehicles. This is not a good solution though as analyzing fuel consumption norms set by MPK reveals that the differences in fuel consumption between different bus types are not so huge. For example, an 8.6-m Solaris Alpino, which meets the EEV standard, has a fuel consumption standard of 32 l/100 km (0.63 l/100 km per passenger place, or 0.63 l/100 pkm at full capacity (the author will hereafter be using this measure). 12-m-long, 104-passenger Solaris buses use between 37 and 39 l/100 km, depending on the engine type. The buses manufactured by MAN use between 37 and 43 l/100 km and their capacity is 94–107 passengers. So the fuel consumption fluctuates between 0.36 l/100 and 0.4 l/100 km. The longest, 18-m Solaris buses can carry up to 175 passengers or, in the case of MAN buses—168 passengers at 50 l/100 km for Solaris or 50–51 l/100 km for MAN with the consumption at the level of 0.29–0.3 l/100 pkm. This means the energy efficiency of the largest buses is twice as high as of the smallest buses in use (MPK 2014).

Without doubt, the highest transport performance is obtained by passenger cars—over 11.5 million pkm/day. At average occupancy rate of 1.4 passenger means 8.2 million vehicle km (KBR 2013). The breakdown of cars in terms of engine displacement and type of fuel used was analysed.[7] Then it was adjusted against the data derived from the Comprehensive Traffic Survey (KBR) and combined it with the number of vehicles registered in Poznan agglomeration. Thus, a detailed chart was arrived at for passenger cars in use (Table 3).

Fuel consumption can differ from individual to individual for a number of reasons: engine displacement, fuel type, driving style (aggressive, ecodriving) as well as the characteristics of the surrounding area and traffic intensity (city, motorway, combined), congestion level and other factors. Especially congestion influences

[7] LPG powered cars were qualified as diesel cars due to their comparable energy consumption per unit of distance.

the consumption level considerably. The author's research from 2008 indicates that average yearly congestion level in Poznan during morning rush hours between 7 and 9 a.m., calculated by means of travel time index (TTI) was 2.36 (Igliński 2008). It means that each journey during morning rush hours in Poznan was almost 2.5 times longer than in free flow traffic conditions. At that time, further research was carried out on the relationship between fuel consumption and travel time (traffic congestion level).

At free flow traffic conditions and warmed up engine and without any load (apart from the driver), a test vehicle (1,599 cm^3 capacity, 83 kW max power output) used ca. 6 l of petrol per 100 km.[8] However, in normal conditions the consumption rose to 9 l/100 km and in very high level of traffic congestion, which was also the case, the consumption rose to as much as 12–14 l/100 km. The relation between fuel consumption and travel time is described by a linear function:

$y = 0.0066x + 4.1043$ at coefficient of determination $R^2 = 0.87$, in which y—consumption volume (l/100 km) and x—travel time(s) (Igliński 2008).

There are no detailed data on traffic congestion in Poznan district, where the congestion level is lower than in Poznan itself. Similarly, there are no data on the traffic on roads connecting Poznan with Poznan district, especially main roads, where the traffic congestion level is very high. Most transportation is carried out in Poznan and between Poznan and Poznan district. Because of the ca. 25 % growth in number of cars registered in Poznan agglomeration since the 2008 study, the author assumes that during traffic rush hours, when the highest number of obligatory journeys takes place, the mean TTI in Poznan agglomeration is 2.0. At this level of traffic congestion, the mean consumption of fuel rises by around 35 % in comparison to free flow traffic conditions (Table 4).

So the values of weighted arithmetic mean (taking into consideration the number of vehicles in a given group (Table 4)) for fuel consumption in passenger cars in Poznan agglomeration are: 9.3 l/100 km for petrol-fuelled cars and 7.8 l/100 km for diesel-fuelled cars.[9] Within one day and for a distance of 15.8 km the total consumption of fuel is 521.5 thousand l of petrol and 205 thousand l of diesel. The heating value of one l of petrol is 9.7 kWh and of diesel fuel—10.7 kWh so the energy expenditure necessary for transport performance of 100 pkm in a passenger car in Poznan agglomeration is 62.9 kWh.

This means that passenger car transport (62.9 kWh/100 pkm) is two times less effective than by bus (29.2 kWh/100 pkm) and four times less effective than by

[8] The section of 5 km in length, on which the research was conducted is a dual carriageway with two or three lanes and a speed limit of between 50 and 80 km/h, with long distances between crossings (a few of them being elevated road intersections). So driving along this section corresponds to a combined driving rather than just city driving mode.

[9] It must be added that an average car in Poland is 16 years old. In Poznań agglomeration, it is a bit lower due to high economic activity and many new, company cars. Still, an average car is over ten years old. Not all the cars are roadworthy, either, and more and more cars have air conditioning, which influences the fuel consumption level, so as a result, the actual consumption may be even higher.

Table 4 Mean fuel consumption (l/100 km) against congestion level in different groups of cars (Own analysis based on manufacturers' data for the most popular car models)

Engine displacement (cm^3)					
Up to 1,399		1,400–1,999		Over 2,000	
Petrol	Diesel	Petrol	Diesel	Petrol	Diesel
7.4	6.8	10.1	8.1	14.9	11.5

tram (15.2 kWh/100 pkm). The yearly energy consumption may be estimated at 2200 million kWh for passenger cars, 106 million kWh for buses and 56.2 million kWh for trams. It means that the inhabitants of Poznan agglomeration used 156 million l of petrol and 61 million l of diesel fuel in 2013 for their typical obligatory and non-obligatory journeys within the agglomeration.

8 Conclusion

In the face of the already-achieved, or at least imminent peak oil and with constant growing demand for transportation, the inescapable consequence will be a rise in oil prices in world markets. It can only be stopped by another economic crises. A crisis is a fairly weak remedy for the problem, which additionally causes a number of unfavourable side effects. Technological progress may contribute to lower oil consumption by its more effective use. Hybrid cars may be one example. This may in turn lead to the Jevons paradox as a lower consumption level will result in more frequent travel and lengthening of the distances covered. So, over a long period of time, oil consumption is not only not likely to decrease, but quite the opposite. Obviously, hybrid cars are not the only solution aimed to stop being dependent on oil. Each solution has a number of limitations. In modern electric engines and batteries, rare-earth metals are used, whose supply is very limited and remains mostly under control of China. Additionally, batteries have a very short life and are a serious burden to the environment. Engines running on compressed natural gas have similar limitations to typical internal combustion engines, as gas supplies at the current consumption use is estimated to be sufficient for around 50 years. Hydrogen-powered cars are still being developed and it is hard to assume their economic and energetic effectiveness could be improved any time soon. Changing the type of propulsion to a more energy-efficient causing less pollution will not solve one of the most common, key problems tormenting cities—traffic congestion and the costs thereof.

Instead of continuing the current development trends and maintaining the domination of vehicle transport while waiting for another technological revolution to happen in order to make the world independent of oil, it would be better to use one of the off-the shelf, tested solutions. The widely accessible, punctual and safe public transport whose frequency of service is adjusted to the demand will improve the energy efficiency of passenger transport in cities. Especially transportation by rail (tram, light rail, underground etc.) in line with bicycle and pedestrian traffic (both characterized by near-zero energy-intensity), supported by appropriate spatial planning and proper restrictions regarding car transport are able to achieve that. Increasing the share of public transport in the overall transport performance in the face of peak oil and growing oil prices will decrease the costs of functioning of urban (agglomeration) transportation systems. As well as that, it will help reduce the external costs of transport, limit the costs of maintenance and costs of transportation infrastructure development due to considerably lower land take in comparison with the transport capacity. Also, it will improve the attractiveness of cities and attract new inhabitants at the same time suppressing the suburbanization processes.

Limiting urban sprawl and increasing population density in cities will decrease the distances between traffic sources and destinations which will directly contribute to lowering the energy-intensity of transport. In addition, it will increase the competitive advantage of public transport and pedestrian and bicycle traffic. On the other hand, there is a huge technological and organisational potential which can enable to lower the energy-intensity of public transport, thus lowering the emission of greenhouse gases and improving the level of sustainability of passenger transport. The fleet needs to be constantly replaced for less-energy intensive at the same time maintain its high technical condition. In the areas or sections where the demand for transport is highest where the bus service is provided, it would be worth considering the introduction of tram lines or trolleybuses. Both trams and trolleybuses use up much less energy per passenger kilometre, and, more importantly, are powered by energy which can be generated entirely from renewable resources. Educating drivers in the field of ecodriving must be emphasised as ecodriving can bring significant energy savings. Savings achieved by fluent driving without the need to stop or wait at the traffic lights will be brought about by the implementation of ITS and introducing first priority to trams and buses at intersections. There is no doubt the organization and management should be improved, too. It is essential to adjust the capacity of the fleet and the frequency of service to the truly reported demand, and improve the routes of the lines, at the same time remembering not to limit the supply too much, which could cause a fall in the demand.

References

Aleklett K (2012) Peeking at peak oil. Springer, New York, pp 76–79

BIT (2014) Plan zrównoważonego rozwoju publicznego transportu zbiorowego dla miasta Poznania na lata 2014-2025. BIT, Poznan, pp 42, 43, 122

BP (2014a) BP energy outlook 2035. Summary tables. BP, January. http://www.bp.com/en/global/corporate/about-bp/energy-economics/energy-outlook.html. 12 Aug 2014

BP (2014b) BP statistical review of world energy. Workbook. BP, June

Calthorpe P (2013) Urbanism in the age of climate change. Island Press, Washington

Carlyle R (2013) What would happen to the current fracking activity and subsequent booms generated if oil $/bbl were to drop? "Forbes". http://www.forbes.com/sites/quora/2013/01/08/what-would-happen-to-the-current-fracking-activity-and-subsequent-booms-generated-if-oil-bbl-were-to-drop/. 14 Aug 2014

CNN (2014) http://money.cnn.com/data/commodities/. 11 Aug 2014
COM (2011) 144 final, pp 9–11
Delft (2011) External costs of transport in Europe. Update study for 2008. CE Delft, Infras, Fraunhofer ISI, Delft September 2011, p. 5
Dennis K, Urry J (2009) After the car. Polity Press, Cambridge
EIA (2014) Drilling productivity report for key tight oil and gas regions. U.S. EIA, July
Eurostat (2013) Energy, transport and environment indicators. Edition 2013, Luxembourg
French P, Chambers S (2010) Oil on water. Tankers, pirates and the rise of China. Zed Books, London
Gilbert R, Perl A (2010) Transport revolutions. Moving people and freight without oil. New Society Publishers, Gabriola Island, p 119
Sachs G (2009) The long-term outlook for the BRICs and N-11 post crisis. Global Econ Paper 192:24
GUS (2004) Transport—wyniki działalności w 2004 r., Warszawa
GUS (2013) Transport—wyniki działalności w 2012 r., Warszawa
GUS (2014a) http://stat.gov.pl/bdl/app/dane_podgrup.display?p_id=702691&p_token=0.24858197724444864
GUS (2014b) Miasta w liczbach 2012, Warszawa
Heinberg R (2013) Snake oil. How fracking's false promise of plenty imperils our future. Post Carbon Institute, Santa Rosa, pp 50, 78, 85, 115, 120
Hughes JD (2013) Drill, baby, drill. can unconventional fuels usher in a new era of energy abundance? Post Carbon Institute, Santa Rosa, pp 106, 118, 125
IATA (2013) Fact sheet: fuel, December. http://www.iata.org/pressroom/facts_figures/fact_sheets/Documents/fuel-fact-sheet.pdf. 13 Aug 2014
IATA (2014) Fact Sheet: Industry Statistic, June. http://www.iata.org/pressroom/facts_figures/fact_sheets/Documents/industry-facts.pdf. (13.08.2014)
IEA (2009) Transport, energy and CO_2. Paris, p 126
IEA (2013) World energy outlook 2013. Paris, pp 428–429
IEA (2014) Oil, gas, coal and electricity. Quarterly statistics. First quarter 2014. Paris, pp 8–10
Igliński H (2008) Kongestia transportowa w Poznaniu i wybrane sposoby jej ograniczenia. Transport Miejski i Regionalny 3:6
ITF (2012) Transport outlook 2012. Seamless Transport for Greener Growth, Paris, p 7
KBR (2000) Internal data of the research company
KBR (2013) Internal data of the research company
KPMG (2013) Global retail automotive market. From selling cars on the spot to centrally managing the retail grid. KPMG, August, p 7
Maugeri L (2012) Oil: the next revolution. Geopolitics of energy project. Belfer Center for Science and International Affairs, Harvard University, pp 11–40
MPK (2014) Company internal data
Owen D (2011) Green metropolis. why living smaller, living closer, and driving less are the keys to sustainability. Riverhead Books, Ney York
Sperling D, Gordon D (2009) Two billion cars. Driving toward sustainability. Oxford Press, New York, p 5
Suzuki H et al (2013) Transforming cities with transit. Transit and land-use integration for sustainable urban development. The World Bank, Washington DC
UN (2013) World population prospects. The 2012 revision. Highlights and advance tables. United Nations, New York, p 2
Urry J (2013) Societies beyond oil. Oil dregs and social futures. Zed Books, London, New York, p 101
Yergin D (2013) The quest. W poszukiwaniu energii. Kurhaus Publishing, Warszawa, pp 213–225

Part III
Sustainable Production

Identifying Relationships Between Eco-innovation and Product Success

Marcin Relich

Abstract This chapter is concerned with the study of success factor identification in eco-innovation. Critical success factors are identified on the basis of Enterprise Resource Planning (ERP) database and questionnaires concerning the implementation of eco-innovation. The model of measuring eco-innovation includes indicators connected with fields such as research and development, production, logistics, sales and marketing, as well as eco-innovation implementation that consists of eco-organization, eco-process, and eco-product. The proposed methodology enables the merger of objective indices and subjective judgments with the use of fuzzy logic. In order to identify the relationships between product success and project environment variables, artificial neural networks are used. The proposed approach enables the identification of factors that significantly impact product success. The relationships sought can be further used to forecast the success of a new product that is in the development process and propose changes in the project variables that can increase the chance to develop a successful product.

Keywords Measuring innovation · Eco-organization · Eco-process · Eco-product · Knowledge acquisition · New product development

1 Introduction

Innovation is widely considered a key prerequisite for achieving organisational competitiveness and sustained long-term profits in an increasingly changeable business environment. Consequently, enterprises have to continuously develop new products to grow and mature their innovation capability (Esterhuizen et al. 2012).

