Wolfgang Kersten, Thorsten Blecker and Christian M. Ringle (Eds.)

Next Generation Supply Chains

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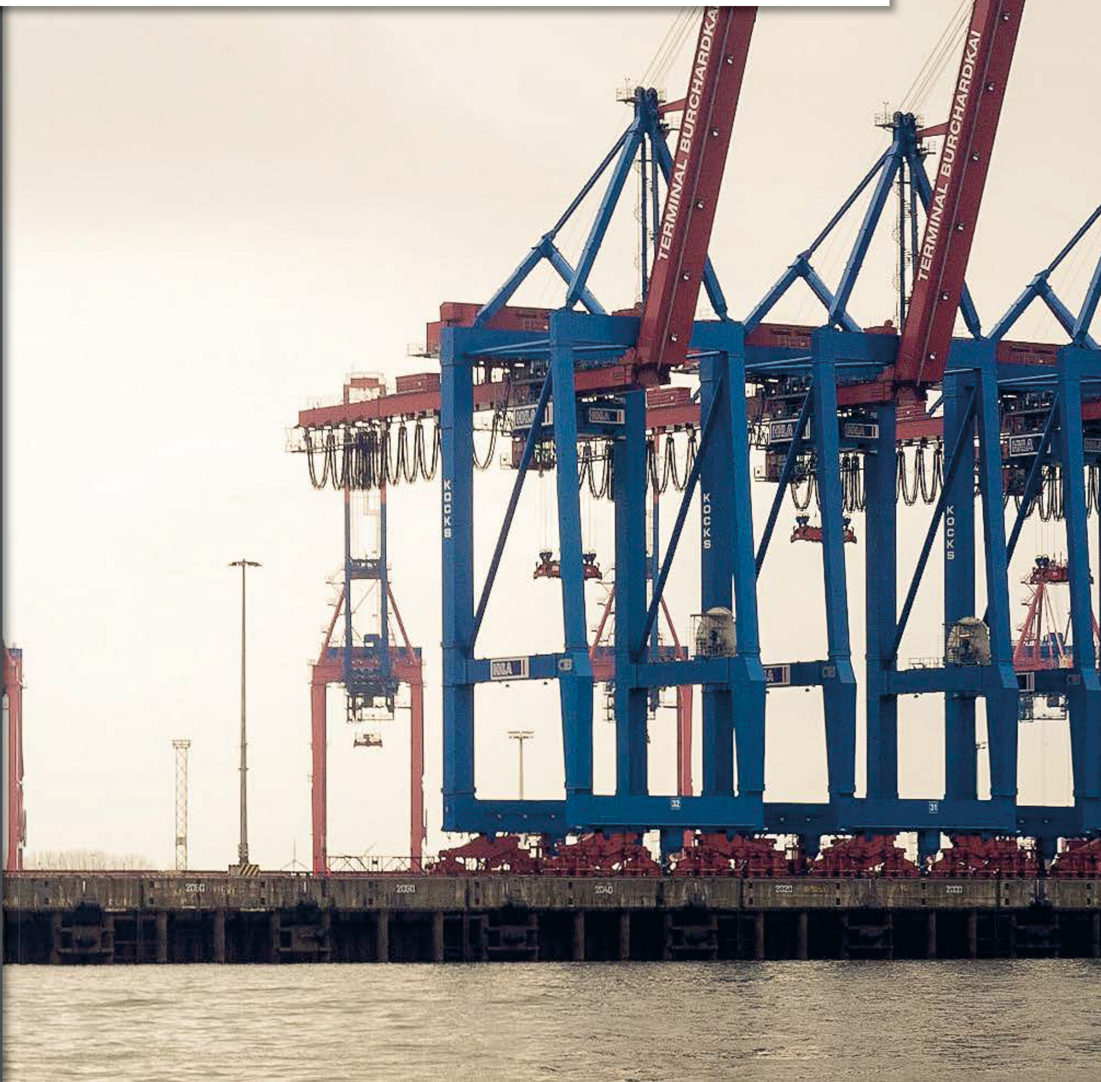

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Next Generation Supply Chains

Trends and Opportunities

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Preface

Today's business environment is undergoing significant changes. Demand patterns constantly claim for greener products from more sustainable supply chains. Handling these customer needs, embedded in a sophisticated and complex supply chain environment, are putting the players under a constant pressure: Ecological and social issues arise additionally to challenges like technology management and efficiency enhancement. Concurrently each of these holds incredible opportunities to separate from competitors, yet also increases chain complexity and risks.

This book addresses the hot spots of discussion for future supply chain solutions. It contains manuscripts by international authors providing comprehensive insights into topics like sustainability, supply chain risk management and provides future outlooks to the field of supply chain management. All manuscripts contribute to theory development and verification in their respective area of research.

We would like to thank the authors for their excellent contributions, which advance the logistics research progress. Without their support and hard work, the creation of this volume would not have been possible. We would also like to thank Sara Kheiravar, Tabea Tressin, Matthias Ehni and Niels Hackius for their efforts to prepare, structure and finalize this book.

Hamburg, August 2014

Prof. Dr. Dr. h. c. Wolfgang Kersten
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Opportunities and Threats

Identification of Megatrends Affecting Complexity in Logistics Systems

Wolfgang Kersten, Birgit von See and Henning Skirde

Abstract

To cope with megatrends companies often react with changes resulting in complexity. Thus, managing complexity results in increasing costs. Especially logistics service providers have to cope with cost pressure and are due to their size often limited in case of resources. In order to assess these costs an adequate complexity cost assessment has to be developed. Before developing such an approach, the question what drives complexity in logistics systems has to be raised and answered. In this paper, 16 megatrends affecting logistics systems are identified through literature review, expert interviews, and a focus group discussion. The identification and discussion of these megatrends with regard to complexity provides a first step towards a complexity cost assessment. Megatrends can thereby function as important drivers of complexity in logistics systems.

Keywords: megatrends, complexity, logistics systems, literature review

1. Introduction

Megatrends like globalization or individualized customer demand are constantly intensifying the competition among companies (Singh 2012, p.25). That is why manufacturers as well as logistics service providers as part of a logistics system have to organize processes as efficient as possible (Vahrenkamp 2005). Especially in logistics, this efficiency is essential in order to successfully cope with the high variety of existing processes and tasks. Sophisticated management systems are required to adequately deal with megatrends like sustainability, cloud logistics or Radio Frequency Identification (RFID). In logistics research, technological trends such as cloud logistics and the implementation of RFID as well as increasing safety requirements regarding catastrophes, strikes and terrorist attacks are focused on (Kersten et al. 2011; Will 2011). Furthermore, ecological and social sustainability of logistics systems are becoming increasingly important. Therefore, these aspects have to be considered when developing innovative approaches for the assessment of costs in logistics systems (Straube and Pfohl 2008).

Megatrends like globalization have a significant impact on the complexity of logistics systems (Fontius 2013, p.134). A common definition of complexity is based on the quantity and variety of elements, their relationship as well as the changeability of elements and relationships (Meyer 2007, p.25). In many cases, companies are struggling because the system they are coping with is too complex (Adam and Johannwille 1998; Rosemann 1998). This excess of complexity results in an excess of costs.

A key question is which level of complexity a logistics company has to achieve in order to successfully cope with megatrends. Therefore, when aiming to improve the level of complexity and the associated cost management, the identification of megatrends and their effects on complexity is a first step.

This paper is subsequently structured as follows: In Chapter 2, megatrends and logistics systems are defined to build up a reference framework. In Chapter 3, megatrends in logistics systems are identified based on a structured literature review. The results of this review are subsequently enriched by expert interviews and a focus group discussion. These megatrends are then compared and connected to complexity in order to establish a starting point for future research. Finally, conclusions are drawn from the connections among megatrends and complexity.

2. Theoretical Background

Before analyzing megatrends in logistics systems, the terms logistics systems as well as megatrends are separately introduced and defined to build up a reference framework. This aims at structuring the research field and to provide a better understanding of different viewpoints on megatrends and logistics systems.

2.1 Logistics systems

Logistics assures availability by providing the right good, in right quantity and quality, to right cost at the right place and time (Bullinger 2009, p.492; Waldraff 2007, p.168). To achieve this target of operating the material flow, the primary physical logistics processes have to be expanded by an anticipated planning and controlling of information flows (Koether 2011, p.37). This expansion constitutes one of the most recent historical developments in logistics. While in the 1970s logistics was typically associated with the principal tasks of transportation, handling and warehousing, today logistics is recognized as an integrative discipline linking companies to supply chains and functioning as a network (Neubauer 2011, p.50). Nevertheless, in Germany transportation (Transport), handling (Umschlag) and warehousing (Lagerung) are considered to be the basic functions of logistics (Pfohl 2010, p.8).
According to system theory, a logistics system can be defined as a construct of a minimum of two elements and their connection (Kestel 1995, p.12; Jünemann 1989, p.12 f.). Elements thereby aim at conducting the material as well as the information flow (Waldraff 2007, p.167 f.). Elements which are accounting for

the fulfillment of logistics tasks, e.g. buildings, machines, organizations (Kestel 1995, p.12), sites, means of transport or persons can be attributed to the logistics system itself. For the actual execution of logistics processes these elements are connected multifacetedly and structured hierarchically (Jünemann 1989, p.12). In addition, the term logistics network has been defined by GUDEHUS (2012, p.598) as a system with a variety of functions, composed by subsystems with each of them having one or few functions.

Considering logistics systems, PFOHL (2010, p.14 f.) differentiates the scope of macro, micro and meta perspectives. While macro logistics systems are defined on a macroeconomic level and therefore constitute a holistic perspective, micro level systems are based on a microeconomic level and are therefore closer to a company specific perspective. The perspective of meta logistics systems is located in between macro and micro systems, e.g. cooperation based systems (Pfohl 2010, p.14 f.).

Figure 1 shows a schematic illustration of a logistics system on a meta level perspective which is referred to in the following of the paper.

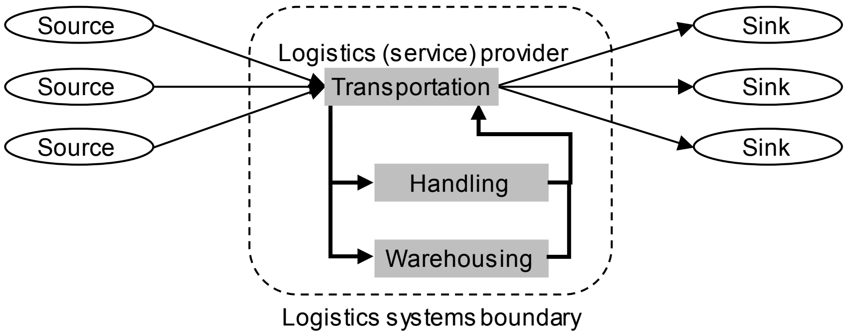

Fig. 1: Schematic illustration of a logistics system

Using system boundaries the logistics system can be distinguished from its environment. However, logistics systems are open systems and therefore influenced by their environment. According to DÜRRSCHMIDT (2001, p.25) influencing factors can be classified into intra-system, outside-system and global factors. An important example of such influencing factors are megatrends. They are described in the following chapter.

2.2 Megatrends

Trends can be characterized as longterm influencing variables on society, companies, and individuals. They describe conscious changes and provide information on the direction of future developments which influence values, purchasing behaviour, lifestyle and economic developments (Stahr 2012, p.66; Fontius 2013, p.16; Pillkahn 2007, p.15). Hence, a trend is considered as a catalyst for innovation and change. According to FONTIUS (2013, p.16 f.) four types of trends can be differentiated with regard to their breadth and the duration of their effects: fashion trends, consumer trends, socio cultural trends and megatrends. Table 1 substantiates how these can be differentiated.

Scope / Duration	Global	Supra-national	National	Regional
Long-term (> 25 years)	**Megatrends** (profound effect)			
Medium to long-term (5 – 10 years)		**Socio cultural trends** (major changes in attitudes, necessities and manners)		
Medium-term (5 – 8 years)			**Consumer trends** (changes in consumer behavior)	
Short-term (< 5 years)				**Fashion trends** (short-term high attentiveness and attractiveness)

Tab. 1: Differentiation of trends (Fontius 2013, p.17)

To constrain the extent of this paper, megatrends are focussed because they dominate the other types of trends.

The term megatrend was first suggested by the sociologist NAISBITT (1982) who describes large social developments. The literal meaning is composed of the Greek word “mega” (great) and the English “to trend”. Megatrend therefore means “a great tendency” or in the broader sense “a great development”. Based on the same understanding, NAISBITT (1982, p.1 f.) identified ten megatrends at his present time that were assumed to have decisive consequences on the American society. Especially the transformation from the industrial society to an information society and the globalization of the economy were predicted. Several years later at the beginning of the 1990s, the term megatrend was used to describe reactions to the renewed uncertainty of the turn of the millennium. Megatrends helped to identify future developments in the 21th century (Naisbitt and Aburdene 1992, p.9). The originally social definition of megatrends was expanded by an economical, political and technological perspective. Furthermore, investigations indicate that megatrends develop very slowly and effect society for at least a decade (Naisbitt and Aburdene 1992, p.9 f.).

Moreover, megatrends fulfill the following criteria. They are (Horx et al. 2007, p.33; Stahr 2012, p.67; Fontius 2013, p.17):

- Longterm, meaning that megatrends last 25 to 50 years,
- Ubiquitous, meaning that megatrends are present in all social systems, e.g. politics, economy, leisure,
- Global, meaning that megatrends have a worldwide presence, whereby specific characteristics vary from country to country,
- Robust, meaning that megatrends tolerate temporary throwbacks.

3. Megatrends in Logistics Systems

The term megatrend implies that they are ubiquitous. From this perception, the conclusion could be drawn that megatrends affecting logistics systems are covered by general megatrends. Thus, they could be identified from a universal catalog of megatrends. However, the effects that megatrends have on different branches vary to a great extent (e.g. the trend 'electric and alternative-energy vehicles' has a higher influence on logistics than on the public health sector). This is why a specific analysis on megatrends with a focus on logistics has been carried out for this paper.

The objective of this survey is to filter megatrends with regard to their relevance for logistics. This relevance is substantiated by the research community as well as by pracititioners in order to derive a manageable amount of megatrends with regard to a subsequent complexity analysis. The survey is structured into three paragraphs (Figure 2). First, a literature review is carried out. Second, practical insights are gathered by a focus group discussion. Both of these results are then, third, merged in order to derive a profound basis for further megatrends in logistics research.

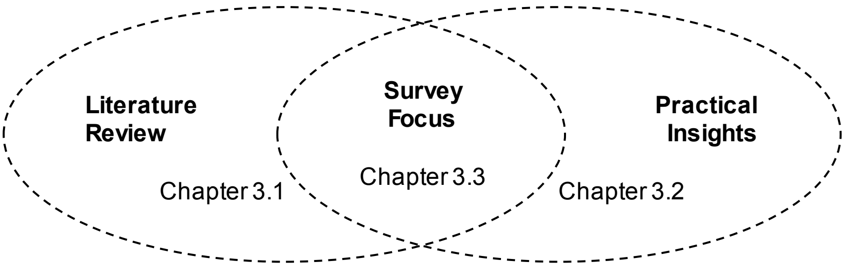

Fig. 2: Schematic illustration of the megatrend analysis

3.1 Literature Review

The objective of the literature review in this chapter is to identify a catalog of megatrends affecting logistics systems. Thereby, a profound basis is provided for a further identification of megatrends in industry, focussing on logistics.

3.1.1 Approach

First of all megatrends from literature were identified. The literature review reveals that no differentiation between the four types of megatrends introduced in Chapter 2.2 is accounted for. Most authors use the term 'trend'. Hence, for the literature review this term is considered in the broadest sense.

Trend surveys exclusively for logistics emerged in 1988 when the German Confederation of Logistics (BVL) in cooperation with the Technical University of Berlin first established a survey focusing on trends and strategies in logistics (Baumgarten and Ziebell 1988). To this day, there is a large number of essays and surveys which discuss megatrends in logistics and try to forecast their effects (Jünemann 2000; Kille 2008; Klumpp 2010; Münchow-Küster and Zelewski 2012; Straube et al. 2013). For this paper, literature from the last ten years was analyzed. The resulting trends from the literature review were aligned and structured with regard to their relevance for logistics. Trends were then prioritized based on a frequency analysis with regard to their occurance in literature. Trends being thematically connected to each other were additionally assigned to superior megatrends. Thus, they are double counted. Further investigation was conducted on the chronological appearance of trends in literature.

3.1.2 Results

Table 2 shows the result of the literature review. As already mentioned in Chapter 3.1.1, most authors use the term trend, merely MIKOSCH (2008), STRAUBE and CETINKAYA (2009) and LUBIN and ESTY (2010) describe megatrends.

30 trends with regard to logistics were identified in the literature covering the past ten years. Subsequently, a frequency analysis was carried out in order to derive initial implications on the relevance of the trends mentioned. Thus, important trends in logistics turned out to be sustanability, IT-integration, networked economy, new technologies, globalization as well as security. While most of these trends are constantly named over time, especially the trend sustainability initially named in 2008 has become increasingly important during the past years.

Megatrend	Baumgarten (2004)	Straube (2005) ***	Straube (2007)	Baumgarten (2007)	Kille (2008)	Mikosch (2008)	Straube / Pfohl (2008) ***	Straube / Cetinkaya (2009)	Straube et al. (2009)	Klumpp (2010)	Lubin / Esty (2010)	Wittenbrink (2010)	Münchow-Küster / Zelewski (2012)	Schuh (2012)	Däneke (2013)	Handfield et al. (2013) ***	Straube at al. (2013)	**sum**
Sustainability / Green logistics						x	x	x	x	x	x	x				x	x	**9**
New technologies		x		x			x	x		x			x			x		**7**
IT-integration			x	x						x			x	x	x			**6**
Security				x			x	x		x			x			x		**6**
Networked economy	x		x	x				x								x		**5**
Globalization		x	x				x	x								x		**5**
Outsourcing	x	x			x					x								**4**
Customer expectations / Individualization		x							x							x		**3**
Cost pressure							x						x			x		**3**
RFID* - radio-frequency identification				x						x								**2**
Cloud computing**													x	x				**2**
GPS* - Global positioning system										x			x					**2**
Talent shortfall													x			x		**2**
E-Business													x					**1**
Telematics**													x					**1**
Demographic change							x											**1**
Transparency in supply chain										x								**1**
Social responsibility							x											**1**
Value-oriented customer		x																**1**
Compliance							x											**1**
Container traffic													x					**1**
Electric and alternative-energy vehicles										x								**1**
Eastern European expansion of the EU		x																**1**
Industry 4.0**															x			**1**
Capacity management / extension										x								**1**
Logistics controlling													x					**1**
Human centered logistics										x								**1**
Simulation**													x					**1**
Reverse logistics													x					**1**
Volatility																x		**1**
Competition		x																**1**

* further new technology ** further new IT-integration *** BVL series of studies

Tab. 2: Result of the literature review on trends in logistics

In contrast, several trends were named only a few times. For these trends, further investigation has to be carried out whether they fulfill the requirements of the megatrend definition in this paper or rather feature short or middle term characteristics.

Again, trends were identified which have been first named in literature in the past two years like cloud computing, industry 4.0, volatility and talent shortfall. Because of the currentness of these trends they might turn out to be emerging megatrends or rather tendencies in the future.

3.2 Practical Insights

Literature review mirrors investigations from several researcher. Results of the present survey will be taken in order to develop a cause and effect analysis on megatrends and complexity for logistics service provider. This is why it is necessary to integrate practical insights related to the research topic. Approach and results are described in the following.

3.2.1 Approach

The practical insights presented in this paper were extracted from an interview study. The sampling of the interview participants is based on a focus group. Focus groups consist of a small group of experts (Puchta and Potter 2004, p.6). Typically, such a group is constituted by five to ten experts who have either a homogeneous or heterogeneous background (Flick 2006, p.193).

For this investigation a heterogeneous group was sampled. The sample consists of eight experts with varying backgrounds out of five companies. By examining these several perspectives, a broad view of logistics systems is assumed.

With regard to a future analysis of the impacts on basic logistics functions like transportation, handling and warehousing (Chapter 2.1), participants within these disciplines were chosen to be part of the focus group (Table 3). Another classification is provided with regard to the size of the individual companies. The objective of this classification is to highlight small and medium-sized companies (SME). In addition, consultants were interviewed to derive a holistic overview of logistics systems based on the experience from a number of client companies.

As a preparatory work for a focus group discussion on megatrends in logistics, individual semi-structured interviews were conducted with the members of the focus group. Hereby, megatrends rather than trends were focused. The interviews were partially transcribed into a profile matrix (Maxwell 2013, p.108 f.). From this matrix based transcription megatrends were identified and indexed.

Company	SME	Logistics function of the company	Partici-pants	Position
A	y	Transportation, Handling, Warehousing	2	Executive Quality Manager
B	y	(Individual) Transportation, Handling, Warehousing	1	Executive
C	y	Handling, Warehousing	1	Executive
D	y	Consulting	2	Consultant Partner
E	n	Consulting	2	Consultant Consultant

Tab. 3: Members of focus group

3.2.2 Results

Table 4 shows the results of the semi-structured interviews on megatrends in logistics systems. 18 megatrends were individually named by single participants. Although a focus was set on megatrends, the question whether these namings represent actual megatrends or rather trends needs further discussion.

Megatrends like sustainability, globalization and demographic change were named most frequently. Furthermore, according to the experts, IT-related megatrends like transparency in supply chains, IT-integration, E-business or RFID technology are megatrends that logistics systems have to cope with.

Megatrend	A	B	C	D	E	sum
Sustainability / Green logistics		x		x	x	3
Globalization		x		x	x	3
Demographic change	x		x	x		3
Transparency in supply chains	x		x		x	3
IT-integration	x			x		2
E-Business / Online Shopping			x		x	2
RFID - radio-frequency identification	x				x	2
New technologies	x					1
Customer expectations / Individualization				x		1
Cost pressure			x			1
Talent shortfall			x			1
Container traffic		x				1
Electric and alternative-energy vehicles		x				1
Reverse Logistics	x					1
Smartphone	x					1
Euro-pallet		x				1
Speed		x				1
Lobbyoriented society		x				1
Political apathy		x				1
Work-life balance		x				1
Employee satisfaction			x			1
Urbanization				x		1
Mobility				x		1
Increased information gathering by customer					x	1
3D printing					x	1

Tab. 4: Results of the interviews on megatrends in logistics systems

3.3 Consolidation of the Results

Aim of this step is to filter megatrends that are supposed to be further considered for an effect analysis on complexity. This is achieved by a comparison of the results within a focus group discussion.

3.3.1 Approach

Both independent results were merged in order to identify those megatrends to consider for a future complexity analysis. A preselection was made by choosing megatrends being named by both, literature as well as practitioners. The results of the literature review and the semi-structured interviews as well as the preselection were then discussed and evaluated within the focus group described in Chapter 3.2.1. Focus groups can be used in order to discuss a topic related to a research problem within a small group of experts (Puchta and Potter 2004, p.6). This discussion led to an extensive view on megatrends taking different perspectives of a logistics systems into account. As a result of the focus group megatrends for further analysis were documented.

3.3.2 Results

Figure 3 presents the results of the comparision and discussion of megatrends regarded as relevant in literature and by the practitioners. 15 megatrends named in literature were stated as relevant by the experts in the semi-structured interviews. Several megatrends that are emphasized in literature were also found to be relevant by the practitioners. Noticeably, the megatrend demographic change and transparency in supply chains which were named most frequently by practitioners (Table 4), have only minor occurrence in literature (Table 1). Furthermore, megatrends exist with a high score in the frequency analysis in literature but were considered being less relevant by the practitioners, both in the interviews as well as in the focus group discussion. This is the case for megatrends like networked economy, security or outsourcing. Especially the megatrend outsourcing is no longer a megatrend according to the expert of company C. This expert has observed a turnaround towards an increasing vertical integration in logistics.

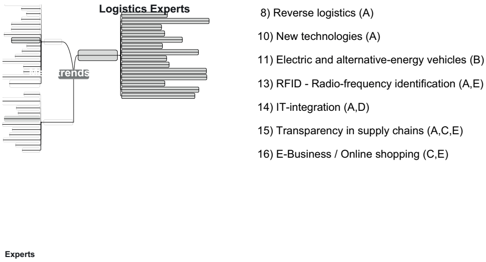

Fig. 3: Consolidated results of literature review and focus group discussion

Furthermore, there are ten megatrends which were named by respectively one practitioner but have not been found in literature. The investigation has shown that the term megatrend is inconsistently defined among companies. This inconsistency might be the reason why these megatrends have not been found in literature.

The discussion within the focus group has shown that globalization is a superior megatrend which influences many other megatrends and trends. The megatrends listed can be brought into a hierarchical order (e.g. the megatrend individualization as a result of globalization). The discussion of megatrends within the focus group has shown that an actual megatrend can seldom be distinguished from its effects.

The focus group approved the preselection of megatrends (those named by both the literature as well as practitioners) for further investigation. Discussions of the megatrends being named by only one medium, either in the literature or by one of the experts led to the conclusion to add the trends 3D printing as well as compliance. By the focus group 3D printing has been seen as a current trend which could further spread out and become a megatrend with a significant influence on logistics. Another critical megatrend for logistics is compliance. This aspect has been named by experts as a driver of complexity and was added to the list of megatrends being focused. This leads to the point where megatrends and drivers of complexity should be compared regarding their influences. A first implication can be derived from this perception that megatrends might function as drivers of complexity.

In the following, the 16 chosen megatrends are described as a basis for further complexity analysis.

1) The megatrend ‘globalization’ has a close connection to 'networked economy'. Because of increasing globalization companies are challenged to build up fast and robust supply chains (Baumgarten 1996, p.53). Networked economies are the result of growing complexity within companies and supply chains. Internal complexity is often growing because companies try to reduce the complexity elsewhere utilizing cooperations and networks (Straube and Cetinkaya 2009, p.138). Globalization can be considered being a complexity driver because it enables a relocation of production sites as well as an opening up of new markets. Thus, it influences the complexity of the entire logistics system (Straube 2007, p.1005). Globalization can be classified as an external driver, whereas networked economies represent a driver within the logistics system (Handfield et al. 2013, p.14 f.).
2) Increasing 'customer expectations' and 'individualization' is one of the results of globalization. It causes an increasing number of product variations and a differentiation of service patterns (Handfield et al.

2013, p.15 f.). To fulfill customer expectations it is best to identify and integrate customer requirements at an early stage into the process of building up a logistics strategy (Baumgarten and Walter 2000, p.8).

3) Because of growing global competition companies are challenged to work cost efficient. This 'cost pressure' is another megatrend (Handfield et al. 2013, p.19 f.). For logistics systems this pressure is intensified by increasing logistics costs originating from rising costs for energy and fuel (Straube and Pfohl 2008, p.6) as well as fees like duty or toll costs (Münchow-Küster and Zelewski 2012, p.7).

4) According to MÜNCHOW-KÜSTER and ZELEWSKI (2012, p.6) a rising tendency can be observed with regard to the importance of 'container traffic'. This mirrors megatrends like globalization and E-business. The expert from company B mentioned container traffic in the same breath with the euro-pallet. Both of these standardizations in logistics function as an answer to the rising variety and complexity of products and processes.

5) 'Demographic change' reflects the aging of society. This megatrend has an increasing influence on logistics. Influences can be divided into two extents: employees and customer. Due to demographic change well qualified employees are limited. Talent shortfalls (which as a result of demographic change are described in no. 6) enforces companies to put efforts in training and ergonomics. Demographic change from the customer perspective leads to rising and changing demands in case of products and services (Straube and Pfohl 2008, p.14).

6) 'Talent shortfall' is said to be the megatrend most challenging for logistics in the next years. This megatrend currently turns out to be a result of the demographic change (Handfield et al. 2013, p.8). Especially for young people working in the logistics sector seems to be rather unattractive. While HANDFIELD et al. (2013, p.25 f.) investigate a lack of skilled labor jobs like managerial controlling or planning

functions, the focus groups laid a focus on the operational level, in detail the lack of qualified truck drivers and warehouse staff. This megatrends leads not only to labor shortage but also to knowledge management problems caused by the future retirement of the current employees (Handfield et al. 2013, p.24 f.).

7) A very important megatrend is 'sustainability'. The concept of the triple bottom line states that sustainability should cover an environmental, economic as well as a social perspective (Elkington 1998). With regard to logistics the term sustainability is often recognized synonymously as its fraction of 'green logistics' (Kersten et al. 2010, p.371; Handfield et al. 2013, p.16) which only takes environmental aspects into account. Because of growing customer demands and tight legal policies, sustainability is getting more and more important. Therefore, the megatrend is most frequently mentioned in the recent literature (Straube et al. 2013, p.7). Especially in current empirical studies the importance of this megatrend becomes apparent (Klumpp 2010, p.10; Handfield et al. 2013, p.8). Nevertheless, there is still a lack of sustainability assertion on the management level, which is why it could be a competitive advantage to step up the effort on sustainability in an early stage of time (Lubin and Esty 2010, p.76; Wittenbrink 2010, p.19).

8) The megatrend sustainability directly enforces the trend 'reverse logistics'. The importance of return-to-use aspects and thereby reverse logistics rises (Münchow-Küster and Zelewski 2012, p.6). This has a direct influence on logistics. Experts feel confronted with both an increased transport volume but also a diversification of requirements.

9) The megatrend 'compliance' with regard to logistics is enforced by politics. Especially forwarding agencies are increasingly influenced and restricted by regulations. In addition, these regulations are constantly changing. This uncertainty and the associated need for business adaptions challenges logistics companies in being flexible

and ties up resources (Straube and Pfohl 2008, p.14). According to experts from company A, compliance also leads to product changes resulting in altered transport requirements.

10) 'New technologies' is another megatrend influencing logistics. Its importance also becomes apparent by analyzing individual new technologies, for instance the Global Positioning System (GPS) (Münchow-Küster and Zelewski 2012, p.20 ff.) and RFID (Klumpp 2010, p.10). Furthermore, new information and communication technologies (ICT) provide the basis for IT-Integration (as a megatrend) and influence them significantly. Especially RFID is important to logistics. As an interface to IT-systems, it enables a broad availability of information for supply chains (Baumgarten 2007, p.991).

11) The trend 'electric vehicles and alternative-energy vehicles' is named by KLUMPP (2010, p.10). Participants of the focus group pointed out that this trend is a direct effect of the trend 'green logistics'. Furthermore, alternative-energy vehicles can be regarded as an effect of compliance demanded because of legal reasons (Esch and Dahlhaus 2013, p.501). The refueling infrastructure for alternative-energy vehicles is not yet sufficient for commercial applications in the overland transport logistics sector. For instance, hybrid vehicles are most efficient in city traffic and therefore not prevalent in overland fleets (Zieringer 2010, p.122).

12) '3D printing' was not identified as a trend in literature. One expert (company E) stated that this technology might have a significant impact on logistics, leading to a reduced amount of goods to be transported. Thus, 3D printing has the potential to become an important megatrend. The focus group agreed to register 3D printing as a trend because of this possible development. According to LEHMACHER (2013, p.84) this technology might change global trade characteristics. This would obviously have a significant influence on transport volume, enforcing logistics service providers to develop new

business models (e.g. offering 3D printing shops) (Lehmacher 2013, p.84 ff.). Today 3D printing is at the peak of inflated expectations on the hype cycle (Gartner cited in Strauss 2013, p.252 f.). Nevertheless, whether this revolutionary technology (Rayna and Striukova 2014, p.119) will be established is more or less unpredictable (Lehmacher 2013, p.85).

13) 'RFID' is a technology for wireless identification of products or carriers in logistics systems. Using this technology, data is generated, thereby information transparency is increased. This can be used in order to optimize processes and information flows (Baugarten 2007, p.991). According to KLUMPP (2010, p.10) RFID ensures transparency and security within the supply chain and can be seen as an important trend. This trend has the potential to cope with an increasing complexity.

14) One of the megatrends referred to most frequently is 'IT-Integration', both in general as well as in the field of logistics. Because of the development of the latest ICT systems, a company's relationships with customers as well as suppliers could be simplified. At the same time many processes regarding global sourcing, production or distribution could be accelerated (Baumgarten 1996, p.54). The development of the internet is considered as a crucial milestone of IT-integration (Straube 2007, p.1005). Especially current empirical studies point out the importance of this megatrend (Klumpp 2010, p.4; Münchow-Küster and Zelewski 2012, p.19 ff.).