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Product innovativeness reflects the degree of information searching, behavioural change and learning effort required by customers to adapt to the new product, and a company's experience with similar product development projects in the past (Langerak and Hultink 2006). Although the success of a new product also depends on environmental uncertainties that are beyond a firm's control, companies can improve the accuracy of new product evaluation (Ozer 2005) and try to recognize the possibilities of improvement of new product development on the basis of their own accessible resources.

A key challenge faced by new product development projects is how to acquire knowledge, sustain innovation rate among products, and manage the project in order to reduce the risk of failure of the product (Cooper 2003). Both the acquisition of outside knowledge (e.g. through market research) and the development of internal knowledge (e.g. through company software databases, questionnaires, etc.) is critical and can help in seeking factors that have had an impact on the success of previous products. However, further considerations focus mainly on the aspect concerning the use of internal databases.

Product development and manufacturing industries have an important role in the transformation of society towards sustainability (Gaziulusoy et al. 2013). Within the area of product innovation, there are several different activities connected with sustainable approaches, for example eco-labelling, environmental management systems (e.g. ISO 14001), environmental legislation, extended producer responsibility, corporate social responsibility and guidance for social sustainability (e.g. ISO 26000). Growing awareness concerning environmental sustainability has become more and more a business reality (Hallstedt et al. 2013). Since the Brundtland report in 1987, a wide debate has emerged on eco-innovation (e.g. eco-design, cleaner production) and sustainability-oriented innovations that can be considered as the integration of ecological and social aspects into products, processes, and organizational structures (Klewitz and Hansen 2014). This report pointed to the importance of companies to create, redesign, adapt, and diffuse environmentally oriented technologies (WCED 1987).

Incentives for sustainable development from an enterprise perspective may include improving company image, increasing profitability, or energizing employees (e.g. Neville et al. 2005; Hallstedt et al. 2013). Moreover, stricter legislation, resource constraints and consumer requests can speed up the adjustment of companies to operating in the field of eco-innovation development and a more sustainable society (e.g. Ammenberg and Sundin 2005; Spangenberg et al. 2010).

Increasingly, environmental issues have been recognized as sources of strategic change (Aragón-Correa et al. 2008). Ecological factors have become part of innovation research (Schiederig et al. 2012), and eco-innovation practices such as cleaner production, life cycle assessments, and eco-design have found their way into companies (Huber 2008). These issues have resulted in the development of a stream of research on sustainability-oriented innovations with a broader focus on environmental, social and, economic dimensions (e.g. Hall 2002; Paech 2007; van Kleef and Roome 2007; Wüstenhagen et al. 2008; Schaltegger and Wagner 2011). Sustainability-oriented innovations require management deliberation on economic, social, and ecological aspects (Hansen et al. 2009; Paech 2007), so that they become integrated into the design of new products, processes, and organizational structures (Rennings 2000; Klewitz and Hansen 2014).

The aim of this research is to develop an approach that identifies the relationships between the success of new eco-products and the key factors in the field of project management and eco-innovation implementation that influence this success. The proposed model contains data from Enterprise Resource Planning (ERP) systems and questionnaires concerning implementation of eco-innovation. Human statements are often based on subjective judgments that can be expressed in an imprecise form. One of the techniques that can be operated with the notation of linguistic variables is fuzzy set theory, which has been chosen to describe the subjective judgments of interviewees.

The originality of this research concerns the proposed model for measuring the success of an eco-product that takes into account the structure of an ERP system and subjective judgments concerning eco-innovation implementation. The proposed methodology enables the identification of key success factors of a product on the basis of the qualitative and quantitative data that may be stored in an ERP system or collected through questionnaires. The relationships between eco-innovation and success of a product are sought with the use of artificial neural networks and can be used for forecasting the success of products that are in the development process, as well as for proposing changes in project management that can increase the chance of developing a successful product.

The remaining sections of this chapter are organised as follows: Sect. 2 presents the measurement of innovation capacity, sustainability in the context of innovation, and elements of eco-innovation implementation. A model of measuring innovation in the context of an ERP database and sustainability-oriented innovations is described in Sect. 3. A methodology for forecasting the success of a product is shown in Sect. 4. An illustrative example of the proposed methodology, which presents the description of eco-product implementation with the use of fuzzy weights, identification of relationships in company's database, and the use of the sought relationships for forecasting and if-what analysis, is presented in Sect. 5. Finally, some concluding remarks are contained in Sect. 6.

2 Background

2.1 Measurement of Innovation Capacity

Many approaches have been proposed to measure the innovation management of companies and identify the conditions of a successful innovation process (Guan et al. 2006; Wang et al. 2008; Chiesa et al. 2009; Boly et al. 2014). Table 1 presents selected approaches to innovation capacity metrics.

The literature review on innovation capacity metrics summarised in Table 1 shows that the majority of the proposed approaches is based on the evaluation

Table 1 Innovation capacity metrics

Authors	Evaluated factors	Aggregation method
Chiesa et al. (1996)	Concept generation	Descriptive profile of the factors
	Process innovation	
	Product development	
	Technological acquisition	
	Leadership	
	Resources	
	Systems and tools	
Yam et al. (2004)	Learning capacity	Parametric identification (multilinear regression)
	R&D capacity	
	Resource allocation	
	Manufacturing capacity	
	Marketing	
	Organizational capacity	
	Strategic planning	
Guan et al. (2006)	Learning	Data envelopment analysis (DEA) (input-output model)
	R&D	
	Manufacturing	
	Marketing	
	Organization	
	Resources	
Wang et al. (2008)	Exploratory factors of innovative companies	Non-additive fuzzy integral
	R&D capacity	Fuzzy multi-criteria decision-making (MCDM)
	Decision aid tools	
	Marketing	
	Manufacturing capacity	
	Capital	
Tsai et al. (2008), Wang and Chang (2011)	Technical innovation technique	Analytic hierarchy process (AHP)
	Product	
	Process	
	Managerial innovation	
	Creativity Marketing	
	Organisation	
	Strategy	
Cheng and Lin (2012)	Strategic planning	Hybrid fuzzy-multi-criteria decision aid (MCDA)
	Marketing	
	Innovation infrastructure	
	Knowledge and skills	
	Technological innovation capabilities	
	External environment	
	Manufacturing capabilities	

(continued)

Table 1 (continued)

Authors	Evaluated factors	Aggregation method
de Medeiros et al. (2014)	Market, law and legislation knowledge	Descriptive profile of the factors
	Interfunctional collaboration	
	Innovation-oriented learning	
	R&D investments	

of multiple factors. These factors are identified as leverage to manage innovation processes. Innovation research often takes into consideration innovation characteristics, innovation types and the hierarchical locus of innovation (Gatignon et al. 2002). Other studies emphasize the importance of measuring input and output to innovation, as well as processes which act on and transform the inputs (Chiesa et al. 2009) or suggest that metrics are tailored in three views: capability, resources and leadership (Muller et al. 2005). According to Wang et al. (2008), measuring innovation capacities requires simultaneous consideration of multiple quantitative and qualitative criteria that can concern resource allocation capability, capability to identify competitors' strategy and satisfy market requirements by developing new products.

The concept of the use of multiple quantitative and qualitative criteria to measure eco-innovation, and in the context of input and output variables is considered in this study. Measuring innovation according to quantitative criteria can be based on data that is stored in an information system within the enterprise (e.g. ERP system). The issue of access to data and the use of ERP systems to evaluate the new product development process is neglected in the above approaches. Moreover, the presented approaches reveal the scarcity of the use of fuzzy-neural techniques to identifying the key factors of product success. This provides the motivation to develop a model of measuring eco-innovation that is based on quantitative data from ERP systems and qualitative data collected from questionnaires concerning eco-innovation implementation in the dimensions such as organization, process, and product.

2.2 Sustainability and Innovation

The organizational-level concept of company sustainability can be considered as systematic management efforts by enterprises to balance environmental and social with economic goals in order to minimize harm to and increase benefits for natural environments and societies (e.g. Dyllick and Hockerts 2002). Companies often focus on or start with improvements in either environmental or social dimensions in their activities toward sustainability (Klewitz and Hansen 2014). Innovation is an important means in the context of sustainable development (Hansen et al. 2009; Schaltegger and Wagner 2011). It may be defined, in general, as the implementation of a new or significantly improved product (e.g. change in product properties), process (e.g. changed delivery methods), marketing method (e.g. new product packaging) or organizational method (e.g. changes in workplace organization) in business practices, workplace organization, or external relations (OECD 2005). It should be emphasized that innovations need to be successfully diffused in the market (e.g. products) or implemented (e.g. processes) to achieve an economic impact, that is, go beyond inventions (OECD 2005). An innovation has to have a significant degree of novelty for the firm (be it self-developed or adopted) and can also be new to the market or world (OECD 2005).

2.3 Eco-innovation Implementation

Eco-innovations are considered as one of the key factors for companies directing their business activities toward sustainability through innovation. Environmental issues are now recognized as sources of strategic change and drivers for innovation strategies (Aragón-Correa et al. 2008). Eco-innovations represent new or enhanced processes, organizational forms, as well as products or technologies that are beneficial to the environment in that they reduce or avoid negative environmental impacts (Rennings 2000; OECD 2005; Beise and Rennings 2005). Each of these three general types is further elaborated with regard to the environmental dimension (Cheng and Shiu 2012; Klewitz and Hansen 2014):

- Organizational innovations concern commitment to implementing new forms of eco-innovation management. Eco-organizations cannot reduce environmental impact directly, but they can facilitate the implementation of eco-processes (e.g. in manufacturing) and eco-product innovations. The implementation of eco-innovation in eco-organizations includes eco-training programs, eco-product design programs, the introduction of eco-learning techniques, the creation of management teams to deal with eco-issues, and eco-management systems.
- Process innovations refer to the introduction of manufacturing processes that lead to reduced environmental impact, such as closed loops for solvents, material recycling, or filters. Eco-process implementation involves the improvement of existing production processes or the addition of new processes to reduce environmental impact. New processes can be additive solutions or be integrated into production processes through substitution of inputs, optimization of production, or reclamation of outputs.
- Product innovations are improvements or entirely new developments of products and services. For instance, eco-design may improve products through more eco-benign materials (e.g. organic, recycled materials), high durability, low energy consumption while the development of environmental or sustainable technologies (e.g. renewable energy technologies) represent entirely new products (Hart and Milstein 2003; van Hemel and Cramer 2002). Because the principal environmental impact of many products stems from their use (e.g. fuel consumption and CO_2 emissions of cars) and disposal (e.g. heavy metals in

batteries), eco-product implementation focuses mainly on a product's life cycle in order to reduce environmental impact. According to Pujari et al. (2004), product life cycle analysis involves all aspects of a product from its creation, through its use, to its disposal.

The above-described dimensions of eco-innovation implementation constitute a model of measuring innovation that is elaborated in the next section.

3 Model of Measuring Innovation

In general there are two approaches to collect data concerning innovation and use it to the measurement of innovation. The first is connected with benchmarking and the second with the internal assessment of innovation performance in a company. Benchmarking allows a company to compare its performance, relative to an average or to other firms. It leads to better understanding of the company's current practices and makes use of systematic comparison of practices and performance with those of others, in order to develop improvement actions and sustain company innovativeness for long-term growth (Maravelakis et al. 2006). However, the usefulness of benchmarking is limited by the gathering of reliable data concerning competition. Self-assessment of measures of innovation may also be prone to bias but are based on data from the company (e.g. financial statements, bill of costs, employees' statements) and seem to be more objective than benchmarking, therefore, this approach is further considered.

Data for measuring eco-innovation can be collected from questionnaires (concerning for instance innovation-oriented learning, organizational techniques, communication in new product development, etc.) or retrieved from a company's information system (e.g. from an ERP database). ERP systems operate, collect and store data connected with the daily activities of enterprises (e.g. production orders) as well as information on previous product development projects (Relich 2013). In recent years, the advancement of information technology in business management processes has placed ERP system as one of the most widely implemented business software tools in various enterprises. The use of an ERP system is especially significant in production enterprises, in which the number of operational processes is enormous. A typical ERP system consists of modules that reflect the activity of an enterprise, e.g. sales and marketing, purchasing and material management, manufacturing, R&D, accounting and finance (May et al. 2013).

The proposed model consists of variables that describe product success in terms of its innovativeness (output data) and variables that are suspected of having significant impact on product success (input data). The model has been elaborated on the basis of a previous study that included observation of successful companies and analysis of literature (see Table 1) as well as from the perspective of data stored in an ERP system, including the project management module. The use of an ERP system in the context of the product innovation process and product life cycle is presented in Fig. 1. Data concerning production, logistics (including materials

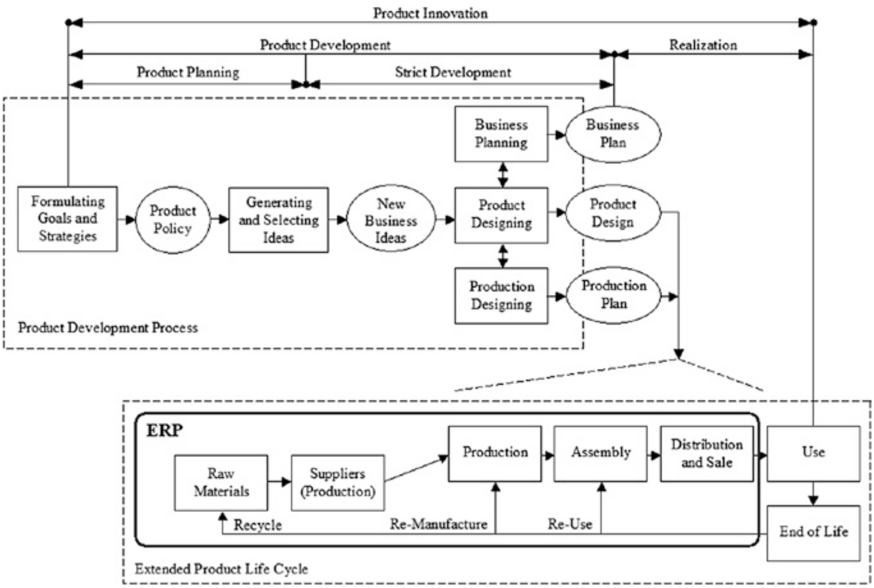


Fig. 1 The product innovation process with product life cycle [adapted from Sarkis (2003) and Hallstedt et al. (2013)]

management, suppliers, warehouses, distribution), and sales is stored in an ERP database and can be further used for designing products and production.

The set of potential factors of product success has been derived from an extensive exploratory and mainly descriptive study with a qualitative research approach. The study is based on a review of literature and previous research results. In contrast to theoretical studies and research on how sustainability can be integrated in product development, this study contributes to the use of an ERP system to measure implementation of eco-innovation and identify the key factors that impact on the success of product.

Product success can be measured in sales volume, net profit, export rate, success rate of R&D products, market share, etc. Taking into account the different product lifetime and return on product development expense, return on investment, sales volume, and profitability, are chosen as the measure of product success for the output variables. In turn, the input variables contain the field of R&D, production, logistics, sales and marketing, as well as eco-innovation implementation. Each of these fields consists of performance indicators that are presented in Table 2. This hierarchical structure allows the decision-maker to compare the influence of each field on the innovation metrics. Figure 2 illustrates an approach dedicated to identifying the key success factors for improving the new product development process. The input-output system enables the identification of critical factors that individually or jointly affect product success and finally company's competitiveness.

Data in the model contains both objective indices (e.g. from ERP system) and subjective judgements that depend on the employee's knowledge and experiences.

Table 2 Performance dimensions and indicators in evaluating the success of products

Performance dimension	Performance indicator
R&D	Planned cost of new product development
	Planned time of new product development
	Percentage of R&D annual investment in sales volume
	Number of team members for developing a new product
	Number of ideas for developing a new product
	Number of similar products in design platform to a new product
	Number of R&D employees leaving the company to total employees in R&D in the last year
Production	Percentage of manufactured parts that meet the required design specifications
	Product quality level (the number of failures in a prototype)
	Time from design to final product
	Number of employees with management and engineer's experience
	Productive capacity (actual/maximal)
	Number of resource overloads
	Number of work orders
Logistics	Number of suppliers selling required materials
	Number of subcontractors
	Delivery duration
	Delay of delivery
	Changes of price list
	Number of materials in warehouses
	Number of warehouse transfers
Sales and marketing	Percentage of budget dedicated to customer analysis or verification
	Number of interactions with customers during the project
	Number of customers included in the project team
	Number of changes in product specification according to customer's
	demand and complaints
	Marketing expenditures for a new product
	Number of creative promotion activities and innovative advertisements
	Number of competitive products on the market
Eco-organization implementation	Our unit management often uses novel systems to manage eco-innovation
	The use of eco-innovation is one of our unit management policies
	Our unit management often collects information on eco-innovation trends
	Our unit management often actively engages in eco-innovation activities
	Our unit management often communicates eco-innovation information with employees
	The concept of eco-innovation has been applied to our unit management

(continued)

Table 2 (continued)

Performance dimension	Performance indicator
	Our unit management often invests a high ratio of R&D in eco-innovation
	Our unit management often views outward environmental pressure as reasonable
	Our unit management often communicates experiences among various departments involved in eco-innovation
Eco-process implementation	Our unit often updates manufacturing processes to protect against contamination
	Our unit often updates manufacturing processes to meet standards of environmental law
	Our unit often employs new manufacturing processes so as not to contaminate the environment
	Our unit often introduces new technologies into manufacturing processes to save energy
	Our unit often updates equipment in manufacturing processes to save energy
	Our unit often establishes recycling systems into manufacturing processes
Eco-product implementation	Our unit often emphasizes developing new eco-products through new technologies to simplify their packaging
	Our unit often emphasizes developing new eco-products through new technologies to simplify their construction
	Our unit often emphasizes developing new eco-products through new technologies to simplify their components
	Our unit often emphasizes developing new eco-products through new technologies to easily recycle their components
	Our unit often emphasizes developing new eco-products through new technologies to easily decompose their materials
	Our unit often emphasizes developing new eco-products through new technologies to rarely use processed materials
	Our unit often emphasizes developing new eco-products through new technologies to use natural materials
	Our unit often emphasizes developing new eco-products through new technologies to reduce waste as much as possible
	Our unit often emphasizes developing new eco-products through new technologies to reduce damage by waste as much as possible
	Our unit often emphasizes developing new eco-products through new technologies to use as little energy as possible

The objective indices can be specified in a precise form as crisp values and stored in or retrieved from an ERP database. In turn, the subjective judgements can be collected from questionnaires, described in the imprecise form as fuzzy numbers. The subjective judgements concern, for example, the field of communication and creating a working environment that impacts on new product development, and finally on product innovativeness. Table 2 presents a sample of performance indicators in the context of measuring innovativeness. The choice of these indicators

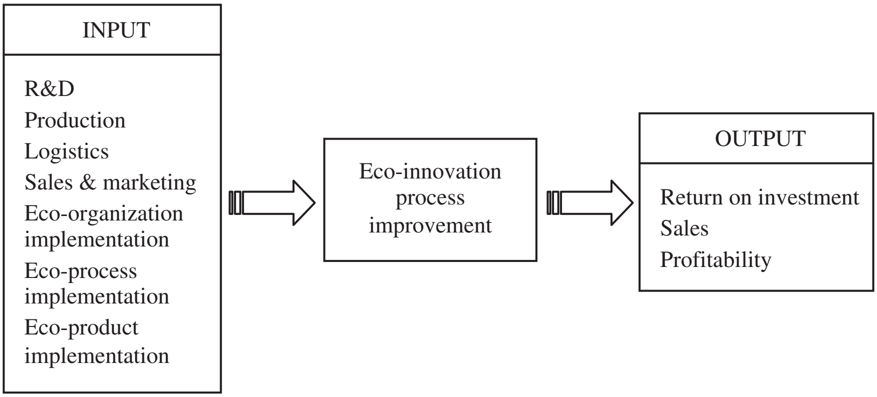


Fig. 2 Input-output system of innovativeness process improvement

has been determined on the basis of literature review (e.g. Cheng and Shiu 2012) and their potential impact on the output variables.

Performance dimensions presented in Table 2 correspond to the fields occurring in an industrial enterprise that develops new products. These fields refer to the departments in an enterprise, for instance, R&D, manufacturing, logistics, marketing and sales, and their performance indicators can be retrieved from an ERP database. Performance indicators for marketing take into account the customer perspective that places emphasis on customer relationship management, including the identification of customer requirements and complaints. The field of eco-innovation implementation includes three dimensions: eco-organization, eco-process and eco-product, and is based on the questionnaires.

The presented model is based on assumptions such as access to data of past successful and unsuccessful projects, including their cost, duration, team members, and current market position of a product, as well as measurement of eco-innovation implementation with the use of a questionnaire, whose results can be codified and quantified. The model enables the identification of relationships between the success of a new product and the key factors in the field of project management that influence this success, and can be considered in terms of learning from past experiences and failures to improve the innovativeness of products in the development process.

The solution of the considered problem includes seeking answers to the following questions: is there a significant relationship between the project management parameters and the success of a product? Do accessible resources in a company improve the effectiveness of project management, and finally, the success rate of a product? What parameters should the current projects be given to increase their chances of success? What set of input variables has the strongest impact on the output variables (the success of a product)? The sought relationships can indicate the directions of improvement of products that are in the development process and, as a result, increase the chance to develop a successful product and support the company's innovativeness.

4 Methodology for Forecasting Success of a Product

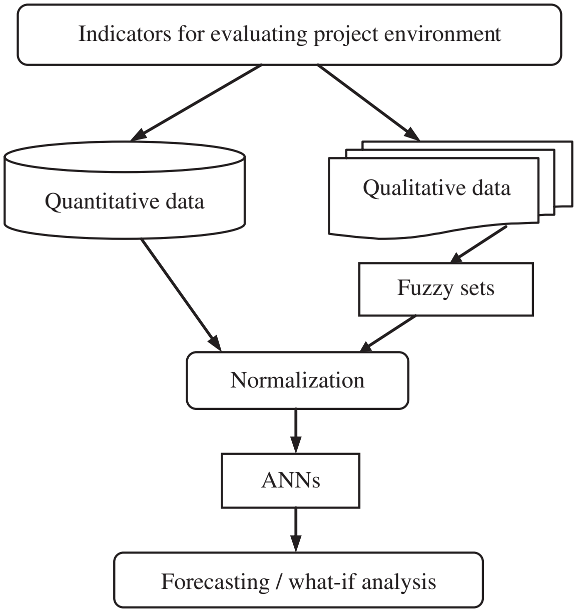
The proposed method aims to improve a new product development in order to increase the chances for the eco-product success after its launch. This approach assumes that on the basis of previous projects it is possible to identify the relationships between project parameters and product success, and use them to indicate the possible directions for products that are in the development process. One of the characteristics of the developed approach is that it takes into account qualitative and quantitative data and enables the identification of relationships in an enormous database. For seeking relationships in large datasets, artificial neural networks (ANNs) have been chosen. In turn, for description of the qualitative data, fuzzy set theory has been used.

Figure 3 presents the procedure for identifying the factors that have impacted on product success and forecasting the success of products that are in the development process.

4.1 Fuzzy Numbers for Measuring Implementation of Eco-innovation

Measurement of eco-innovation implementation is based on a questionnaire that includes closed-ended questions concerning, for instance, potential barriers to communication during project execution such as lack of trust among project team

Fig. 3 Project performance evaluation model



members, resistance to sharing information among members, effectiveness of team discussions, etc. The survey aims to identify the attitudes of employees towards implementation of green methods in organizational, manufacturing, and designing processes. Inquiries for measuring eco-innovation implementation are presented in Table 2.

The statements of respondents result from subjective judgments and are usually specified in the imprecise form, for example, as the following phrases: "strongly agree", "agree", "neither agree nor disagree", "disagree", "strongly disagree". A respondent can choose one or more of these linguistic variables. If a respondent chooses a limited number of linguistic variables to answer to a question, then the fuzzy set theory can be used to evaluate the implementation of eco-innovation. Moreover, the answers from team members may differ significantly depending on the individual perceptions or personality of the respondent (Relich and Jakabova 2013). Therefore, the evaluation is conducted in an uncertain and fuzzy environment. Compared to traditional binary sets (where variables may take on true or false values), fuzzy logic variables may have a value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the value may range between completely true and completely false. The notion of truth can be considered as a means of representing and reasoning with partial knowledge which is closer to human subjective judgments that precise statements.

Fuzzy set theory is based on the concept of fuzzy set membership, where the membership functions are used to calculate the degree of membership of a fuzzy eco-innovation metric (indicator) to different sets, expressed by linguistic terms such as e.g. very low, low, medium, high, and very high (see Fig. 4). The shape of a fuzzy number and the scale of a linguistic variable depends on the user's needs. In this study, a subjective judgement concerning level of indicator is assigned to the scale from 1 to 5.

Traditional questionnaires concerning implementation of eco-innovation usually include a checklist for answers, and allow the respondent to choose only one answer for each item. However, problems arise when the respondent has more than one answer. Asking the respondent to make only one decision for each item may result in the data becoming inaccurate. Hence, to improve the traditional survey, this research proposes the use of fuzzy logic. An improvement over the

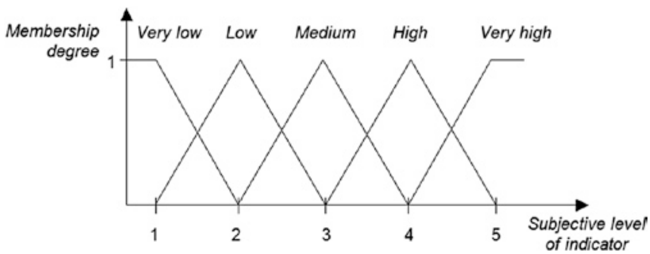


Fig. 4 Membership function

Table 3 Evaluation of using natural materials for developing new eco-products

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Corresponding semantics
	1	2	3	4	5	
Respondent 1		0.7	0.3			Partial disapproval
Respondent 2					1	Absolutely approval
Respondent 3			0.4	0.6		Partial approval
Respondent 4	0.8	0.2				Almost total disapproval

shortcomings of the original scale is that the respondent can make several answers for each item, and can give each answer as a percentage. If the respondents can express their judgement as a degree of membership corresponding to the linguistic variables, it becomes possible to give a real number between 0 and 1. A sample of answers to the statement "Our unit often emphasizes developing new eco-products through new technologies to use natural materials" is illustrated in Table 3.

The weight corresponding to a linguistic variable is different among respondents (employees in an enterprise), since personal preferences are subjective and fuzzy according to complicated, diverse, and indeterminate human behaviour.

4.2 *Artificial Neural Networks for Forecasting*

Artificial neural networks (ANNs) are an important class of tool for quantitative modelling. Today, neural networks are treated as a standard data mining tool and used for many data mining tasks such as pattern classification, time series analysis, prediction, and clustering. Neural networks are computing models for information processing and are particularly useful for identifying the fundamental relationship among a set of variables or patterns in the data. The popularity of neural networks is due to their powerful modelling capability for pattern recognition. Several important characteristics of neural networks make them suitable and valuable for data mining. First, as opposed to the traditional model based methods, neural networks do not require several unrealistic a priori assumptions about the underlying data generating process and specific model structures. Moreover, the mathematical property of the neural network in accurately approximating or representing various complex relationships has been well established. Furthermore, neural networks are nonlinear models. As real world data or relationships are inherently nonlinear, traditional linear tools may suffer from significant biases in data mining. Neural networks with their nonlinear and nonparametric nature are more effective for modelling complex data mining problems. Finally, neural networks are able to solve problems that have imprecise patterns or data containing incomplete and noisy information with a large number of variables. This fault tolerance feature is appealing for data mining problems because real data is usually noisy and does not follow clear probability structures which are typically required by statistical models (Zhang 2010).

The proposed approach enables the description of subjective judgements and objective indices taking into account the crisp and fuzzy numbers. For instance, the number of project team members may be described in the accurate form, whereas the resistance of sharing information may be described in the fuzzy form. As a result, the evaluation of success rate for a new product seems to be more complete and suitable. The application of fuzzy set theory allows the linking of numeric information (gained from ERP system) with linguistic information (gained from employees). The next section presents an example of the use of the proposed approach to forecast net profit value for a product in the development process.