15) Focus group members directly relate the trend 'transparency in supply chains' to IT-integration. This trend, which was named with respect to logistics by KLUMPP (2010, p.10) mirrors the use of data and ICT. This usage first allows tracking and tracing via GPS or RFID, second provides realtime information allowing for prediction of problems and third facilitates the collection of data for measuring performance (Notteboom 2013, p.89). MEIER et al. (2008, p.311 ff.) show a

causality between transparency and complexity in supply chains. According to them, rising transparency leads to increasing complexity (Meier et al. 2008, p.315).

16) 'E-Business' is one of the results of new ICT. The internet dramatically changed the relationships among companies and their customers as well as the cycles of business processes (Baumgarten and Walter 2000, p.6 f.). But that is how innovative business ideas and bidirectional communication with the customers are enabled (Jünemann 2000, p.9).

4. Conclusions and Opportunities for Further Research

When providing a cost management system for logistics, the identifcation of megatrends is essential due to their effects on complexity. Within the scope of this study, 16 megatrends relevant for logistics systems were identified. The study was conducted as a combination of a literature review and a focus group with eight experts from five companies guaranteeing different perspectives on logistics systems. An extension of the sample in the future might contribute to the validation of the initial results.

For the trends identified, effects on complexity will have to be analyzed with the aim to set up a complexity cost assessment for logistics systems. Therefore, trends will be evaluated according to their range of influence on complexity.

In the course of the study, a need for further research with regard to the following questions has been identified:

- How can megatrends be distinguished from each other and ordered hierarchically?

Investigation showed that trends identified were not differentiated. Many interferences were identified which is why the trends need to be further distinguished from each other. Fontius (2013) showed a possible concept to structure trends as a function of time and scope. This may lead to a way how to first group trends and then bring them into a hierarchical order. This directly leads to the following question:

- How do megatrends affect each other?

Due to the fact that trends identified in this study were obviously located on different levels (e.g. new technologies and RFID), causes and effects of megatrends need to be analyzed. This could be achieved by developing a trend network showing cause-effect relations. These relationships will help to answer the question being raised at the beginning of this paper:

- What effects do megatrends have on complexity?

With regard to complexity, the study showed that several megatrends were regarded as direct drivers of complexity by the experts (Chapter 3.3.2). This finding needs to be further evaluated for all of the trends identified.

- Which megatrends function as a complexity driver?

Answering these questions raised above will help to map cause-effect relationships on megatrends, complexity and the associated costs.

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Planning Approach for Robust Manufacturing Footprint Decisions

Philipp Sprenger, Matthias Parlings and Tobias Hegmanns

Abstract

The manufacturing footprint strategy of European automotive companies has been determined in the preceding decades by a reduction of labour and operational costs and the development of new markets. Today, the automotive sector is characterised by growing number of logistic-related requirements like customisation, just-in-sequence supply and assembly of vendor parts (FAST 2025, 2013). This leads to the development of footprint planning as a multidimensional and complex decision problem with a significant impact on the competitiveness and finances of the business (Häntsch and Huchzermeier, 2013; Farahani et al., 2013).

In response to this challenge, a literature review of footprint planning and facility selection methods and models for designing supply chain networks will be presented. The comparison of existing approaches shows the necessity of new models that allow robust and adaptable footprint decisions while especially considering project and market-related uncertainties. These uncertainties demonstrate the need to revise the footprint strategy continuously.

Derived from the state-of-the-art analysis, a holistic planning work flow that supports decision makers in automotive industries from a supply chain design perspective with a special focus on the uncertainty of future business opportunities is presented. This approach integrates qualitative planning modules for knock-out-analyses and use-value-analyses and integrates quantitative modules (e.g. Monte Carlo simulation) for future project allocation. This planning procedure adopts a project-driven approach and allows for a multidimensional evaluation of different footprint scenarios, based on an uncertain future project and contract situation.

Keywords: manufacturing footprint decision, supply chain design, uncertainties, robustness

1. Introduction

Today, automotive business currently has 2% growth in Europe, which is much lower than the US market (6%) or the 8% growth of the Asian-Pacific market (Bratzel et al., 2013). In particular, competition between automotive companies in Europe is intense. OEMs are still working on cost and price reduction and the development of new sales arguments, which lead to innovations like more customer-specific products, shorter product life cycles and multiple models and platforms, to assert their positions in this market (Klug, 2010).

This strategic orientation of the OEM additionally has a strong impact on the supplier side and the design of their manufacturing and logistic networks. The innovations not only influence engineering and manufacturing, but also significantly impact logistics. Competition for suppliers has developed from a purely cost-oriented approach that focuses on labour and manufacturing costs for perspective integrating logistics performance and value-added services. This leads to the development of footprint planning as a multidimensional supply chain management decision problem with a significant impact on the competitiveness and finances of the business (Häntsch and Huchzermeier, 2013; Farahani et al., 2013).

The decision of where a supplier should locate new manufacturing sites is determined by several uncertainties. This could be market-related uncertainties such as changes in incoming projects or changes during a production project like volume variation, in addition to environmental uncertainties like availability of labour. As project a new customer order, in the sense of a new mid-to long-term delivery contract is understand. From the perspective of the supplier, these contracts represent projects that evolve in different phases over time. From early negotiations with high uncertainty about realisation to confirmed contract which then are specified in joint process of the OEM and supplier. Even confirmed contracts experience changes, such as in volume, parts, logistic requirements, which may lead to fundamental adaptations of the logistic concept and footprint decision. These decisions go beyond facility location problems. Rather, footprint decisions evaluate a firm's value-creation process from a supply chain and business perspective. In particular, this problem lies in creating a robust and adaptable manufacturing footprint decision that considers uncertainties and provides for a solid and competitive manufacturing location and a long planning horizon, while simultaneously allowing for the continuous revision of the footprint strategy.

The first objective within this paper is the depiction of footprint decisions issues for suppliers in automotive supply chain networks. Furthermore a comparison of existing approaches for decision support will be presented. Based on the literature review of robust footprint planning, facility selection methods and planning approaches for the design of supply chain networks, an evaluation in accord with outlined requirements will be presented. A potential planning approach will be presented similarly.

The paper is organized in five major sections. Section 2 introduces key terms like supply chain design and robustness, and details requirements for decision support methods. Section 3 uses a literature review to demonstrate the necessity of a planning approach for robust and adaptable footprint decisions. Section 4 briefly presents the implications of the development of a planning approach. Section 5 summarizes the findings of this paper and discusses the need for robustness in footprint planning in the automotive industry.

2. Footprint decisions from a Supply Chain Management perspective

In the following section, relevant key-terms for footprint decisions are introduced. To obtain a common understanding of footprint decisions, complex supply chain networks are analyzed from a strategic supply chain management perspective. Furthermore, characteristics of footprint decisions are described and the understanding of robustness within this field is presented.

Supply chain management involves not only the efficient movement of goods in a supply chain, but also the strategic decisions such as product production location, the customer allocation to distribution facilities and the design of sourcing, production and distribution processes. These strategic and long-term questions can be summarized as supply chain design (SCD). SCD integrates all long-term and strategic planning problems in supply chain management. Parlings et al. (2013) distinguish SCD tasks in three levels: Superodinate SCD tasks, supply chain structure design tasks and supply chain process design tasks. Structural supply chain design tasks include make-or-buy decisions, supply chain partner selection, product and customer allocation, dimensioning of capacities and facility selection. Based on a literature review of major SCM-related journals between 2008 and 2013, Parlings et al. (2013) state that footprint planning is the most common planning problem in supply chain design. Daskin et al. (2005) and Chopra and Meindl (2010) identify footprint decisions as a key driver for supply chain performance and as the most critical and difficult decision in supply chain design.

Footprint decisions are not only part of the supply chain design, but have been the subject of years of economic research. Weber (1909) determined hard and soft location factors in the beginning of the last century. Kinkel and Buhmann (2009) wrote that accounting for both soft location factors and hard measurable factors results in a more informed choice, which increases the long-term competitiveness of a facility. Thus, a permanent planning approach that allows for an ongoing evaluation is required. While comparing different locations and supply chain configurations, the robustness of a footprint scenario should be measurable in multiple dimensions such as costs, responsiveness, reliability, agility and assets. Melo et al. (2009) note that the role of footprint planning is decisive for supply chain network planning and that there are several planning approaches accounting for total cost and investments. Furthermore, there is a need for planning approaches in real-life problems, which involve more than costs and investments.

Before answering the question how to support footprint decision, it is important to determine what the decision is about. From the following we will see that the understanding of footprint planning is more than the solving the facility location. Rather, footprint planning is taking into account a firm's value-creation process from a supply chain and business perspective.

There are several criteria which allow a definition of the footprint planning problem. Arnold et al. (2008) are distinguishing footprint planning in internal facility planning and facility location. The internal planning is taking the building and resources within the building into account. The facility location problem is taking care about where to locate a facility and how the footprint of a company should look like. Chopra and Meindl (2010) are separating role or function (manufacturing or warehousing) and the location (geographical dimension) of a facility. Bankhofer (2001) and Neuner (2009) also distinguish the function and the location, and use other criteria to define the planning problem, such as network dimensions and qualitative or quantitative evaluation. Within this research contribution, the scope is on the decision process where to locate a facility. Beyond this rough classification, the facility location problem can be categorized according to different criteria.

To solve the footprint problem, manufacturing facilities in a multinational supply chain network should be evaluated by quantitative and qualitative targets. In addition to the measurability of targets, the footprint decision needs to be robust. The concept of robustness, in combination with decision-making under uncertainty, is discussed in many articles with varying meanings.

The strategic nature of long-term planning problems like footprint planning must consider qualities of an uncertain future (Owen and Daskin, 1998). Some scholars have distinguished model, algorithm and solution (decision) robustness (Klibi et al., 2010; Mulvey,et al., 1995; Freiwald, 2005). In this paper, the understanding of robustness in a manufacturing footprint decision is linked to strategic supply chain planning decisions. A robust supply chain design will not lose its superiority when conditions change when compared to other design alternatives (Bretzke and Barkawi 2010). Developing this idea further, a robust supply chain network is able to carry its functions for a variety of plausible future scenarios (Klibi et al., 2010).
Given the problem and the coherence of supply chain design, footprint decisions and robustness, the following requirements can be deduced.

Requirement 1: SCM-based footprint decision.
Manufacturing sites of global automotive suppliers are parts of complex internal and external supply chains. These manufacturing locations should be monitered as a part of a supply chain network. Isolated footprint planning will destroy many planning potentials and adversely affect coordination of the distribution and procurement sides of the network. Manufacturing footprint decisions have an essential impact on the overall supply chain performance, especially when considering the high vertical integration of the internal supply chains of suppliers (Daskin et al., 2005). The footprint decisions should be integrated in the supply chain configuration, to ensure an efficient and operational supply chain network used on both a daily basis, and a long planning horizon (Klibi et al., 2010).

Requirement 2: Multi-objective evaluation
In practice manageable methods that provide quick and measurable results are required. Many companies, especially small and medium-sized enterprises, still based footprint decisions on simple qualitative or quantitative cost studies

(Kinkel and Buhmann, 2009). These unilateral evaluations can lead to wrong decisions, which can have enormous consequences on the business.

Requirement 3: Robustness

To account for a highly dynamic environment with unpredictable changes, the footprint decision should be robust for new projects while being similarly prepared for the logistic requirements during the project life time. For example, the uncertainty of contract negotiations should be taken into account, so that flexibility is created to adapt to changing contract conditions, such as volume, redesigns or other logistic requirements in later phases. Automotive suppliers struggle with model changes, facelifts and the frequent redesign of products. The footprint decision should be robust to both environmental and social uncertainties, such as changes of political situations or changing availabilities of labour.

Requirement 4: Adaptable to a dynamic project environment

The variance of future order situations and the current project makeup should be considered during the entire decision process of a new manufacturing footprint. An adaptable planning approach for robust footprint decision is required.

Requirement 5: Permanent decision support

Permanent footprint decision support is required as significant changes on the supply chain network and its manufacturing site can be considered in early stages of the footprint planning process. Previous footprint decisions can be repealed if necessary. A permanently available, reactive decision support method can support further planning steps, such as the quotation process, where an effective location can positively influence competitiveness.

Figure 1 summarizes the requirements for a robust and adaptable manufacturing footprint decision in supply chain design.

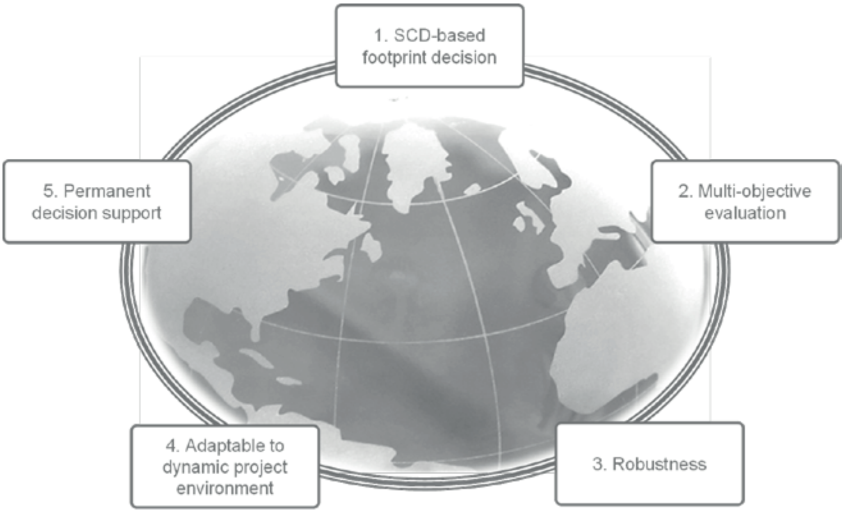

Fig. 1: Requirements for a robust manufacturing planning approach

3. State of the Art Review

This chapter presents a state-of-the-art review of different methods for supporting manufacturing footprint decisions. In the second subsection, supply chain design approaches that utilize the presented methods are analyzed in detail. This evaluates approaches where the manufacturing footprint decisions impact the supply chain network. The last subsection summarizes the results of the literature review and provides an intermediate conclusion.

3.1 Methods in manufacturing footprint planning

Recently, methods that allow for the assessment of interdependencies between hard and soft location factors like investments and levels of education on evaluation systems, have been published in response to different planning problems relating to footprint planning in the context of strategic supply chain management (e. g. Daskin et al., 2005; Klibi, et al., 2010; Amin and Zhang, 2013; Farahani et al., 2014). Methods allow for evaluation. Figure 2 shows typical quantitative and qualitative methods for evaluation.

Traditionally, qualitative methods are used to reduce the number of potential footprint scenarios to a manageable number. Methods like use-value-analysis are widely used in practice. These methods generally use a criteria-scheme which is scored and weighted by experts and have a significant advantage in that many location factors can be considered without the need for a high amount of quantitative input data (Kinkel and Buhmann, 2009). In contrast, quantitative methods require measureable data to be effective. At the same time, these methods provide a comprehensible result. Most of the presented quantitative methods focus on economic targets, such as costs, profit or investment calculations. Many of these methods are limited by the linkage between soft location factor and economic or performance targets.

Using information processing, some qualitative and some quantitative methods can be distinguished as static or dynamic methods. Reference in long-term footprint decisions is one of the important key factors (Freiwald, 2005). Several quantitative methods like net present value method or pay-of-calculation methods allow for a dynamic assessment. These dynamic methods account for parameter changes based on prognoses over an extended planning horizon. Unpredictable changes with large influences on the footprint decision, such as

Quantitative methods	Qualitative methods
▪ Static and dynamic capital budgeting ▪ Break-Even-Analysis ▪ Costs, profit and earning calculation methods ▪ Net present value method ▪ Static and dynamic payoff period calculation methods	▪ Use-value analysis ▪ Checklist methods ▪ Country risk indicators ▪ Scoring methods ▪ Tradeoff studies ▪ Profile method ▪ Analytic hierarchy process

Fig. 2: Method classification (Kinkel and Buhmann, 2009; Günther and Tempelmeier, 2005; Neuner, 2009)

changes in the incoming order situation or changes during a production project like volume variations which do not meet the forecasts, cannot be taken into consideration. If considering uncertainties typical for automotive supply chain networks, these methods reach their limits (Kinkel and Buhmann, 2009).

Furthermore, methods for footprint decisions support can be either deterministic or stochastic (Freiwald, 2005). Stochastic methods are especially used to account for uncertainties when working with probabilities and distribution functions. In Operations Research, optimization and simulation are often used as methods which model stochastic coherences (Freiwald, 2005; Amin and Zhang, 2013). To evaluate the robustness of a supply chain network and the facilities therein, a simulation-based sensitive-analysis is recommended (Bretzke and Barkawi, 2010). The change in a footprint will have an effect on the network, the supply chain and its performance. Simulation is a manageable method to measure these effects and to determine coherences of structural (footprint) or parameters (changing demands) of a complex system (Kuhn et al., 2009). Simulation is the representation of a system (in our case a supply chain network) with its dynamic processes in an experimentable model to reach findings which are transferable to reality (VDI 3633, 2010).

Based on the requirement of an adaptable and quick decision support, the advantages of qualitative methods are obvious. Using a small number of quantitative input data, measurable results can be provided. Due to several aggregations during the scoring process, the scored results of use-value-analysis can become incomprehensible (Adam, 1996). Strategic network decisions and robust footprint decisions should not be made exclusively on methods with highly abstracted results.

3.2 Planning approaches for supply chain design

Kinkel and Buhmann (2009) point out that there is no single method that integrates all variables of a complex decision and covers its depth completely. A combination of methods should be implemented in a planning approach. Thus, a literature review of different SCD planning approaches is presented in detail. Approaches were selected that are well known in practice and research, starting from the year 2000. Suitable keyword, supply chain design, strategic supply chain management and robust footprint decision in supply chain design were derived from the problem description and analyzed according to the requirements given in the first section.

The planning approach from Sabri and Beamon (2000) supports decision-makers according to multi-echelon (four echelons) supply chain design. A unique characteristic of this method is the simultaneous optimization of strategic and operative structure problems. The strategic sub-model optimizes the supply chain configuration and the related material flows. The operational sub-model is integrated into planning the strategic sub-model in order to accommodate uncertainty, such as customer demand variations, and to evaluate costs, customer service level and flexibility (Sabri and Beamon, 2000). This level of detail can be increased by implementing optimizations. However, the manufacturing footprint planning covers only a small part of the planning approach.

Chopra's and Meindl`s planning approach additionally describes a framework for decision support in network configuration. According to supply chain strategy, structural problems will be solved when using optimization (Chopra and Meindl, 2001). This approach is similar to everyday planning in operations. Chopra and Meindl (2010) have shown that a solution can be realized with the help of MS Excel, which is a general use calculation software. Realistic uncertainties and dynamic factors of a supply chain disappear with highly abstracted KPI-analysis. However, Chopra and Meindl have designed a highly practical conceptual planning approach for strategic network problems, which allows quick decision support. This planning approach, however, does not support adaptation.

The planning approach from Wolf and Nieters consists of eight planning steps. In the first step, a project team is set up. Secondly, the planning tasks need to be defined. The next step describes the generation of planning data. The next two steps describe the modelling process and the parameterization of data.

Step six and seven give the analyses (simulation or optimization) and evaluation methods. The last step supports decision makers (Wolff and Nieters, 2002).

Reiner and Schodl's approach provides a support for the evaluation of different supply chain optimizations. The efficiency is comparable to the satisfaction level of the customer. The approach regards both enterprise-specific and product-specific requirements. The approach provides different KPI, but the focus is on supply chain efficiency (Reiner and Schodl, 2003). This is a highly aggregated approach, and it is not developed specifically for footprint decisions in supply chain design. However, it can be transferred, and it provides a framework for the integration of supply chain strategy into the manufacturing planning problem.

Kinkel et al. (2004) developed a scenario-based planning approach designed for footprint decisions. In contrast to the other planning approaches that are presented in this subsection, this approach focuses on the footprint decisions while accounting for the network perspective as a constraint. The approach provides modules for facility controlling, scenario management, knowledge management and for the optimization of the existing footprint. Kinkel does not provide methods like simulation to account for uncertainties. This approach works with optimistic, realistic and pessimistic scenarios.

The planning approach from Freiwald (2005) describes a decision support model based on a mathematical supply chain design optimization model. Dimension and network structure capacity and material flow are considered in addition to the cooperation with different suppliers (Freiwald, 2005). This planning approach considers different uncertainties and allows for an evaluation of robustness, but disregards adaptability.

Günther's and Tempelmeier's planning approach describes a quantitative procedure for footprint planning. In detail, it is a discrete optimization model for a fixed number of footprint scenarios (Günther and Tempelmeier, 2005). The evaluation is based fixed costs and transportation costs. The planning approach does not provide any KPI's for supply chain performance or efficiency. Günther and Tempelmeier provide with general heuristics and an optimization framework. There is no regard for other factors like performance.

The planning approach from Goetschalckx and Fleischmann (2005) consists of four planning steps which are developed in an iterative procedure. They consider quantitative and qualitative factors and provide methods for optimization, simulation and benchmarking (Goetschlackx, 2000). This approach is very generic and do not focus specifically on manufacturing footprint decisions.

The planning approach for strategic supply chain planning, according to Seidel (2009), begins with the definition of enterprise strategies and targets. It names planning fields and performs an analysis of potential. Based on the established scenarios, a basic material flow optimization will be implemented. Using the results of this optimization, a detailed simulation of the supply chain design planning problem will be constructed. This is an iterative planning procedure and the results can be used for both the decision and implementation.

Kuhn et al. (2010) have developed a general procedure for strategic logistics planning based on Seidel's planning approach. The central method is the simulation of both basic and detailed planning. This approach provides also other methods for evaluation. In comparison to Seidel's model, the implementation phase is much more detailed.

The planning approach by Straube et al. describes a procedure that evaluates different scenarios and gives a comparative framework. Parts of the evaluation include logistic performance KPI's and ecologic efficiency. The approach consists of five different planning steps. This planning approach provides the demand on internal resources in addition to typical logistics KPI's like costs, performance and quality. The focus of the approach is primarily on sustainability (Straube et al., 2011). This planning approach can only be used for preexisting scenarios.

After the presentation of different planning approaches that are relevant for the following subsection, an intermediate conclusion is given. Within this conclusion the results are summarized and reviewed.

3.3 Intermediate conclusion

This literature review has shown that there are several qualitative, quantitative, static, dynamic, deterministic and stochastic methods that are used in footprint decision support. Regarding complex manufacturing networks with market and environment-related uncertainties, single methods are limited and should be used in planning approaches. Different planning approaches have been evaluated in accord with outlined requirements (see figure 1).The results of the review are summarized in Table 1, and consider the requirements of Section 2. Nearly all presented planning approaches regard different planning problems of the supply chain design and deliver a cost evaluation in the majority of cases. Seidel's approach provides KPIs and an indicator system for multi-dimensional evaluation. This approach uses methods like optimization and simulation. But most supply chain design planning approaches are too generic, and footprint planning is just a generic problem. Particularly, Kinkel's planning approach contrasts the other presented procedures, because the focus is on footprint planning. This approach weights qualitative and quantitative factors and targets and is scenario-based, but does not address the impact on the supply chain and its configuration. Nearly all presented approaches regard dynamic demands and changing capacity.
However, the impact of future variations in order situation and current project constellation on supply chain configuration and individual performance is not a detailed part of manufacturing footprint decisions. Variations that come up quickly will have a large impact on the decision are not in the scope of current planning approaches. The comparison of existing approaches shows that there is no single method that simultaneously accounts for all outlined requirements. This necessitates new models that allow for robust and adaptable footprint decisions while especially considering project, market and environmental uncertainties while continuously evaluating itself. An approach to regard these gaps in footprint decision support is presented in the following section.

Requirements/ Authors	1.	2.	3.	4.	5.
Sabri/Beamon, 2000	(X)	X	-	-	(X)
Chopra/Meindl, 2001	X	X	-	-	-
Wolf/Nieters, 2002	X	X	(X)	(X)	-
Reiner/Schodl, 2003	-	-	-	-	(X)
Kinkel et al., 2004	(X)	X	(X)	-	-
Freiwald, 2005	(X)	(X)	X	-	-
Günther/ Tempelmeier, 2005	X	-	(X)	(X)	-
Goetschalckx/ Fleischmann, 2005	(X)	(X)	-	-	(X)
Seidel, 2009	(X)	(X)	X	-	-
Kuhn et al., 2010	X	X	X	-	-
Straube et al., 2011	X	X	-	-	-

Tab. 1: Summarized requirement evaluation of SCD planning approaches

4. Planning approach for robust footprint decisions

In this section, a new planning approach for footprint decisions is presented. In relation to the requirements, (see figure 1) there are many theoretical scenarios to locate a manufacturing plant. Given a high number of potential locations, the planning approach should provide static and/or qualitative methods for reducing the number footprint decisions to a manageable number. The planning approach should provide for support of robust and adaptable footprint decisions while especially considering project and market-related uncertainties that reflect the need to continuously revise the footprint strategy. The planning approach in Figure 3 is an example of how to support decision holders in the automotive industry make future footprint decisions. Generally, a plant is used for multiple customers, and the footprint strategy can be aimed at reducing costs and following customer. The planning approach which is displayed in the figure combines the requirements in 6 different modules.

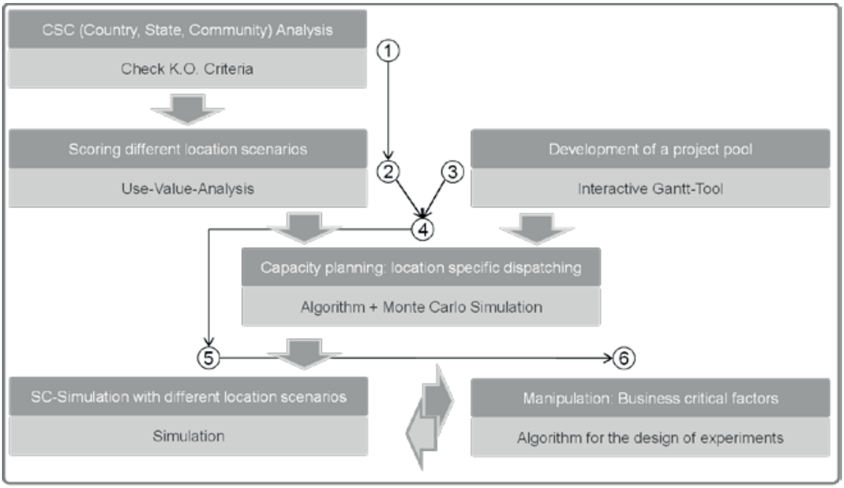

Fig. 3: Planning approach for robust manufacturing footprint decisions

1. Module: Country, State and Community-analysis (CSC)

Within the CSC-analysis countries, states and communities will be evaluated according to enterprise-relevant knock-out criteria. Criteria can be, for example, the minimal number of customers in a country for which at least more than one customer can be supplied just-in-sequence within a defined time window. Alternatively, infrastructural criteria can be used, such as the ability to reach an international airport within at least two hours. There are several lists of location factors (Wisner et al., 2005; Kinkel et al., 2009). The result will be a list of communities, states and countries that may be potential manufacturing locations.

2. Module: Use-Value-analysis

Using the results from the CSC-analysis, experts of the company will evaluate the potential facility locations according to other location factors in a use-value-analysis. The method especially accounts for soft location factors. For some factors, like corruption level or political instability, a quantification of the impact is quite difficult. Therefore the weighting and the scoring should be done by experts within the company. The result will be a short list of regions and communities for a potential manufacturing plant, ordered by company related priorities.

3. Module: Development of a project pool

As mentioned before, a lot of footprint decisions are triggered by the revenue and sales-planning of a company. Today, there is an entire industry that provides suppliers and OEM with new platforms and innovation trend information in addition to sales volumes forecasts. A systemized method is required to monitor the network occupation and to track the required capacities for the long-term planning horizon. A possible method can be an interactive Gantt-chart. This chart can support both the business planning team and the footprint planning team in a company. With relevant decision data, the current capacity situation can be monitored and new footprint decisions can be triggered.

4. Module: Dispatching

The combination of information and internal sales planning can be used as import for rough analysis of future business projects within a new footprint. All possible future business opportunities are collected, evaluated and given confidence level. Information about to volumes can be added from providers like Verband der Automobilindustrie (VDA), IHS or internal sales information.

To account for uncertainty, uncertainty a Monte Carlo simulation is used and linked with the project specific confidence level. Concurrently, the main cost drivers such as manufacturing costs and/or incentives will be calculated using a linear programming method. As a result, the potential locations are listed with a cost evaluation depending on the project constellation of the upcoming years.

5. Module: Supply Chain Simulation

Planning module CSC-analysis, use-values analysis and dispatching will be used to lower the number of potential locations and to transform and safe relevant data for further planning steps of simulation. In a first step, different supply chain configurations are modelled and evaluated using the method of simulation. For example, input parameters project information from the dispatching module and are used within the simulation model as system loads. Depending on the different project constellations, different sourcing strategies, transportation variants and distribution strategies will be modeled.

6. Module: Manipulation of business critical parameters

In a second step, parameters of the simulation model are systematically manipulated and systems behavior are investigated. Manipulated parameters are, for example, volumes, exchange rates and custom rates efficiency factors of a plant. Based on an empirical analysis of the model's behavior, an evaluation of robustness is possible. For a reliable realization of different simulation experiments, Virtual Experiment Fields (VEF) and experiment plans are defined. VEF are an effective approach to increase the speed of decision support based on simulation (Deiseroth et al., 2013).

5. Conclusion and Outlook

Within this paper, the motivation has been to examine the need for robust and adaptable footprint decisions in the automotive industries. To respond to the requirements, a review of relevant SCD planning approaches covering the topic of integrated robust footprint decisions in strategic supply chain management has been carried out and the terminology in this context has been analyzed. The findings have been summarized and critically evaluated in terms of meeting the named requirements. Nearly all presented planning approaches regard different planning problems of the supply chain design and deliver a cost evaluation in most cases. In particular, Kinkel's planning approach contrasts the other presented procedures, as the focus is on footprint planning. However, nearly all presented approaches regard dynamic demands and changing capacity.

However, the impact of future variations in order situation and current project constellation on the supply chain configuration and individual performances is not a detailed part of the manufacturing footprint decisions. In particular, the impact of market and environmental uncertainties and on the supply chain and its manufacturing footprint should be analyzed in more detail. Thus, an approach for a robust manufacturing footprint decision has been developed. This approach integrates different methods for decision support throughout a decision making process. However, the application of the developed planning approach must still be carried out. Moreover, a concrete concept for implementation is required in addition to an analysis of how to use a specific input data to support a powerful planning approach.

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Future Problems in Logistics Due to Demographic Change

Matthias Klumpp, Sascha Bioly and Christian Witte

Abstract

This research paper describes the impact of demographic change on the transport and logistics sector. Therefore, besides a literature review and a management option discussion in the end, the paper contains the following two main sections and methods: First an empirical report of a 2014 survey conducted in the research project “DO.WERT” regarding the working conditions of truck drivers in Germany (working hours, wages, motivation, qualification; n=483). Second, an optimization prognosis (GAMS conceptualization) for the German truck driver labor market in 2030 including increased traffic volumes, restricted carbon dioxide emissions as well as a market-based wage cost function draft. Existing research has shown that major disruptions in the “triangle” of increasing traffic volumes, decreasing populations and also politically intended decreases in carbon dioxide emissions have to be expected, for example for logistics wage and also freight rates markets.

Keywords: demographic change, transport volume simulation, road transport wage simulation, transport mode prognosis

1. Introduction

Demographic change in the form of less people and population shares within the workforce age will hit Germany and other European countries in the next 30 to 50 years. This may have severe consequences for specific economic sectors and industries as for example Thun, Größler and Miczka report for the German manufacturing industry (2007). First discussions are also starting regarding the logistics industry (e.g. Bioly, 2014; Kutlu, Klumpp and Bioly, 2013), highlighting the obviously increasing conflicting targets of economic growth, increasing traffic volumes and carbon reduction objectives while facing a shrinking workforce in logistics.

Therein the crucial occupational group of truck drivers in road transport has received special attention, for example as Min and Emam have shown for the impact on business results in the USA (2003). At the same time, especially this group is facing unfavorable social and working conditions already today (de Croon et al., 2004) - which will worsen due to a general lack of motivated and available people to enter this specific job segment in logistics: In Germany alone, up to 300.000 of altogether 800.000 truck drivers are expected to be retired in the next ten years - without proper concepts and ideas how and with which persons to replace them (BAG, 2012). As the most recent report from the European Commission outlines in April 2014, this problem is increasing due to time pressure, technological developments and requirements as well as health and security risks in road transportation (Europäische Kommission, 2014, p. 21). This may well further increase the already significant cost differences in trucking and road transport throughout Europe (figure 1).

Therefore, this research contribution outlines the significance of this occupa-tio¬nal group for the whole logistics industry by discussing empirical results regarding working conditions 2014 in Germany (section 2), combining this with a draft simulation study regarding expected wage effects of demographic change (section 3) and a first draft of possible countermeasures and human resource concepts specifically for this group (section 4).

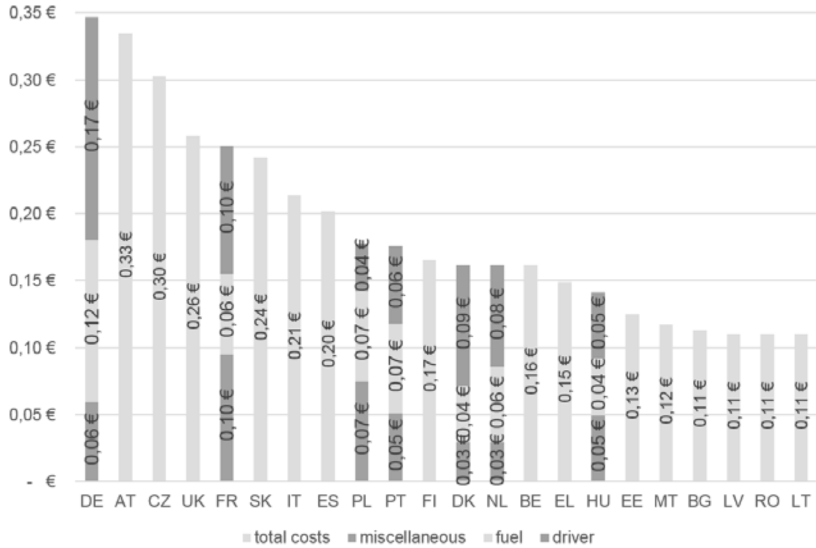

Fig. 1: Variable costs for trucking in Europe (Europäische Kommission, 2014, p. 12, 16)

2. Empirical Status Quo Description

During the first half of 2014 a survey was conducted in the research project “DO.WERT” regarding the working conditions of truck drivers in Germany regarding working hours, wages, motivation and qualifications. Truck drivers were asked in personal sessions at their work place, in trainings and seminars as well as e.g. in driver evening meetings (organized by the German police). Altogether 483 persons took part in the survey; the following results are reporting some highlights from the study.

(a) Gender: 96.4 % of drivers with professional experience are male, 3.6 % of them are female. With a view to the trainees, the proportion of female drivers with 6.3 % is twice as high. The proportion of male trainees here is 93.7 %. In the sophisticated examination of the group of trainees it is significant that 16.9

% of them are female trainees for becoming specialists in driving vehicles, but the proportion of professional female drivers in training is only 1.5 %.
(b) Appreciation: The appreciation which is brought to the trainees and the drivers with professional experience, by this it is assessed overall mediocre to negative. Altogether, the surveyed drivers feel despised by the society. About half of the respondents (55.3%) indicate that they were 'rather little' to 'very little' or to 'none' appreciated by the society (figure 1). Only 14 % feel 'very much' or 'rather much' appreciated by the society. 31 % valued this with 'mediocre'. On average, the rating is 3.6 on a scale from '1 = very much' to '5 = very little/none'. The standard deviation is 1.1.
With an average of 3.2 the respondents on side of the customers feel better appreciated. A quarter said that they are 'very much' or 'rather much' appreciated by customers, almost 40 % rate this as 'mediocre', 37 % feel 'rather little' or 'none' appreciated (next figure).
The appreciation the dispatcher have given to the drivers is rated on average with 3.1 and with a standard deviation of 1.2.

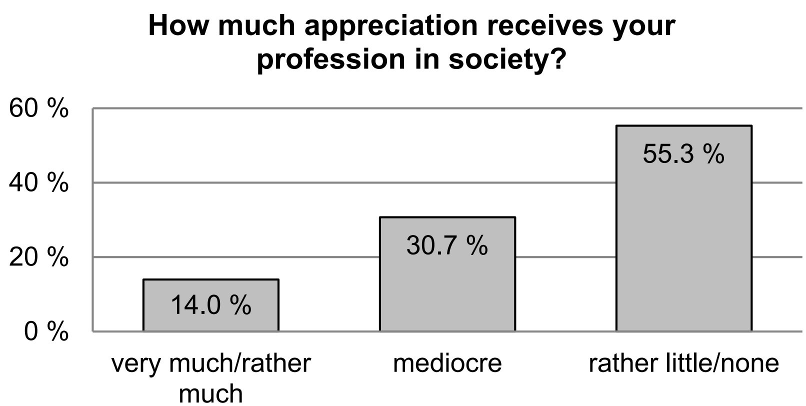

Fig. 2: Appreciation of vehicle drivers in society

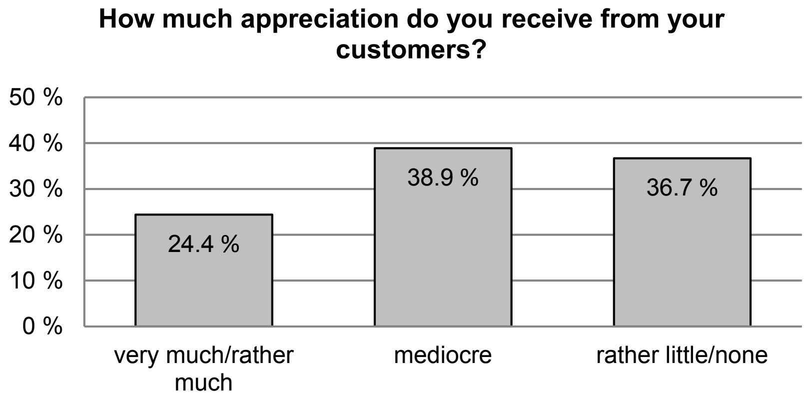

Fig. 3: Appreciation of customers

Nearly a third of the respondents is appreciated 'very much', 'rather much' or 'mediocre' by this group of people. 36 % feel 'rather little' or 'none' appreciated at this point.

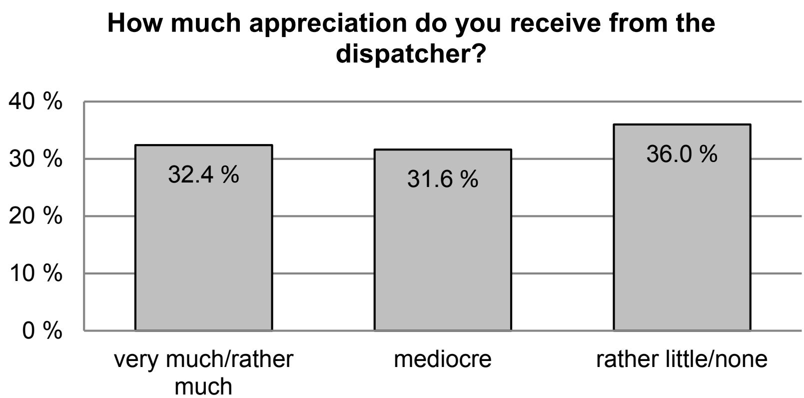

Fig. 4: Appreciation of dispatchers

(c) Career shifting: In figure 4 the result of the survey concerning the total entire professional and the period of professional experience in the current activity is shown. 0.9 % of all drivers specified that they had gathered more than 5 years of professional experience. 18.3 % of the respondents have been working for more than 5 years as a truck driver. This leads to the conclusion that a majority of the drivers completed an apprenticeship in this. Similar statements can be made in the groups of 6-10 years and 11-20 years. 9 % of the respondents have 6-10 years of professional experience. However, 19.7 % of the respondents work in their current work as a truck driver. 23 % possess between 11 to 20 years of professional experience. 28.4 % said that they have the same professional experience in their current activity. In the groups of 21-30 years and more than 30 years the proportion between the two surveys changes. The duration in the current job is shorter than the entire professional practice years. The greater the professional experience, the shorter the duration in the current job. This suggests a high proportion of career changers.

(d) Income and wages: The following figure shows the result of the survey with drivers regarding their monthly gross income. The monthly gross income regarding this survey is normally distributed. The majority of the drivers have a monthly gross income between 2000 € to 2499 € per month. These are 43 % of all surveyed drivers. 22.7 % of all drivers have a gross income between 1500 € to 1999 € and 23.7 % earn 2500 € to 2999 € per month. The minority of the drivers feature less than about 1499 € and more than 3000 € gross income per month.

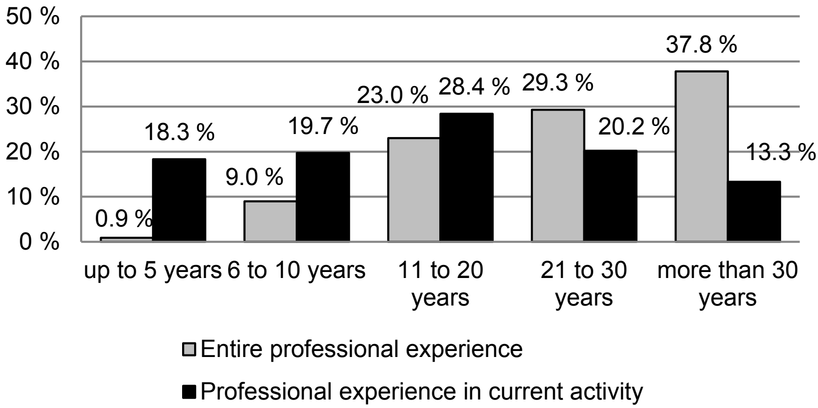

Fig. 5: Professional experience of vehicle drivers

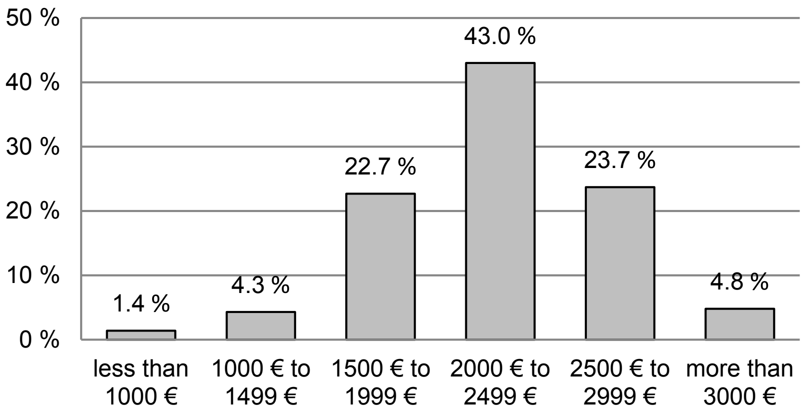

Fig. 6: Monthly gross income of vehicle drivers

3. GAMS Model Driver Wages - Outline

Already in 2013, a general GAMS model integrating the overall traffic volume, carbon emission restrictions as well as estimated per-kilometer-cost for the

European land transport modes road, rail and water (inland waterways) has been developed.

The General Algebraic Modeling System (GAMS) is a high-level modeling system for mathematical programming and optimization. It consists of a language compiler and a stable of integrated high-performance solvers. GAMS is tailored for complex, large scale modeling applications, and allows you to build large maintainable models that can be adapted quickly to new situations. GAMS allows the user to concentrate on the modeling problem by making the setup simple. The system takes care of the time-consuming details of the specific machine and system software implementation. GAMS is especially useful for handling large, complex, one-of-a-kind problems which may require many revisions to establish an accurate model. The system models problems in a highly compact and natural way. The user can change the formulation quickly and easily, can change from one solver to another, and can even convert from linear to nonlinear with little trouble (GAMS, 2014).

The model formulation is provided here in order to acknowledge the intended changes and extensions later in the chapter (Bioly, Klumpp, 2013):

GAMS Model (2030)

SETS

i modal capacity 2030 / road2011, train, ship, road2015, road2020, road2025, road2030 /

j modal use 2030 / use /;

PARAMETERS

a(i) capacity in mio. tkm

/ road2011 371000, train 230000, ship 191000, road2015 44000, road2020 42000, road2025 39700, road2030 371000 /

b(j) demand

/ use 1000000 /;

TABLE d(i,j) co2 emissions in gr per tkm

```
USE
          road2011        45.75
          train           24
          ship            28
          road2015        45.75
          road2020        45.75
          road2025        45.75
          road2030        45.75;
TABLE e(i,j)      costs per tkm
USE
          road2011        0.0500
          train           0.0550
          ship            0.0350
          road2015        0.0512
          road2020        0.0554
          road2025        0.0623
          road2030        0.0721;
PARAMETER c(i,j) co2 per mode;
          c(i,j) = d(i,j);
PARAMETER f(i,j) costs per mode;
          f(i,j) = e(i,j);
VARIABLES
          x(i,j) co2 emission per mode
          y(i,j) costs per mode
          w costs in total
          z co2 in total;
POSITIVE VARIABLE x
POSITIVE VARIABLE y;
EQUATIONS
          co2total        co2 emission over all
          coststot        costs in total
```

```
            supply(i)            obtain limit per mode
            demand(j)            demand of transport;
CO2TOTAL … sum((i,j), c(i,j)*x(i,j)) =l= 9999999999;
SUPPLY(i) … sum(j, x(i,j)) =l= a(i);
DEMAND(j) … sum(i, x(i,j)) =g= b(j);
*COSTTOT … sum((i,j), f(i,j)*x(i,j)) =l= 46500;
COSTTOT … z =e= sum((i,j), f(i,j)*x(i,j));
MODEL TRANSPORT /all/;
SOLVE TRANSPORT using lp minimizing z;
DISPLAY x.l, x.m;
```

In an extension this model is enlarged by replacing the generally assumed fixed cost rates per ton kilometer per mode with a dynamic variable cost function (at least for the road transport mode) including a volume-sensitive wage part for truck drivers. The basic groundwork and possible functions for this wage cost equation to be included in the overall cost minimizing model are described as follows: (i) The overall cost-minimizing objective function is kept as before; (ii) the specific cost determination function is separated / enhanced for the transport mode road; (iii) included in the road transport cost function is a wage determinant for truck drivers, according to the empirical total cost share of personnel cost in the road transport sector (EU data); (iv) the wage cost rate is defined further as standard linear function of a fixed wage set and an increasing ware share depending on the overall freight volume transported on roads and hitherto the overall demand for truck driving personnel (according to standard market assumptions for labor markets); (v) the overall road transport cost function is determined per ton kilometer in order to allow the model easily to shift transport volume between modes (though in many cases costs may actually be "step-fixed" due to full/empty running complete trucks, a linear approach for each single ton kilometer is practically not feasible but within this linear model).

In the previous model the transport rates per ton-km are fixed by 5 cents for the road, 5.5 cents for the train and 3.5 cents per ton-km for the ship. A more realistic representation includes dynamic prices, which are influenced by offer and demand, at least in the medium and long term view. The composition of cost to road transport for Germany includes personnel costs of 56%, fuel costs of 35% and other costs (17%). A very similar structure of costs exists in the Netherlands and in Denmark (NL: 47%, 35%, 18% DK: 56%, 26%, 18%). Other European countries deviate from this, however, the division in Poland provides 20% personal, 38% fuel and 42% other costs (c.p. Europäische Kommission (2014), p. 12).

When modeling in GAMS corresponding country specifics have to be taken into account. Following parameters for Germany are assumed for the rest and in addition, to optimize the fuel and other costs are represented as fixed: transport costs on the road (0.05 euros per tkm), means personnel costs (56%) in amount of 0,028 euros per ton-km. The labor costs can have different progressions and varied methods of calculation are possible:

On the one hand, labor costs can be linear with increasing demand. Here are virtually only positive slope of the straight (blue line). The second is a function with jumps for the labor costs at certain intervals, then jump to the next pay level upon reaching a critical demand for a certain amount and interval are fixed again (red line). Another possibility is an exponential curve, as demand increases, the pool of potential drivers is getting smaller (green line).

Apart from the different developments then arises the question of the calculation. Conceivable here are two basic approaches: one is the integral from 0 to the transport capacity m1 (blue dotted area). Here, it is assumed that results in an increase in personnel costs have no direct impact on the other drivers. On the other hand, you can argue the total cost as a square with the two multipliers p1 price in Euro and haulage capacity m1 in ton-km. The latter is a rather longer-term view, which assumes the price adjustment develop (here in the form of higher wage costs) over time throughout the system homogeneous.

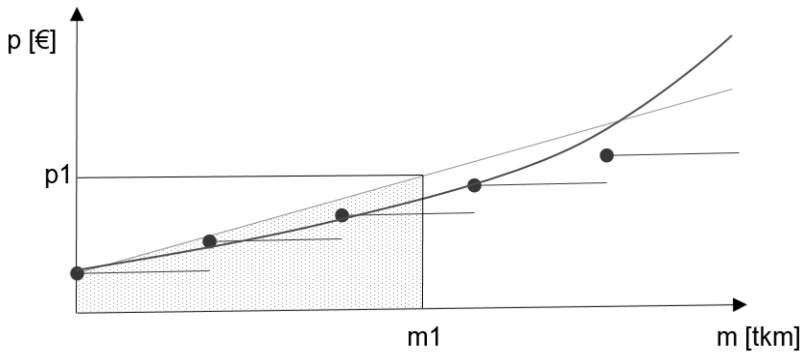

Fig. 7: Possible forms of a dynamic truck driver wage function

The two questions (history of wage cost function and calculation of the total cost in the system) should be clarified before from the previously (with static prices) provided GAMS model into a dynamic GAMS model. These mode-specific functions must be determined individually for all modes of transport. For this purpose, among other things it has to include the future offer of operators (drivers) - which directly affects the slope of the graph.

The traffic forecast for the coming years give of course no exact figures of future traffic flows. But almost certainly it can be assumed that compared to today the traffic performance continues growing because of a growing economy.

In the economic policy debate the need of maintenance for roads and bridges occurs and it is talked about the inescapable expansion of infrastructure in the future. In Germany this is accompanied immediately to the discussion about the origin of funds and the use of funds for these activities. And there is a dispute for necessary future modal splits which are satisfying the demand while being sustainable.

For decades now the demographic change is observed and analyzed. The discussions about the more or less acute shortage of skilled labor, which will sooner or later hit Germany, are in full swing. Even today forwarders and logistics service providers complain in general about staffing problems. But what exactly will that mean for logistics in Germany?

It is to suggest that a shortage of offer (in infrastructure and transport capacity) with a simultaneous increase in request (growing of traffic) will have medium and long term impact on the price of transport services. The infrastructure issue will need to be clarified in state custody - maybe by toll systems to increase revenue or new or other taxes. However, there is another aspect: the driver and not the individual drivers in itself, but the (personnel) costs.

What is the cost development at the different modes of transport? It is undisputed that the different transport modes are more or less labor intensive. While a truck driver can move 24-25 tons at 8-9 hours a day, train drivers or boaters can accordingly provide other (higher) transport services per day. It is assumed that an increase in the price (air traffic is not taken into account here) road freight per ton-kilometer is therefore highest burdened.

4. Measures and Concepts for the Future

In order to mitigate the described effects of demographic change in the logistics labor market, companies would have to develop measures the tackle this development. According to the following figure there are four areas theoretically discernible in order to deal with the problem area, alas shortages of available labor in general (Bioly, Sandhaus, Klumpp, 2014, p. 4; Stölzle, Ivisic, 2013).

First it is obvious, that the enlargement of the weekly or monthly productive working time (e.g. driving for truck drivers) is a major optimization field and chance to tackle the described problems (i). Furthermore, a second approach is the (ii) increase of the total workforce by attracting more and new personnel for logistics and driving professions. Third, working efficiency within the dedicated working hours may (iii) be improved especially by support structures and instruments, e.g. computer and software support e.g. for planning and control (navigation, communication). Furthermore, a second approach is the (ii) increase of the total workforce by attracting more and new personnel for

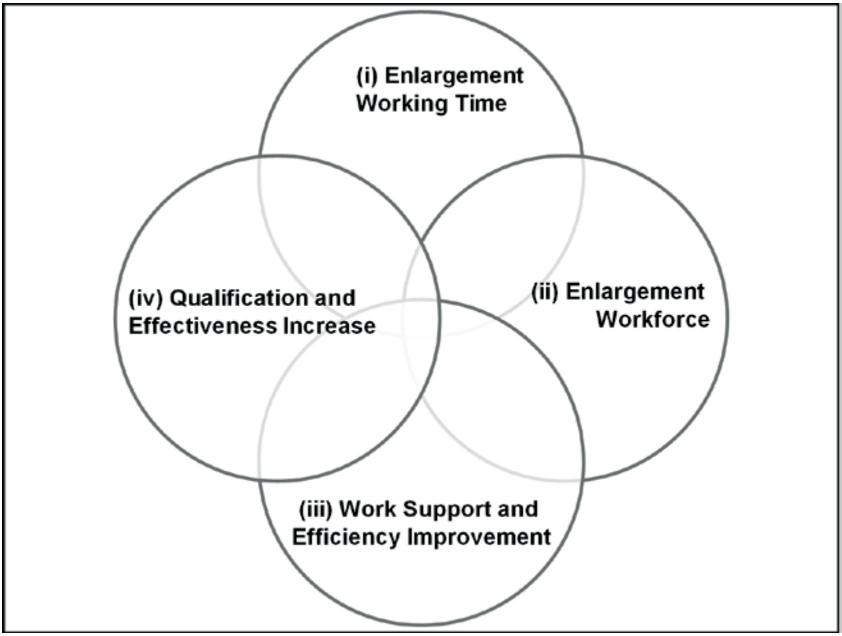

Fig. 8: Potential fields for measurements

logistics and driving professions. Third, working efficiency within the dedicated working hours may (iii) be improved especially by support structures and instruments, e.g. computer and software support e.g. for planning and control (navigation, communication). Last but not least, (iv) the qualification and therefore overall effectiveness of the logistics and driving personnel may be enhanced by specific measures (training, qualification, testing). Altogether these measures are also inclined to "support" each other, respectively to strengthen their individual benefits, e.g. when higher qualified personnel may work more efficient with navigation and fleet management equipment at even a "progressive" improvement rate as navigation support and added knowledge e.g. regarding customer specifics may help each other to find even more effective ways in transport and logistics (e.g. by suggesting "cumulative" transport intervals once per week instead of daily deliveries). For the first of

these areas (i) a case report is outlined in order to explain this structural approach:
In order to extend the available productive working time e.g. for truck drivers, only the productive working time per week may be a feasible option as other approaches regarding the extension of "total life working time" at the beginning (shorting school/education times) and at the end (postponing retirement) may are not applicable (Bioly, Sandhaus, Klumpp, 2014, p. 13-15). During one week with a maximum of 45 hours driving time according to the relevant EU legal framework, only 22.7 hours are actually used for driving in the present situation (average across all fields of short and long distance truck drivers). Therefore, especially at the beginning and the end of driving shifts per day a change and optimization is feasible, e.g. for the question of loading and unloading vehicles at the depot (i.e. CEP services). At this phase, other personnel or even the implementation of automated loading and unloading equipment may be a solution: Automated truck loading systems (ATLS) are technically implemented since the 1980s (IPL, 2008). But the crucial point and process of actual truck loading - inside the truck - is not yet implemented in significant numbers (less than 1 percent of all cases), in contrast to many practical automated intralogistics systems ("Fahrerloser Transportsysteme - FTS"). Though suppliers of such systems as e.g. the Dutch "ANCRA" corporation advertise these systems with their manifold advantages, leading in essence to a reduction of loading times from 40 minutes on average to a minimum of 5 to 8 minutes:

- Reduction of overall handling costs (compared to forklift handling);
- Less personnel required;
- Less moving equipment to be purchased and maintained;
- Less handling "ramps" / gates necessary;
- Smaller total handling space required (smaller hub buildings);
- Less quality problems and damaged goods;
- Increased security for personnel (reduced number and severity of accidents).

This is naturally highly dependent on the total handling and transport volume; though the most interesting advantage besides the reduced number of required personnel in the above described context also the further advantages especially regarding security are important. According to different sources up to one fourth of all accidents with logistics personnel are happening in transition handling with forklift trucks (UK numbers by "Health and Safety Executive"). Therefore a strategic investment and switch to automated loading systems may be a general quality and effectiveness driver. First implementation corporations are e.g. Procter & Gamble in Tapeji del Rio (Mexico), Unilever in Chicago (USA) and Heineken in Zoeterwoude (Holland), examples and video descriptions are available (http://goo.gl/ZgT9OH). Though it has to be highlighted for this case application that specific restrictions e.g. for security have to be incorporated, no matter which person or even machine is actually loading and unloading the truck (secure loading and unloading as responsibility of the industry as well as logistics company according to § 22 StVO and HGB in Germany:

"According to the German Commercial Code (HGB), the carrier must provide a so called 'reliable loading.' This implies that the vehicle complies with the prescribed dimensions, weights and axle loads according to the transported goods. Based on the Employment Protection Act the carrier also has to ensure that the driver knows and observes the rules of proper cargo securing."

This has to be observed even when other personnel or machines are implementing the loading, implying that significant checking and controlling times have to be allocated to the driver anyway.

5. Conclusion and Outloook

The presented article has shown the dominant importance of demographic change for the logistics sector, exemplified with the core part of truck drivers and their work for logistics.

The described empirical results highlight the problems already today, especially general and professional appreciation towards truck drivers. This situation will probably worsen and then again increase the labor gap and therefore imply possible shortages in trucking supply for logistics. This would imply significantly rising transport rates as well as driver wages as indicated in the outlined GAMS optimization model as a first draft.

For further research and also the impact on business practice and public policy, the main effects as identified here have to be supported and tested by further inquiries, maybe also in a combination of empirical testing and quantitative simulation as outlined in this paper.

In any case, the question of availability, motivation and qualification of logistics personnel as for example truck drivers is a keystone of the future development of logistics in Germany and Europe.

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Logistics Trends 2020: A National Delphi Study Concerning the German Logistics Sector

Stephan Zelewski, Alessa Münchow-Küster and René Föhring

Abstract

The logistics sector is subject to profound changes that are caused by technological innovations as well as by structural changes in the implementation of logistics business processes. Therefore, it is important for companies to recognize such changes in an early stage and to prepare for them strategically. This applies not only for directly concerned logistics service providing companies, but also for forwarders in general.

Within a Delphi study, a team of the University Duisburg-Essen researched pioneering changes in the logistics sector and the underlying change driving forces. Over one hundred logistics experts from economy, science and politics have been systematically questioned about future logistics trends with the help of an online questionnaire. The survey stretched over four rounds in total with Delphi-typical quantitative and qualitative feedback for the participants.

Altogether, about 500 hypothetical logistics trends – of organizational-conceptual as well as of technological kind – have been identified and evaluated regarding their economical relevance. At the end of the Delphi study, 10 organizational-conceptual and additional 10 technological essential logistics trends emerged. They were carefully examined in three dimensions: probability of occurrence, desirability of occurrence and impact on the logistics sector. The key results of this current Delphi study will be presented and commented from a business point of view. Action fields important for a strategic positioning of logistics companies in their future competitive environments will be illustrated in particular.

Keywords: delphi study, empirical research, logistics trends, online survey

1. Motivation and Overview

In consequence of the growing globalization, the tightening of resources, the technological progress and because of the openly increasing environmental awareness the logistics sector is continually confronted by profound and far reaching changes within its economical, technological and political-social environment. It is crucial for a strategically prospective, proactive management of logistics companies to recognize presumable future trends in logistics in one of these environments, to rate the action relevancy concerning the own company and to gear oneself up as soon as possible for those future trends in logistics that have been regarded as particularly relevant. It is necessary to that end to plan and to implement respective measures concerning the development of a company with strategic foresight. Such development measures can reach from the conversion to innovative technologies at an early stage via the introduction of new forms of organization and equally new economical concepts regarding processes and systems through to increased investments into the own human capital by means of in-company training and development as well as inter-company training and development.

For the previously outlined proactive management haulage companies require orientational knowledge concerning the changes within the logistical environment and regarding which changes can most probably be expected to become "future trends of logistics". However, such orientational knowledge is usually impossible to acquire for individual companies because the resources regarding time and personnel necessary to that end are only hardly available in the day-to-day routine of the company. Furthermore, studies with long-term focus do often not come into being in practical operations in the face of the ubiquitous stress of competition caused by competitors and in the face of the pressure to succeed induced by stockholders – despite the general acknowledgement to being in need of strategic planning. The pressure on operative problems often curtails open spaces enabling long-term focused strategic thinking drastically. This also especially applies to the logistics sector as its companies mostly are in a very fierce cost competition.

Against this background a Delphi study on trends in logistics up to the year 2020 has been carried out by the Institute of Production and Industrial Information Management of the University Duisburg-Essen. The study will – for the sake of shortness – in the following be called "Logistics Trends 2020". The Delphi study's goal was to ascertain, collect and systematically process expert knowledge on future anticipated relevant organizational-conceptual and technological developments in logistics. This expert knowledge was then supposed to be made available as orientational knowledge to the interested public, especially to the practical operations. The Delphi study took place in the course of the joint project "Logistik Online Forwarding 2020" (LOGFOR), which was accompanied by the Institute for Logistics & Service Management of the FOM University of Applied Sciences in Essen. The institute functioned as the project partner in charge. Added to this there also were several practice partners. Especially the Schenker Deutschland AG, the GFW Duisburg, the Chamber of Industry and Commerce responsible for the cities of Essen, Mülheim an der Ruhr, Oberhausen located in Essen as well as the Niederrhein Chamber of Industry and Commerce responsible for the cities of Duisburg, Wesel and Kleve located in Duisburg.

In this abbreviated form the Delphi study "Logistics Trends 2020" cannot be all-encompassingly introduced. Instead this paper confines itself to describing the methodical design of this study in chapter 2, and in chapter 3 to presenting the most important results. In chapter 4 implications are being examined which resulted from study results for logistics companies.

For those who are interested in details regarding the Delphi study "Logistics Trends 2020" can find a comprehensive documentation in Zelewski and Münchow-Küster (2012a). In addition to it competing, however less differentiated studies concerning future trends in the logistics sector can be found especially in Winklbauer, et. al. (2009) as well as in PwC and IFK (2012).

2. Design of the Delphi Study

In an overview paper like this it is not possible to elaborate on the methodical basics of Delphi studies. Instead a short characterization of the Delphi method, which underlies every Delphi study, has to be sufficient: The Delphi method is a general schema for the systematic aggregation of judgments made by several experts who are adept in problem areas which are characterized by incomplete and especially extremely vague knowledge. It specifies a multistage-iterative, mediated and anonymized group communication process conducted in written form. This group communication process is primarily adjusted to a tendential convergence of the expert judgments and ideally even to a consensus of the partaking experts. For that purpose a controlled feedback on interim results is given to the partaking experts.

For detailed descriptions and also partly critical analysis of the Delphi method interested parties can refer to relevant subject literature; confer e.g. Häder and Häder (2000), Linstone and Turoff (1975/2002), Loo (2002), Vorgrimler and Wübben (2003), Okoli and Pawlowski (2004), Brown (2007), Nielsen and Thangadurai (2007), Cuhls (2009), Gregersen (2011), Zelewski and Münchow-Küster (2012b). Especially the profound and also easily understandable remarks of Häder (2009) can be pointed to.

In the center of the Delphi study "Logistics Trends 2020" stood the research question: "What will be the organizational-conceptual and technological trends in logistics in the German-speaking world up to the year 2020?". With the reference to the German-speaking world an elicitation of expertise of experts in logistics "in all of Germany" was to the fore because of "pragmatic" reasons of the used language in discourse and because of the familiarity of business cultures.

However, the commuting area of the study was not limited to experts in logistics coming from Germany, but also experts in logistics from Austria and Switzerland and in some few (German speaking) individual cases from Belgium, Denmark and Luxembourg as well were involved. In addition to this no limitation on Germany and the German-speaking world regarding the contents was made. Considering globalization, which was mentioned in the beginning and which belongs to the everyday business of numerous companies in the logistics sector, it was clear right from the start that problems and questions regarding future trends in logistics would be answered and looked at by experts not only focused on one national submarket but against the background of internationally interconnected logistics services.