5 Proposed Methodology Example

The illustrative example consists of three parts that refer to the presented methodology:

- using fuzzy weights to describe the subjective judgement of employees,
- using ANNs to determine the relationships between input output variables,
- forecasting of net profit for new product and if-what analysis for determining directions of changes.

5.1 Description of Eco-product Implementation with the Use of Fuzzy Weights

The use of the proposed methodology to evaluating implementation of eco-innovation is presented in Table 4.

The procedure of obtaining the score for each indicator consists of the following stages:

1. Evaluation of the importance of each indicator by employees (e.g. from R&D department)
2. Calculation of the average of fuzzy values for each respondent
3. Calculation of the average of fuzzy values for each indicator, e.g. "Our unit management often uses novel systems to manage eco-innovation"
4. Calculation of the score for each eco-dimension (organization, process, product)

For example, on the basis of weights presented in Table 4, the indicator "Our unit management often uses novel systems to manage eco-innovation" is evaluated as follows: respondent 1 chose the weight 0.3 for "Neither agree nor disagree" (3), and the weight 0.7 for linguistic variable "Agree" (4), which gives a result of 3.7 $(0.3 \cdot 3 + 0.7 \cdot 4)$.

Table 4 Evaluation of eco-innovation implementation

Indicator	Respondent	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Score–team member	Score–indicator
		1	2	3	4	5		
Our unit management often uses novel systems to manage eco-innovation	1			0.3	0.7		3.7	3.875
	2				1		4	
	3			0.4	0.6		3.6	
	4				0.8	0.2	4.2	
…	…						…	…
Our unit often emphasizes developing new eco-products through new technologies to use as little energy as possible	1		0.5	0.5			2.5	2.975
	2			0.8	0.2		3.2	
	3			0.7	0.3		3.3	
	4		0.1	0.9			2.9	

5.2 *Identification of Relationships*

In this research, a multilayer feed-forward neural network has been applied by the use of the back-propagation algorithm, and optimisation weights according to the Levenberg-Marquardt algorithm (LM), gradient descent momentum and an adaptive learning rate (GDX) algorithm. The neural network structure has been determined in an experimental way, by the comparison of learning and testing sets for the different number of layers and hidden neurons. RMSE have been calculated as the average of 20 iterations for each structure of neural network with a number to the extent of 20 hidden neurons.

In order to eliminate the overtraining of ANN (too strict function adjustment to data) and to increase the estimation quality, the data set has been divided into learning (P1-P62) and testing sets (P63-P77). The learning process of ANN aims to seek the minimal error in the testing set. The results as the root mean square errors (RMSE) for the learning and testing sets are presented in Table 5. The results for ANNs are compared with the linear model calculating according to the ordinary least squares method.

The results presented in Table 5 indicate that the least error in the testing set was generated with the use of ANN trained according to the GDX algorithm. The least RMSE in the learning set was calculated according to the LM algorithm

Table 5 Comparison of RMSE for different models

Model	RMSE	
	Learning set	Testing set
ANN—GDX	2.0106	3.2662
ANN—LM	0.00003	4.4569
Linear model	0.9620	15.5144

but the RMSE for the testing set was greater than that obtained through the use of the GDX algorithm, which can result from the overtraining of ANN and the lack of its generalization abilities. It is noteworthy that RMSE generated with the use of ANNs is smaller for testing set than RMSE for the linear model. In the next step, the ANN structure can be used to forecasting of the dependant variable (net profit for a product that is in the development process).

5.3 Forecasting and If-What Analysis

The non-linear relationships between input and output data are stored in the structure of a neural network. If new data for a product in the development process is lead to the trained network, then the result is the forecast of net profit for a product. Let us assume that for the actual project data, 35 variables are input to ANN. As a result, the output of ANN indicates the projected net profit for a product. Moreover, the use of what-if analysis can indicate the directions of changes in project environment that should increase the probability of net profit for the developed product (Relich 2014).

Table 6 presents a two-dimensional analysis for number of ideas and number of team members in a new product development. For instance, if number of team members equals 4 and number of ideas generated in the development process of product equals 40, the forecast of net profit equals 4.84 monetary units. The decision-maker can use this analysis for simulating net profit value for various criteria.

The presented analysis can be extended to support a higher number of dimensions (for others input variables) and towards the sensitivity analysis to support the decision-maker in the choice of project environment parameters that can be changed.

Table 6 Example of what-if analysis

Number of ideas for developing a new product	Number of team members for developing a new product	
	4	5
30	3.76	3.90
35	3.94	4.35
40	4.84	5.14
45	7.82	9.42
50	11.32	12.41

6 Conclusions

A key component in the success of industrial companies is their ability to sustain innovativeness, i.e. the ability to continuously develop innovations. The rapid evolution of technology, fast changing markets, environmental legislation and increasingly demanding customers has led to a need to develop high quality new products more efficiently and effectively, and according to green and sustainable manufacturing. Development of new and potentially successful products is a crucial process in maintaining a company's competitive position. To increase the chance to achieve a successful product, the identification of key success factors of innovation is needed.

The presented approach aims to identify the key success factors of past products for improving the innovation of new products that are in the development process. The data is collected from employees who evaluate the implementation of eco-innovation, along with data retrieved from ERP systems, which are now being used by more and more industrial enterprises. The proposed method takes into account both qualitative and quantitative data, and uses the neural network techniques and fuzzy logic approach to identify the factors that have a significant impact on product success. These relationships are further used to forecast the success of products that are in the development process.

This study offers insight into how decision-makers' can seek to manage product development in a more sustainable way, by exploring how product-developing companies can use an ERP system to identify the key factors of product success and improve the process of development of innovation. Moreover, by identifying seven areas (R&D, production, logistics, sales and marketing, eco-organization, eco-process, eco-product) and several indicators in each area, this study contributes to the understanding of what areas/indicators are especially significant in developing new products.

The proposed approach presents new insights and advances to literature on the topic of measurement of the implementation of eco-innovation, using fuzzy numbers to describe subjective judgments and the artificial neural network to seek the relationships between the implementation of eco-innovation and success of a product. The benefits of the presented approach include the use of the sought relationships to identify a set of the most promising products from within the development process, and determine the most profitable proportion of eco-products in a company's product range. Consequently, these actions enable an increase of company's competitiveness.

The main limitation of the proposed approach is connected with considering new products as modifications of previous products that belong to the same product line. In the case of radical improvements in a new product variant, there can be a lack of sufficient data to identify key success factors. Moreover, the presented approach is based on data from ERP systems, which are mainly used in medium and large companies, rather than in small businesses. Future research could be focused on the development of the proposed approach towards a reduction of the mentioned limitations.

References

Ammenberg J, Sundin E (2005) Products in environmental management systems: drivers, barriers and experiences. J Clean Prod 13(4):405–415

Aragón-Correa JA, Hurtado-Torres N, Sharma S, García-Morales VJ (2008) Environmental strategy and performance in small firms: a resource-based perspective. J Environ Manage 86:88–103

Beise M, Rennings K (2005) Lead markets and regulation: a framework for analyzing the international diffusion of environmental innovations. Ecol Econ 52:5–17

Boly V, Morel L, Assielou G, Camargo M (2014) Evaluating innovative processes in French firms: methodological proposition for firm innovation capacity evaluation. Res Policy 43:608–622

Cheng CC, Shiu EC (2012) Validation of a proposed instrument for measuring eco-innovation: an implementation perspective. Technovation 32:329–344

Cheng YL, Lin YH (2012) Performance evaluation of technological innovation capabilities in uncertainty. Procedia Soc Behav Sci 40:287–314

Chiesa V, Coughlan P, Voss C-A (1996) Development of a technical innovation audit. J Prod Innov Manage 13:105–136

Chiesa V, Frattini F, Lazzarotti V, Manzini R (2009) Performance measurement in R&D: exploring the interplay between measurement objectives, dimensions of performance and contextual factors. R&D Manag 39(5):487–519

Cooper LP (2003) A research agenda to reduce risk in new product development through knowledge management: a practitioner perspective. J Eng Tech Manage 20(1):117–140

de Medeiros JF, Ribeiro JLD, Cortimiglia MN (2014) Success factors for environmentally sustainable product innovation: a systematic literature review. J Clean Prod 65:76–86

Dyllick T, Hockerts K (2002) Beyond the business case for corporate sustainability. Bus Strategy Environ 11(2):130–141

Esterhuizen D, Schutte CSL, du Toit ASA (2012) Knowledge creation processes as critical enablers for innovation. Int J Inf Manage 32:354–364

Gatignon H, Tushman M, Smith W, Anderson P (2002) A structural approach to assessing innovation. Manage Sci 48(9):1103–1122

Gaziulusoy A, Boyle C, McDowall R (2013) System innovation for sustainability: a systemic double-flow scenario method for companies. J Clean Prod 45:104–116

Guan JC, Yam RCM, Mok CK, Ma N (2006) A study of the relationship between competitiveness and technological innovation capability based on DEA models. Eur J Oper Res 170(3):971–986

Hall J (2002) Sustainable development innovation: a research agenda for the next 10 years. J Clean Prod 10:195–196

Hallstedt SI, Thompson AW, Lindahl P (2013) Key elements for implementing a strategic sustainability perspective in the product innovation process. J Clean Prod 51:277–288

Hansen EG, Grosse-Dunker F, Reichwald R (2009) Sustainability innovation cube: a framework to evaluate sustainability-oriented innovations. Int J Innov Manag 13:683–713

Hart S, Milstein M (2003) Creating sustainable value. Acad Manag Executive 17:56–67

Huber J (2008) Technological environmental innovations (TEIs) in a chain analytical and life-cycle-analytical perspective. J Clean Prod 16:1980–1986

Klewitz J, Hansen EG (2014) Sustainability-oriented innovation of SMEs: a systematic review. J Clean Prod 65:57–75

Langerak F, Hultink EJ (2006) The impact of product innovativeness on the link between development speed and new product profitability. J Prod Innov Manage 23(3):203–214

Maravelakis E, Bilalis N, Antoniadis A, Jones KA, Moustakis V (2006) Measuring and benchmarking the innovativeness of SMEs: a three-dimensional fuzzy logic approach. Prod Plann Control 17(3):283–292

May J, Dhillon G, Caldeira M (2013) Defining value-based objectives for ERP systems planning. Decis Support Syst 55:98–109

Muller A, Välikangas L, Merlyn P (2005) Metrics for innovation: guidelines for developing a customized suite of innovation metrics. Strategy Leadersh 33(1):37–45
Neville BA, Bell SJ, Bülent M (2005) Corporate reputation, stakeholders and the social performance-financial performance relationship. Eur J Mark 39(9/10):1184–1198
Organisation for Economic Co-operation and Development (OECD 2005) Oslo manual. Guidelines for collecting and interpreting innovation data, 3rd edn. OECD Publishing, Paris
Ozer M (2005) Factors which influence decision making in new product evaluation. Eur J Oper Res 163:784–801
Paech N (2007) Directional certainty in sustainability-oriented innovation management. In: Lehmann-Waffenschmidt M (ed) Innovations towards sustainability. Conditions and Consequences. Physica, Heidelberg, pp 121–140
Pujari D, Peattie K, Wright G (2004) Organizational antecedents of environmental responsiveness in industrial new product development. Ind Mark Manage 335:381–391
Relich M (2013) Knowledge acquisition for new product development with the use of an ERP database. In: Proceedings of the federated conference on computer science and information systems, pp 1285–1290
Relich M, Jakabova M (2013) A decision support tool for project portfolio management with imprecise data. In: Proceedings of the 10th international conference on strategic management and its support by information systems, pp 164–172
Relich M (2014) A declarative approach to new product development in the automotive industry. Environmental Issues in Automotive Industry. Springer, Berlin, pp 23–45
Rennings K (2000) Redefining innovation—eco-innovation research and the contribution from ecological economics. Ecol Econ 32:319–332
Sarkis J (2003) A strategic decision framework for green supply chain management. J Clean Prod 11(4):397–409
Schaltegger S, Wagner M (2011) Sustainable entrepreneurship and sustainability innovation: categories and interactions. Bus Strategy Environ 20:222–237
Schiederig T, Tietze F, Herstatt C (2012) Green innovation in technology and innovation management: an exploratory literature review. R&D Manag 42:180–192
Spangenberg JH, Alastair FL, Blincoe K (2010) Design for sustainability: the interface of sustainable production and consumption. J Clean Prod 18(15):1485–1493
Tsai MT, Chuang SS, Hsieh WP (2008) Using analytic hierarchy process to evaluate organizational innovativeness in high-tech industry. In: Proceedings of the decision sciences institute 2008 annual meeting, Baltimore, pp 1231–1236
van Hemel C, Cramer J (2002) Barriers and stimuli for eco-design in SMEs. J Clean Prod 10:439–453
van Kleef J, Roome N (2007) Developing capabilities and competence for sustainable business management as innovation: a research agenda. J Clean Prod 15:38–51
Wang CH, Lu IY, Chen CB (2008) Evaluating firm technological innovation capability under uncertainty. Technovation 28:349–363
Wang TJ, Chang L (2011) The development of the enterprise innovation value diagnosis system with the use of systems engineering. In: Proceedings of the international conference of system science and engineering, pp 373–378
World Commission on Environment and Development (WCED 1987) Report of the world commission on environment and development: "our common future". General assembly document A/42/427. http://www.un-documents.net/wced-ocf.htm. Accessed June 2014
Wüstenhagen R, Hamschmidt J, Sharma S, Starik M (eds) (2008) Sustainable innovation and entrepreneurship. Edward Elgar, Cheltenham
Yam RC, Guan JC, Pun KF, Tang EP (2004) An audit of technological innovation capabilities in Chinese firms: some empirical findings in Beijing, China. Res Policy 33:1123–1140
Zhang GP (2010) Neural networks for data mining. In: Maimon O, Rokach L (eds) Data mining and knowledge discovery handbook, 2nd edn. Springer, New York, pp 419–444

Ergonomics as Significant Factor of Sustainable Production

Agnieszka Kujawińska, Katarzyna Vogt and Fryderyk Wachowiak

Abstract Europe 2020 is development strategy set by European Union for next decade. According to José Manuel Barroso (2014) in EU continuously changing intelligent and sustainable economy growth is needed as it is favorable not only to put attention and protection about natural environment and ecosystem but also to bigger proactive social commitment. Parallel work on these priorities should help EU organization as also member countries in economy prosperity grow in global perspective through increase of employment, productivity, social cohesion. Moreover it should be achieved also by negative influence on environment downscaling (especially in waste management) and bigger employers responsibility awareness of working conditions.