The above-mentioned central research question of the Delphi study was differentiated into several dimensions in order to be able to gain a wide range of orientational knowledge for the business practice. Therefore the following working hypotheses were taken as a starting point: Assumingly there are different perceptions from scientists, practitioners and politicians of organizational-conceptual on the one hand and of technological future trends in logistics on the other hand. Furthermore the ways these trends will be seen probably differentiate into three dimensions: considering the probability of the trend realization, considering the desirability of the trend realization as well as considering their impact on the logistics sector.

On the basis of these working hypotheses two knowledge goals were followed with the help of the Delphi study. The first goal was to generate and aggregate ideas in order to identify as many candidates for organizational-conceptual and for technological trends in the area of logistics as possible. The second goal was to filter out those trends out of the identified trend candidates which will be economically most relevant for the logistics sector in the future. In accordance with the previously mentioned trend dimensions the assessment of relevance happened on the one hand with regard to the probability of realizing a trend in the area of logistics up to the year 2020, with respect to the desirability of the trend realization as well as with reference to the supposed impact of the trend realization on the logistics sector within the named period of time. On the other hand, in the course of the assessment of relevance it was differentiated between the three groups of stakeholders, the scientist, the practitioners and the politicians.

1,300 experts from the fields of science, economy and politics were invited to take part in the Delphi study. 118 of the addressed experts agreed to take part in the Delphi study.

This corresponds to a participation ratio of approx. 9.1%. The drop-out rate was, at the end of the last survey round, approx. 73.7%. This high figure can be put down to fatigue, which is typical for Delphi studies. 31 experts took part in the last survey round, of which 21 (67.7%) were scholars and 10 (32.3%) were practitioners. No experts from the group of politicians, who had contributed to the first round, had persevered to the fourth and final survey round. This was surprising as politicians, free from the day to day pressures of operational (or also scientific) everyday life, would be expected to take a persistent part in the Delphi study, especially with their frequent support of employees, and their interests, but also publicly stating their beliefs of “shaping the future”.

The first survey was a purely exploratory study and was thus a qualitative survey of the experts which should identify as many of the logistical trends until 2020 as possible. As a unique selling point in comparison to other Delphi studies, and other technological foresight studies, the experts were requested from the start to differentiate logistical trends as either organizational-conceptual or technological developments. In this way the study would not be “technologically driven” like numerous other studies that are prevalent in futures studies. With the Delphi study “Logistical Trends 2020” equal importance would be placed on identifying and evaluating business trends in the logistics sector as technological trends.

In order to avoid possible misunderstanding especially on the side of the practitioners and politicians, who often equate the attribute "economically" – unjustified with regard to the content – with a purely profit-oriented way of thinking, the Delphi study did not explicitly use the term "economical" but discussed on organizational-conceptual trends.

All in all more than 500 hypotheses on presumed organizational-conceptual and technological developments in the logistics sector were generated in the first survey round as candidates for future trends in logistics. In the following three further survey rounds, which were aligned qualitatively as well as quantitatively, the hypothetical knowledge on potential trends in logistics was systematically edited by the monitoring team of the Essen Institute of Production and Industrial Information Management and reflected back to the experts. With this feedback it was planned to gain a consensus – or at least an approximate convergence – of the judgments of the experts in the course of the Delphi study.

For this purpose the at first more than 500 hypotheses on presumed organizational-conceptual and technological developments in the logistics sector were reduced to a number of only 103 trend candidates, a number "easier to manage". This happened on the passage from survey round one to survey round two. The congestion of the range of the further questioned trend candidates was necessary on the one hand in order to keep the strain of the surveyed scholars, practitioners and politicians within a "reasonable" limit regarding their expert judgments. On the other hand the step of congesting the number of candidates was also necessary in order to bundle up content-related equivalent or at least very similar hypotheses into only one hypothetical trend in logistics each.

On this basis, the experts were asked to judge the trend candidates, which had been identified in the first survey round and which had been edited (congested) by the monitoring team. On one side, the expert judgments were supposed to cover the probability of the trend realization in the area of logistics. On the other side, they were also supposed to refer to the desirability of the trend realization within the own company (with respect to practitioners) or within the own area of research or responsibility (with respect to scholars or politicians).

In the fourth and last survey round a concentration of expert judgments followed with the result of a compact range of those trends in logistics whose realization had been estimated the most probable by the experts during the third survey round (essential trends in logistics). Only the ten most probable trends in logistics each organizational-conceptual on the one hand and technological on the other hand were considered. As a result of this concentration it was possible to confront the experts with a third evaluation dimension. In the final fourth survey round they were supposed to rate the most important trends in logistics regarding the impact of their realization on the logistics sector as well.

Each expert judgment was needed to be entered on a four step rating scale which corresponds to a simplified ("approximated") Likert scale. The even number of four rating levels each was preset deliberately in order to deny the experts the possibility of rating along the lines of "fleeing into the undecided middle". Therefore, they were induced to either decide on a "positive" or alternatively on a "negative" decision stamping. Additionally the answer option "prefer not to say" was provided so that experts who did not regard themselves capable of giving a profound judgment concerning a special question were given a possibility to explicitly express it. By this means it was avoided to feeling obliged to choose "some" random answer option in case of lacking power of judgment. This would have led to a content-related distortion of the evaluation of the experts' answers.

In the beginning of the third and fourth survey rounds of the Delphi study the quantitative information on the interim results of the each preceding survey rounds was given to the surveyed experts in the form of a statistical group answer. This statistical group answer consisted for each supposed trend in logistics of the arithmetical mean score and the median as an expression of the trend of the expert judgments on the one hand and of the standard deviation in order to inform about the extent of the deviation of the provided expert judgments on each trend up to this point on the other hand. In addition to this the frequency distributions of the expert judgments displayed on the underlying four step rating scale were visualized graphically. This feedback information served to brief the experts on the current trend of the aggregated expert judgments and on the current extent of the approximation to a consensus. The experts were also asked to explain their trend-unconformable expert judgment with regards to the content in case that their judgment differed from the emerging trend. Both aspects – the feedback of organizational-conceptual group answers as well as the request for qualitative explaining of divergent expert judgments – are typical for the course of a Delphi study as the course's goal is to induce a consensus of the surveyed experts or at least to cause a tendential convergence of the experts' judgments.

In the following the results of the Delphi study "Logistics Trends 2020" are presented and commented in an overview. They resulted from the end of the fourth survey round. Because of the necessary shortness only the study results, which were gained considering the sum of all partaking logistics experts, are elaborated. A differentiated reflection which differentiates between the three groups of stakeholders, the scholars, the practitioners and the politicians, is denied here at this point; for this confer the detailed results in Münchow-Küster and Zelewski (2012).

3. Results of the Delphi study

3.1 Organizational-conceptual trends in logistics

On the basis of Figure 1 (see next page) it is recognizable that the ten most relevant trends in logistics of organizational-conceptual manner are judged throughout with high proportion regarding all three dimensions, the probability of their realization in the area of logistics, the desirability of their realization within the own company or research area as well as the impact of their realization on the logistics sector.

The experts certified the highest probability of realization to the increase in the importance of the management of risks and security in the logistics sector as well as the increase in the importance of fee charging regimes, e.g. such as customs, tolls and other road pricing systems. On the contrary, the increase in the importance of industry know-how regarding the area of logistics was judged as being least probable.

Concerning the estimates of trends in logistics regarding the desirability of their realization similar high values can be observed. The highest desirability proves to be the logistics trend "Supply chain management in general". On the opposite, the both logistics trends "Increase in the importance of e-procurement" and "Increase in the importance of industry know-how" turn out to be the least desirable.

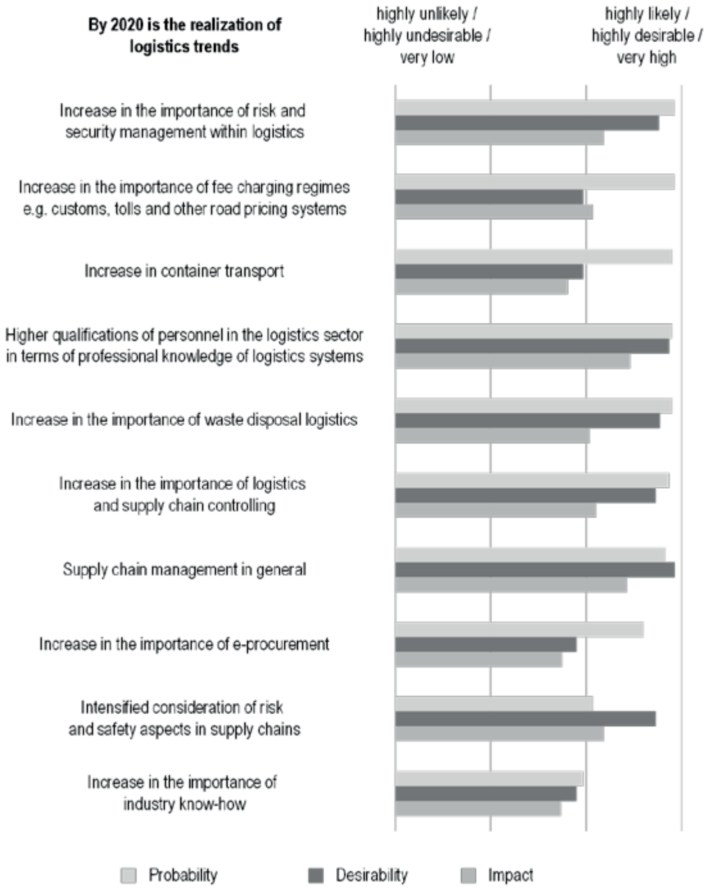

Fig.1: Estimates regarding organizational-conceptual trends in logistics

The result named last is astonishing because the relatively low desirability of increasing industry know-how regarding the area of logistics goes directly against the obvious strategic positioning of companies of the logistics sector which obtain an advantage with respect to competitive differentiation with the help of their specific industry know-how in relation to other competitors.

The experts estimate the impact of the logistics trend "Higher qualifications of staff in the logistics sector in terms of specialized knowledge of logistics systems" to be highest. It is closely followed by the effects of the logistics trend "Supply chain management in general". The logistics trend "Increase in the importance of industry know-how" comes in last place. This last place should be put into perspective, though, as it only refers to the positioning within the scope of the ten most probable trends in logistics. Regarding the whole picture with an absolute view the impact of this trend in logistics is still judged as "rather high".

3.2 Technological trends in logistics

Figure 2 (see next page) displays the ten essential trends in logistics of technological manner whose probability of realization is judged throughout as very high by the surveyed experts. The logistics trend "Application of telematics" and "Computerization, viz. deeper penetration of logistical systems with information and communication technology (ICT)" are considered to be most probable. On the opposite, the logistics trends "Implementation of simulation models and methods (in the area of logistics)" as well as " Traffic information systems to reduce greenhouse gas emissions" are regarded to be least probable.

Another rank order arises as a result concerning the desirability of realization of technological trends in logistics. The logistics trends "Networking and integration through IT systems", "Traffic information systems to real time route management" and "Real time capability of transport information systems" take the first place each.

The realizations of the logistics trends "Implementation of GPS systems", "Electronic marketplaces for haulage services (Freight exchanges)" and "Application of mobile computing" are only considered rather desirable.

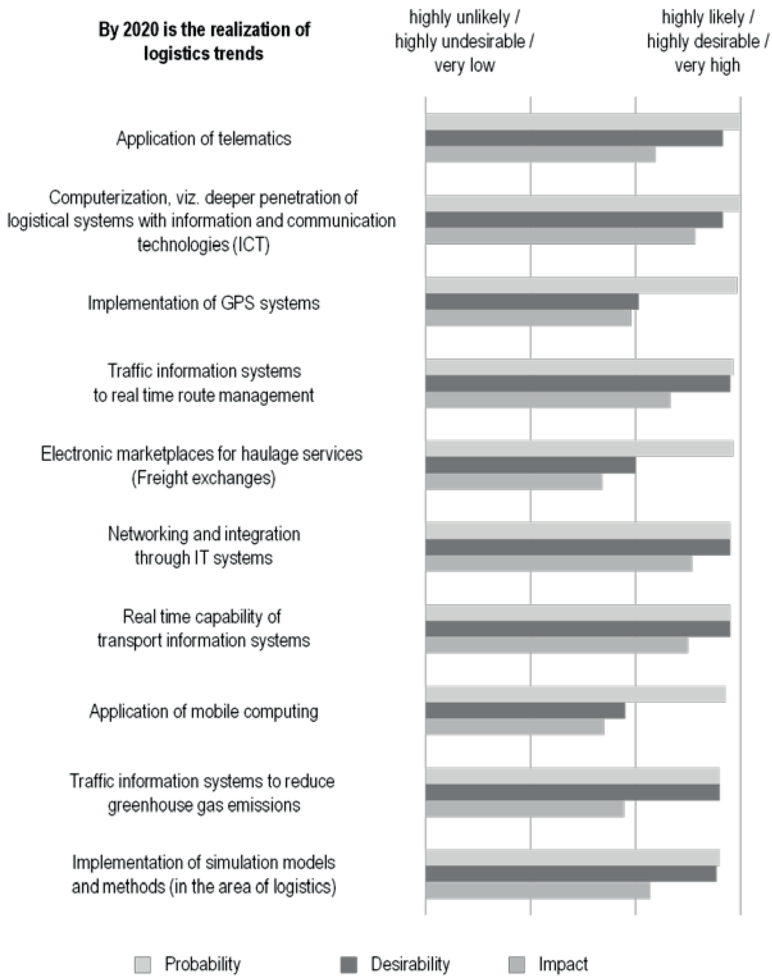

Fig. 2: Estimates regarding technological trends in logistics

The realizations of the logistic trends "Networking and integration through IT systems", "Computerization, viz. deeper penetration of logistical systems with information and communication technology (ICT)" as well as "Real time capability of transport information systems" are associated with very high impact on the logistics sector. In contrast, the experts judge all the other technological trends in logistics more reservedly by considering their impact as being only "rather high". Especially the impact of the logistics trend "Electronic marketplaces for haulage services (Freight exchanges)" is considered much lower in comparison to the impact of all the other logistics trends of organizational-conceptual or technological manner. This depicts a surprising result because the application of electronic market places is usually attributed a high impact in economical professional literature, but also on the logistics sector as well.

4. Implications for companies of the logistics sector

From the point of view of organizational-conceptual trends it is noticeable that the increasing importance of fee charging regimes, like e.g. customs, tolls and other road pricing systems, is considered and ranked the trend in logistics with the highest probability of being realized. This instantly means for companies of the logistics sector that it is necessary to plan on with a tightened cost pressure in the long run in consequence of the sovereignly imposed additional charges. Because of the high competitive intensity with regard to production and logistics companies this tightened cost pressure will probably not be able to be passed onto the customer base by means of increasing prices. It is far more probable that it will cut down the profit margin of the logistics companies. Therefore logistics companies with an only low capacity to compete are supposed to be exited from this competitive market. In the face of this supposed development it does not astonish that this logistics trend regarding its desirability has been placed sixth place, that is the second to the last place. On the contrary, it is even surprising that this trend in logistics was not placed on the lowest rank with a distinctly higher mean score – in accordance with a very high extent of undesirability.

It is remarkable that the increasing importance of the management of risk and security was likewise judged as a substantial trend in logistics with the same high probability of realization. Therefore provides for logistics companies the opportunity to gain a differentiating advantage in the competitive environment by proactive acting, e.g. by investing even now into sophisticated systems for the management of risk and security. This differentiating strategy enables individual companies which invest especially early and especially sustainably to escape – at least partially – from the supposed increasing cost pressure, which can be expected regarding the initially explained trends in logistics.

The logistics trend of an increasing importance of logistics and supply chain controlling, which has been ranked third after all regarding its probability of realization by the experts, indicates the same problem solution. The reason is controlling systems, which allow the implementation of informatively monitoring orders end-to-end in space and time ("tracking and tracing") as well as regarding the contents as well, are able to support the introduction of effective systems for the management of risk and security. For example, a continuous shipment tracking makes it possible to provide information on the current temperature of a temperature sensitive shipment or information on an incorrect or even unauthorized opening of a packing or of a transport container. In case such controlling information is provided by means of a system for the management of risks and security, it is possible to recognize e.g. the risk of missing a deadline or the risk of transported goods getting ruined or spoilt as well as the risk of security breaches during a transport and then to introduce countermeasures in good time. In this way it is possible to implement the economical concept of supply chain event management into the operational practice with the help of an integrative consideration of the two logistics trends "Increase in the importance of risk and security management within logistics" and "Increase in the importance of logistics and supply chain controlling".

Eventually, it should be emphasized that the trend regarding the enhancing of professional competence of the personnel with respect to the professional knowledge on logistical systems was ranked second place concerning its probability of realization by the surveyed experts. Therefore it is recommended to the companies in the logistics sector to invest into the respective in-company or inter-company training and development.

From a technological point of view it proves itself remarkable that no individual logistics trend in particular stands out regarding its relevance for companies in the logistics sector, but rather a combination of five trends in logistics. It concerns – ranked according to the probability of their realization – the application of telematics as well as the computerization, it concerns the application of GPS systems, traffic information systems to real time route management as well as the real time capability of transport information systems. A combination of all these five technological trends in logistics seems to be the thing to do in order to implement the concept of the "continuous" shipment tracking including corresponding added value services. In addition to this it is also possible to hereby strengthen the efficiency of the above mentioned economical concept of supply chain event management within the operational practice.

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Vision of a Service Value Network in Maritime Container Logistics

Jürgen W. Böse, Carlos Jahn and Raman Sarin

Abstract

Against the backdrop of stagnant or slow volume growth in the international container transport, liner shipping companies make considerable efforts to reduce costs and provide better service quality. Due to the strategic character of decisions associated with the implementation and reorganization of liner services, solution approaches that enable a substantial reduction of total round-trip time without appreciable extra costs are regarded as promising. For this purpose, the authors develop the idea of a Maritime Service Value Network representing cooperation among container terminals as well as at least one ship routing company and one meteorological service provider. The network aims at acceleration of container liner services with (ideally) cost-neutral operations measures. The proposed concept can provide the container terminals with considerable competitive advantages and simultaneously put the liner shipping companies in a strong position for successful integration in global supply chain networks. The full paper gives an estimate of the magnitude of existing time saving potential and the associated economic and operational impact. Additionally, a rough description of the network idea is presented and obstacles for network coordination are highlighted.

Keywords: container liner service, service value network, time savings, weather routing

1. Introduction

Stagnant or slow volume growth in many parts of the word leads to overcapacities in the maritime container transport and is associated with fierce competition among shipping companies. As a result, the companies make considerable efforts to reduce their costs and provide services differentiating them from the products offered by competitors (Asteris et al., 2012). Against this background, quality criteria of transport services are becoming more and more significant. Recent studies show that beside the meaningful criteria "freight rate", the importance of criteria like "transport punctuality and time" or "port call frequency" has increased in container shipping (e.g. Gailus and Jahn, 2013). For container terminals functioning as major service providers for shipping companies at ports, a change in vessel handling requirements arises from this development noting that the time-related service aspects are of high relevance (Lu et al., 2011).

In this regard, measures taken by a container terminal individually have a small chance to succeed due to limited controllability of factors that are relevant to the competition. Considering that the round-trip times of global liner services can amount to two months (or more) and the number of port calls partly is binary, the share of handling time of one port in the total time is just as modest as its importance for the competitiveness of the liner service. Additionally, the acceleration of vessel handling processes is not necessarily beneficial in all the cases, e.g., the dependency of a port on tides can promptly “destroy” the newly gained time advantage. In other words, isolated efforts of single terminals to improve their ability to compete by means of process acceleration might cause limited benefits in particular situations, yet this approach is far from being termed as a good or effective solution. Due to the strategic character of decisions associated with the implementation and reorganization of liner services, solution approaches that lead to substantial reduction of total round-trip time of liner vessels and induce additional costs (not relevant for competitiveness) seem to be promising.

In the light of the foregoing discussion and inspired by emerging global terminal networks of large shipping companies (Notteboom and Rodrigue, 2012), the authors develop the vision of a MARITIME SERVICE VALUE NETWORK (MSVN) consisting of container terminals, a ship routing company and a globally active meteorological service provider. The objective of the cooperation is to accelerate both vessel handling at ports and the sea voyage between them through highly cost-efficient measures. By time-related integration of accelerated processes at ports and on sea, the achievement of appreciable composite effect of time savings is ensured for the round-trip of liner vessels.

2. Loops and liner services under investigation

2.1 Structure of interregional loops and choice made

In container shipping, the origin port of a voyage ordinarily corresponds to the destination port, i.e., the vessel paths take the form of vast loops connecting specific ports in the same region (feeder or regional services) or in different regions of the world (global or interregional services). A container vessel usually calls the ports of a loop in a defined sequence being termed as "string".

		interregional distance[1]	# loops	# ports per loop[2]	round-trip time[2]
Asia - Northern Europe	Maersk Line	19.850 km[3]	4	16 ... 20	76 ... 83
	CMA CGM		7	9 ... 18	70 ... 84
	Hapag Lloyd		5	10 ... 13	74 ... 75
West Coast North America - Northern Europe	Maersk Line	6.425 km[4]	3	5 ... 10	27 ... 34
	CMA CGM		4	5 ... 11	28 ... 42
	Hapag Lloyd		8	3 ... 12	17 ... 41
West Coast South America - Northern Europe	Maersk Line	10.230 km[5]	3	10 ... 13	43 ... 49
	CMA CGM		3	11 ... 15	42 ... 56
	Hapag Lloyd		2	8 ... 14	47 ... 52

[1] one way, [2] from ... to, [3] Hamburg - Shanghai, [4] Hamburg - Newark, [5] Hamburg - Rio de Janeiro

Tab. 1: Characteristics of loops from and to Northern Europe (CC, 2014; HL, 2014; ML, 2014)

For analyzing the effects of acceleration measures in container shipping, the focus is on loops with ports located in Northern Europe (NE) as well as in other regions of the world. Due to the kind and volume of foreign trade of Central European countries, most and largest loops exist on the routes to Asia, North

America and South America. Table 1 shows characteristics of such loops operated by major shipping companies. The paper composes appropriate study design based on Maersk Line loops as the shipping company provides comparatively comprehensive information about its liner service network and the underlying loop structure via internet (ML, 2014). Table 2 shows the loops under investigation with few important characteristics. For each route, two loops are considered except for the Intra-European route. Always a loop with comparatively many ports and a loop with comparatively few ports are considered for each route. So the related loops primarily differ in their string length (number of loop ports) and loop length (total travel distance).

	Maersk loop	TA2	TA4	AE10	$AE10_{short}$	Levant	$Levant_{short}$	Samba	$Samba_{short}$	BGF-N17
route	region of origin	NE		NE		NE		NE		NE
	region of destination	WCNA [I]		Far East		Near East		WCSA [II]		NE
ports	# ports in origin region	3	3	7	6	3	3	4	3	4
	# stopover ports [III]	0	0	4	4	5	2	2	2	0
	# ports in destin. region	9	2	9	3	3	1	7	1	0
	# loop ports	12	5	20	13	11	6	13	6	4
region of origin	total travel distance (km)	855	1.080	3.340	2.850	940	940	1.440	1.440	2.339
	avrg. interport distance (km)	428	540	557	570	470	470	480	480	585
	% of travel distance	4,0%	7,8%	7,5%	7,2%	6,1%	6,8%	5,4%	6,3%	100%
region of destination	total travel distance (km)	8.280	1.665	10.590	5.600	1.730	0	4.015	0	0
	avrg. interport distance (km)	1.035	1.665	1.324	2.800	346	0	669	0	0
	% of travel distance	38,3%	12,0%	23,7%	14,1%	11,3%	0,0%	15,0%	0,0%	0,0%
inter-regional	total travel distance (km)	12.480	11.150	30.835	31.175	12.660	12.870	21.335	21.335	0
	avrg. interport distance (km)	6.240	5.575	5.139	5.196	3.165	3.218	5.334	5.334	0
	% of travel distance	57,7%	80,2%	68,9%	78,7%	82,6%	93,2%	79,6%	93,7%	0,0%
	length of loop (km)	21.615	13.895	44.765	39.625	15.330	13.810	26.790	22.775	2.339

[I] WCNA: West Coast North America, [II] WCSA: West Coast South America
[III] The classification of loop ports as "stopover port" is made by authors.

Tab. 2: Characteristic of loops under investigation[1]

[1] AE10short: Gdansk, Aarhus, Gothenburg, Bremerhaven, Rotterdam, Port Tangier, Suez Canal, Tanjung Pelepas, Yantian, Tanjung Pelepas, Suez Canal, Port Tangier, Bremerhaven, Gdansk.

LEVANTshort: Hamburg, Alexandria, Port Said East, Salerno, Felixstowe, Antwerp, Hamburg.

SAMBAshort: Tilbury, Rotterdam, Bremerhaven, Antwerp, Algeciras, Santos, Algeciras, Tilbury.

If the Maersk Line service network does not provide an appropriate loop, the required string of ports is synthetically generated by adaptation of an existing one (ordinarily by shortening). It should be noted that the loops "SAMBAshort" and "LEVANTshort" include only one South American or Near East port respectively and as a consequence, it possesses no local travel distance in the region of destination.

2.2 Characteristics of liner services

Loops considered as sequence of ports and sea sections form the basis for establishing liner services. Due to liner shipping's nature, the vessels call the loop ports according to a given timetable associated with a certain inter-arrival time for ports (e.g. weekly or biweekly) and port call frequency. For guaranteeing a specific call frequency or aligning the throughput capacity of a liner service to regional demand, frequently several vessels operate in a loop at the same time. Furthermore, a change in vessel size is a typical measure for systematically adjusting the throughput capacity of a service to the demand. Table 3 shows main characteristics of liner services considered for analysis.
It shall be pointed out that the smaller loop of each route is operated by vessels of capacity lower than those of the larger loop. This is due to the lower interregional transport demand or number of loop ports, respectively.

Maersk service	TA2	TA4	AE10	*AE10 $_{short}$*	Levant	*Levant $_{short}$*	Samba	*Samba $_{short}$*	BGF-N17
loop nature	real world	real world	real world	*synthetic*	real world	*synthetic*	real world	*synthetic*	real world
no. of vessels	6	4	12	*10*	5	*4*	7	*5*	1
avrg. vessel capacity	4.530 TEU	2.825 TEU	17.580 TEU	*11.000 TEU*	4.270 TEU	*3000 TEU*	7.780 TEU	*2.300 TEU*	820 TEU
avrg. vessel length	290m	220m	400m	*350m*	260	*220m*	300m	*220*	140m
port call frequency	weekly	weekly	weekly	*weekly*	weekly	*weekly*	weekly	*weekly*	weekly

Tab. 3: Characteristics of liner services under investigation

Considering real world conditions, shipping companies usually use vessels of different sizes while offering liner services. For instance, the Maersk AE10 service is based on three 15.500 TEU and nine 18.270 TEU vessels.

3. Analysis of vessel acceleration measures

3.1 Liner services - status quo and assumptions made

The round-trip time of a liner vessel, i.e., the time between leaving the origin and reaching the destination port, is primarily determined by the number of ports, the travel distance between the ports, the handling performance of involved container terminals (i.e. boxes per hour and vessel), the number of containers to be handled at the ports and the travel speed of the vessel. Basically, the round-trip time is composed of three different time components: 1.) travel times (between ports), 2.) (un-)mooring times (at ports) associated with necessary times for pre-/post-processing of handling operations and 3.) the actual handling times. Regarding the travel times of liner services detailed information is presented on the Maersk Line's homepage (ML, 2014). The other two components of vessel round-trip time are not available without further ado and so some assumptions have to be made. Table 4 shows the assumptions for (un-)mooring & pre-/post-processing times of different vessel sizes being part of the analysis. They are based on both scientific findings (e.g. Chen and Huang, 1999) and practical experiences of the authors. Moreover, the actual vessel handling time is primarily determined by the terminal performance capability at quayside as well as the amount of containers to be discharged and loaded at the container terminal. Assumptions concerning the former are deduced from many years of experience authors collected in practice.

vessel capacity	820 TEU	2.300 TEU	2.825 TEU	3.000 TEU	4.270 TEU	4.530 TEU	7.780 TEU	11.000 TEU	17.580 TEU
handling performance (cont./h/vessel)	50	75	75	75	85	95	115	120	150
(un-)mooring & pre-/ post-processing (h/vessel)	0,25	0,50	0,50	0,50	0,75	0,75	1,00	1,25	1,50

Tab. 4: Time and productivity assumptions for processes at quay wall

With regard to the handling volume, it is assumed that the vessel capacity is always fully used and that the vessels are completely discharged and loaded in the region of origin and in the region of destination.

port type	ports of origin region	stopover ports	ports of destination region
TEU factor	1,5	1,5	1,5
container split between ports	uniformly distributed	x % of vessel capacity at all ports	uniformly distribution
vessel handling volume / port	vessel capacity * 2 / # origin region ports	x % of vessel capacity * 2	vessel capacity * 2 / # destination region ports

Tab. 5: Assumptions about the port handling volume

For reasons of simplification, the containers are to be uniformly distributed among the ports in both regions and all ports are characterized by the same TEU factor (see Table 5). Analogously, a uniform distribution of handling volume between the stopover ports is assumed. However, a certain percentage of vessel slots shall only be occupied by transshipment containers (varying between services) and reused at stopover ports.

For the Intra-European service, the assumptions made are that the vessel capacity is fully used and between 20% and 60% of loaded containers are replaced by new boxes at each port. Figure 1 shows the vessel round-trip time with its inherent time components (status quo). It can be seen that the component "travel time" represents the dominant time share for all analyzed services.

Additionally, the figure shows that the services on the same route with appreciably fewer ports are not characterized by a correspondingly lower share of handling time. Regarding the throughput capacity of a vessel's round-trip (sum of container loaded at all loop ports), the above mentioned assumptions lead to three determinants: the vessel size, the number of stopover ports and the transshipment volume being handled at these ports.

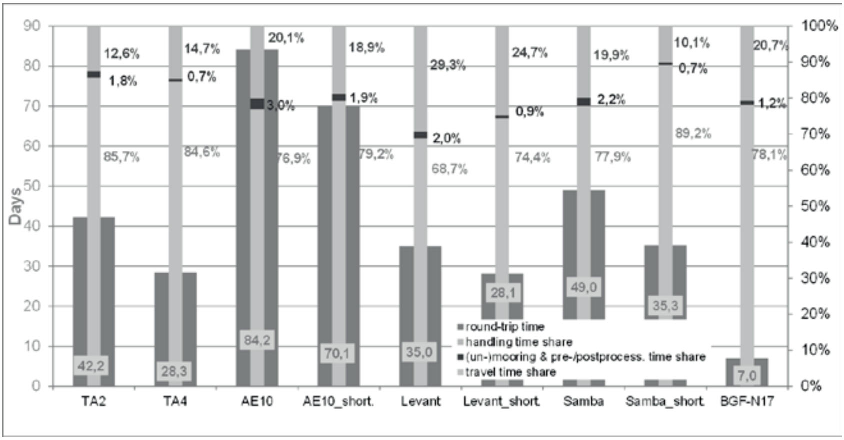

Fig. 1: Round-trip time of liner service vessels and its time shares

3.2 Cost-efficient measures for acceleration of liner services

Due to the high competition pressure in maritime container transport, both the involved liner shipping companies and the container terminals have spent a lot of effort in the recent years to improve the economic viability of their operations processes. Following, solution approaches are highlighted that are effective in achieving objectives but induce no or comparatively low extra (unit) costs. That is, the same or a similar factor input enables a noticeably higher output. Usually, organizational innovation or improvements in combination with sophisticated IT systems fulfill this requirement.

With regard to acceleration of terminal processes at quay wall, a distinction is made between approaches being associated with changes in the organizational concept and algorithm-based approaches for resource control as well as innovations measures concerning the IT systems in use. The former deals with determining the operations modes of production factors in short- and medium-term view by appropriate organizational rules or strategies, respectively. The algorithm-based approaches, in particular, are related to the use of quantitative methods from the field of Operations Research (OR) for order-driven resource allocation and routing. Finally, the latter improves quality and quantity of the available operational data forming the basis for effective planning and control of terminal processes.

Practical experiences show that the implementation of new organizational concepts and/or basic changes in the IT landscape can lead to performance improvements in the double digit percentage range. Considering the handling processes of container vessels, the following concept-, algorithm- and IT-based Port Operations Measures for Realizing Time Savings (POM.RTS) needs to be highlighted exemplarily:

- Dual cycle operations of quay cranes: container discharging and container loading together forms single crane move (e.g. Goodchild and Daganzo, 2007; Preuß, 2012; Zhang and Kim, 2009).
- Twin-lift operations of quay cranes during discharging AND loading of vessels: a twin-lift crane move consists of two 20' containers. Highly motivated staff and a sophisticated decision support system enable twin-lift operations even during the loading process.
- Flexible pooling and dispatching of horizontal transport vehicles at quayside with the assistance of a positioning system enabling automatic localization of transport vehicles in use and orders being processed (e.g. anonymous, 2000; Ho and Liu, 2009; Kellberger and Münsterberg, 2014).
- Using transport vehicles of all the terminal areas in times of low system load for container pre-stowage close to dedicated berthing places. Thus, the travel distance of vehicles can be reduced during the actual handling process.
- Extensive cross-company integration of IT systems (between shipping companies and terminals as well as the shippers and consigners in the hinterland) increases the availability of operational data for all involved parties and thus, for example, appreciable improvements in

short-term resource planning become possible (e.g. Ilmer, 2005; Jürgens et al., 2011).

- Usually, algorithm-based resource control is preceded by changes in the organizational concept or would cause these changes. Practical experiences and scientific studies show that the application of OR methods can lead to appreciable improvements in terminal operations (but mostly in a lower range, as such, by concept change). Further information about the methods in use and their economic impact is to be found in numerous publications (e.g. Meisel, 2009; Murty et al., 2005; Park et al., 2011; Ursavas, 2014). An overview in this regard is provided by the literature surveys from for example Bierwirth and Meisel (2010), Carlo et al. (2014-a and 2014-b), Islam and Olsen (2013), Le-Anh and De Koster, (2006), Stahlbock and Voß (2008) or Steenken et al. (2004).
- Against the background, one main bottleneck in quayside operations is the horizontal transport (Saanen, 2004), it can even make sense to increase the number of vehicles, if additional units are available at the terminal and the variable vehicle costs are comparatively low. This is the case, for instance, with automated vehicles or with terminal facilities located in low-wage countries. Practical experiences show that, up to a certain extent, the arising extra costs are in a range of not being relevant for competitiveness.

With regard to time and fuel savings on the sea voyage, the topic "Weather Routing" (WR) is discussed more intensively in science and practice in the recent past (e.g. Chen, 2013; Hinnenthal, 2007; Lin et al., 2013; O'Brien, 2012; Padhy et al., 2008; Szłapczynska and Smierzchalski, 2009; Walther et al., 2014). Today, WR, in general, is understood as a particular type of vessel navigation which does not primarily align decision-making to the shortest path. WR-based navigation decisions additionally consider present and forecasted weather as well as sea conditions in conjunction with the vessel characteristics and the objectives specific to the shipping company. Considered separately, weather and sea conditions are defined in the terms of wind speed and direction, wave height, ocean current, visibility due to fog, threatened safety due to ice-bergs and deck ice, etc. (Bowditch, 2002). Typical objectives of shipping companies being associated with Weather Routing Measures (WRM) can be multifarious, e.g. reduction of fuel consumption, realizing the estimated times of arrival at ports, realization of travel time savings or ensuring vessel safety. Against the backdrop of the paper's focus, the main interest in WRM is the reduction of travel times (more or less cost-neutral) by application of WR-driven navigation decisions. Consequently, the question arises which time saving potential can be exploited by WR. Basically, WRM for Realizing Time Savings (WRM.RTS) are very effective and provide large benefits in sea regions characterized by navigationally unrestricted water and adverse weather conditions occurring many times a year. Such conditions lead to a number of alternative route choices and make weather an essential route determining factor. Practical experiences show that the expectation of time savings in the double digit percentage range is reasonable under such premises (e.g., Gershanik, 2011; Weber, 2007). Thus, a potential for savings from the WR's point of view is particularly possible in case of longer travel distances in open seas, as is the case with intercontinental sea voyages, for instance.

3.3 Cumulated effects on vessel round-trip time - a mean valued based analysis

The explanations about the impact of POM.RTS and WRM.RTS in section 3.2 form the basis for determining the range of handling and travel time reduction being assumed for investigation. Regarding round-trip time savings induced by WRM, an average decrease of travel time between 0% and -5% is considered for all loop sections. Additionally time savings by POM are supposed to range between -5% and -25% at each of the associated ports.

Supposing that highly sophisticated POM.RTS and WRM.RTS are not yet a part of terminal and vessel operations, the changes in handling and travel time, mentioned before, are applied to all liner services being part of the analysis (see section 2.1). In the cases in which the amount of time reduction is questionable due to the reasons discussed in section 3.2, the respective part of the diagram curve is highlighted by a dotted line. Figure 2 shows the resulting savings in round-trip time for all liner services.

For each route under investigation, the figures attest that with increasing travel distance and vessel size, the impact in savings grows as well. With respect to the number of vessels in use, the time savings become significant if they exceed the vessel inter-arrival time for the ports of a liner service. In case of time reduction in a lower range, benefits for shipping companies are there as well but in other dimensions (see below).

Due to the assumptions made in section 3.1, the (pure) number of ports in the origin and destination region has no influence on the effectiveness of POM.RTS. However, the curve profile of the service "TA2" and "LEVANT" reveals that the existence of stopover ports can gain considerable importance for success of POM.RTS. Having in mind the container throughput which is additionally induced by stopover ports on a round-trip (see section 3.1), in case of the LEVANT service, the interregional throughput volume is appreciably

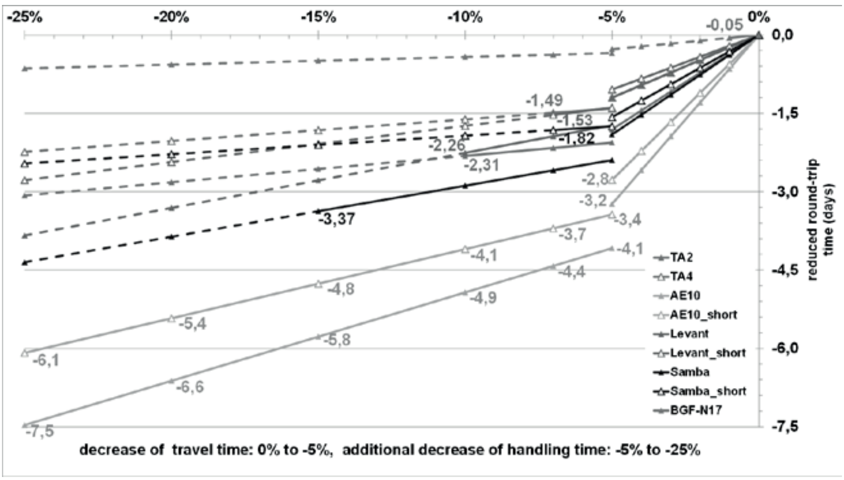

Fig. 2: Effects on round-trip time by WRM and POM

enlarged by the means of transshipment containers at the 5 stopover ports. For each stopover, a re-allocation of about 30% of vessel slots is supposed. In contrast to the LEVANT service, the TA2 service possesses no stopover ports. Basically, it should be noted that the effectiveness of POM.RTS rises with the vessel size increase and the increase in number of stopover ports or the amount of transshipment cargo to be handled at related "pit stops", respectively. Furthermore, the effectiveness of WRM.RTS is mainly determined by the length of loops and the share of open sea travel distances.

Following, the economic and operational benefit of decrease in vessel round-trip time is exemplarily explained. For this purpose, two impact cases are differentiated and possible reactions of shipping companies are highlighted: CASE a) the amount of time savings is higher than the vessel inter-arrival time for loop ports and CASE b) the amount of time savings is lower than the vessel inter-arrival time for loop ports.

- Reaction a1): For shipping companies it opens up the possibility to save a service vessel completely and keeping the same service capacity and quality as before. The resulting economic impact is tremendous. Gudehus and Kotzap (2012) estimate the charter rate of a 5.000 TEU container vessel (without fuel costs) at 23.000 US$/day. Considering the liner services under investigation, the AE10 service allows a fleet size reduction by one vessel if POM.RTS and WRM.RTS are maximally effective.
- Reaction a2): The shipping company keeps the number and kind of vessels as they are and analogues to a1) the port call frequency rises. Associated with fleet acceleration, the annual throughput capacity of each service vessel increases and thus the annual throughput capacity of the liner service as well. Regarding the service "AE10", the port call frequency grows from 52 calls per year (vessel inter-arrival time of 7 days) to yearly 57 calls (vessel inter-arrival time of 6,4 days). Additionally, the annual vessel and liner service throughput capacity increases by 9,6%, i.e., by 12.697 containers per vessel and by

12*12.697 containers for the liner service (assuming re-allocation of 15% of vessel slots at each stopover port).

- Reaction a3): Another alternative (not discussed here any further) is to deploy the number of vessels as before and reduce the size of vessels while keeping the annual throughput capacity. As a result the port call frequency of the liner service increases, the annual vessel and liner service throughput capacity do not change and the service costs go down due to smaller size of vessels in use.
- Reaction b1): The shipping company does not change the kind and number of vessels and make use of the time savings for integration of one or more (additional) ports in the related string. Depending on the location of added port(s) the measure improves the liner service accessibility in the respective region.
- Reaction b2): Again, there are no changes in vessel use. Gains in round-trip time savings are considered as time buffer and this enlarges the scope of (re-)action for the operations management and with that improves the service punctuality.
- Reaction b3): Analogues to b1) and b2) the fleet structure is kept. The resulting time savings are used for reduction of vessel speed on sea while retaining the timetable of liner service. So slow steaming measures become possible or can be even furthered. Considering the liner service "A10short", the average vessel speed is about 16 knots (i.e. slow steaming is already applied). Using the time gained by acceleration measures for the purpose of further slow steaming, the average vessel speed can be reduced to approx. 14,5 knots without any adaptation of the liner service's timetable. According to Notteboom and Vernimmen (2009), slowing down a 10.000 TEU container vessel in this speed range leads to savings in fuel consumption of about 20 tons per day. The service "AE10short" comprises of ten 11.000 TEU vessels each with about 288 sea days (see section 3.1). Hence, liner service operations can yearly save between 57.000 tons and 58.000

tons of fuel by applying the acceleration measures suggested in this paper.

- Reaction b4) Finally, it should be noted that reaction a2) and a3) can also be applied in CASE b). To what extent the related approaches make sense or are beneficial has to be evaluated on a case by case basis.

4. MSVN - a cooperation of container terminals together with at least one ship routing company and one meteorological service provider

Considering the promising results presented in section 3, the systematic acceleration of liner vessels appears highly attractive from economic and operational point of view of liner shipping companies. A basic prerequisite for applying POM.RTS and WRM.RTS in a coordinated manner is a close cooperation among all associated parties, i.e., the container terminals located at the loop ports together with at least one ship routing company and one globally active meteorological service provider as well as eventually the liner shipping company as vessel operator and customer. Only the mutual understanding as (network) partners and the strong integration of customer enables an effective time-related integration of accelerated operations processes being necessary for achieving the maximum possible composite effect of time savings.

In this regard, it should be mentioned that the cooperation partners possess a comparatively diversified character. Nevertheless their range of services is complementary from the perspective of container liner shipping. Usually, there are no production- and competition-related interdependencies between them - if at all, container terminals located in the same region might be competitors for the handling volume arising in their hinterland.

With respect to the joint value added to customer, the tremendous complexity of logistics service as well as its generation in a modular fashion by purposefully combining complementary core competencies of autonomously acting service providers is to be emphasized. Such characteristics are typical for service value networks already practiced by IT and Web service providers as business model (Basole and Rouse, 2008; Hamilton, 2004; Momm and Schulz, 2010) as well as existing in scientific work which includes recent publications and conference tracks in the field of information systems and technology (Chan and Hsu, 2012; Gordijn et al., 2012; Schulz et al., 2012).

Against this background, the authors consider the form of cooperation among container terminals, ship routing company and meteorological service provider as logistic SVN in the maritime sector. Noting that there are differences existing between the related MSVN and the known (IT-based) SVN in the field of e-services, e.g., the missing "network's ability to orchestrate a complex service ad-hoc" or the necessity that MSVN "must be run on and by ubiquitously accessible information technology" (Blau et al., 2009-a).

Due to the potentially achievable collaboration benefit (illustrated in section 3), the basic advantages of SVN (Blau et al., 2009-b) and the successful SVN operations examples especially in the e-service industry (Blau et al., 2009-a), the idea of the maritime SVN is considered by the authors as a promising approach for improving the competitiveness of container terminals operating intercontinental liner services in a highly competitive market environment. In concrete terms, the constitutive MSVN partners (see Figure 3) perform the following care tasks:

CONTAINER TERMINAL: The terminals involved provide for the MSVN customers (i.e. shipping companies with contractual MSVN agreements) a premium handling service at dedicated berths which is based on highly sophisticated POM.RTS (see section 3.2). To stay competitive, it is of great importance that additional costs of premium vessel handling are compensated (more or less) by adequate productivity increase so as to keep the costs per container on the same level.

SHIP ROUTING COMPANY: A promising approach for cost-efficient reduction of travel time on sea is an advanced navigational concept which systematically

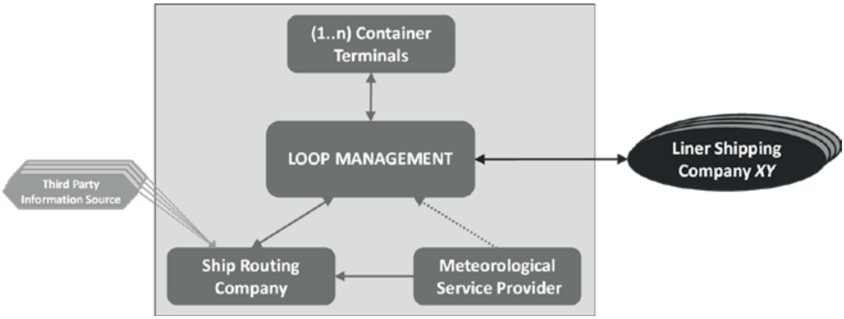

Fig. 3: MSVN partners and main information flows between them

considers weather and sea conditions for decision-making (see section 3.2). Nowadays, there are several companies worldwide which are specialized in providing WR-based navigational services to an outstandingly effective degree. To ensure best possible navigation decisions for vessel control with high travel time savings, it makes sense to consider a ship routing company as a further constitutive partner of the MSVN.

METEOROLOGICAL SERVICE PROVIDER: An absolute prerequisite for achieving high navigation quality is the availability of comprehensive weather data for all relevant sea areas and the ability to aggregate this data to build valid weather forecasts. For this reason, a globally active meteorological service provider is to be incorporated in the network as well. Such companies have at their disposal many years of experience in collecting, processing and providing forward projection of weather data. Therefore, they are equipped with the necessary competence to provide weather data as well as forecast information in the quality and quantity needed for highly effective vessel navigation.

LOOP MANGEMENT: For ensuring quality of MSVN service, a loop management is to be established as central instance. Prior to and during a vessel round-trip, the loop management is supplied with a wide range of information: comprehensive planning and operations information about the production processes are made available by the container terminals and the shipping company in-charge, WR-based navigation recommendations are given by the ship routing company and present or forecasted weather information, respectively, is provided by the meteorological service provider. The loop management collects and aggregates this information and makes it available for the process owners to support decision-making. Moreover, the loop management triggers acceleration measures at ports and on sea, in case of time-related deviations from the timetable based on the expected operational impact of POM.RTS and WRM.RTS. Basically, the loop management has the function of a rather moderating network instance with limited decision-making and instruction authority. For the latter, the responsibility ultimately lies with the process owners, i.e., with the container terminals and the liner shipping companies as MSVN customers. Against this background, the loop management aims to reach a consensus on the control measures required for keeping the accelerated timetable. The management activities are primarily based on the internal agreements between the MSVN partners as well as the agreements between the MSVN and the liner shipping companies. In case of doubt, i.e., if related agreements do not cover the arising problem and hence define no organizational framework for deducing appropriate solution approaches, the loop management does not decide autonomously but initiate countermeasure(s) in accordance with the parties involved who would bear the probable additional expenditure incurred by these activities.

5. Summary and outlook on future research

The case-related analysis of POM and WRM for cost-efficient process acceleration in container liner shipping shows that their composite effect on round-trip times can be appreciable if particular pre-conditions are met. Furthermore, the examples of economic and operational impact resulting from these time savings reveal the large benefit of applied acceleration measures for liner shipping companies. In other words, the improvements in liner service operations can provide the shipping companies with noteworthy advantages against their competitors, simultaneously putting the involved container terminals - functioning as core service providers - in a strong market position.

The basis for implementing such (advanced) services forms a close cooperation among all the parties involved in the acceleration processes at ports and on sea. Because of the many advantages of SVN concept (e.g. flexibility regarding changing market requirements, enabler for innovative/outstanding service offers or multiple troubleshooting options), from the author's point of view, related networks represent an effective approach for resolving the collaboration task mentioned above.

The constitutive partners of the maritime SVN are container terminals in various regions of the world as well as at least one ship routing company and one globally active meteorological service provider, while liner shipping companies function as customers of the network. The MSVN is fitted with a central instance, the loop management, which coordinates the internal network activities as well as matches the elaborated control measures to the requirements of customers.

Due to generally non-existing relationships among the network partners (if at all, then container terminals of the same region might be competitors) and the extensive integration of the MSVN customers in the actual production process, the decision-making and instruction authority of the loop management is very limited. With regard to this challenging coordination task, only contractual agreements and the hope for willingness of involved parties to collaborate will not be enough in order to ensure sustainable savings in round-trip time and push the network to a highly competitive market position. The competitiveness of MSVN is mainly determined by the effectiveness of its network management and the resulting quality of service. Thus, the management holds a key function for the network’s success.

Considering the peculiarities of container liner shipping business as well as the characteristics of MSVN, further research work is required to identify or (if necessary) develop appropriate mechanisms for purposeful coordination of network partners. Furthermore, the design and operations of MSVN also raise other questions, for example, in terms of network service composition, like the interpretation of "modular service components" from the logistics point of view or the possibilities of useful "implementation" of related components in respect of real-world requirements.

In this context, it should be noted that relatively large amount of research work about SVN is already done in the field of e-services (e.g. Blau, 2009; Conte, 2010; van Dinther, 2010). Thus, a comparison of similarities and differences between the nature of SVN in e-service and (maritime) logistics can provide valuable insights about the alienability of already developed solution approaches. An essential prerequisite for making the vision of MSVN real is the availability of design and coordination instruments that are (also) highly effective under actual conditions of application. This forms the basis for successful achievement of MSVN objectives in practice.

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II.
Sustainability Efforts Within the Supply Chain

Logistics Performance Measurement for Sustainability in the Fast Fashion Industry

Anna Corinna Cagliano, Muhammad Salman Mustafa, Carlo Rafele and Giovanni Zenezini

Abstract

The fast fashion sector is characterized by a short time-to-market which adds to the fluctuating demand faced by this industry where competition requires to introduce a number of new designs in clothing each season. In such a context, some firms have started creating independent companies in charge of managing logistics operations. This strategy allows a direct control over logistics activities enabling to save time and costs and increase quality. However, in order to obtain the promised benefits, independent logistics companies need to be sustainable from both an operational and an economic point of view. To this end, an appropriate performance management appears to be essential. The paper develops a structured performance measurement system for an independent logistics organization part of an Italian fast fashion company. After reviewing the existing logistics performance measurement models, the LOGISTIQUAL model was selected because it balances all the perspectives of the logistics service. The company processes were mapped to identify the activities to be monitored. KPIs were defined and classified according to each performance area of LOGISTIQUAL. Prior to its implementation, the performance measurement system was validated by applying the indicators to past data. This work provides fast fashion firms with a methodology to design and implement logistics performance measurement dashboards that can be used to understand the current organizational behavior. Such knowledge assists in defining effective strategies to ensure competitive

advantage and long term sustainability. Also, monitoring performances stimulates people to operate in order to achieve the company’s goals.

Keywords: supply chain management, logistics, fast fashion industry, key performance indicators.

1. Introduction

Nowadays, the ever increasing competition in the fast fashion industry forces companies to introduce several new designs in clothing for each season. In order to gain sustainable and enduring success and growth in this environment, fashion companies need to build a strong brand identity, especially with young consumers (Ross and Harradine, 2011), as well as implement effective brand extension strategies, which means that companies need to increase their offering by reaching new market segments characterized by different price targets (Truong et al., 2009; Stegemann, 2006). Besides these marketing and product-oriented factors, on the operational level managing and controlling the whole distribution process is fundamental for fashion companies (Caniato et al., 2011). Fast fashion companies, such as Zara and H&M, created an efficient supply chain in order to produce new clothing items rapidly to quickly respond to consumer demand (Watson and Yan, 2013). This demand-pull model requires following consumer trends and reducing the lead time for arrival of new products to stores. Furthermore, consumers' purchases are characterized by being impulsive and following the latest fashion trends (Ghemawat and Nueno, 2006, Cagliano et al., 2011). As a consequence, the demand is highly fluctuating and this adds pressure to logistics activities, requiring agile supply chains (Purvis et al., 2013). Keeping in mind the abruptness and the quick approach of logistics needed in the fast fashion industry, some firms have developed their independent logistics companies. From an organizational point of view these are stand-alone entities, but they are typically controlled by the manufacturing company that founded them. Their mission is to perform the entire logistics process for such company, in an exclusive way. Several groups, mainly in the apparel, footwear and food&beverage industries, such as Benetton, Geox, Granarolo, and Heineken, have already adopted similar strategies in the last ten years (Gorziglia, 2012). Such approach allows companies to focus on their core business, as logistics outsourcing strategies, while maintaining a direct control over their supply chains, which could not be completely achieved when partnering with logistics service providers. This in turn gives some specific advantages, such as saving time and costs related to logistics operations and reducing expenses caused by quality issues during the delivery process. In order to verify that such promised benefits are actually gained by an independent logistics company, thus contributing to its operational and economic sustainability, performance management appears to be of paramount importance (Gunasekaran et al., 2004). Performance management, in fact, provides the basis for monitoring and maintaining organizational control (Yigitbasioglu and Velcu, 2012). The first step of performance management is evaluating performances through indicators, which directly describe the effectiveness and efficiency of processes and are useful for assessing how a firm compares against its competitors. This property is fundamental in a highly competitive environment, where companies struggle to reach a sustainable competitive advantage (Schläfke et al. 2012; De Waal and Kourtit, 2013).

This work develops a dashboard for performance measurement for the independent logistics company (hereafter named Logistics Company) created by an Italian firm operating in the fast fashion industry (hereafter named Fast Fashion Company). The dashboard is based on the Logistiqual model. Performance measurement enables the Logistics Company to define effective strategies to ensure competitive advantage and stimulates people to operate in order to achieve the set goals. Also, the outcomes of the analysis can support fast fashion companies in either developing their logistics performance measurement systems or improving them.

The paper is structured as follows. First, the focus company is presented together with the methodology of the research. After that, the analysis of relevant performance measurement models is carried out and the dashboard is proposed. Finally, discussions and conclusions are provided.

2. Company presentation

The Fast Fashion Company is one of the most important companies in the industry. It counts more than 13,000 employees, has 9 production plants, and sells its products in 33 different countries through 2,100 retail stores and 130 outlets. Its logistics activities have been always monitored and it has been implementing a performance measurement system for several years. This experience has allowed the company to become confident with logistics activities in the Fast Fashion arena. In the light of this acquired familiarity, the company has created its own Logistics Company dedicated to the management of the logistics activities. This choice has been inspired by the need to optimize the available resources and by the opportunity to improve the quality of the logistics service in order to comply with the latest market trends. Furthermore, current volumes do not fully exploit logistics facilities and this implies inefficiencies. Also, transport costs are significantly increasing. Finally, the company faced a lack of experienced and reliable providers that could offer the high level of service required. Such circumstances have encouraged the management to create an independent organization dedicated to logistics activities. The mission of this new Logistics Company is to become a model in the fast fashion market in the provision of logistics services. It is expected to yield advantages in terms of reduction in logistics costs, increase in revenues through the acquisition of new customers, and decrease in the organizational complexity. In the end, such effort is expected to turn into a competitive advantage for the Fast Fashion Company.

3. Methodology

The research has been carried out according to the following steps. First, main performance measurement models and associated Key Performance Indicators (KPIs) existing in literature are reviewed and an appropriate reference framework is identified. Second, the logistics processes of the focus company are mapped to find out the activities to be monitored. To be more precise, the supply chain is decomposed in processes; for each of them sub-processes and stakeholders are identified. Then, operational KPIs for each sub-process are selected by looking at both the indicators retrieved in literature and those already used by the Fast Fashion Company. Finally, economic aspects are assessed. In particular, the costs associated with the operational performances under analysis are measured. The obtained dashboard is validated by applying the selected indicators to past data, between January 2012 and October 2012, in order to check their ability to actually represent the real behavior of the logistics process at issue.

4. Analysis of performance measurement models

Several supply chain performance measurement models have been proposed in literature. Some of the most widely applied ones are here compared in order to find a suitable framework supporting the design of a KPI dashboard for the Logistics Company. In particular, the following models are analyzed: Logistiqual (Rafele, 2004; Grimaldi and Rafele, 2007), Balance Scorecard (BSC) (Kaplan and Norton, 1996), SCOR (Supply Chain Council, 2010), Performance Prism (Neely, et al., 2002) and the Gunasekaran and others' model (Gunasekaran, et al., 2004).

The Logistiqual model aims to assess the level of logistics service perceived by customers, being them either other companies in the supply chain or final consumers. Based on SERVQUAL (Parasuraman, et al., 1988), a well-established model for service quality measuring, Logistiqual evaluates the logistics performance of a company by means of three macro-classes: Tangible Components, Ways of Fulfilment, and Informative Actions. Each of them includes some sub-classes (e.g. the Tangible Component macro-class is divided into Internal Assets, External Assets, Personnel, and Inventory/Availability sub-classes) inside which specific KPIs can be placed according to the logistics service at issue. The detailed description of performance dimensions and sub-dimensions makes Logistiqual a quite simple tool to be applied by organizations not very familiar with performance measurement models. In fact, the existence of sub-classes in addition to macro-classes provides users with a valid guideline in order to identify all the specific aspects of a logistics process that should be monitored. The Logistiqual model is also quite flexible because it does not bind the user to predetermined performance indicators, but appropriate metrics can be defined according to the context under investigation.

The second model that is discussed is the BSC. It is a framework for organizing performance measurement processes in supply chains (Brewer, 2002) made up of four dimensions: Financial, Customer, Internal Business Process, and Learning and Growth. Besides financial indicators, reflecting past events and not suggesting how an organization should operate to create future value, the BSC also includes non-financial measures, which can be viewed as drivers of future performances. Long, medium, and short run KPIs are usually part of the BSC. Compared to Logistiqual, the BSC only defines general performance dimensions, without suggesting detailed aspects to be measured for each of them. Additionally, the BSC is not specifically focused on the logistics service but it analyses also different supply chain processes, such as for instance product innovation.

The SCOR model aims to provide a structured approach to supply chain analysis by means of five processes: Plan, Source, Make, Deliver, and Return. Each process is decomposed into sub-processes and elementary activities. Performance measures and best practices are defined for each activity. The purpose of this model is to improve the management of supply chains and support communication among their members. SCOR gives a standard description of management processes as well as of the relationships among them. Thus, the main goal of SCOR is not assessing performance but rather offering a reference framework to represent supply chain processes. Moreover, like in the BSC, processes other than the logistics one are considered, such as the manufacturing or the resource planning process.

The structure of the Performance Prism is quite similar to that of Logistiqual. This model looks at performance from five interrelated perspectives: Stakeholder Satisfaction, Strategies, Processes, Capabilities, and Stakeholder Contribution. Each of these categories has a number of sub-categories inside which KPIs can be defined. For instance, Strategies includes corporate strategy, business unit strategy, brand, product, service strategy, and operating strategy. The Performance Prism is quite comprehensive in nature as it considers a large variety of supply chain aspects, such as business strategies, processes for developing new products or services, demand generation, demand fulfilment, and planning and managing the enterprise. Again, it is not exclusively focused on the logistics process.

Finally, the supply chain performance measurement model developed by Gunasakaran and others is based on the three planning levels within an organization, namely strategic, tactic, and operational. Additionally, the model is organized around the four main supply chain processes: Plan, Source, Make/Assemble, and Deliver. For each intersection of a process and a planning level, single performance indicators are specified. Such model assesses the performance of all the main supply chain process, even those that do not deal with logistics. Furthermore, its structure lacks an intermediate layer between the macro-dimensions (i.e. planning levels and processes) and detailed KPIs. Such layer would help users in identifying the relevant activities whose performances are to be measured.

The literature review suggests that all the analyzed frameworks can be potentially applied to a fast fashion company. However, their purposes and structures are different. Among them, the Logistiqual model proves to be the most suitable tool in order to define a performance dashboard for a company whose core business is providing a logistics service. Three reasons can be mentioned. First, Logistiqual is specifically dedicated to assessing logistics performance. Second, it gives a comprehensive view of both the inventory control and the transport service, the two main concerns of the company at issue. Third, the Logistiqual structure, made up of not only macro-classes but also sub-classes, is able to assist users in taking into account all the important performance areas, avoiding neglecting some of them.

5. Logistics process mapping

The main processes associated with the new Logistics Company are warehousing and transport. The first one includes all the activities from unloading raw materials to shipping garments to retail stores. The Fast Fashion Department, the Administrative Department of the Logistics Company, and its central warehouse are the main stakeholders involved. The warehousing process can be split in three different parts: the inbound sub-process, which encompasses all the activities until the unloading, the warehouse sub-process, and the outbound sub-process, including those tasks carried out after picking. The process begins with the check of the bill of lading of the incoming items. If the control is positive, the unloading is authorized and the inbound sub-process finishes. The warehouse sub-process defines the activities carried out in the central warehouse. Garments arrive at the warehouse with a label applied by the supplier during the production phase. This label gives information about the model, the fashion season, and the size. Through a sampling, some garments are inspected in order to check their quality. If the items have to be urgently delivered to retail stores, the outbound process is directly activated through a cross-docking procedure. Because the cost of potential mistakes made during cross-docking is lower than the cost associated with a late delivery, some warehouse operations are avoided in order to save time. Instead, not urgent items go to the count phase. All the items are counted in case of new suppliers;

a sample count is applied otherwise. After this stage, the items are ready to be stored based on the fashion season, the model, and the size. When the warehouse operator receives an order, the picking process is carried out and then the dispatching preparation phase can be performed. Items are processed by two automated sorting conveyor systems, one for folded garments and the other for hung garments, and are associated to customers through an identification number. The package is then carried out by an operator that also controls if the items match with the order. Items that cannot be managed by the sorter because of their dimensions are processed separately, in a manual way. The outbound sub-process includes the measurement of the weight, and the loading of the consignment. After that the transport process starts. Deliveries are managed by the Transport Office and are carried out through logistics service providers (LSPs) that collect the items in the central warehouse. It is worth mentioning that, until recent years, the Fast Fashion Company used to send its products to a network of regional platforms, which served as consolidation centers for several local retailers. The new Logistics Company instead relies on a more centralized distribution process, enabling shorter lead times to stores. As a consequence, the number of deliveries is increasing, leading to the need for the Fast Fashion Company's management to rely heavily on the integration between the internal warehousing process and the LSPs' distribution process.

6. KPI definition and classification

The knowledge provided by the process mapping task as well as the analysis of the structure of the Logistiqual model allows to understand the critical areas and activities that need to be monitored. Together with the management and the personnel of the Logistics Company the specific aspects to be measured are identified. Then, based on the analysis of existing literature and the company experience appropriate performance indicators are defined. In particular, both operational and economic KPIs are considered in order to evaluate not only how efficiently the Logistics Company carries out its activities but also how such performance influences economic outcomes. The following sections discuss relevant indicators in detail together with the results of the validation test.

6.1 Operational performance indicators

Operational performance indicators assess factors having relevant impacts on competitiveness, such as time, quality, flexibility, productivity, and inventory availability. As mentioned in Section 3, operational KPIs for the Logistics Company at issue are selected and classified according to Logistiqual model. Appendix A shows the complete operational performance dashboard.

6.1.1 Tangible components

The Tangible Components macro-class of Logistiqual basically includes KPIs assessing the performance of the central warehouse and the productivity of its personnel and facilities.