Keywords Ergonomics · Sustainable production · Human · Development

1 Sustainable Development and Social Responsibility of Enterprise

Definition of sustainable development formulated in 1987 related to development which satisfy current needs of society and at the same time keeping chances for future generations to fulfill it also (United Nations 1987). Moreover authors underline that this principle should become binding rule not only for nations, governments, authorities, but also for manufacturing companies. Definition was described in details by United Nations Organization in 2002 (UNO) as quoted: "sustainable development is (…) a development that satisfy basic needs of people, preserve, protect and recover health and integrity of Earth ecosystem, without threats of impossible needs satisfaction by future generations and without exceeding long-term Earth ecosystem volume limits" (Światowy Szczyt Zrównoważnego Rozwoju, Johannesburg 2002).

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Sustainable development definition determines understanding of economics basis in another way until now. The essence of economics according to balanced development rules is taking into consideration into evaluation of decision making process its influence on social as also natural environment in long-term perspective. To fulfil that requirement or principle simultaneously analysis and implementation of economic, ecologic and social processes should be done. First area is interpreted as economics growth maintenance. Second area relates to protection of natural resources and environment for future generations. The last area refers to companies responsibility for employees. For example companies should secure access to work, food, medical care as also other issues. Important aspect from company point of view is also approach to processes. Manufacturing process should not only be associated with main production processes but also with supporting activities as an example machine maintenance (Jasiulewicz-Kaczmarek 2013).

According to Westgard sustainable manufacturing system should be defined in long-term perspective and refer to joint consideration of competitive efficiency and working conditions (Westgaard and Winkel 2011).

Sustainable development in case of company often is associated with Corporate Social Responsibility (CSR) and fact that companies as voluntarily takes into consideration social interest, environment protection and relations with different suppliers while company strategy creation.

Idea of CMR should be considered multidimensional with regard to many factors, for example globalization, media growth as also competitiveness as also social awareness increase. Hence, CSR shape and form of social responsibilities presented in Table 1 in particular company are dependent on economic, political and social aspects.

In literature based on Corporate Social Responsibility subject, issues relate to functioning of big companies, concerns, small and micro companies as well (Gellert 2009). Research results presented in literature confirm that manufacturing companies in aspect of sustainable production more often try to implement proper practices with the aim of securing health and work safety (Cleal 2009). European Agency for Safety and Health at Work (EU-OSHA) with headquarter in Bilbao underline that work safety is one of integral part of business social responsibility conception and employees belong to key stakeholders of each organization (EU-OSHA 2012).

Aspects of challenges that relates to demographic issue cannot be left and not discussed while indicating main trends important for business. Demographic forecast describing an issue of UE communities aging (in 2060 almost every third person among 517 million EU citizens will be 65 or even more) should cause changing way of thinking about employees, their psychophysical abilities and in sequence also working conditions adjustment to employee's needs (change of work places ergonomics). Employers will need to manage adjustment of work mode, work ranges as also equipment availability to needs of older employees (Forum Odpowiedzialnego Biznesu 2014).

Recommendations given to companies that plan to release and execute assumptions of business social responsibilities with reference to employees include activities/actions as follows:

Table 1 Social responsibility forms

Internal	External
Employees well-being: medical care, help in paying debt, sick leave, fringe benefits due to situation caused by employers	*Natural environment*: contamination minimization, below level stated in norms even if competitors do not aim at that that, energy savings (especially not renewable sources)
Working conditions: standards of workplace environment increase, social benefits beyond current rules/norms apply	*Products*: taking into consideration risks and threats that result from careless products usage by customers
Work tasks designing: Employees satisfaction increase more that economic efficiency, fatigue in work limitation aspiration, work diversity	*Market and marketing/brand*: not selling products on particular markets, ethical standards for advertisement
Psychophysical abilities and limitations awareness: day and night rhythm, shift work system, psychical disorder/load at work, anthropometric dimensions/ranges, musculoskeletal disorders, reasoning and taking decision abilities (Więcek-Janka 2008)	*Supplier*: fair commercial rules, "black" supplier list Employment: positive discrimination favouring minorities, employment stop
	Culture: activity in aid of local community, new employees adaptation process, company culture and language

Source Based on Lewicka-Strzalecka (1999)

- working conditions improvement (with consideration to safety and hygiene of work) and job satisfaction increase,
- balance between private and occupational life maintenance,
- equal chances of job accessibility and proper working condition for all employees assurance,
- occupational competences system implementation in organization,
- trainings and occupational development assurance for employees (job development paths planning, needs versus talents),
- organization brand creation thorough aware personal policy,
- assurance of effective communication with employees and in relation supervisor-employees as well and giving feedback about quality of performed tasks,
- proper tasks/responsibilities delegation, also through inviting employees to join and participate in operational decision making process in company,
- proper wages and bonus systems, as also financial support for employees (ex. pensionable insurance systems, interest-free loans).

Safety, hygiene and ergonomics at work became steady and significant part of CSR with reference to social perspective (Segal et al. 2003). Segal and others consider parts of ergonomics as important part of social responsibility sense because health, safety and employees working comfort are the one used to evaluate status and development and company functioning.

With company point of view sustainable ergonomic program should be interpreted in three key areas. First area relates to meaning and scope of social responsible management of employees and its influence on already set up or planned set up working conditions. Second area includes aspects of technics and technology impact on conditions and quality of employees work. Whereas the last area takes into consideration need of defining and set up of work places, optimal not only with regard to employee abilities and limitations but also with reference to environmental politics and influence of human activities on ecosystem.

Ergonomic program of sustainable development needs application of risk analysis and proper evaluation methods of effect with regard to health, costs, and benefits due to its implementation (Markova et al. 2012).

On one side activities in range of working conditions improvement result in advantages that refer to company image outside. On the other side (what is more important) through frequent influence on increase of work productivity and quality level of processes in company, that actions increate occupational/task motivation within employees (Zwetsloot and Starren 2004). Attention to working conditions is undoubtedly one of key aspects in reaching high output performed by single employee, groups of employees as also whole organization.

2 Ergonomics as Significant Factor of Sustainable Production

Better and better possibilities of basic nutritional, medicinal as also developmental needs satisfying, that means continuous aspiration to improve employees life conditions should determine main goals for development of companies based on knowledge and treating employees as precious source. To realize that assumption companies needs to keep human as key object in human-machine-environment system. This depiction constitute basis of microergonomics. In many-objected depiction, interpreted as a system, in macroergonomics scope, internal structure of dependent objects of technical system, internal relations between object, as also dependency on external environment are taken into consideration (Jasiak and Misztal 2004).

Each company can gain benefits from activities due to working conditions improvement within confines of sustainable development. Practice shows that even primary improvement result in productivity, efficiency, competitiveness and employee motivation increase (Wachowiak and Kujawińska 2014). Optimal working system design and relations between particular components should assure capacity maintenance in conditions that enable to employee widely develop (intellectual, psychological and social) as also that results in sustainable development of all processes related to job.

Awareness of benefits that follows from ergonomics application in industry is rather common. Many authors present results in the field of applied ergonomics. Hamrol and Kowalik (2006) examine and determine influence of selected environmental factors on quality of electrical wiring for cars manual assembly. Battini et al. (2011) confirmed impact of ergonomics on assembly processes output. Helander and Burri (1995) measured viability of ergonomics and quality improvements in electronics manufacturing process. Slowikowski (2003) specified system premises applicable for ergonomics in companies and determined relations occurring in management of activities that refers to aspects of ergonomics in enterprise. Talib and Rahman (2008) presented an issue of ergonomics and TQM integrity. MacLeod (2006) in his paper showed methods of profits gaining due to ergonomics application. Reifur (2008) evaluated ergonomic background of assembly stations with reference to work output in condition of stress. Falck et al. (2002) specified influence of assembly station ergonomics aspects on quality of product as also yield in automotive industry.

Implementation of ergonomics solutions in enterprise leading to sustainable its development results in material as also intangible benefits. Material benefits give companies real financial profits gained through among of other as follows:

- productivity increase,
- effectiveness increase,
- number of production scraps decrease,
- number of quality defects decrease,
- employees fluctuation decrease,
- sick leaves and costs related decrease (equivalent paid in time of sick leave, cost of replacement employment contract, cost of rehabilitation, cost of compensation etc.).

Among of intangible benefits, desired from single employee, company community and employer points of view should be listed as below:

- working conditions improvement,
- musculoskeletal disorders decrease and job satisfaction improvement,
- motivation for better job performance increase (do work good in first time),
- better working time utilization,
- work safety increase and occupational illness elimination,
- biological cost of work decrease,
- better work place and working system organization,
- company image in community improvement (better PR).

Ergonomics application has also social meaning. Sociological context is especially visible in effort and management activities focused on working conditions for employees improvement. Obviously employee response in more effective work and bigger occupational motivation relates to sociological aspect of ergonomics. Company activities focused on attention to proper working conditions set up also positively influence on company goal evaluation by employees. Employees are then more willing to identify with company goals and also have desired attitude to work.

In practice ergonomics influence on sustainable company community development in facet of balance between private and occupational life assurance (work-life balance). This approach according to Carayon and Smith (2000) has an impact on organization and working system in aspect of company restructuring and reorganization, adaptation of working organization new forms, man power and/or tasks diversity implementation, new communications and IT technologies implementation, as also production running in shift working system (Hamrol et al. 2014). Among of disadvantages of shift working system, as Siedlecka (2007) emphasized, should be mentioned group intolerance effect toward shift system as an examples: sleep disruptions, chronic fatigue, gastric-intestinal disturbances, psychoneurotic disorders, heart-vascular problems, bigger alcohol, coffee, tranquillizers, sleeping pills consumption.

Below presented case shows evaluation of shift working system by employees as also their opinions correlation to real production output and effectiveness of performed tasks.

3 Case Study

Companies responsibility for set up of proper working conditions for employees is not only duty that comes from law regulations but also from psycho-social as also organizational and operational needs. Work places creation minimally adjusted to requirements referring to average employee is not sufficient to ensure effectiveness and efficiency of technological processes. Attention concentration on human as precious source of knowledge, abilities and job experience determine company success. Proper diagnosis and analysis of employees needs is also important issue in that aspect. Paying attention at employees as social group and organizing work based on group analysis is not sufficient. Operational effectiveness can be work out through analysis of abilities, limitations and needs of single operators already on recruitment stage.

By analogy to ergonomics aspect should be interpreted widely beyond issue of ergonomic work place physical creation. Significant is fact of work place adjustment to employee anthropometric dimensions/ranges. Moreover proper parametrization of microclimate conditions is needed to minimize risk of occupational illnesses. These aspects determine minimal work place requirements, necessary to fulfill excellently, but not only the ones. Additionally working time, working methods, as also applied working systems should be emphasized while taking into consideration ergonomic working conditions. One of popular working systems especially for medium or high series production is shift working system with three shifts working system on top.

Three shifts working system secure operational comfort in companies. It allows producing bigger production series in comparison to one shift production. Additionally it creates bigger flexibility for companies and possibility for quicker reaction on customer requirements changes and being competitive on market of progressive technology. Unfortunately that system has parallel also many limitations directly influencing on employees quality of life. Work in three shifts system disturb employees day and night rhythm (biorhythm), often has negative impact on health and many times cause problems in social life. Time flexibility in three shifts working system is quite limited and requires private life and issues related adjustment to operational life.

Table 2 Human failures in production processes classification (own source)

Operator decision	Real process/product status	
	Acceptable product	Not acceptable product
Acceptable product	OK	Second type of failure
Not acceptable product	First type of failure	OK

From operational effectiveness point of view, work in three shifts working system is connected with risk of two types of human failures (Table. 2). First type of failure are failures that are results of improper sub products or ready goods classification. This type of failure influence on quality costs increase of manufactured products. Second type of failures are also called missing of overlooked failures. In case of missed failures there is a risk of sending out defective product to customer.

Causes of failures presented in Table 2 could be many and different. Beginning from aspects of work place ergonomics, work ergonomics, to psychological, physical, behavioral, sociological or social factors. In so far as part of failures can be corrected, formed, or improved, rhythm of activities strictly related to human biological abilities and limitations is not changeable.

Special case study presented by authors is visual inspection in production process. It is undoubtedly one of production steps with human playing the main role. Visual inspection effectiveness depends mostly on human abilities/possibilities, predispositions and working conditions as well. Special case is alternative, organoleptic, visual inspection, still the cheapest control comparing to different control types, nondestructive but with a big risk of human error appearance as described above.

For proper analysis of ergonomic work places aspect as also work methods in sustainable production processes, their influence on single operators should be examined. Analysis should not be influenced by outcome for group of operators. Average effectiveness for group of operators indicates discrepancy between the strongest (the most effective) and the weakest (the least effective) operators in group. Group means team of employees working in particular area, production nest, or work place, with similar level of abilities and status of training.

Analysis of three shifts working system influence on visual inspection effectiveness was performed in manufacturing company, producing electronics subassemblies for automotive industry. Researches carried out during 33 weeks. Data was collected from three production shifts (morning-I—6 a.m. to 2 p.m., afternoon-II—2–10 p.m., night-III—10 p.m. to 6 a.m. next day) about missing failures made by fours sequentially placed visual inspection. Visual inspection effectiveness analyzed with FPY[1] index. Bigger index then bigger visual inspection figure.

Data analysis of visual inspection effectiveness collected for group of operators shows that effectiveness fluctuation is not visible on different production shifts but rather between groups of operators (inspection stations) (Figs 1 and 2). Regardless

[1] First Pass Yield (FPY) [0–100 %] is number of found nonconformance to total number of nonconformance available to find.