Among them, “Sorter utilization” is an interesting metric given the importance of the automated sorting conveyor systems in the warehouse sub-process. In fact, it allows to monitor the daily utilization of these machines. The KPI is measured for the two sorting conveyors separately and is defined as follows:

$$Sorter\ utilization = \frac{Nº\ of\ hours\ of\ operation\ in\ a\ day}{Daily\ production\ capacity}$$

If overtime is not scheduled, the production capacity of each sorting conveyor system is equal to 10 hours per day. On average, the utilization of the folded garment conveyor ranges between 30% and 130%, when the quantity of items to be processed requires working more than 10 hours per day. The utilization of the hung garment conveyor is between 10% and 90%. Considering the nature of items involved in this process, there is a high need for a dynamic, flexible and fast warehouse, requiring therefore more automation.

The percentage of utilization of the warehouse is expressed by the indicator “Warehouse utilization”, which is computed on a daily basis.

$$Warehouse\ utilization = \%\frac{N^{\underline{o}}\ of\ stored\ items}{N^{\underline{o}}\ of\ items\ that\ can\ be\ stored}$$

This KPI can be evaluated for both folded and hung garments separately or for all the kinds of items together, irrespective of their size. Nonetheless, it is considered an accurate indicator for medium-sized garments, which accounts for the most percentage of stored items. This KPI is meaningful for at least two reasons. First of all, it returns a clear indication of the seasonality of sales: in fact, it reaches its peak, which is around 65%, in the early months of each season, which are February and August. In addition to this reason, the warehouse utilization can be used to estimate potential revenues deriving from renting out space during the off-peak periods. Figure 1 shows the warehouse utilization for folded garments, from January 2012 to October 2012.

The global performance of the warehouse can be expressed by the "Number of items dispatched per hour":

$$N^{\underline{o}}\ items\ dispatched\ per\ hour = \frac{N^{\underline{o}}\ outgoing\ items\ in\ a\ day}{N^{\underline{o}}\ working\ hours\ in\ a\ day}$$

Fig. 1: Warehouse utilization for folded garments

This indicator is also a proxy of productivity, which is here evaluated based on the number of outgoing items because the activity of preparing garments for dispatching is the most time consuming one in the warehousing process. The application of the metric to past data shows that the number of items dispatched per hours goes from a minimum of 30 units to a maximum of 320 units, depending on the size of orders and the characteristics of the items to be processed.

Finally, the effectiveness of the inventory management strategy can be controlled by “Inventory turnover”:

$$Inventory\ turnover = \frac{N^{o}\ outgoing\ items}{Average\ n^{o}\ items\ in\ stock}$$

This KPI is measured on a monthly basis and enables to assess how many times the inventory is renovated in such period. Figure 2 shows the values of Inventory turnover from January to September 2012.

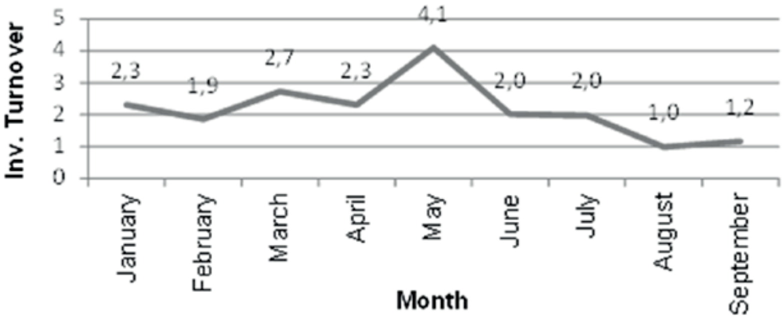

Fig. 2: Inventory turnover

6.1.2 Ways of fulfillment

Many aspects can be measured by the Logistics Company in the Ways of Fulfilment macro-class of the Logistiqual model. For a fast fashion organization, whose competitive advantage is mainly constituted by time, three issues are worth to be mentioned: the flexibility to quickly accommodate every kind of order, the timeliness of deliveries, and the total flow time of items in the warehouse.

One important aspect related to the flexibility of the service provided by the Logistics Company is its capability to process not ordinary orders. This capability is expressed by the indicator “Ability to satisfy not ordinary orders”:

$$Ability\ to\ satisfy\ not\ ordinary\ orders = \frac{Nº\ of\ not\ ordinary\ orders\ satisfied}{Total\ nº\ of\ not\ ordinary\ orders}$$

Table 1 shows the values assumed by the KPI from January until September 2012 for national deliveries. The data show a very high level of service provided.

Month	Total nº of not ordinary orders	Nº of not ordinary orders satisfied	Ability to satisfy not ordinary orders
January	3	3	100%
February	21	21	100%
March	6	6	100%
April	11	11	100%
May	1	1	100%
June	9	9	100%
July	21	21	100%
August	16	16	100%
September	8	7	88%
Total	96	95	99%

Tab. 1: Ability to satisfy not ordinary orders

“Time for managing not ordinary orders” calculates the time from the request for a not ordinary order issued by the Sales Department of the Fast Fashion Company and the arrival of a logistics provider at the warehouse to perform the service. It mainly assesses the efficiency of the Transport Department. Fast fashion requires supply velocity and thus order management procedures are as standard as possible. Therefore, not ordinary orders are connected to opening, closure or revamping of retail stores. They need to be carefully managed in order to comply with the timing of these planned events. The metric is assessed every month. Past performance proves that the focus organization is able to fulfill such orders in about 0.5 days.

"% on time deliveries" allows the Transport Department to monitor the performance of the LSPs. It is measured on a daily, weekly or monthly basis as required:

$$\%\ on\ time\ deliveries = \frac{Nº\ on\ time\ deliveries}{Total\ number\ of\ deliveries}$$

The number of on time deliveries is obtained by calculating the indicator "Delivery time" (Lead time sub-class of Logistiqual) for each delivery and comparing it with the standard value corresponding to the geographical area where the customer is located. If the actual delivery time is less or equal to the standard time, the delivery can be considered on time. Table 2 presents the values assumed by the KPI from June until September 2012 for national deliveries. As it can be seen, most of the deliveries have been performed on schedule.

Area	Jun-12	Jul-12	Aug-12	Sep-12
North	93%	96%	84%	93%
Center	91%	93%	81%	87%
South	88%	94%	74%	86%

Tab. 2: Percent on time deliveries - Italy

Finally, "Total warehouse flow time" is a useful indicator to evaluate the performance of the warehouse sub-process. It gives the average number of days between the time an item enters the warehouse and the time it leaves it. The Logistics Company computes the KPI on a monthly basis as:

$$Total\ warehouse\ flow\ time = \frac{Average\ nº\ items\ in\ stock}{Average\ number\ of\ outgoing\ items\ per\ day}$$

The total warehouse flow time from January until September 2012 is around 10-15 days except for August when it reaches one month. This is due to a decision to bring forward the suppliers' delivery of items for the incoming fashion season, with a consequent increase in the average level of inventory and in the warehouse flow time. This also influences the value of the KPI in September (Figure 3).

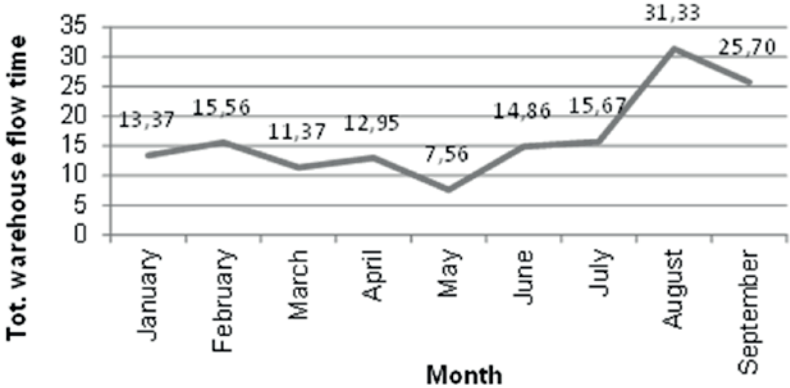

Fig. 3: Total warehouse flow time

6.1.3 Informative Actions

The Informative Actions macro-class includes metrics concerned with the time to solve problems about the order fulfillment process, the level of customer satisfaction, the management of products after they have been delivered to retail stores, and the easiness of use and effectiveness of the Fast Fashion Company website.

The metric “Customer satisfaction” is measured on a yearly or seasonal basis and is defined as:

$$Customer\ satisfaction = 1 - \frac{N^{o}\ of\ claims}{Total\ n^{o}\ of\ deliveries}$$

Before the creation of the Logistics Company, customer claims were managed by the Sales Department of the Fast Fashion Company in collaboration with the Logistics Department. The new Logistics Company aims to deal with claims by directly interfacing with the retail store managers.

“Website accessibility” and “Easiness of online operations” assess the Fast Fashion Company website that, besides giving information about products, also supports the retailers’ interaction with the company. They can be measured once a year through an online questionnaire to retailers. These are quite important aspects because the website should facilitate retailers' operations with a consequent indirect benefit for final consumers.

Customer satisfaction depends on several aspects. One important aspect can be identified with the number of incorrect deliveries, which is expressed by the indicator "% incorrect deliveries". A delivery is defined as incorrect in case of a missing item, or when it contains more items than ordered.

$$\%\,Incorrect\ deliveries = \frac{N^{o}\ of\ incorrect\ deliveries}{Total\ n^{o}\ of\ deliveries}$$

In order to be effective, this KPI is computed on a weekly and monthly basis.

Figure 4 shows the value of the KPI for the first 36 weeks of 2012 (from January until September). It is worth mentioning that a significant correlation between the peak of deliveries and the level of service provided exists. In fact, faults in the delivery service are more frequent when more deliveries are performed.

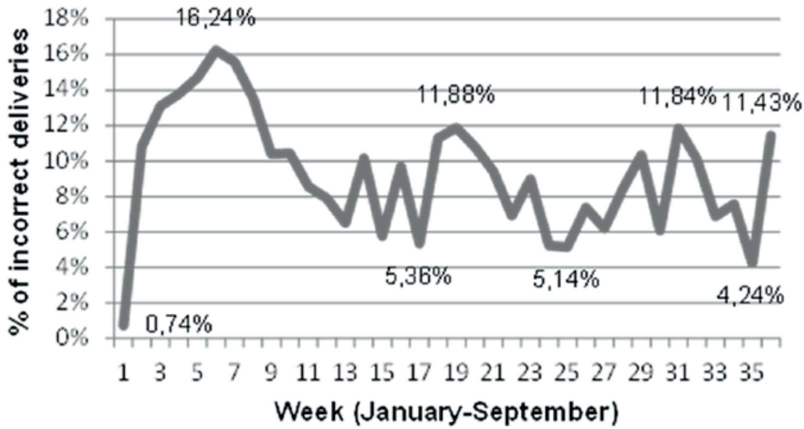

Fig. 4: Percent of incorrect deliveries

6.2 Economic performance indicators

The economic indicators are mainly costs associated with the two processes of the new Logistics Company: warehousing and transport.

Warehouse management costs can be divided into overheads, labor costs, and in-sourcing costs. Overheads include energy costs, maintenance expenses, assurance costs, amortization, etc. They are fixed costs that do not change with the quantity of items that are processed. Labor costs are represented by the salaries of the employees of the Logistics Company and again they do not depend on the quantity of items. Finally, in-sourcing costs refer to temporary workers whose salary depends on the number of items processed. Therefore, a value per item can be defined for such costs.

Transport management costs are based on yearly contracts with logistics service providers that define the cost of the service either per item or per container. These values depend on the distances, the volumes, and the frequency of shipments. In the case of fast fashion, air shipments, which are paid according to either the weight or the volume of products, are rare as well as full truck loads. Transport costs can be monitored for each different geographical area that is served.

7. Discussion

Developing independent logistics companies is a strategy to focus on core competences while ensuring a direct and complete control on supply chain activities that is not possible if logistics operations are outsourced to LSPs. However, the approach is effective only when these new organizations are sustainable from both an operational and an economic point of view allowing achieving the promised benefits in terms of costs, time, and level of service.

This contribution develops a dashboard of indicators to measure the performance of a recently founded independent logistics company in the fast fashion industry, where short lead times and superior quality are key competitive factors. The proposed approach provides the case organization with a structured methodology to quantitatively assess the behavior of its logistics system as well as the associated effects on customers. This assists in constantly monitoring processes and controlling them by implementing policies to have performances meet the business goals. Furthermore, the implementation of the dashboard stimulated information sharing among the Logistics Company’s functions as well as motivated people to operate in order to achieve the set goals. From a methodological point of view, such approach benefits from adapting a well consolidated performance evaluation model in order to reflect the actual conditions of the processes under consideration. Logistiqual revealed to be a valuable model for monitoring logistics processes. In fact, its taxonomy of performance dimensions allowed to focus on all the relevant activities that need to be controlled. Additionally, it led to the identification of KPIs that can be easily calculated with the data already available in the information system of the Fast Fashion Company.

The suggested methodology can be useful not only to define a new performance measurement system but also to update an existing one according to the changing needs of an organization.

The work poses some limitations. First of all, the developed method requires a strong organizational commitment in order to be applied, which may lack in some companies. Also, the suitability of the dashboard for the Logistics Company has been just validated through its application to past data prior to the actual adoption by the firm at issue. A post validation of the outcomes of its implementation should be performed in order to fully state the effectiveness of the approach. Moreover, the economic part of the dashboard is less developed than the operational part, also due to the fact that the Fast Fashion Company was traditionally more focused on assessing operational performance. In order to complete the measurement system, it would be appropriate to define stronger relationships between operational and economic KPIs. Finally, it would be interesting to study how the proposed approach works in different industries and how it should be modified to comply with their peculiar characteristics.

This is where future research is directed. In collaboration with the Logistics Company the authors are planning to monitor the results of the application of the dashboard over an appropriate period of time in order to check their consistency and refine the measurement system should it be necessary. After that, the operational activities determining the economic performance and the related KPIs will be identified and analyzed in order to understand the economic impact of a given level of service. Finally, the dashboard will be tested in multiple cases and industries.

8. Conclusions

The work proposes a dashboard of KPIs to measure the performance of an internal firm managing the logistics activities for an Italian company leader in the fast fashion industry. The ex-ante validation revealed that this structured set of metrics is able to appropriately reflect the behavior of the Logistics Company thus supporting the implementation of strategies to ensure long term organizational sustainability. Further analyses of the outcomes of the implementation of the approach, together with refinements, are required. Also, applying the dashboard to different industries would give insight about its improvement.

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APPENDIX A. THE LOGISTICS COMPANY OPERATIONAL PERFORMANCE DASHBOARD

Sub-classes	Indicators
Internal assets	Sorter performance
	Sorter utilisation
	Warehouse utilisation
	N° of items processed per hour
	Warehouse utilisation
External assets	N° of logistics service providers
Personnel	Productivity of warehouse personnel
	Productivity of loading/unloading activities
	Warehouse management productivity
	N° of items dispatched per hour
	Productivity of the Fast Fashion Office personnel
	Productivity of the Transport Department personnel
	Logistics Company turnover
	Problem solving attitude

Sub-classes	Indicators
Inventory availability	Inventory turnover Inventory accuracy % high errors % medium errors % low errors

Tab. 3: Tangible Components Macro-Class

Sub-classes	Indicators
Flexibility	% personalised items Item flow time with cross-docking % cross-docked items Time for managing not ordinary orders Ability to satisfy not ordinary orders % not ordinary orders % customs operations causing delays % ordinary dispatches
Service care	Delivery accuracy Late shipments Item quality Logistics service provider reliability % on time deliveries % deliveries with no damages Logistics service provider effectiveness % items shipped on clothes hangers

Sub-classes	Indicators
Supply conditions	Vehicle saturation
	Container saturation
	Container optimisation
	Average delivery delay due to container optimisation
	Average N° of items per container
	N° of deliveries per store
	Average N° of items per delivery
	% deliveries of hung items
	Transport mode
	Performance of item transfer between stores
Lead time	Total warehouse flow time
	Delivery time

Tab. 4: Ways of fulfillment Macro-Class

Sub-classes	Indicators
Order management	Time to solve order management problems
After sales	% end of season returns
	Customer satisfaction
	% incorrect deliveries
	% items missing or not in the correct quantity
	% high errors
	% medium errors
	% low errors
E-business	Website accessibility
	Easiness of online operations
	Effectiveness of online notification of wrong deliveries

Tab. 5: Informative Actions Macro-Class

Design of Sustainable Transportation Networks

Wendelin Gross and Christian Butz

Abstract

The stakeholders of companies have increased their focus on sustainability of the business activities in the course of a societal paradigm shift towards inter-generational equity. The triple bottom line of economical, ecological, and social sustainability has become a standard model for the overall purpose of businesses. Therefore, companies in retail and manufacturing sectors tend to improve their carbon footprint and reduce emissions of Greenhouse Gas (GHG). The scope of this work is the strategic design of logistics network according to sustainability criteria by means of mathematical optimization methods. GHG emissions of road transportation for the delivery of goods to manufacturing sites or the point of sale are taken into account. The paper applies a facility location model to identify ecologically and economically efficient network configuration for given demands, road infrastructure, and equipment. The proposed research design provides insight into the trade-off between cost efficient and emission efficient network design, and presents metrics that can be applied to a facility location problem in order to pursue the ecological sustainability target. The application in two scenarios show the viability for real-world sized data sets.

Keywords: sustainability, network design, facility location, supply chain management

1. Introduction

The stakeholders of companies have increased their focus on sustainability of the business activities in the course of a societal paradigm shift towards intergenerational equity. The triple bottom line of economical, ecological, and social sustainability (Elkington 1998) has become a standard model for the overall purpose of businesses (Tacken et al. 2014, p. 56). Therefore, companies in retail and manufacturing sectors tend to improve their carbon footprint and reduce emissions of Greenhouse Gas (GHG), and set their strategic goals respectively.

Transportation of passengers and goods accounts for 24% of GHG emissions in Europe in 2012, and the trend is towards increasing emissions compared to most other sources such as electricity production (EEA 2014, p. 115). Despite the fact that transportation is a major cause of emissions and the increasing pressure from stakeholders on companies, planning of transportation networks is not yet commonly targeted for potential emission reduction (for the case of logistics planning in Germany see Horváth & Partners 2013, p. 11). Still, minimizing transportation costs remains essential for the company's competitiveness and remains the predominant network planning objective. However, over the recent years, sufficient standards for calculating costs and simulating GHG emissions in transportation have been developed, such as DIN/EN 16258, and empirical data on road vehicle emissions is available (DIN 2013, HBEFA 2010).

The purpose of the research behind this paper is to investigate the trade-off between transportation networks designed to a purely cost efficient approach with a network design that is optimized to minimal GHG emissions. Therefore, this work in progress paper aims at presenting, analyzing, and discussing an approach for sustainable network design, which will be derived from a standard cost efficient network design method. A facility location model is formulated and applied to two scenarios based on real-world data.

In the first section of this paper, the scope of work is further narrowed. Then, the existing body of literature on network design with a focus on facility location models with sustainability is briefly depicted, followed by the model description. Two scenarios are used for the evaluation of the approach. The scenarios serve for the calculation of trade-off and for the comparison of ecological and economical network design. Finally, conclusion and outlook close the paper.

2. Scope of work

The scope of this work is the strategic design of logistics network according to sustainability criteria by means of mathematical optimization methods. GHG emissions of road transportation for the delivery of goods to manufacturing sites or the point of sale are taken into account. The paper applies a facility location model to identify ecologically and economically efficient network configurations for given demands, road infrastructure, and transport equipment.

Seuring/Müller identified external pressure and incentives set by stakeholders as triggers for sustainable supply chain management in their deep literature analysis (Seuring and Müller 2008, p. 1703). Two groups of stakeholders are of particular relevance for the sustainability of the supply chain: Customers and public government.

Customer's perception of ecological sustainability becomes more important in industrialized countries and raises demand for sustainable products and services. Public governance tries to set incentives to reduce energy consumption and pollution such as emission dependant vehicle tax or penalties on electrical energy (Tacken et al. 2014, p. 56). As incentives and pressure by stakeholders apply to the focal company of the supply chain, according to Seuring and Müller, it will be assumed that the triggers are equally valid for the network design decision of a single company. This assumption is relevant because of this work's scope on the design of transportation or logistics networks - a planning task of a company or an enterprise. Still, transportation networks that perform the physical distribution are a connector of companies in supply chains, but their design is not yet a cross company task. Further reading on the relation of logistics and supply chain management is vastly available (e.g. overview in Larson 2004).

The aforementioned triple-bottom-line comprises the economical, ecological, and social dimension of sustainability. However, again referring to Seuring and Müller, the focus in management related literature on sustainability lies on the ecological dimension or on the integration of economic and ecologic sustainability respectively (Seuring and Müller 2008, p. 1702). The following work covers ecological and economical sustainability with GHG emissions and costs of road transportation as indicator.

3. Literature review

3.1 Strategic network design

Three planning levels are generally distinguished depending on the time horizon: strategic, tactical and operational. Network design is a task that is bound to considerable capital investment in the case of production facilities, or bearing high planning and set-up efforts. Therefore, and because service quality depends on the location of the facilities in relation to other facilities, it is considered a strategic task (Melo et al. 2009, p. 403)(Klose and Drexel 2003, p. 4)(Owen and Daskin 1998, 424).

The general purpose of transportation and storage in logistics is the requirement for the transformation of physical goods in space and time. Production and consumption of goods usually do neither occur at the same place nor at the same time. Therefore, transformation in space (transportation) or time (storage) is necessary. Logistics aims at bundling these transformation processes regardless of company's divisions, markets, or product groups for the sake of efficiency (Weber 2008, p. 55). This results in transportation or logistics networks consisting of locations (nodes) and transport relations (arcs).

Planning tasks within network design and configuration comprise structural planning (location planning) including the number of active facilities, their geographical location, and the respective productive steps to be undertaken at the location. Furthermore, all transport relations between sites for production, storage, and retail as well as stock levels and the assignment of transshipment points to productions sites are part of the network design and configuration (Ballou 1995, p. 40). The former of these tasks is also referred to as routing, the latter as allocation. As the input parameters undergo changes over time, e.g. rising energy costs and regionally fluctuating demands, the planning of these networks is a repetitive task of logistics or supply chain management (Wolff and Gross 2008, p. 127).

The task of location planning in logistics networks is to identify the most efficient network configuration that serves customer's demand for goods, which are generated or produced in facilities, through transshipment points. More general, a number of spatially distributed sinks and sources have to be connected via transshipment points. Thus, the result of the planning is a network configuration that defines the number and the location of transshipment points, and their connecting links to sources and sinks, so that all demand is satisfied and the goods are delivered via transshipment points.

The connecting links between sinks, transshipment points, and sources are measured by a given metric that represents distances or costs for instance. Additionally, constraints can be applied in order to model domain specific requirements (Melo et al. 2009, p. 401). In business practice, the task of location planning is divided into several steps within a standard process. According to a frequently applied concept of Butz et al. and others, the core process comprises the 3 steps modeling, optimization, and assessment of the results (Butz et al. 2010, p.24; see also Wolff and Nieters 2002, and Brauer et al. 2010).

The optimization step within the network design requires quantitative methods and the formulation of the input data such as demands and customer locations in a mathematical model. The resulting optimization problem is also referred to as facility location problem, which has been subject to intense studies within Operations Research (OR) and applied mathematics. The application of facility location within supply chain management and logistics network design is a common approach since OR entered into SCM research (see ReVelle et al. 2008 and Klose and Drexl 2005 for a review and comprehensive description of different facility location problem types).

The abovementioned metric for measuring the arcs (connections between nodes) is a mathematical term for assessing (weighing) the individual good's flow between the nodes. The metric is of major importance for the outcome of the location planning because of two reasons. First, it highly influences the resulting network configuration. Second, it is a significant indicator for the model quality because it reflects the congruency of the model weighs and the real world weighs, e.g. costs. In the application domain of logistics networks, the metrics applied for measuring the arcs represent costs. That is for two reasons: first, to receive the predominantly relevant information from the network model; second, to base the decisions in network design on the predominantly relevant parameter. In strategic network design, however, costs are frequently assumed to be a linear function of distance. Then, spatial distances replace costs as metric for the network design.

3.2 Location planning

Facility location decisions (location planning) play a critical role in the strategic design of supply chain networks. While there is a broad body of literature on facility location in the application domain of transportation networks, the works that include ecological sustainability have only emerged recently. More specifically, the use of non-linear cost and emission metrics is still underdeveloped.

Within the vast body of literature on facility location, 7 journal papers have been selected according to the focus on non-linear metrics and ecological sustainability. Additionally, the coverage of uncertainty or robustness has been included because of relevance for further research (see Table 1 for summary). The origin of the investigated works in various disciplines such as operations

research, supply chain management, and applied mathematics illustrates relevance and multidimensionality of the subject network design.
Bookbinder and Reece propose an iterative 4-step approach for a facility location problem that includes the routing of vehicles in the outbound distribution. The facility location as first step in the approach deals with a linear metric, which is then refined by the outcome of the second step, the vehicle routing. Therefore, while the metric for the facility location is linear, the overall metric becomes non-linear (Bookbinder et al. 1988).

Main Author	Year	non-linear Metric	Ecological Sustainability	Uncertainty/ Robustness	Application in industry
Book-binder	1988	x	-	-	(Show case)
Wasner	2004	x	-	-	Parcel distribution
Hugo	2005	-	x	-	(Show case)
Shen	2007	x	-	-	4 generated data sets
Harris	2011	-	x	-	Automotive
Pishvaee	2012	-	x	x	Medical
Amin	2012	-	x	x	(Show case)

Tab. 1: Literature on location planning and sustainability (sorted by year of publication)

The work of Wasner and Zäpfel as well is an approach of integrating the vehicle routing and the facility location. They further developed the iterative approach to a parallel approach by the introduction of variables that link the routing and facility location. Within the inbound transports, they apply a metric that is non-linear towards lot size. For the outbound tours, a linear metric is used (Wasner and Zäpfel 2004).
Hugo and Pistikopoulos set up a planning model for the location of plants with regard to market demands, raw material supply, and production technologies.

They aim at minimizing the environmental impact of the resulting network. As their focus is on the decision how to produce goods in the network, they do not apply transportation emissions. Also, their cost metric is linear (Hugo and Pistikopoulos 2005).

Shen and Qi formulate a standard facility location model (p-median). Their approach for the outbound transportation costs is the use of a formula for the approximation of the distance from the transshipment point to the sink that assumes delivery tours. Therefore, the outbound cost metric turns non-linear (Shen and Qi 2007).

The work of Harris et al. aims to assess the impact of the traditional cost optimization approach to strategic modeling on overall logistics costs and emissions. Their approach uses linear metrics for cost and emission. The latter is modeled with fuel consumption and conversion rates taking truck utilization as parameter into account. Note that emissions are calculated for assessment only after the designing the network purely on cost base (Harris et al. 2011).

Pishvaee et al. set up a facility location model of a production network that comprises the decision about production sites based on costs and emissions in production and transportation, and uncertainty. The applied metrics for transportation costs and emissions are linear. In order to deal with uncertainty, they use a fuzzy logic approach to solve the bi objective (cost and emission) model (Pishvaee et al. 2012).

Amin and Zhang investigate facility location comprising the decision on plant and collection centers for recyclables (closed loop network). They apply a linear cost metric. The extension of the model they propose to multi objectives includes the environmental impact. However, the environmental impact excludes transportation aspects (Amin and Zhang 2012).

4. Research design

Research is designed to investigate the difference between transportation network design that is purely cost efficient and on that is purely eco efficient in the sense of GHG emissions. The design comprises commonly applied mathematical modeling and optimization of transportation networks.

The first step comprises gathering and preparing the input data for the scenarios. This resulted in two scenarios, one based on a hypothetical supply and demand structure, and one based on real-world data of a company. The second step is to formulate the general mathematical model of the transportation network including demand, costs, and target function. Two metrics representing the costs are formulated: One for cost optimization, and the other for emission optimization. Then, the model with both metrics is applied to the scenarios resulting in two optimal network configurations each: the cost optimal and the emission optimal. For reference and validation, a third network configuration has been generated for each scenario, which is optimized without a metric, i.e. on transportation distance, in this step. That is for the purpose to show that the trivial solution without any metric is not dominant.

Finally, total transport costs and emissions of the resulting network configuration are assessed using the same metrics in order to receive the four key indicators for each of the scenarios that allow comparison of cost and emission efficient network configurations. The indicators are displayed normalized. Also, the number of transshipment points in the resulting network configuration is provided (see Table 2 for the scheme of results).

Scenario	Total Cost	Total Emission	# of transshipment points
Cost efficient network configuration (cost optimization)	100%	%	#
Emission efficient network configuration (emission optimization)	%	100%	#
Reference network configuration (distance optimization)	%	%	#

Tab. 2: Key indicators for network assessment and comparison of solutions (scheme)

5. Model formulation

5.1 Network layout

The network design problem is formulated as a facility location program in a 2-echelon-layout. This is a standard model for the distribution of goods from sources, e.g. production sites, to sinks, i.e. customers. Two metrics for assessing and measuring the arcs cover cost and GHG emissions. Both metrics distinguish between transportation from source to transshipment point (inbound) and from transshipment point to sink (outbound). The costs metric is derived from real world transportation tariffs. GHG emissions are modeled according to DIN/EN 16258 and the HBEFA database (DIN 2013, HBEFA 2010) of emission factors. For modeling and optimization, the commercial planning software 4flow vista (version 4.2) has been applied.

The general type of model is a facility location model with a given set of allowed transshipment points (nodes) between sources and sinks (Figure 1). In terms of OR, the model represents a p-median problem (Klose and Drexl 2005 p. 7).

The model is also referred to as hub location model in literature (Klose and Drexl, 2005 p. 20).

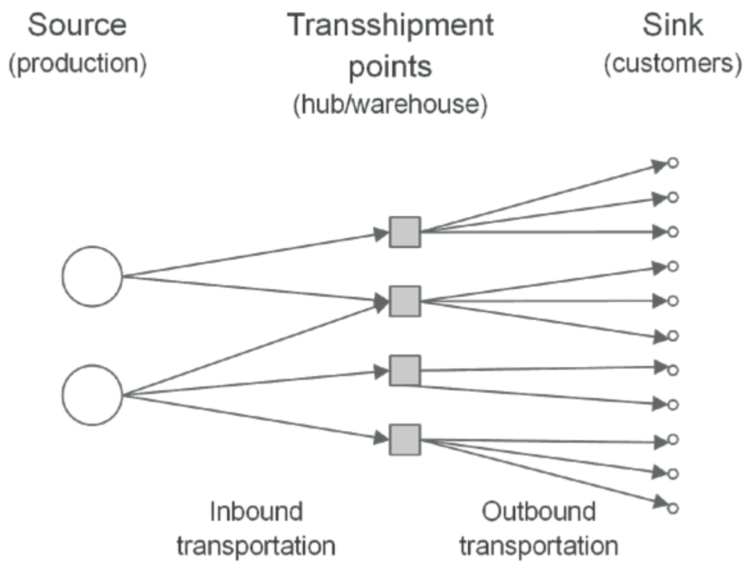

Fig. 1: Network (scheme)

The parameters for the hub location (p-median) comprise in general the demand at each sink and the distance between each possible relation of sink and node, and source and node (Owen and Daskin 1998, p. 425). However, to receive good results for the transport network planning, further parameters are used. First, instead of using solely distance, non-linear metrics for transportation costs and GHG emissions are applied. Second, the distances between the nodes are derived from real world road infrastructure (road distance).

The set of possible transshipment points has been derived from publicly available information bases, aiming at a representative coverage of the relevant European regions. Existing transshipment points of larger logistics service providers have been identified and included in the model. In total, there are 376 transshipment points available (see Figure 2 for the spatial distribution of possible transshipment points). For the sake of uniformity, 2 reference locations have been added. The scenarios presented in section 6 contain the very same reference locations in terms of latitude and longitude (see Figure 3). This allows the comparison of the spatial distribution of transshipment points and network sinks.

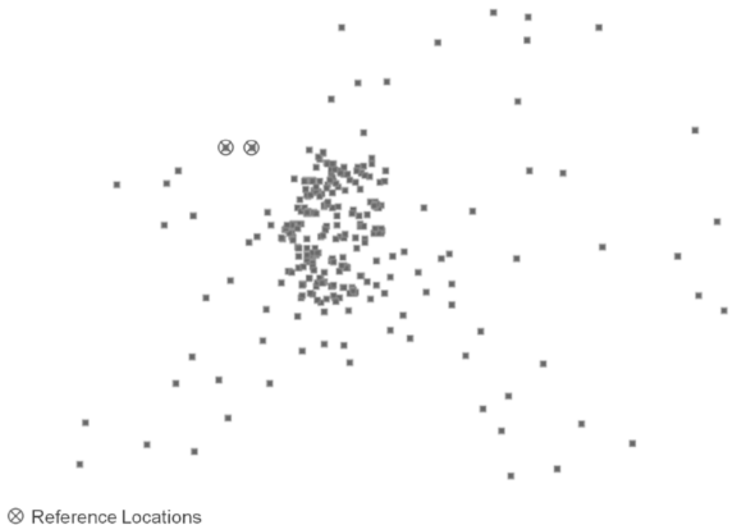

Fig. 2: 376 possible European transshipment points in the model (spatial distribution in the 2-dimensional plane)

The facility location model objective is minimizing total 'costs', which in this case can be costs or emissions. Therefore, inbound and outbound costs build the target functions, (1) for costs, and (2) for emissions.

Target functions:

$$min! \sum_{\substack{Inbound\\relations}} cost_{Inbound,i} + \sum_{\substack{Outbound\\relations}} cost_{Outbound,j} \quad (1)$$

$$min! \sum_{\substack{Inbound \\ relations}} emission_{Inbound,i} + \sum_{\substack{Outbound \\ relations}} emission_{Outbound,j} \quad (2)$$

As mentioned above, the cost and emission metrics are crucial for the model outcome (see next section). Note, that the model does not yet comprise costs and emissions for the facilities themselves. However, assuming that costs and emissions per shipped article are equal in all locations, the location costs and emissions are not relevant for the optimization result. Thus, economies of scale for locations are not included in the model for the sake of rigidness. This can be subject of further enhancement of the model.

5.2 Cost and emission metric

The metrics for assessing and measuring the transports in the network were designed as non-linear functions in the first place. The reason behind non-linearity in transportation lies in economies of scale. Firstly, non-linearity applies towards the lot size of the shipment in order to reflect the fact that cost and emission per pallet and kilometer depend on truck utilization. In simple words, the less packed a truck is, the higher the costs and emissions for each pallet are. Secondly, non-linearity applies towards the total spatial distance of the transport. Here, the case is different for costs and emissions. While costs are modeled as non-linear towards distance according to observations in the real world, emissions are modeled as linear towards distance. That is due to the assumption that GHG emissions of a truck remain constant per kilometer no matter how far the transport goes.

For inbound transportation in distribution networks, that is the transports from the sources to the transshipment point full utilization is assumed. In terms of logistics, full truck loads (FTL) deal with the transportation. Therefore, the cost and emission metrics turn linear towards lot size for inbound transportation. Table 3 summarizes the main characteristics of the cost and emission metric.

The cost metric (3) and (4) is based on several real world tariffs that have been collected from industry, retail, and logistics service providers, and combined to form a representative cost metric. The metric allows for full truck load (FTL) transportation, which is basically a price per truck per kilometer, and less than truck load (LTL) transportation. LTL tariffs refer to a single shipment, which is a price per lot size per kilometer. Both, FTL and LTL tariffs are non-linear towards distance.

	Inbound	Outbound
Cost	Linear (lot size), non-linear (distance); region-specific, truck-specific; real world tariff (FTL)	Non-linear (distance, lot size); region-specific, truck-specific; real world tariff (LTL)
Emission	Linear (distance, lot size); truck-specific, traffic-dependant; emission data base (FTL)	Linear (distance), non-linear (lot size); truck-specific, traffic-dependant; emission data base (LTL)

Tab. 3: Characteristics of metric for inbound and outbound transportation

The lot size can be either provided as weight or volume, depending on the more critical constraint of the truck, which is payload or volume. Because the goods that are used in the scenarios are light weight, the lot size refers to volume as more critical constraint. Additionally, regionally differing prices in Europe are covered in the metric on a country level.

For the emission metric (5) and (6), standard approaches for assessing transportation emissions have been applied. According to the norm DIN EN 16285, emissions should be derived from the real fuel consumption of the truck fleet, which is computed into GHG emissions with a fuel-to-emission conversion rate. As this approach is not applicable in a planning environment with real fuel consumption not available, the norm supports the calculation of emission based on distance and emission factors (DIN 2013). Emission factors are empirical functional relations between pollutant emissions and the activity that causes them, which is in this case road transportation (Franco et al. 2013, p. 84).

For the emission metric, these factors have been derived from the emission database HBEFA, which is based on extensive empirical studies (see De Haan and Keller 2004 for detailed insight on the first edition of HBEFA). The database provides emission factors according to truck type and truck utilization.

Furthermore, road type and traffic situation are included. Here, according to the planning environment of strategic network design, highways and a dense free flow traffic situation are applied.

Concerning the truck utilization, the relevant criterion for emissions is the weight of the truck load, as the filling degree of the loading bay does only affect the emissions if it adds weight to the truck. Therefore, lot size within the emission metric refers to weight. However, the metric ensures that the volumetric capacity of the truck cannot be exceeded even if a larger shipment would be possible by the maximum payload.

Cost metric:

$$\mathrm{cost}_{\mathrm{Inbound,i}} = \mathrm{d_i} * \mathrm{V_i} * \mathrm{cvol}_{\mathrm{T,R}} \quad (3)$$

$$\mathrm{cost}_{\mathrm{Outbound,j}} = \mathrm{d_j} * \mathrm{V_j} * \mathrm{cvol}_{\mathrm{T,R,D,L}} \quad (4)$$

Emission metric:

$$\mathrm{emission}_{\mathrm{Inbound,i}} = \mathrm{d_i} * \mathrm{M_i} * \mathrm{evar_T} \quad (5)$$

$$\mathrm{emission}_{\mathrm{Outbound,j}} = \mathrm{d_j} * \left(\frac{\mathrm{M_j}}{\mathrm{capm_T}} * \mathrm{evar_T} + \mathrm{efix_T}\right) \quad (6)$$

Indices:

i: index of relation inbound

j: index of relation outbound

T: index of truck type

R: index of region of origin and destination (matrix)

D: index of distance class

L: index of lot size class

Parameters:

d: road distance

cvol: cost per volume unit

capm: capacity (weight) of truck

evar: variable GHG emissions per truck (utilization dependant)

efix: fix GHG emissions per empty truck

Variables:

M: mass (weight) of goods on relation

V: Volume of goods on relation

The facility location model as described above has been modeled and solved in the commercial planning tool set 4flow vista (version 4.2).

6. Scenarios

The model with cost and emission metric respectively as stipulated above is applied to two data sets, referred to as scenarios in the following. The scenarios are based on real-life data (see Figure 3 for the spatial distribution of sinks on a 2-dimensional plane).

Network #1 represents a hypothetical data set with typical demand distribution over Europe according to the economical strength of regions, and a single source (see Gross et al. 2010 for details on the data generation).

Network #2 is derived from a real world company that maintains several own production sites and as well delivers goods directly from suppliers within the network.

The two scenarios have been selected in order to provide indication on some relevant directions for further research, and on applicability of the approach in different settings and prerequisites. Therefore, one scenario network represents a hypothetical, generated data set and the other one was derived from a company's real-world data. Also, the networks are of different size in terms of the number of sinks, total throughput, and the number of sources (see Table 4 for key parameters).

In both scenarios, the transportation distance is calculated as the shortest path on the existing European road infrastructure. Commonly available commercial service has been used for distance calculation.

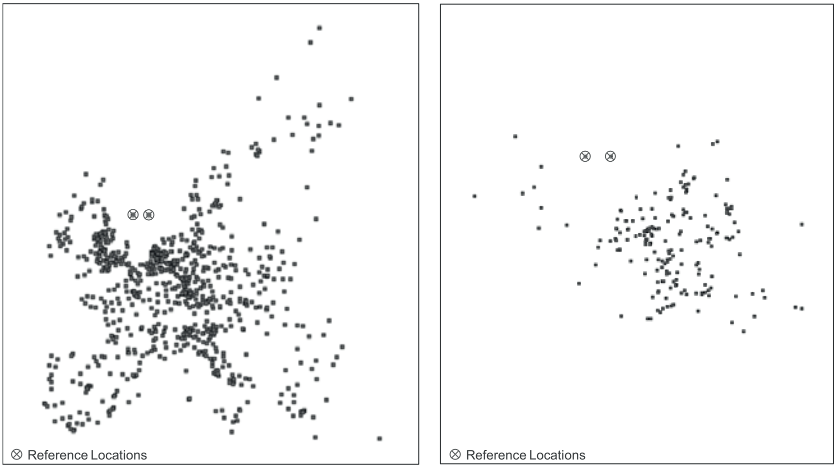

Fig. 3: Spatial distribution of sinks in Europe in the scenario networks in the 2-dimensional plane (left: Network #1, right: Network #2)

	Network #1	Network #2
# of sources	1	18
# of sinks	939	304
# of articles	1	424
Total throughput	8,535,490 m³/y	2,019,316 m³/y
Inbound frequency	1/w	1/w
Outbound frequency	1/w	1/w
Traffic situation	Dense free flow	
Road type	Highway	
Truck type	Euro-V truck with standard trailer	

Tab. 4: Key parameters of scenario networks

7. Results

The facility location model shows the difference between the outcome of network design focused on costs and emissions respectively. The trade-off between the cost efficient and the emission efficient network configuration is between 2% and 54%. Comparing the scenarios, the Network #2 (based on a real-world situation) effectuates the higher trade-off than Network #1 (based on a hypothetical, generated situation). The reference network configuration without metric for the network arcs (based on distance) bears in all cases higher cost and emission than the cost and emission efficient network configuration. Besides the figures of total cost and emission, the number of transshipment points in use in the network configurations is of interest.

In Network #1 (see Table 5 for key indicators), the trade-off between cost efficient and emission efficient network is 3% in costs and 2% in emissions. The sustainable network design results in 3% higher total costs than the standard approach of cost efficiency. The total emissions in the cost efficient network are 2% higher than in the sustainable network design. Roughly 25% more transshipment points are in use in the sustainable network compared to the cost efficient one (194 compared to 154). This indicates a major structural difference in two network configurations.

The scenario Network #2 shows greater divergence between the cost efficient and the emission efficient network configuration than Network #1 (see Table 6 for key indicators). The trade-off in total costs is 54%, and 16% in total emissions. A sustainable network design approach would save 16% of emissions at a cost increase of 54% compared to the cost efficient network configuration. Similar to Network #1, the number of active transshipment points is higher in the emission efficient network configuration than in the cost efficient one; in this scenario by 39% (167 compared to 120).

Network #1	Total Cost	Total Emission	# of transshipment points
Cost efficient network configuration (cost optimization)	100%	102%	154
Emission efficient network configuration (emission optimization)	103%	100%	194
Reference network configuration (distance optimization)	127%	113%	54

Tab. 5: Key indicators for cost and emission efficiency of Network #1

Network #2	Total Cost	Total Emission	# of transshipment points
Cost efficient network configuration (cost optimization)	100%	116%	120
Emission efficient network configuration (emission optimization)	154%	100%	167
Reference network configuration (distance optimization)	149%	127%	195

Tab. 6: Key indicators for cost and emission efficiency of Network #2

8. Conclusion and Outlook

The proposed research design has provided insight into the trade-off between cost efficient and emission efficient network design, and showed metrics that can be applied to a facility location problem in order to pursue the ecological sustainability target. The application in two scenarios show the viability for real-world sized data sets.

The scenario Network #1 shows only limited differences between cost and emission efficient network. Reasons for that are assumed to stem from the single source network structure because this provides limited options for the assignment of transshipment points to sinks. Significantly larger difference can be observed in the real-world scenario Network #2. This can underline the relevance of both data sets in order to identify the critical input parameters in further investigations.

The increase in the number of active transshipment points in both scenarios forms a trend towards more decentralized network configurations when sustainability is taken into account. This trend points towards the importance of truck utilization, which is generally higher in inbound transportation, for emission efficiency. In the cost efficient network configuration, the effect of shorter, less efficient outbound transportation distances might level the effect of higher inbound utilization.

Further analysis of the solutions is required in order to understand, which input parameters are most important for the outcome. Also, the applicability of the resulting network configuration in the real world requires investigation. Therefore, the effect of cost and emission of the transshipment points should be integrated in the first place. As well, operational constraints, such as a maximum number of active transshipment points need to be covered. Different truck types are another possible enhancement in order to close the gap between model and reality. The assumption of linearity of emissions towards total distance of the transport relation can be another aspect for further research. Here, a promising approach might be the inclusion of different average truck speed for shorter distances. Different truck types for inbound and outbound transportation or even for the single relations, e.g. depending on the distance, can also be applied within a model extension. For the calculation of outbound transportation distance, approaches that aim at including or approximation a vehicle routing model could be of interest.

Another question of interest would be, if and how a transition from one configuration to the other is possible. The resulting effort and costs should be of

utmost relevance. Finally, the integration of cost and emission metric into a single, multi-objective metric should be the paramount goal. The considerations on risk management and uncertainty of the input parameter can be included into the model in order to anticipate the volatility of demand and external factors during the planning horizon.
Still, the strategic sustainability targets of companies are not transferred to operations such as logistics management and network design. After first methodical research on sustainable network design has been provided in this paper, further research is required to design a framework that includes sustainability in the paramount strategic and operational planning and performance measurement.

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Exploring Sustainability in Construction Supply Chains

Margherita Pero, Eleonora Bottani and Barbara Bigliardi

Abstract

In EU, 50% of total energy consumption is due to activities related to the construction industry. The number of employees in this industry is increasing. In Denmark, for instance, 25% of the employees in the private sector are employed in the construction industry. Due to this strong impact on both society and environment, increasing sustainability in this sector is highly important. However, despite models for Sustainable Supply Chain Management have been proposed in literature (Seuring and Muller, 2008), still the application of these models to construction industry is understudied (Adetunji, Price and Fleming, 2008). Collaboration between all the players along the supply chain (SC) is fundamental to reach sustainability performance (Rosas, MacEdo and Camarinha-Matos, 2011; Vachon and Klassen, 2008), and the impact on sustainability performance of a product is mainly defined by its design, thus requiring also a strong integration within the company's departments. Therefore, the aim of this paper is to study the approach to sustainability used by construction companies, and to investigate whether and how an integrated approach to sustainability, both inside the company and along the SC, can be leveraged to increase the effect of sustainability practices. With this purpose, two in-depth exploratory case studies have been performed within the construction industry in Italy. Based on the preliminary results, a research framework has been developed. This serves as basis for further investigation on the relationships between contingencies (e.g., firm size and ICT

implementation level), sustainability practices, both internal to the company and along the SC, and sustainability performance.

Keywords: sustainability, supply chain, construction industry

1. Introduction

One of the most widely accepted definitions of sustainable development was provided by the World Commission on Environment and Development (1987), and states that sustainable development is the development that meets the needs of the present generations, without compromising the ability of the future generations to meet their own needs. It is currently recognized that sustainability covers three main aspects (Harris and Kennedy, 2001; Goldman and Gorham, 2006; Colla et al., 2008; Dyllick and Hockerts, 2002), i.e.:

1. The economic perspective. An economically sustainable company is able to produce goods at the minimum cost;
2. The environmental perspective. An environmentally sustainable company avoids the over-use of depleting resources or, as an alternative, privileges the use of resources which have less potential for depletion (Tsoulfas and Pappis, 2006);
3. The social perspective. A socially sustainable system should ensure, among other, fair distribution of opportunities, adequate provision of social services and gender equity (Harris, 2003).

Despite the relevance of the three pillars listed above, sustainability is mainly approached from the environmental point of view, while other perspectives, i.e. the social and economic ones, are somehow neglected (Pullman, Maloni and Carter, 2009; Hahn and Scheermesser, 2006). Some authors also point out the objective difficulty of evaluating social sustainability, because of the lack of specific and quantitative key performance indicators (Colla et al., 2008). According to this orientation, in this paper we focus on the environmental aspect of sustainability.

Achieving environmental sustainability requires exploiting sustainable practices for the provision of a product/service to the final customer, throughout the whole product life cycle, from the conception to the end-of-life. Indeed, from the environmental point of view, manufacturing and logistics activities can have a relevant impact, ranging from emissions into the environment, to the consumption of resources, up to the product’s end-of-life (Rebitzer et al., 2004). In some industrial contexts, those impacts can become particularly relevant: among others, the fashion industry (Bigliardi and Bottani, 2012), the food industry (Manfredi and Vignali, 2014) and the construction industry (Bragança, Vieira and Andrade, 2014) are recognized as contexts where sustainability is a key issue.

To this latter extent, the construction industry is currently facing continual pressure to increase the sustainability of its practice. Indeed, sustainability has, in recent years, become one of the most important performance-related issues within the construction industry (Adetunji, Price and Fleming, 2008). More precisely, sustainable practices in construction are expected to minimize resource consumption, maximize resource reuse, exploit renewable and recyclable resources, protect the natural environment, create a healthy and non-toxic environment, and ensuring quality in creating the built environment (Kibert 1994; Boddy et al., 2007). Kneifel (2010) also states that the construction (housing) industry has potential to accelerate the spread of the energy crisis and to cause environmental problems, ranging from excessive energy consumption to pollution of the surrounding environment. In many countries, the construction industry is also responsible for the consumption of relevant resources. According to the European Union, the construction industry employs approx. one third of the total energy in Europe; that value increases up to 50% in other complementary activities (e.g., transport or the manufacturing of raw materials) are included in the computation (European Commission, 2009). The construction industry is also responsible for about 35% of all greenhouse emissions. Similar considerations hold for the US, where the construction industry has considerable impacts on the environment, economy,

and society: it employs approx. 30% of the raw materials and 25% of water, and produces 30% of the waste of the country (Kucukvar and Tatari, 2013). At the same time, the construction industry is a main industrial field of Europe. In Denmark, for instance, 25% of the employees in the private sector are employed by the construction industry. At European level, the construction industry (including contractors, manufacturers of construction products and professional construction services) generates almost 10% of the gross domestic product, and provides 20 million direct jobs (European Commission, 2013).
On the basis of the considerations above, in this paper we propose a framework for the analysis of sustainability practices in the construction industry. The chosen methodology of analysis is multiple case study-based research, which is used to explore the use of sustainability practices among construction companies.
The paper is organized as follows. The next section reviews the relevant literature related to sustainability in the construction industry. Section 3 details the objective of the study and the research methodology followed. In section 4, we present the results from the case studies. Section 5 summarizes the main findings of the study, discusses the main limitations and implications and proposes future research directions.

2. Literature review

The term "sustainable construction" was proposed in 1994 to describe the responsibility of the construction industry in attaining sustainability (Hill and Bowen, 1997). Hence, sustainable construction addresses the role of sustainability within the built environment and includes the ecological, social and economic factors of a construction project (Kibert, 2008), according to the three main pillars of sustainability mentioned previously. Nonetheless, other authors (e.g., Hill and Bowen, 1997) claim that there are four pillars of sustainability for the construction industry, namely: social, economic, biophysical and technical. The biophysical pillar covers the issues related to atmosphere, land, underground resources, marine environment, flora and fauna, while the technical pillar reflects the quality of the building structure.

In a recent conceptual paper, by reviewing the relevant literature on construction industry, Agyekum-Mensah, Knight and Coffey (2012) propose a 4Es (i.e., Economic, Effectiveness, Efficiency and Ethics) and 4 poles (Economic, Social, Environmental and Technology) model of sustainability in construction. According to the authors, the first pole ("economics") suggests that the construction industry should be able to sustain itself financially, avoiding cost overruns. From the "social" point of view, the construction industry is a labor intensive industry and a main industry field of Europe. Therefore, its social function is to increase labor opportunity and reduce poverty. As regards the "environment", the construction industry is expected to design environmental friendly buildings and structures. Indeed, an excessive use of resources is critical for the ecosystem not only because of the depletion of resources, but also because of other concerns, such as the destruction and long-term change of natural habitats and distortions of the potable water supply (Bringezu, 2002). Finally, the "technology" for a particular construction project should be chosen by the project management team through their techno-socio-economic environmental assessment.

The construction industry grounds on individual processes such as design, energy consumption and materials in achieving sustainability. However, all of these aspects are part of the project management process. From the above description, therefore, it is clear that an efficient project management plays a crucial role in improving sustainability of the construction industry. In the case of the construction industry, project management activities spans from pre-construction to post construction, according to the scheme in Figure 1 (adapted from Caron, 2009). More precisely, following a chronological scale, the main operating processes of a construction project include: (1) the design of the product (e.g., building); (2) the procurement of raw materials and components for the construction; (3) the construction and assembly activities; (4) the first start and testing of the product; (5) its activity; and (6) its end-of-life.

An effective project management strategy has potentials to significantly improve the sustainability of the construction project. As an example, a proper management of the construction project can decrease the current cost of the construction industry, the related overruns and delays. To this extent, literature suggests some sustainability practices that can be adopted at the various steps of the construction project, taking into account not only the construction company but also its upstream players, which also contribute to sustainability (Bringezu, 2002). A summary of some of those practices is proposed in Table 1.

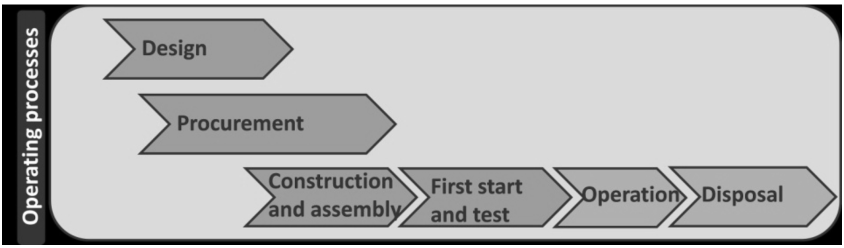

Fig 1: operating processes of a construction project

Project's Phase	Sustainability practices and tools
Design	Lifecycle product/process design and costing; design for reuse and disassembly, life cycle assessment (Beamon, 2008; Carter and Rogers, 2008; Beamon, 1999; Agyekum-Mensah, Knight and Coffey, 2012; Adetunji, Price and Fleming, 2008; Tan, Shen and Yao, 2011) Availability of information related to the energy efficiency of the construction (Rezgui, Wilson and Li, 2010) Development of specifications for suppliers describing the requirements in terms of environmental impact (Azevedo et al., 2011; Zhu et al. 2008)

Project's Phase	Sustainability practices and tools
Procurement	Selection and evaluation of suppliers based on sustainability criteria (Vachon and Klassen, 2006; Verdecho, 2010; Sarkis, Meade and Presley, 2012) Use of environmental certifications (Zhu et al. 2008) Recruitment of resident employees and procurement of local materials, to enhance the local economy (Adetunji, Price and Fleming, 2008) Use of environmental efficient transport policies (Carter and Rogers, 2008; Adetunji, Price and Fleming, 2008) Use of environmental friendly raw materials (Zhu et al. 2008) Use of decentralized distribution systems, with shared stock capacity and transport activities (Beamon, 2008) Collaborations with suppliers to decrease the environmental impact of the final product (Azevedo et al., 2011)
Construction and assembly	Increasing the company's innovation and technological capabilities, to increase the sustainability of the construction process and the final product (Tan, Shen and Yao, 2011) Minimizing emissions, waste, energy and water consumption during the construction (Adetunji, Price and Fleming, 2008) Improving health and safety of the workplace (Carter and Rogers, 2008) Training of employees (Adetunji, Price and Fleming, 2008) Ensuring fair conditions for employees (Adetunji, Price and Fleming, 2008) Using energy from residual or alternative fuels instead of energy from fossil fuels (Beamon, 2008)
First start and test	Certification of the sustainability practices (Adetunji et al., 2008)

Tab. 1: sustainability practices as a function of the project phase and related literature

At the same time, the adoption of sustainability practices could be difficult to a construction company, for a number of reasons. First, the know-how related to sustainability practices is often limited to the single company and does not cover the whole construction supply chain, which is a requirement to be fully sustainable (Vachon and Klassen, 2006; 2008). Also, it is often unlikely that a construction company owns a perfect knowledge of the sustainability practices of this context, because the related know-how is somehow fragmented and difficult to access (Rezgui, Wilson and Li, 2010; Adetunji, Price and Fleming, 2008). A further main barrier is the cost of sustainability practices: it often happens that practices that are sustainable from the environmental point of view are not profitable from the economic perspective (Carter and Rogers, 2008). For instance, certifications of compliance to sustainability standards, released by known authorities, may have a significant cost (Adetunji, Price and Fleming, 2008). The company’s position inside the supply chain and its (consequent) bargaining power could be a further barrier to the implementation of sustainability practices (Azzone and Noci, 1998; Adetunji, Price and Fleming, 2008).

The above overview suggests that there are several studies related to the sustainability of the construction industry. However, the current literature leaves some open questions. Specifically:

- most of the research focuses only on the environmental facet of sustainability in the construction industry, while other perspectives (e.g., the social or economic) are relatively new and less explored (Bringezu, 2002);
- there is still no general consensus on the definition of sustainability and its relationship with the construction industry; consequently, there is no consensus on which aspects should be considered in evaluating the sustainability of a company that operates in this sector and the output it produces (Matar, Georgy and Abou-Zeid, 2010; Pearce and Vanegas, 2002);

- limited attention is paid to the management of collaborative, non-core activities such as the management of sustainable practices (Vachon and Klassen, 2006; 2008).

Starting from those gaps, this study focuses on the analysis of sustainability in the construction supply chain and tries to contribute to the literature by developing a framework to explore this topic inside the selected industrial field.

3. Objectives and methodology

Based on the outcomes from the literature review presented in the previous section, and in particular moving from the research gaps identified at the end of the same section, the main objective of our study is to explore the use of sustainability practices among construction companies. Specifically, we provide evidences from the field, by analyzing two real examples of construction companies that adopt sustainable practices. Companies were selected among the eight companies participating to the "Responsible Building" project, sponsored by the local association of the construction companies, whose objective is to spread sustainable practices among the companies in the construction industry. In order to reach the objective stated above, we adopted a methodology that was a combination of literature analysis and case study-based research. At first, a review of the specific bibliography was performed to identify the main sustainability practices adopted by construction companies, their drivers and barriers, the contingent factors as well as the main performance indicators to be used in the industry investigated.

As the second step of the research, multiple case studies were developed. The case studies had the primary aim of understanding the use of sustainability practices among construction companies. They were carried out with a series of semi-structured interviews, with the manager of each company, over a three-week period in March 2014. Interviewees were given a brief introduction about the study, its aim, as well as the questions contained in the questionnaire used as guidelines for the interviews. When required, an overview of the concepts investigated was provided. The questionnaire included four sections: the first one aimed at collecting general information about the company and the interviewee, while the second one contained questions on the SC configuration as well as the internal organization of the company. The third and fourth sections aimed at investigating which sustainability practices, among those identified in the literature review, are adopted in real contexts and the way they are managed. The same analysis was extended also to sustainability drivers and barriers.

4. Results from the case studies

This section presents the main evidences from the case studies. In this study, each kind of project that is managed differently from the others in the same company, i.e. the role of the interviewed company changes, is taken as a unit of analysis. Therefore, one and three units of analysis were identified in company A and B, respectively:

- For company A:
  - all construction projects of the company
- For company B:
  - "B-Subcontractor": All those projects when company B is involved mainly as general contractor managing the building phase (in yard);
  - "B-Project finance": All those projects when company B is involved as part of the financing consortium; and
  - "B-Self-promoted": All those projects where company B manages all the phases directly, being itself the commissioning body.

For each unit of analysis, the distinguishing features of the phases as well as the sustainability practices used were investigated.

4.1 Sustainability: areas of interest, drivers and barriers

The two companies analyzed differ in terms of size and the area of sustainability which they are more interested in. Specifically, company A is a small enterprise (about 15 employees – for approx. 10 M Euros of revenues in 2012), mainly concerned with the environmental facet of sustainability. Conversely, company B is specialized in the development of large real estate projects and the redevelopment of complex areas. The company's revenue in 2012 accounted for approx. 530 M Euros. Company B is strongly committed to sustainability, both under the environmental and social responsibility perspectives. In fact, the company participates in projects for improving the Corporate Social Responsibility of construction companies, and asked its suppliers to implement (voluntarily) monitoring systems for improving workers' safety in the yard. Similar drivers push both companies to sustainability, i.e. pressure from customers and competitors' moves. In fact, both companies perceive sustainability as a competitive tool to gain market shares, since both of them claim that customers are more and more interested in sustainability and that competitors are becoming more sustainable too. "Sustainability of the building is a must-to-have for the customer", states one of the interviewee in company A, whereas company B is mostly concerned with sustainability especially for those projects that they manage entirely, (i.e. the "B-self promoted" unit of analysis). Managers, who in both companies are strongly committed to sustainability (as demonstrated by the fact that both companies are involved in the abovementioned "Responsible building" project), are actively supporting the implementation of sustainability practices. Interestingly, both companies state that the pressures of suppliers or public opinion is not enough strong to become a real driver to move companies to sustainability. Despite the similarities, in company A, according to the interviewee, sustainability is still in some cases pursued by the company with the aim to comply with law requirements and to reduce the risk of penalties; this does not apply for company B. As far as the barriers are concerned, both companies claim that the whole industry seems still not to completely understand the importance of sustainability, also - among the others - because sustainability is perceived to increase materials and procurement costs, which is not well balanced by the increase in revenues, at least in the short term. In company B, this perception has led, for those projects not completely controlled by company B ("B-Subcontractor" and "B-Project finance"), to a limited management commitment to sustainability, which was a barrier to the implementation of sustainability practices.

4.2 Projects phases

At first, we investigated how each phase of the construction project is managed inside the two companies. We noticed that, although the activities performed within each phase were quite similar, the extent to which these activities were performed by resources internal to the interviewed company (i.e., the level of ownership of the phase) was different depending on the unit of analysis. Details can be found in the following sub-sections.

4.2.1 Company A - project phases

Company A operates as general contractor, but has different levels of ownership on the different phases of the projects (see figure 2). A typical construction project is divided into three phases: Design Phase, i.e. the activities related to the definition of the specifications of the project; Procurement Phase, i.e. the activities related to the definition of the suppliers of the materials to be used in the project; Building Phase, i.e. the activities related to the actual building in the yard. Company A controls the whole design phase, possibly supported by external designers whenever the number of internal designers is not sufficient. The same applies for the procurement phase, where suppliers are selected by company A among the ones already pre-selected and available in the suppliers' base of the company. Finally, other companies, under the supervision of company A, carry out the building phase completely.

		Phase		
		Design	Procurement	Building
Level of ownership	High	A B-Self promoted	A B-Self promoted	B-Self promoted B-Subcontracting B-Project finance
	Medium	B-Project finance		
	Low	B-Subcontracting	B-Subcontracting B-Project finance	A

Fig. 2: Level of ownership of the project phases for all the units of analysis

4.3 Company B - project phases

For company B, the level of ownership of the project phases depends on the kind of project analyzed, i.e. on the unit of analysis. In particular, all the phases of "B-Self promoted" projects are managed directly and entirely by company B, whereas the customer strongly influences the design as well as the procurement activities in the case of "B-Subcontracting" and "B-Project-finance". As for the design, in "B-project finance", being company B one of the financing partners, it can influence the design of the building to some extent. Conversely, when "B-Subcontracting" is at stake, company B has limited possibility to influence the final design of the building. In the case of procurement, instead, in both situations the customer pre-selects the suppliers in the procurement phase.

4.4 Sustainability practices

In this section, we present the results related to the approach to sustainability shown by the companies, as well as to the sustainability practices used by the interviewed companies in the analyzed units of analysis.

4.4.1 Company A - sustainability practices

Due to the small size of the company, there are no departments expressively dedicated to the project design and purchasing steps respectively. However, all along the project lifecycle, meetings involving internal and external designers, the purchasing manager and the suppliers are frequently held to discuss on material choice and technical solutions. Similarly, there is not a company's manager dedicated to sustainability. All the people involved know the company policy for sustainability and must apply it. Table 2 lists the practices used in company A. It is noteworthy that a practice can be applied with different approaches. For instance, practices can be applied only within the walls of the company (internal focus) or can be extended to the suppliers. In this case, some practices are implemented by leveraging on the collaboration with the other partners (collaborative approach), whereas others are used to control the work performed by other partners (control focus).

4.4.2 Company B - sustainability practices

In company B, there is not a specific role appointed to sustainability, although there is a person managing quality and environmental management system (in line with the ISO 9001-14001 standards). In the case of "B-self promoted", both the proposal manager, from the sales department, and the project manager are strongly concerned with sustainability.

According to the interviewed project manager of company B, “the decision not to outsource building phase is one of the main elements that determined the success of company B: aligning the objectives of these two roles, while keeping the complete control of the building phase, allows to obtain a building that is, at the same time, the most possible sustainable and attractive for the customer”.