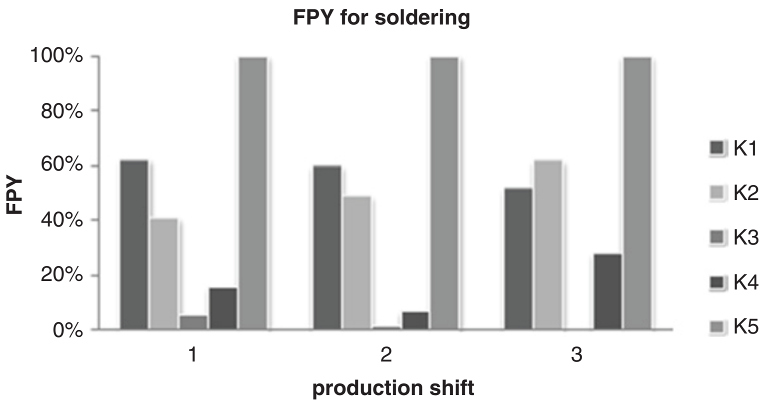

Fig. 1 Visual inspection of soldered components in three shifts working system

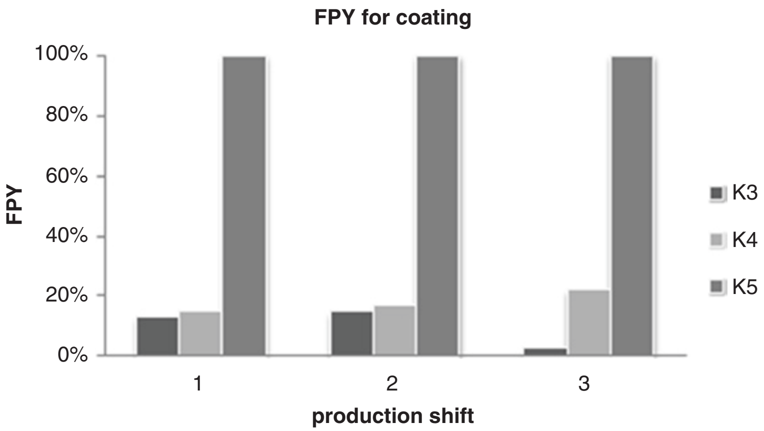

Fig. 2 Visual inspection of conformal coating coverage in three shifts working system

of defect location on products effectiveness changeability differs but only slightly between production shifts. Real disproportion of effectiveness between morning, afternoon and night shifts results from changeability of operators performance, trained to work on different inspection stations.

Taking into consideration source production data on single operator level presented in Fig. 3 and Table 3 difference in inspection effectiveness can be noticed. Differences are the result of unique for each person abilities and limitations to work in different hours during and day and night rhythm. Each operator activity is not the same in biological day and night rhythm and relates either to occupational time or private time.

On chart in Fig. 3 it is visible that in population of operators for visual inspection are operators who work more effective on morning shift (ex. OP1 and OP6) comparing to the rest. Moreover it should be noticed that they are also operator working in a

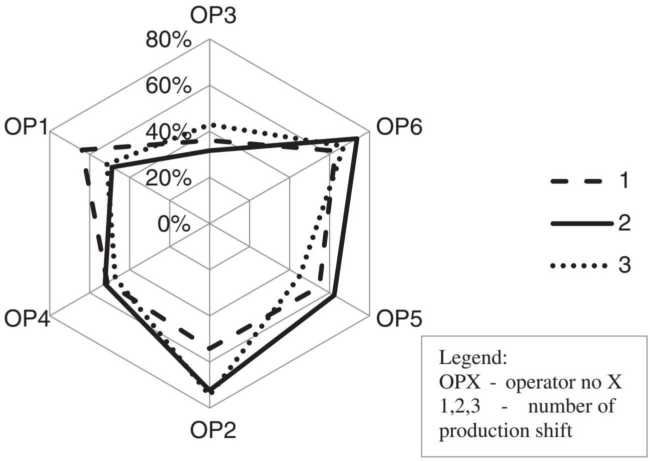

Fig. 3 Visual inspection effectiveness for single operator in three shifts working system (own source)

Table 3 FPY index value of quality effectiveness for different operators working in three shifts working system and job experience range (own source)

Operator	Job experience (year range)	Average effectiveness of operators in FPY (%)		
		Production shift		
		1	2	3
OP1	1–5	64	49	51
OP2	6–10	54	72	75
OP3	6–10	36	32	43
OP4	6–10	51	52	47
OP5	>15	55	62	45
OP6	>15	63	74	67

row better on night shifts (ex. OP2 and OP6). This diversity relates to unique human biorhythm. This factor divides population of operators into subgroups characterized with proper per hour work effectiveness during day and night. Unfortunately day and night effectiveness of performed tasks is variable and also dependent on other influencing factors. As an example can be listed situation context, daily mood, health discomfort or musculoskeletal disorders. Impact of that additional factors is visible in lower work effectiveness level. Additional ("disturbing") factors make up risk parameter and mostly appears sporadically and accidentally.

Paying attention to biological rhythm of operator activity already on stage of recruitment for controller position enable to limit to possibly maximum extent human errors appearance, especially failure of missed defects. Moreover ergonomic work organization drawing attention not only to single operators biorhythm but also to proper working conditions on work places should result in effectiveness of visual inspection as well as other production processes increase.

4 Summary

Ergonomics as significant factor of sustainable production constitute one of key aspect of modern companies functioning. That aspect that relates also to social responsibility is not only limited to protection of precious virtues of natural environment but also refers to care about employees and awareness that they are significant part of company. Value of human capital is difficult to estimation, completely not measureable, but still priceless, especially in cognitive, decision or innovative processes.

References

Battini D et al. (2011) New methodological framework to improve productivity and ergonomics assembly system design, Int J Ind Ergon 41:30–42

Carayon P, Smith MJ (2000) Work organization and ergonomics, Elsevier, London

Cleal B (2009) CSR and the working environment in small enterprises: a beautiful friendship? Understanding Small Enterprises, Copenhagen

EU-OSHA (2012) CSR and safety and health at work, Office for Official Publications of the European Communities Dictus Publishing, Bilbao

Falck A (2002) The influence of assembly ergonomics on product quality and productivity in car manufacturing—a cost-benefit approach, Nordic Ergonomic Society Conference, Finland

Forum Odpowiedzialnego Biznesu (2014) Trendy CSR. http://odpowiedzialnybiznes.pl/wpcontent/uploads/2014/03/Trendy-CSR-2014.pdf Warszawa

Gellert FJ (2009) The relationship between ageing workforces and Corporate Social Responsibility. Understanding Small Enterprises, Copenhagen

Hamrol A Kowalik D (2006) Wpływ wybranych czynników środowiska pracy na jakość procesu ręcznego montażu samochodowych wiązek kablowych. Archiwum Technologii Maszyn i Automatyzacji, Poznań, Vol 26 nr 2, pp 229–238

Hamrol A, Kujawińska A, Vogt K (2014) Analysis of shift work system influence on visual inspection effectiveness. AHFE, Kraków

Helander MG, Burri GJ (1995) Cost effectiveness of ergonomics and quality improvements in electronics manufacturing, Int J Ind Ergon 15:137–151

Jasiak A, Misztal A (2004) Makroergonomia i projektowanie makroergonomiczne. Politechhnika Poznańska, Poznań

Jasiulewicz-Kaczmarek M (2013) The role of ergonomics in implementation of the social aspect of sustainability, illustrated with the example of maintenance. In: Arezes P, et al (eds) Occupational Safety and Hygiene. Taylor&Francis Group, London, pp 47–52

José Manuel Barroso. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:2020:FIN:EN:PDF COM (2010) 2020 final, COMMUNICATION FROM THE COMMISSION EUROPE 2020. A strategy for smart, sustainable and inclusive growth, Brussels 3 March 2010

Lewicka-Strzałecka A (1999) Etyczne standardy firm I pracowników. IFIS PAN, Warszawa

MacLeod D (2006) The ergonomics kit for general industry. Taylor and Francis, USA

Markova P, Beno R, Hatiar K (2012) Sustainable ergonomic program—basic condition for implementation of CSR, Slovakia

Reifur B (2008) Metoda oceny uwarunkowań ergonomicznych stanowisk montażowych a wydajność pracy w warunkach stresu. Technologia i Automatyzacja Montażu, Warszawa, vol 3, pp 39–44

Segal JP, Sobczak A, Triomphe CE (2003), CSR and working conditions. European Foundation for the Improvement of Living and Working Conditions, http://www.uni-mannheim.de/edz/pdf/ef/03/ef0328en.pdf, Dublin

Siedlecka J (2007) Praca zmianowa—problem ciągle aktualny. Praca i Zdrowie, Warszawa

Słowikowski J (2003), Zastosowanie ergonomii w przedsiębiorstwie—przesłanki systemowe. Bezpieczeństwo Pracy, CIOP, Warszawa, vol 9, pp 18–21

Światowy Szczyt Zrównoważonego Rozwoju Johannesburg (2002), dostępne pod. http://www.unic.un.org.pl/johannesburg/

Talib F, Rachman Z (2008) Integration total quality management and ergonomics: an approach to enhanced organization performance. Indian Institute of Technology, Roorkee

Wachowiak F, Kujawińska A (2014) Influence of selected ergonomics factors on the effectiveness of quality control, case study. Advances in Human Factors and Ergonomics 2014 Proceedings of the 5th AHFE Conference 19–23 July 2014 20 Volume Set: Proceedings of the 5th AHFE Conference 19–23 July 2014 Kraków pp 210–222

Westgaard RH, Winkel J (2011) Occupational musculoskeletal and mental health: significance of rationalization and opportunities to create sustainable production systems—a systematic review, vol 42(2), Elsevier, London

Więcek-Janka E (2008) Psychophysical bases of pronouncement of psychosomatic diseases at polish micro-entrepreneur. AEI, Las Vegas

United Nations (1987) Report of the world commission on environment and development. A/RES/42/187 United Nations Department of Economic and Social Affairs (DESA), New York, USA

Zwetsloot G, Starren A (2004) Corporate social responsibility and safety and health at work. European Agency for Safety and Health at Work Research Report from the European Agency for Safety and Health at Work, Issue 210, Bilbao

IT Support of Production Efficiency Analysis in Ecological Aspect

Adam Kolinski and Boguslaw Sliwczynski

Abstract For final customer are important currently not only product quality, but also the environmental performance of the production process. That's why it is crucial issue to present complex method for production process efficiency analysis, which includes ecological aspects and connections or feedback with other processes in enterprises. The main contribution of this chapter is presentation of author's concept of complex analysis of production process efficiency method supported by IT tools. Scientific research was based on analysis of available IT tools for support of production process efficiency in ecological aspect.

Keywords Eco-efficiency · Production efficiency · IT systems support

1 Introduction

Efficiency assessment is quite a difficult issue as the subject matter literature offers numerous publications presenting more and more methods of setting and assessing efficiency. Therefore, managers are made to use more and more difficult analytical tools supported with information technology tools as well as management information systems in order to define production process efficiency. The research study carried out by the authors shows that despite common use of information technology systems for supporting enterprise's management, there is little implementation of IT solutions when it comes to analysing efficiency. This makes it difficult to carry out an efficient analysis of processes in enterprise. In theoretical

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considerations over the production process efficiency in ecological aspect is not much highlighted, which creates a necessity to develop a complex method for analysing production process efficiency.

The main role of information technology tools is to support gaining, processing and distributing data, which makes the process of making decisions by the management more efficient. Nowadays, a very competitive factor is the information flow time, which shortens processes in enterprise. It is also a very important aspect of management actions concerning the analysis and assessment of enterprise's efficiency as the time of making strategic and operational decisions relies on these actions. Continuous time pressure makes it difficult to analyse data and draw the right conclusions. Therefore, it seems to be vital to implement IT solutions in analytical tasks not only in a production process but also in a process in company and supply chain. The main task of IT tools supporting efficiency assessment is to assist managers in a process of enterprise's management. Controlling IT systems have been undervalued and their implementation and practical use have been very scarce and general. Nowadays, IT tools for supporting the assessment of production processes efficiency are taking on a special meaning, especially for companies oriented on gaining a competitive dominance on the market.

These are mainly large and medium companies which generate the biggest demand for collecting, processing and storing data with the help of IT tools supporting decision making. Due to fragmentation and diversity of this sector we can distinguish three stages for IT support of production process efficiency:

- carrying out efficiency analyses based on spreadsheet programs,
- implementation of analytical tools in an environment of ERP class integrated systems for managing enterprise,
- developing dedicated IT systems to specific of sustainable production processes and related with other elements of material flow in a supply chain.

2 The Usage of the Analytical IT Tools in Business Practice

The aforementioned considerations have urged authors to carry out research studies to assess the extent of using IT tools supporting an analysis of production process efficiency. Figure 1 shows the research methodology of using IT tools supporting an efficiency analysis of production process in business practice.

The research study has been carried out using a questionnaire method and some of the studied subjects allowed to do make observations and direct interviews in the companies. The research study was carried out in the first two quarters of 2013 in 117 production companies in Greater Poland's region. The studied companies in over 68 % represented medium and large companies. The research study concentrated only on the companies which declared using the efficiency analysis to monitor and assess production processes. The main aim of carried research studies

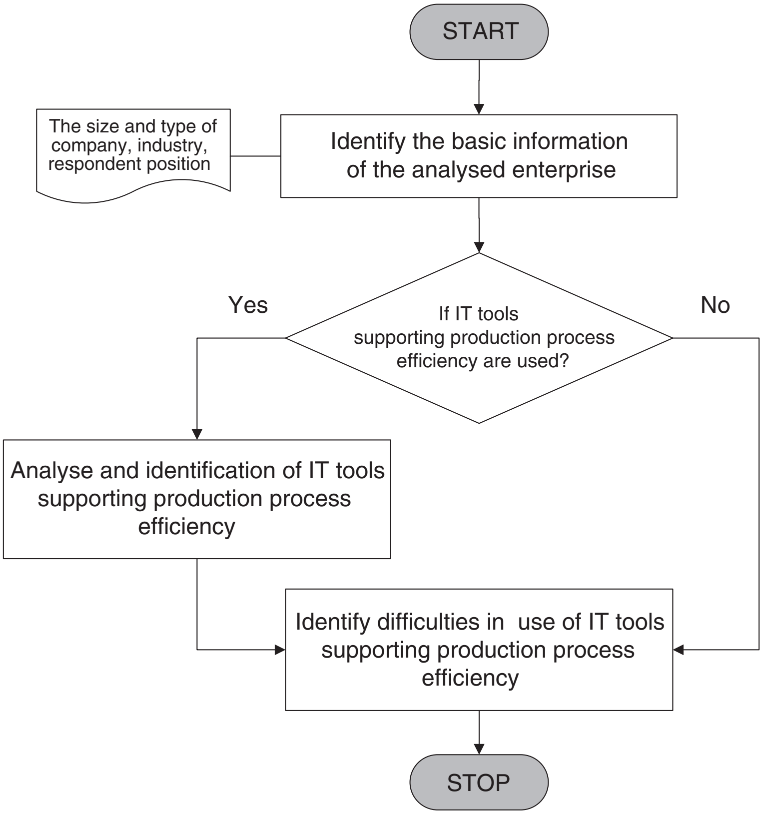

Fig. 1 Scheme of research methodology of using IT tools supporting an efficiency analysis of production process in business practice, own study

was to identify the types of used IT tools including the specifics of carried out efficiency analysis of production processes. The indirect aim, but still important from the point of view of analysing exploited IT tools, is to identify the difficulties and constraints in their efficient use.

Using IT tools supporting analysis of processes efficiency is declared by as many as 90 % of studied production companies. However, it is worth noticing that most of managers bases its analytical actions on using spreadsheet programs such as MS Excel. Especially when it comes to medium and large companies one can identify wider use of ERP systems, dedicated systems or computing simulation programs. A detailed analysis of the extent of using particular IT tools supporting the analysis of production process efficiency is presented in Table 1.

Analysing the research study results we can state that the most often used analytical tool is the spreadsheet program. Over 50 % of companies also use IT systems of ERP class to support the analyses of production process efficiency. This group comprises of medium and large as well as micro and small companies.

Table 1 IT tools supporting the analysis of production process efficiency

IT tool	Percentage of use (%)[a]
Spreadsheet programs (e.g. MS Excel)	82.05
ERP Systems	52.99
Dedicated IT systems (e.g. MES, CIM)	17.09
Computing simulation programs	15.38

[a]Surveyed enterprises were able to choose more than one answer

Table 2 Difficulties in using IT tools supporting the analysis of production process efficiency

Identified difficulties	Percentage of answers (%)[a]
Spreadsheet programs are not sufficient for conducted analyses	44.07
Performing computing simulations is complicated for employees	44.07
ERP system does not guarantee receipt of all necessary data	32.20
Dedicated IT systems do not include functionality of efficiency analysis	28.81

[a]Surveyed enterprises were able to choose more than one answer

In case of medium and large companies the possibility to use ERP system in realisation of complex production processes is dependent on the detail of functional range of used IT tool, whereas in regard to small and medium production companies, it needs to be noticed that usually a low level of complexity of executed process makes it possible to use the functionality of ERP system during an analysis of a production process efficiency.

Interdependent dimensions of operations management (e.g. the time, place, quantity, quality, structure), management resources (e.g. employees, machines and equipment, capital, organizational resources and know-how) and management areas (e.g. purchasing, production, distribution, sales, finance, marketing), require that managers have to consider many scenarios of process implementation and resources allocation, which affects the final effectiveness of the company's assets and the employed capital. Observation of business practice, supported with scientific research allows to identify the basic difficulties in using the presented IT tools supporting an analysis of production process efficiency. A detailed identification of basic difficulties in using IT tools supporting the analysis of production process efficiency is presented in Table 2.

On the basis of identified difficulties it needs to be concluded that IT tools which are now available on the market are generally not sufficient for the specific production processes executed in companies. Therefore, it is necessary to create a concept of a complex IT tool which would enable generating data from ERP systems and dedicated systems as well as using connections in a supply chain and making simulations which facilitate making management decisions.

3 IT Support of the Analysis of Production Process Efficiency

Using spreadsheet programs in planning and balancing of production resources as well as during further efficiency analyses is the simplest and most often used solution. Nevertheless, it is a solution which is not necessarily profitable when it comes to the way of information flow. Most of companies, use not only analyses and reports generated from ERP systems, but also use spreadsheet programs to support decision making process.

ERP systems are used to increase efficiency but not only by better information flow, but also by improve production process. ERP system functionality, from the point of view of production management, should include the following issues:

- creating, modifying and using individual positions of bill of material on each stage of a technological process of a product,
- creating and managing production orders by generating a production structure for the order, creating a production schedule and creating a material demand for the order,
- carrying out analyses of production orders including the costs of orders' realisation,
- short-term and long-term scheduling of production processes,
- generating orders automatically based on existing warehouse status and product rotation as well as on unrealised orders.

Production management in IT systems of this class aims at ensuring normalisation and standardisation of production actions (service of existing technologies), detail production planning, planning the purchase of materials and raw materials, controlling and recording the real course of production processes (orders' services) and the possibility to grasp and control the costs of production in a controlling aspect (Sliwczynski 2011a). A detailed functionality of IT system concerning the management of production processes is presented in Table 3.

Making observations in business practice, one should emphasize the low rate of utilisation of ERP class IT management systems available in enterprises during efficiency analyses of production processes. Such a situation is most often caused by two factors. (1) The functionality of information systems is often complicated and many enterprises have difficulty with copying their analytical processes in the given IT tool. (2) The functionality of ERP systems is insufficient for the detailed efficiency analysis of production processes requiring honest and current data which makes it necessary to apply additional IT tools or dedicated systems supporting the analysed process. Using dedicated systems, technologically separate for different processes in the enterprise, can create a problem of generating data with different structures and standards which will prevent a general efficiency analysis of the enterprise (Santarek and Obluska 2012).

Table 3 Possibilities of using ERP in production management

Functional range	Possible use
Production planning	Automatic generation of production plan on the basis of orders from the recipients (production on order)
	Creating a plan by the user (production for warehouse stock including the service of minimum and maximum statuses)
	Automatic setting of the date of production task launch against the planned date of product delivery
	Carrying out MRP balancing allowing for launching a production order or generation of material purchase demand
	Connecting orders from recipients with a production process- order confirmation connected with stores analysis and production capabilities
Technology	Description of operation in the technology of a product or semi-product manufacture with the definition of production process
	Possibility to create base and alternative technologies
	Service of parallel, sequence and network processes
	A list of input materials and raw materials with substitutes
	Standard working time of operators and machines
Production orders	Automatic record of GIN (Goods Inward Note) and GRN (Goods Received Note) warehouse documents with the possibility to service the shortages
	Service of work records of people (with automatic connecting with the payrolls) and of machines
	Service of cooperation connected with documents of the acquisition of services
	Possibility of using barcodes reader tools
	Scheduling of orders and balancing charges of stores used in production operations
Lowering costs of production	Control of the duration of production processes, allowing to improve their efficiency
	Reducing the stock of raw materials, blanks and finished products
	Current inspection of production costs through the quick access to current cost data and its multi sectional balance sheets
	Optimization of the technology based on analysis of the available resources
Production settlement	Appointing the actual cost of production
	Calculating the cost of the work in progress
	Comparing standard costs and real costs

Using dedicated IT systems for the environmental management [the so-called Environmental Management Information Systems (EMIS)] facilitates the measurement of the environmental influence of processes and technological operations. The EMIS system is integrated, largely automatic IT solution assisting individual stages of decision making in the environmental management. The main aim of EMIS function is planning, monitoring the compliance and assessing the influence of production processes on the environment including the risk management and ISO 14000 and OHSAS 18001 norms. The functionality of the system is also matching with the European IPPC directive of 2008/1/EC concerning integrated prevention and control of pollutants, including industrial emissions, monitoring the noise, etc. Information systems assisting the environmental management integrate a number of advanced analytic functions of operational management of a production process in real time (based on tools of multi-criteria optimization), as well as script analyses, strategic and optimization planning. The functionality of EMIS systems includes:

- module assisting monitoring, reporting (constant and periodic) and analyses of forecasts of all operations carried out having an influence on an environment (freeing pollutants to the atmosphere, generating dangerous waste or exaggerated noise),
- risk assessment and risk management in the situation of accidental freeing of dangerous materials according to different scenarios (e.g. evaporating, chemical fire, explosion, contamination of the soil, etc.).

In business practice the effectiveness of environmental management will depend on the degree of the EMIS systems integration with IT systems, most often of ERP class, supporting the business administration (Funk et al. 2009). It is also necessary to provide an easy access to supplementing data sources which are kept by the remaining participants of the supply chain (Kolinska and Cudzilo 2014). Scope of information and data sources essential for effective sustainable management of the production process in recognition of the supply chain (Fig. 2) includes (Golinska 2010):

- Supplier Information Systems—should provide information regarding Life Cycle Inventory, raw materials/components environmental impact, environmental impacts of supply processes (like preprocessing, storage and delivery),
- Manufacturer ERP/PPC—provides data on procurement, production and sales, especially information about bill of materials (BOM), production orders, production capacities, disassembly BOM (if applicable, DBOM could be also obtained from external data sources),
- Distribution Systems—provide data regarding product distribution, detailed location of sale points and amounts of sales (needed for returns flows forecast and the design of recovery network), as well as should provide assessment of environmental impact of distribution activities,
- Recycling Institutions information systems/data bases—provide data on returns collection, products' returns structure, capacities of recovery network, as well as data on returns forecast,
- External Life Cycle Assessment databases (LCA DB)—provide the estimates on product life cycle assessment based on products classification,
- Manufacturer EMIS—provides material flow networks and energy flows, company environmental data regarding resource consumption and environmental impact of the production process. It addition, the environmental impact assessment of the whole company that cannot be allocated to a particular production process should also be taken into consideration.

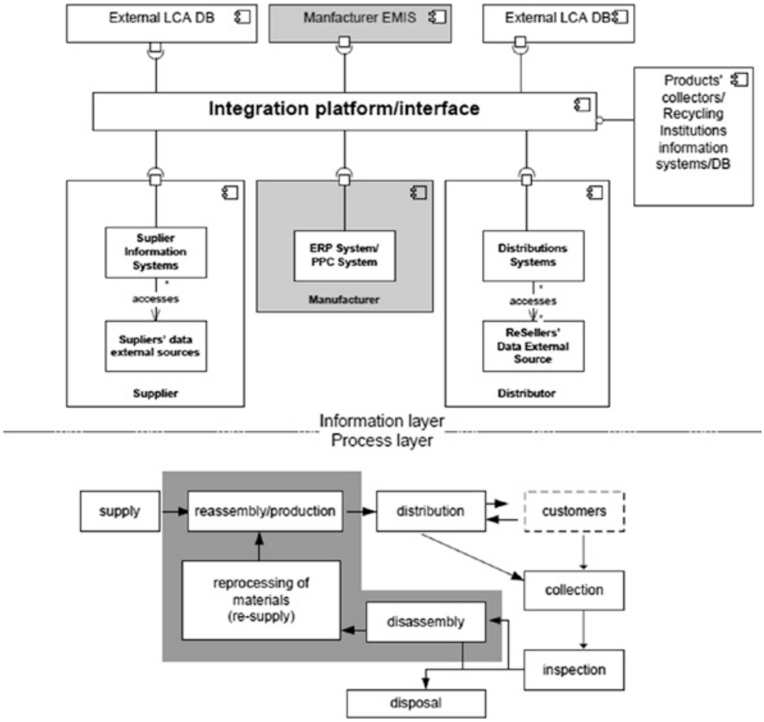

Fig. 2 Integration of scattered data sources in the closed supply chain (Golinska 2010)

Figure 2 shows information and procedural layer integrating the closed supply chain. The suggested outline of integration allows for better integration of data and information between individual phases of the life of a product, including the specificity of the sustainable management at the stages of procurement, production and distribution. Such a concept enables to identify system connections and possible feedbacks of the efficiency analysis of the production process including environmental aspects.

4 Concept of Computerization of a Complex Analysis of Production Process Efficiency

Using dedicated systems influences the time of the completion of decision making in an enterprise by analytical assisting the evaluation of production process efficiency. One should however remember, that multi-criteria efficiency analysis forces generating data from information systems concerning processes occurring in the enterprise as well as data generated in the whole supply chain. The ERP system is a very effective source of honest information concerning the flow of

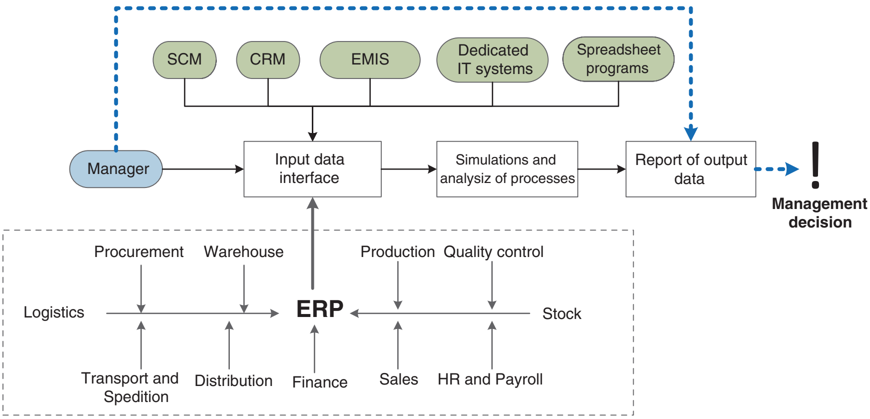

Fig. 3 Concept of computerization of complex analysis of production process efficiency, own study

processes, but thanks to collected information and connections with other systems or dedicated systems an extended tool can come into existence. This tool could be very useful for processing information inside a company and in cooperation with the enterprise's business partners in supply chain (Kolinski and Fajfer 2011). In order to ensure efficient communication between partners, there needs to be a universal, recognized by different information systems and tools assisting the management, format of data and information record.

The concept enabling integration of data coming from the enterprise and its supply chain for the purpose of the production process efficiency analysis is presented in Fig. 3.

Computer assisting of analyses and the evaluation of the production process efficiency will depend on the reliability of the input coming from information systems. The input should be correlated between individual rungs of the management and concern both a chosen strategy of the production management and resource balancing, as well as technological and operating production factors (Kolinski 2012). The concept presented in picture 3 contains carrying out analyses both on the basis of operational data generated from information systems, as well as by making procedural simulations. This concept was based on Author's research deliberations drawn up in the frames of the scientific research project[1] and was used for creation of a IT tool supporting the efficiency analysis of the production process. Taking into account efficiency aspects while creating the concept of logistic processes' computer simulations allows to use one integrated database which

[1] Research project "Simulation of managing the flow of company's material as an instrument of multivariant analysis of transport processes efficiency" No. N N509 549940 is carried out from the financial funds for education granted by the Ministry of Study and Higher Education thanks to the decision No. 5499/B/T02/2011/40.

contains all current and archival information, generated by all processes, affecting the realization of the production process. Information obtained from such a concept allows for:

- streamlining the operational and material-financial planning (budgeting),
- precise monitoring the realization of production and supply programs and their deviations from the actual state,
- analysis of the state and indicating threat with the help of ratio analysis,
- correcting the plan and budget of the production process,
- responding to deviations in executing the plan and budget,
- carrying out analyses and forecasts of investment, projects and results,
- reporting, on the basis of which feedbacks will be generated.

5 Information System of Production Efficiency Modeling and Management Through Processes of Supply Network

Partners in the production supply chain constantly develop information technology, e-platforms of cooperation, cloud computing and other tools of integrating ERP systems at vendors plants to help their customers respond to dynamic market conditions and help them maintain their efficiency and competitive advantage. Depend on the characteristics of the product, two distinct business process management of supply chain configurations offer competitive advantage: one based on efficiency and a second based on market responsiveness (Parmigiani et al. 2011).

Production process efficiency in ecological aspect is interconnected with influencing product value over the complete supply network through deliberate shaping of multidimensional process interdependencies of supply, production and distribution. The cross-sectional data of product flow, processes and resources of vendors in supply network are aggregated in data warehouse shared between partners, integrated and data processing for improving partner's processes efficiency (Fig. 4). IT systems of SCM class are equipped with forecasting and planning functions of production process and also configurations of supply network/chain.

SCM and Advanced Planning systems enable improve efficiency of production processes in supply network by getting real-time data from suppliers, manufacturers, retailers, logistics providers (and other), taking into account many complex variables, such as manufacturing resources capacity, delivery schedule of raw materials, master production schedule and productions cycles, to forecast of customer demands (Sliwczynski 2011b). According to Fig. 4 advanced planning functions in SCM systems enable:

- *supply network/chain design and modeling*—including: process mapping and simulating, recording of chain/network resources descriptions, product defining, process/resources parameters defining (e.g. capacity, throughput, order fulfil time), control parameters and indicators defining (e.g. costs, efficiency, rotation, service level), specifying emergency alarms and critical values,

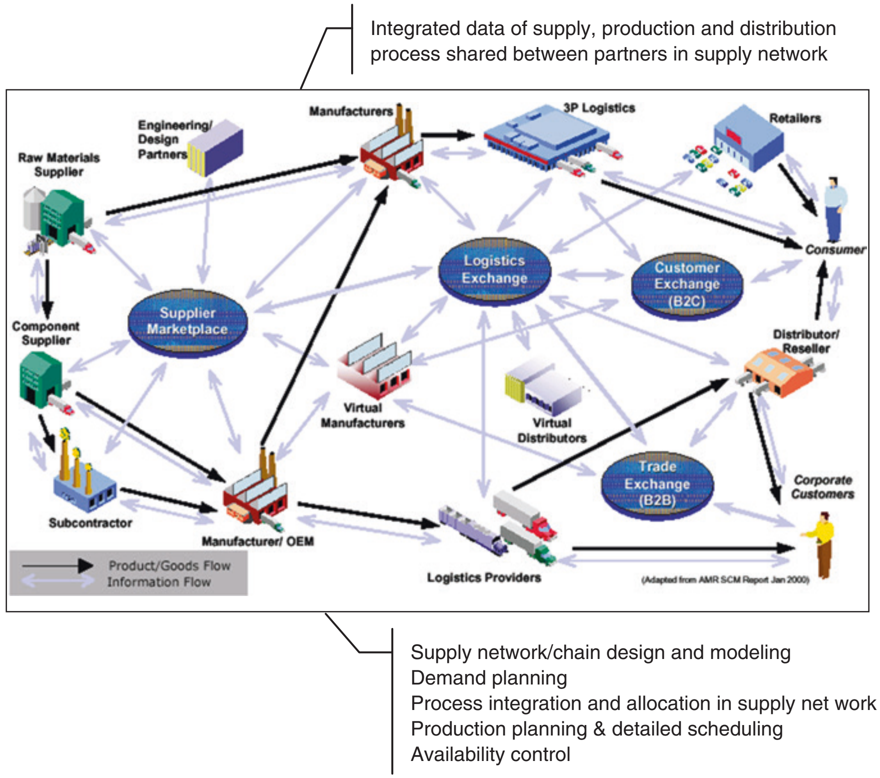

Fig. 4 IT technology and cross-sectional data of product, process and resources shared between partners in supply network, own study

- *demand planning*—including: collecting data from different sources/data warehouses and repositories/for forecasting of market demand, interactive forecasting in many processes and accuracy iteration, planning of product life cycle management, carrying out predefined and self-defined tests on forecast models and forecast results, cause analyses,
- *process integration and allocation in supply network*—including: synchronization of operation for the whole supply chain (integrating purchasing, manufacturing, distribution, and transportation for simulation planning and sourcing decisions), defining optimization criteria (using advanced optimization techniques, based on constraints and penalties), building delivery schedules, demand and deliveries balancing techniques, stock assignment and replenishment techniques, scenarios of delivery strategies,
- *production planning and detailed scheduling*—including: mechanisms of reaction to demand changes, generating production plans under the condition of supply chain resources optimization, planning production capacities and material requirements, scheduling (planograms, Gantt charts), resources using optimization, scheduling overdue and current orders in interaction to distribution and sales network,

- *availability control* control—of the possibility to fulfil orders according to demand (availability checking on the items required is performed on the available to promise quantity /ATP/—quantity calculated from the current stock, planned receipts, and planned requirements), availability control of—materials, production, warehousing, transport capacities, stock.

Global standards of process modelling methodology [e.g. *Unified Modelling Methodology*—(UMM)] and modelling language [e.g. *Unified Modelling Language*—(UML)][2] applied to process specification guarantee equal and clear-cut process interpretation between business partners in supply chain. Common business processes should use cross references across common industry standards—technological, informational and functional—based on i.e. Supply Chain Operations Reference-model—(SCOR).

Information about IT environment of cooperation relationships in production processes include:

- data of production requirements specification,
- data of production resources and technical architecture,
- business and production process specification schema (B&PPSS),
- registry information model (ebRIM) and registry services specification (ebRSS),
- messaging services specification (ebMS),
- collaboration protocol profile and agreement (CPP & CPA).

The general model of enterprise's process management that was assumed by authors as basis for analysis of complex production process efficiency in ecological aspect is shown in Fig. 5.

Effective coordinating of activities (processes) in a supply chain based on harmonizing the actions implemented by different executors (enterprises, business units, individual employees) aimed at achieving a specified objective (e.g. the required product quality, reliability of deliveries, level of resource using, sales volumes, costs and profit level). Simultaneously with operational shaping of the supply chain it is also important to analyze the impact of sustainable operations management on the customer service level and sales revenues, material flow rate and cash conversion cycle as well as value of the working capital employed.

Based on researches results in polish enterprises, instruments regarding efficient management are insufficient to transmit financial and market plans into operational activities, including various scenarios of processes in the sustainable supply chain. The results of the study presented in Fig. 6 confirm the need for analyzing and controlling coherency of market and financial results with the formation of operational activities.[3]

[2] UN/CEFACT—*United Nations/Centre for Trade Facilitation and Electronic Business.*

[3] Own study conducted within a research project: Development of a universal pattern of logistics controlling solutions for Polish enterprises and their supply chains. The study was conducted via detailed audits in 92 enterprises and by means of an interview and opinion poll among managers of 176 enterprises. The study was conducted in 3 chosen sectors—automotive, building and household devices—in production and retail sector, with an even quantitative distribution in the group of small, medium and large enterprises.

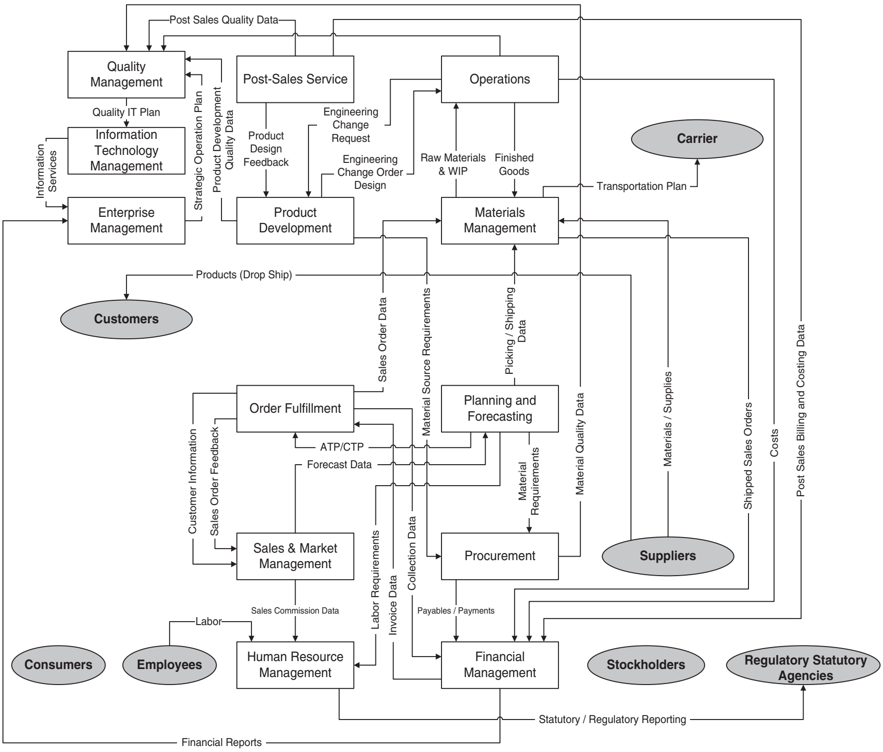

Fig. 5 General model of enterprise's process management in ecological aspect, own study

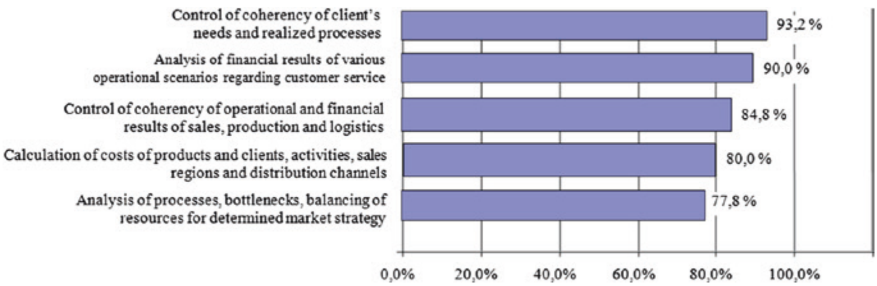

Fig. 6 Results of study regarding the need for analysis and control instruments related to market, financial and operational results in enterprises

Production efficiency supervision requires continuous monitoring of production performance indicators and process parameters to control production activity and tasks execution. An important operating objective of production process management is improvement of the flow efficiency in the whole supply chain and effectiveness in manufacturing resources utilization through elimination of bottlenecks, queues and downtimes.

6 Conclusions and Further Research

The efficiency analysis of the production process is an important factor affecting the competitiveness of enterprises, not only for financial reasons, exquisitely but also ecological. Irrespective of the scope of conducting the efficiency analysis, the environmental aspect is an inseparable element. In the environmental perspective however issues of the production efficiency aren't based exclusively on economic aspects and measures of appointing and assessing them. The Co-author described possibilities of the evaluation and analysis of the economic efficiency in the publication (Kolinski 2013). Operational efficiency also forces the production process into taking environmental aspects into account during technological and operational analysis. A good example can be mathematical models which can optimize not only time and cost of using individual workstations (Kolinski and Kolinski 2013), but can also minimize generating product defects. The degree of concentration on environmental aspects is conditioned by a chosen corporate strategy or the entire supply chain. The minimization of a negative impact on the environment requires incurring substantial expenses which must be reflected in strategic objectives transposed to operational and current objectives.

The complexity of conducting a complex efficiency analysis of the production process in ecological aspect reveals a need to seek IT support. The present chapter shows an idea of using information systems assisting management processes in an enterprise and in a supply chain as well as computing simulation which is aimed at analyzing all alternative solutions influencing the production process efficiency. Elaborated concept enable to improve the decision making process in business practice. The method presented in this chapter helps managers to take the right decision about the implementation of sustainable production processes. The main constraint of application of this method is the difficulty of implications IT tools of operational efficiency. The direction of further research for the Authors is carrying out a multi-criteria analysis of a production process with the use of simulation tool.

References

Funk B, Moeller A, Niemeyer P (2009) Integration of environmental management information systems an ERP systems using integration platform. In: Athanasiadis IN, Rizzoli AE, Mitkas PA, Marx Gómez J (eds) Information technologies in environmental engineering. Springer, Berlin, pp 64–77

Golinska P (2010) From traditional non-sustainable production to closed loop manufacturing: challenges for materials management based on PPC and EMIS integration. In: Teuteberg F, Marx Gomez J (eds) Corporate environmental management information systems: advancements and trends. Hershey, New York, pp 106–120

Kolinska K, Cudzilo M (2014) Comparison of logistics indicators as a way of improving efficiency of supply chains. Res Logistics Prod 4(1):21–32

Kolinski A (2012) The efficiency of the production—the analyse of problems based on the literature research. LogForum 8(2):137–150

Kolinski A (2013) The role of production efficiency regarding ecological aspects. In: Golinska P (ed) Eco production and logistics. Springer, Berlin, pp 93–102

Kolinski A, Fajfer P (2011) ERP integration as a support for logistics controlling in supply chain. In: Golinska P, Fertsch M, Marx-Gomez J (eds) Information technologies in environmental engineering—new trends and challenges, ESE. Springer, Berlin, pp 617–626

Kolinski A, Kolinski M (2013) The use of Hungarian method in the evaluation of production efficiency. In: Knosala R (ed) Innovations in management and production engineering. Publishing House of Polish Association for Production Management, Opole, pp 116–127

Parmigiani A, Klassen RD, Russo MV (2011) Efficiency meets accountability: performance implications of supply chain configuration, control, and capabilities. J Oper Manage 29(3):212–223

Santarek K, Obluska I (2012) Process approach to the evaluation of information systems effectiveness. Inf Sys Manage 1(2):148–159

Sliwczynski B (2011a) Operational controlling—a tool of translating strategy into action. LogForum 7(1, 5):45–59

Sliwczynski B (2011b) Operational controlling of supply chain in product value management. Publishing House of Poznan University of Economics, Poznan