In Table 3, the practices used in company B can be found.

Phase	Practices	Description
Design	Life Cycle Assessment / Eco-Design	The impact of design decisions on environmental performance of the product along the product lifecycle are assessed involving both internal resources and supplier (collaborative approach)
	Training	Internal resources are trained to increase their knowledge in the environmental impact of building (internal focus)
	Rules and procedures	Rules and procedures for eco-design are provided to external designers, then the output provided by these designers are evaluated against the provided rules (control focus)
Procure ment	Vendor lists	Company A in collaboration with other companies in the construction industry is developing a list of suppliers certified to be compliant with environmental and social issue. This list will be available in database shared among different companies (collaborative approach)
	Local sourcing	Suppliers are located nearby

Tab. 2: Sustainability practices used by unit of analysis A

Phase	Unit of analysis	Practices	Description
Design	B-Self promoted	Life Cycle Assessment/ Eco-Design	The impact of design decisions on environmental performance of the product along the product lifecycle are assessed involving both internal resources and supplier (collaborative approach)

Phase	Unit of analysis	Practices	Description
		Suppliers involvement	Suppliers are involved in the early phases of design to identify innovative and sustainable solutions (collaborative approach)
	B-Project finance	Rules and procedures for designers	Rules and procedures for eco-design are provided to the designers of company B. This happens only when the customer is interested in eco-design (control focus)
	B - Subcontracting	Not Applicable	
Procure ment	B-Self promoted	Vendor selection	Suppliers are selected using sustainability performance indicators (control focus)
		Suppliers monitoring	Environmental and social performance of the suppliers are assessed along the project to control the suppliers as well as to support vendor selection for the future projects (control focus)
	B-Project finance	Not applicable	Suppliers are selected by the customer with no involvement of company B.
	B - Subcontracting	Not applicable	

Phase	Unit of analysis	Practices	Description
Building	B-Self promoted B-Project finance B-Subcontracting	Awareness and monitoring of workers' safety in yard	Training on how to improve safety of the workers in yard, risk mapping and definition of prevention and protection measures, for both internal and external resources. (collaborative approach)

Tab. 3: sustainability practices used by company B

5. Discussion and future research

Starting from the results described in the previous sections, a series of conclusions may be drawn. Literature has already discussed that there are drivers and barriers to the implementation of sustainability practices. Results of our case studies confirm this. However, despite the two companies are exposed to similar drivers and barriers, the practices adopted in each unit of analysis are different. Therefore, a more complex model for interpreting these outcomes is needed. Based on our results, the level of ownership might play a role in the relationship between drivers/barriers and sustainability practices adopted. In fact, in those cases when a higher control is used over the phases, companies tend to apply more sophisticated sustainability practices, involving with a collaborative approach - when applicable - the network of suppliers, vice versa, when they have low ownership of the phase, despite the importance of the drivers and barriers is the same. Moreover, certain practices, such as the monitoring of suppliers' performance all along project phase or the use of vendor lists, require resources that small companies might not have.
Thus, on the basis of these considerations, we can derive a framework of relationship and ties in place between sustainability practices and its theoretical antecedents as depicted in Figure 3.

As a further result, based both on the literature review and on the information collected from the interviews, an operationalization of the constructs that constitute such a framework can be provided. As far as the drivers are concerned, we propose as factors to measure this construct, the following ones: pressure from customers, competitors' moves, compliance with laws requirements, risk management, pressures of suppliers, and pressure from public opinion. As for the barriers, this construct may be seen as composed of the following factors: lack of knowledge about the concept of sustainability, increase in the cost of materials and procurement as a consequence of

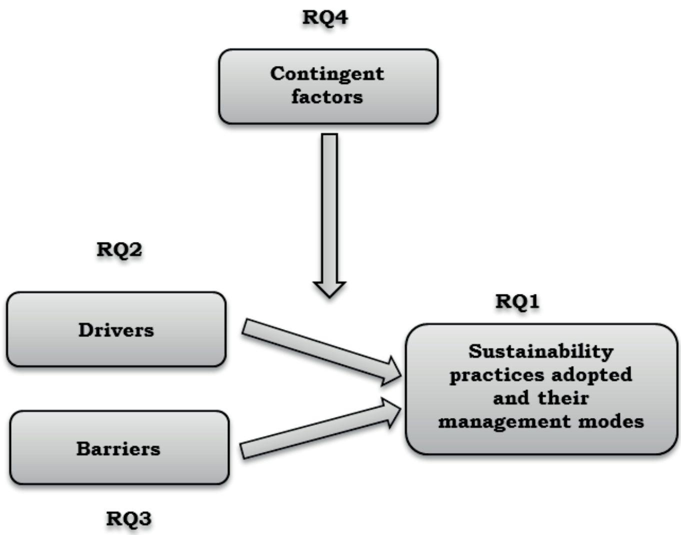

Fig. 3: The research framework proposed

adopting sustainability practices, and low management commitment. We are aware that some of these factors have not resulted to be important in our analysis (e.g., pressures of suppliers or public opinion among the drivers), and also that some of these factors have resulted to be important only for small companies (e.g. better risk management among the drivers). The originality of our work consists in the introduction of the construct "Contingent factors" as control variable: by "Contingent factors" we mean all those factors that can determine the adoption of a given sustainability practice instead of another one. In other words, we expect that, depending on the company's size, on the control on each phase of a construction project, as well as on the level of ownership, the relationship among the other constructs in the framework and the sustainability practice adopted may vary.

Finally, from the research framework depicted in figure 3 it is possible to derive four research questions (RQs) that represent the basis for the future (ongoing) research:

RQ1: Which sustainability practices are adopted by companies operating in the construction industry and how are they managed?

RQ2: Which are the main drivers for the adoption of these practices and their management?

RQ3: Which are the main barriers to their adoption?

RQ4: How contingent factors influence the adoption of sustainability practices?

The results of the present study may have a number of implications for managers in the construction industry. For instance, they may suggest that the types of sustainability practices adopted depend on the SC configuration as well as from the level of sustainability. We recognize as well a main limitation of our study, which refers to the methodology adopted, and, specifically, to the number of case studies. A future development of our research will consider a larger sample of companies belonging to the construction industry, thus allowing the generalization of our results, which was not possible at this stage of the research. Indeed, the outcome of the study, that is the research framework developed, shall be used in order to test the relationships between the constructs hypothesized in the construction industry as well as in several other industries. Moreover, the same framework shall be further improved by considering also the impact that the adoption of sustainability practices may have on the performance of a company, in terms of economic performance, environmental performance and social performance.

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Is Money Really Green? - An Investigation Into Environmental Supply Chain Practices, with a Cost Focus

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Abstract

In the setting of the supply chain and the environment, logistical operations are the most visible and contribute significantly to CO2 emissions (Dekker et al., 2011); Tol (2006) suggests that transportation accounts for 14% these emissions. As most products consumed have a global footprint it is important that logistics is managed with a green and cost effective approach.
For third party logistics providers and in-house logistics operations to reduce CO2 emissions and "green up" their operations, it must be possible to do this whilst remaining competitive in areas such as cost, reliability and performance. Without this, it is unlikely that logistics providers will voluntarily make changes to their operations. This research paper will investigate current green initiatives as well as future approaches and evaluate them, focusing on those which can maintain or reduce costs whilst sustaining performance and reliability.
Investment in environmentally friendly distribution practices has become a must for organisations; the degree to which this is practiced and invested in varies significantly. The motivation for this investment could be for numerous reasons; a genuine care for the environment, legislation, pressure from environmentalists or due to an increase in the cost of fossil fuels. For investment to be facilitated it must be sustainable fiscally, or these practices cannot be continued. Helper et al. (1997) and Conrad and Morrison (1989) suggest that previous attempts to reduce the impact of supply chain practices

have frequently increased costs, thus discouraging investment in such practices.

Keywords: green, cost focus, reliability, performance

1. Introduction

In the later part of the 1900's to the present, there has been a growing focus on the damage that individuals and corporations are causing to the environment. This will undoubtedly continue as long as it is evident that the environment around us is deteriorating; natural resources are depleted, Carbon Dioxide (CO_2) emissions continue to rise and landfill sites become overfilled. Enter green logistics, often facilitated by corporate social responsibility (CSR) and regulative/legislative pressure.

Managers are recognising the importance of appearing green to an organisation's reputation and how that can currently be an order winner, and as regulations become stricter, this will one day act as an order qualifier (Murphy et al., 1995). Some customers are willing to pay extra for green services and products; a survey from Reuters further enforces this idea. "Some 48 percent of the people surveyed also said they were prepared to pay a little bit more for sustainable goods." Similarly the same survey consisting of 20, 000 people from 10 countries also shows that "80 percent would reward brands that adopted sustainable practices" and that "72 percent would punish those that did not." (Reuters, 2009).

Additionally, whilst there is some debate as to when fossil fuels will be depleted, there is a consensus that it will happen. Shafiee and Topal (2009) hypothesise that "fossil fuel reserve depletion times for oil, coal and gas of approximately 35, 107 and 37 years, respectively." As a result of this factor it is necessary to find suitable green alternatives to these fuels.

Whether or not logistics can be made environmentally friendly or green, fiscally and economically effective, and maintain reliability and performance will be the focus of this paper.
This paper will follow an inductive approach, exclusively using secondary data, qualitative and quantitative; from case studies, peer reviewed journals, other academic and industry sources. Exploration of current logistical practices, as well practices considered to be green shall be investigated. Quantitative data will primary consist of CO_2 emission figures, which is considered to be a key performance indicator that can be used to gauge logistical practices and their impact on the environment.

2. Green Logistics/SCM

CSCMP (2011) describes logistics management as “that part of the supply chain that; plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers’ requirements”. Rodrigue et al. (2009) goes on to explain green logistics is “supply chain management practices and strategies that reduce the environmental and energy footprint of freight distribution. The focus is often on material handling, waste management, packaging and transport.” Pazirandeh and Jafari (2013) combine the two explanations and describe green logistics as a form of logistics that is both economically functional and environmentally friendly. Green logistics is all about “the harmonization of efficiency, environmental friendliness and energy conservation” and its goal is to ensure “sustainable development of freight transport…” (Geroliminis and Daganzo, 2005).
The increasing emphasis towards green supply chain management (GrSCM) is predominately motivated by the further decline in the environment, such as lessening availability of raw materials, increasing levels of pollution, carbon dioxide (CO_2) emissions being a common problem and overfilled waste sites

(Srivastava, 2007). “Over the past 10-15 years, against a background of increasing public and government concern for the environment, companies have come under mounting pressure to reduce the environmental impact of their logistics operations” (McKinnon et al., 2010).

Zhu et al. (2007), has suggested that green supply chain and logistics practices, can have three impacts on an organizations performance:

Environmental performance, such as the reduction of CO2 emissions, waste reduction and a decreasing use of materials and therefore generally less waste.

Economical performance, which can lead to increases in some costs and decreases in others. Such as decrease of material and energy cost and increases in the cost of training employees.

Operational performance, such as improved capacity utilization and decreased inventory levels.

A fourth impact can be included; this is the increase in one-off investments, which is quite often typical of green logistics, as new technology/upgrades are required such as vehicles. Green vehicles typically cost more than their traditional counterparts (Dizikes, 2012). For example an electric delivery vehicle can cost up to $150,000, whereas a traditional delivery vehicle is likely to only cost approximately $50,000. UPS (2013) have found by introducing 100 electric delivery vehicles into their fleet, there can be a saving of 126,000 gallons of fuel per year. With the average price of gas per gallon at $4.11 (California Energy Commission, 2014), this would amount to fuel savings of approximately $500,000, not to mention the significant reduction in CO_2 emissions and noise. However these vehicles still need a charging source and where that energy comes from, will dictate the actual net savings in both costs and CO_2 emissions. The current issue is that many charging sources for electric vehicles (EV) currently derive their energy from un-green sources, usually fossil fuels (Thomas, 2012). Consequently, whilst a vehicle may not have any tailpipe emissions, there is still a carbon footprint associated with the energy used to run that vehicle. Thomas (2012) goes on to argue that even if all US light duty vehicles (LDVs) were replaced by a combination of battery EVs and plug-in hybrids, green house gasses (GHGs) would be at most reduced by 25% and oil consumption could be reduced by less than 67%. However if all these vehicles were replaced by fuel cell electric vehicles powered by hydrogen made from natural gas, GHGs would be reduced by 44% and oil consumption by almost 100%.

However if like Tesla, these sources can be derived from clean, renewable and non-polluting energy sources, such as solar, the CO_2 are virtually zero. Tesla are currently making radical improvements to the U.S electric vehicle charging infrastructure, of which, all of this energy is from clean solar energy and their aim is that by the end of 2015 98% of the U.S population will have access to these charging stations (Tesla, 2014). Equally by the end of 2015, the majority of Western Europe will also be covered with these Supercharger stations. While Tesla is radically developing the infrastructure for EVs, the issue currently is that this is specifically for Tesla owners and it is currently incompatible with other EVs; there are talks of this changing and accessibility being made for any EV, where the manufacturer is willing to work to Tesla’s cost structure as well as the vehicular being designed so it is capable of accepting the power that the Supercharger provides (Hruska, 2014).

3. Conflicts and Matches

There are a variety of approaches available for adoption by organizations that will green up logistics and throughout the supply chain, however not all of these are a viable option.

Frequency and size of deliveries can be an issue when it comes to green logistics. Rodrigue et al. (2001) state that with green logistics “the idea is not for smaller and more frequent shipments which would result in more trips by smaller vehicles.” Rodrigue et al. (2001) continues to state that green logistics aims to minimize the number of deliveries (trips) made, therefore implying the use of larger vehicles, filled to capacity and therefore moving more materials or products with less frequent deliveries. This would immediately conflict with any organization following a lean approach, whereby smaller more frequent deliveries are encouraged and therefore a buildup of inventory would occur throughout the supply chain.

A build up of inventory generally equates to higher labour costs as well as handling equipment being required. In addition to this more materials usually leads to problems being hidden, such as quality defects. (Jacobs and Chase, 2008). What initially would appear to be simply extra storage space required soon leads to additional costs which spiral into unimagined costs, in the forms of transport, storage and general waste.

Continuing with the focus of road transportation and the size of vehicle, perhaps the most common green KPI is CO_2 emissions, usually measured in grams per kilometer, CO_2 (g/km). The assumption previously discussed is that more frequent deliveries, in smaller vehicles, will lead to more CO_2 (g/km), however if larger vehicles are used to make less frequent deliveries, these emissions should be lower. Pirog et al (2001) measured the average emissions from three categories of road transport these were; heavy-duty trucks, midsize trucks and light trucks (below).

Transport Mode	Maximum Load (kg)	Fuel Type	Specific total CO_2 emissions (g/ton-km)
Heavy-duty truck	17,300	Diesel	62
Midsize truck	6,000	Diesel	122
Light truck	700	Gasoline (Petrol)	459

Tab. 1: Road Transport CO_2 Emissions (Venkat and Wakeland, 2006)

The three truck sizes and their CO_2 emissions are measured in grams of CO_2 per metric ton per kilometre. The above table shows that the larger the vehicle load size (kg), the less the CO_2 emissions (grams) per ton per kilometre. Jones and Womack (2002) and Venkat and Wakeland (2006) examined a windshield wiper supply chain and use the above figures to create calculate its CO2 emissions from the logistical activities within this supply chain from three perspectives; an agnostic approach, a lean approach, translating to frequent smaller batches and a green approach, large infrequent deliveries. All deliveries use full-truck and direct deliveries and the return trips are assumed to be efficiently used for other purposes.

Strategy	Vehicle size(s)	Delivery frequency *	Specific total CO2 emissions (g/ton-km)
Agnostic/Traditional	Heavy-duty and Midsize trucks	Twice a week/Daily	27,292
Lean	Midsize trucks	Daily	27,816
Green	Heavy-duty trucks	Once or twice a week	12,912

Tab. 2: CO_2 Comparison by Delivery Vehicle Size/Frequency in a Windshield Wiper Business (Venkat and Wakeland, 2006)

*Delivery frequency is dependent on the stage in the supply chain and the intermediaries involved.

While the message communicated from the above two tables, begins to at least suggest that lean and green logistics will have some fundamental conflicts, it also supports the notion that green logistics can reduce costs in some areas. There is a clear link between CO_2 emissions and fuel efficiency, in other words, the fewer emissions produced the more economical or efficient a journey is with regards to fuel consumption.

Another conflict between green and the very nature of logistics is the time and speed involved. “By reducing the time of flows, the speed of the distribution system is increased, and consequently, its efficiency” (Rodrigue et al., 2001).

When organizations achieve this it is often by the most polluting logistics providers and involves using the least energy efficient modes of transportation.
There is an emphasis now on quick logistics, both from an organizational standpoint to reduce lead times so organizations further down the supply chain can in turn do the same. Similarly from a consumer prospective, when something is ordered online, the general consensus is that customers want it delivered for as little as possible, but also as quick as possible. With lean logistics this becomes a greater reality, as not only are costs reduced, but with frequent, smaller deliveries it is more likely that what is being shipped will get there faster. Whereas with green, it could be that there are only one or two deliveries made a day, in large heavy goods vehicles, which are loaded to full capacity, to minimize emissions.
As previously mentioned green's speed and flexibility is also lessened by the modes of transport available which are considered green, and with a demand for almost instant gratification with some buyers, it is necessary to use what is considered a high polluting form of logistics in some cases, such as air transport. It is essential to offer reliable logistics, the key performance indicators (KPIs) for reliability are widely agreed upon as being on time deliveries, with the least possible threat of breakage or damage of goods. Rodrigue et al (2001) state that "the least polluting modes are generally regarded as being the least reliable in terms of on-time delivery, lack of breakage and safety."
"Ships and railways have inherited a reputation for poor customer satisfaction, and the logistics industry is built around air and truck shipments … the two least environmentally-friendly modes" (Rodrigue et al., 2001). Sea freight gives emissions of only 10 to 40 grams of CO_2 per ton per kilometer, seemingly the most environmentally friendly method of logistics, while railway transport has emissions of around 30 to 100 grams of CO_2 per ton per kilometer. Both are considered incredibly environmentally friendly with regards to emissions, however when the drawbacks are considered of both sea freight and railway, it is highly discouraging. Not only is shipping an incredibly slow method of transport, but there are a number of other factors which compound this.

It is important to note the CO_2 emissions emitted by any of the transport modes in figure 1, do not show a complete picture, it merely considers the 'tail-pipe' emissions. Emissions are also produced through the production, refinery, storage and transportation of the fuels used to run these modes (Colvile et al., 2000).

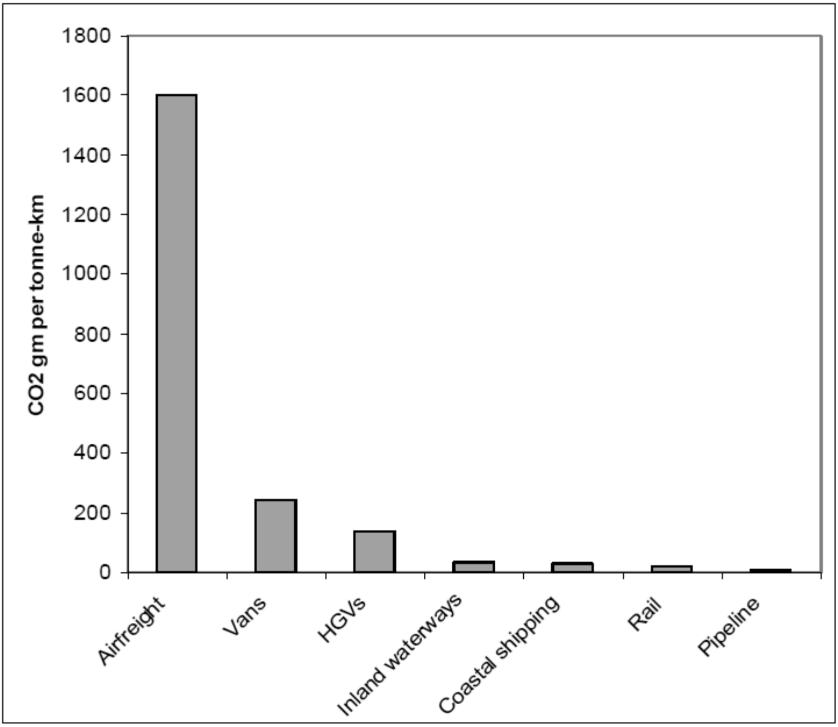

Fig. 1: CO_2 Emissions by Transport Mode (McKinnon. 2008)

4. Conclusions

This paper discusses the approaches available to logistics operations to green up their operations and supply chain management, thusly limiting their impact on the environment. However, it is differentiated from current research by focusing on the impact of the change to environmentally friendly focus versus the traditional approach; the impact on reliability and economically; two factors which need serious focus for an organization.

5. Further Research

I wish to carry out semi-structured interviews for primary data collection. Participants will include logistics practitioners from third party logistics providers in the UK and logistics professionals/consultants. A focus will be on the implementation and post-implementation phases; looking at upfront costs, the time it takes to recoup or offset any additional costs and effects on reliability and performance.

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Relevant Purchase Criteria or Basic Requirement: Customer Perspectives on Green Logistics

Matthias Klumpp, Julia Naskrent and Nikolaus A. D. Hohl

Abstract

Green and sustainable logistics is a major research topic and industry as well as the retail sector encounters an increasing pressure and obligation concerning this matter. But still, empirical tests and numbers about the appreciation of customers regarding sustainable logistics resulting in preferences for selection of products and services are missing.

This research contribution is conceptualizing an answer to this important question using a quantitative approach from market analysis and marketing research: A conjoint measurement analysis with end customer representatives (B2C, n=526) is used to quantify the specific customer utility of various components of sustainability and corporate social responsibility. An investigation of moderating variables shows that these components cause different utilities values among different groups of costumers.

Keywords: green logistics, conjoint analysis, sustainable logistics, sustainable production

1. Introduction

The future development of logistics is inadvertedly connected to sustainability concepts and requirements, pushed by the political and end customer side and gaining momentum due to the overall struggle for competitive advantage and unique selling propositions (Min, Kim, 2013; Klumpp, Clausen, ten Hompel, 2013; Klumpp, Kersten, Brockhaus, 2011). Many research as well as business concepts have outlined the question of how to “green” transportation and supply chains (Lee, Lam, 2012; Bretzke, 2011; Kellner, Ogl, 2012). From this, it has been established that many factors like e.g. knowledge (Wu, Haasis, 2013) or for example the oil price (Gross, Hayden, Butz, 2012) are important drivers for sustainable logistics concepts; concluding evidence also highlights that specific and detailed concepts have to be established for different transport modes, i.e. shipping (Baindur, Viegas, 2012).

But the overarching question of how customers − in this case especially end customers as "final objective" of any supply chain − are actually evaluating and also honoring green logistics as purchase criteria are quite in the dark. Therefore, a B2C evaluation study was conceptualized and carried out by the authors in 2014, using the methodology of conjoint analysis within a quantitative empirical research setup.

After a detailed literature review on the topic green logistics as well as a conceptualization regarding green products and logistics (section 2), the basic characteristics of the conjoint analysis and the implemented empirical survey are outlined in section 3. The following section 4 provides the calculation result from the conjoint analysis, whereas section 5 describes the implications and discussion points for green logistics concepts from derived from these results. The final section 6 outlines questions for further research as well as business practice implications in an actionable approach.

2. Literature Review and Research Concept

From a customer research perspective, the topic of sustainability has focused on estimation of the appreciation of production methods and ingredients (aspects of naturalness: Gifford, Bernard, 2011; aspects of apple growing: Moser, Raffaelli, 2012; aspects of ingredient origin: Hustvedt, Bernard, 2008; aspects of green restaurants: Schubert et al., 2010; aspects of green hotels: Lee et al., 2010). None of these studies analyzed the appreciation of transportation and allocation. "The investigation on consumers' sensitivity to low carbon emission […] is still in its infancy." (Moser, Raffaelli, 2012, p. 142).

First research contributions have already tried to measure consumers real purchasing behavior and possible willingness to pay for green products and product features, e.g. Michaud and Llerena (2011) − in this case for green re-manufactures products there is no increased willingness to pay discernible. Nevertheless, a significant effect of information regarding green features and impacts to purchasing criteria was recognized, implying that customers choose sustainable products preferably if informed about social and environmental criteria regarding the product.

From a customer's point of view, a general favoritism of green products or services (i.e. logistics) cannot be taken for granted. Some studies point out, that some respondents reported that they do not buy green products due to their skepticism about their functionality (e.g. Anderson, Hansen, 2004). Due to the increasing government attention to social and environmental problems, the customer might assume that the problem is being addressed, thus they might decrease their attention on such issues during a purchase decision.

Others believe that the environmental and social responsibility lies with the organizations and not with their purchase behavior (Anderson, Hansen, 2004, p. 43). They expect sustainability characteristics incorporated in all products and services and see it as the companies' duty to provide such products and services. They take it as basic requirement and would not assume a responsibility and impact in their own purchasing behavior. Hence, they will not pay attention and will not value different purchase options in this sense.

The definition of green products as well as green services and logistics is intertwined and based on a holistic understanding of a value chain, which combines all processes and services to an end customer product or service. This implies, that even in very mundane and simple products (e.g. an apple or a banana), many services like e.g. retail, packaging and logistics services are integrated and therefore consumed by the customer. This approach can be labeled an integrated or indirect definition of products and services as all process steps and companies within the value chain are analyzed. Therefore in the end, the concept makes no clear distinction between products and services but rather is a metaphor of the customer's purchase of a bundle of products and services stacked up throughout the supply chain.

This perspective is highly consistent with the basic assumptions of a conjoint analysis, which estimates partial utilities incorporated within a final product or service. Whereas most conjoint analysis in traditional marketing management focus on obvious and functional product and service elements clearly visible for the end customer, our approach represents an "additive supply chain view".

The question is, whether customers really take such product and service characteristics as granted, or if the consumers value them, which means that it increases their utility as well as subsequently their willingness to pay for such features. We want to know, if attributes even if they are not represented in the final product or service, such as green transport in the main haul towards Europe, foster the customer's purchase probability. This paper addresses this issue by conducting a conjoint analysis, using the division of product and services parts throughout the value chain for the example product of jeans pants with different product attributes or components.

3. Empirical Survey

Conjoint analysis is used when products should be designed market-oriented, i.e. according to customer benefits. The conjoint analysis centers on the assessment of the preferences of customers. It is based on the assumption that the total utility of a product (seen here as a bundle of attributes) consists of the sum of the partial utility of its attributes. The overall assessment (considered jointly) of several combinations of the attributes allows assessing their partial utilities (decompositional approach). For this, it is only necessary to make judgment on a fraction of all possible combinations of attributes (see e.g. Green, Srinivasan, 1978; Backhaus, Hillig, Wilken, 2007).

In a broad online survey all over Germany from 28.05.2014 until 09.06.2014 (12 days) altogether about 25.000 professionals as part-time students (FOM University of Applied Sciences) were invited to take part in a conjoint analysis as outlined below. Altogether 346 persons completed the whole questionnaire which took about 20-30 minutes of time to complete. The respondents are equally distributed all over Germany and also between gender and income as well as social stratification criteria. A general "working world" bias has to be acknowledged as all part-time students are in employment and therefore unemployed, older and younger people outside the age-framework for working people are underrepresented as well as older people in general (>40 years). As mostly this selected group is also in the center of marketing strategies and advertising campaigns, this may at least be seen as "indicative" for possible results regarding marketing management measures addressing green logistics.

The implemented online survey was tested beforehand with more than 30 persons in order to exclude communication and technical mistakes and misunderstandings, comments received especially regarding understandability and placement of texts were included into the final used version of the questionnaire.

The conjoint analysis was designed as a choice-based conjoint (CBC), in which respondents repeatedly have to select one alternative from a limited number of product (bundle of attributes) choices. Moreover, respondents could choose the "none-option", if they could not decide between presented two alternatives.

The questionnaire started with a brief introduction in form of a list of some advantaged and disadvantages of transportation means, in order to familiarize the respondents with the topic. It was assumed, that not all respondents knew about the potential problems of transportation means before participating at the survey. An integration of this list right in the beginning also rendered the advantage, that the decisions of the respondents later on in the survey was made without the evaluation at hand − like in real life.

The first part of the survey consisted of the choice-based conjoint for a pair of jeans. This piece of cloth was selected due to its general acceptance among people. It can be assumed, that most people can relate to a purchase situation of jeans. Since jeans pants are produced overseas it is a good item to assess the relevance of sustainable transportation. In addition, jeans comprises some further issues of sustainability: the growing of the cotton (standard or ecological) and the payment of the workers (standard (according to market prices) or fair trade (above market prices). These two issues were integrated as the first attributes for describing the jeans. Afterwards two logistics aspects were presented: the overseas transportation to Europe (by plane or by ship) and the allocation and distribution within Germany, i.e. to retail stores in different cities (by truck or by train). Every presented combination of these attributes was randomly assigned one out of three possible prices.

Together, each presented jeans variation consisted of five different attributes with different specification as listed in table 1.

The different specifications lead to list of 48 different bundles with characteristics concerning the attributes. From these 48 potential products, only 16 were taken for the conjoint analysis according to the procedure recommended by Aizaki and Nishimura (2008), which represent the state of the art of an analysis of partial utility scores in R (statistical computing program). We arranged an orthogonal design and had respondents compare two of the 16 products simultaneously, resulting in eight choice decisions.

	Growing of cotton	Payment of workers	Overseas transport to Europe	Allocation in Germany	Price
Specific. 1	Standard	Market prices	Plane	Truck	19 €
Specific. 2	Ecological	Fair trade	Ship	Train	39 €
Specific. 3					79 €

Tab. 1: List of attributes of jeans pants presented in the survey

Appendix 1 depicts one of these choice sets. The pictures of the pair of jeans were identical, but still were used in the survey for matters of design and activation of the respondents. Table 2 lists the two presented sets in each of the eight questions (the numbers 1-3 refer to table 1 with the particular specification).

After the conjoint analysis, people were asked to answer questions in regard to their environmental concern and demographic variables such as gender. The environmental concern was measured with the help of the scale by Kim and Choi (2005).

price	growing of the cotton	payment of the workers	Oversea transport to Europe	Allocation in Germany		price	growing of the cotton	payment of the workers	Oversea transport to Europe	Allocation in Germany
1	2	1	1	1	← Question 1 →	1	1	2	2	2
3	1	2	1	1	← Question 2 →	1	2	2	1	2
1	1	1	2	1	← Question 3 →	3	2	1	2	2
2	2	2	2	1	← Question 4 →	1	2	1	1	1
2	1	1	1	2	← Question 5 →	1	1	1	2	1
1	2	2	1	2	← Question 6 →	3	1	2	1	1
3	2	1	2	2	← Question 7 →	2	1	1	1	2
1	1	2	2	2	← Question 8 →	2	2	2	2	1

Tab. 2: Design of choice based analysis

4. Conjoint Measurement Results

The conjoint measurement was conducted based on the example of Aizaki and Nishimura (2008) which means that their outlined steps for estimating the model were strictly followed. For this, we created a data set which was used for the function "clogit" in R. According to the last step of the procedure recommended by Aizaki and Nishimura, the function renders the following results as described in table 3.

For an interpretation of these results, the second column − the exponential coefficient (exp (coef)) − is crucial. The general starting point for the number listed in the second column is the number 1, which could be understood as a neutral preference for an attribute. The difference between the numbers listed and the figure 1 now shows if a change in the specification of the attribute (e.g. fair trade payment of workers instead of market based compensation) leads to an utility increase (for numbers > 1), which can be equated with a preference for this attribute.

	coef	exp (coef)	se (coef)	z p
Price	-0.0222	0.978	0.00115	-19.4 0
Cotton grow	0.6530	1.921	0.04815	13.6 0
Payment	0.7736	2.168	0.06462	12.0 0
Overs. Transport	0.8933	2.443	0.05454	16.4 0
Last row	0.5628	1.756	0.04545	12.4 0

Tab. 3: Overall results of the conjoint analysis

For example if the specification changes from 1 to 2 (cf. table 1), then the probability of selection increases.

The intensity of this increase depends on the probability level, which enables to estimate the odds. Odds are defined as the probability for choosing an alternative divided by the probability for not doing so.

For an estimation of the real odds and probabilities it is necessary to assume a constant value, which is in our case by -0.771 (0.462). I.e. with this absolute term the fit of estimation to our data is best. E.g. the odds for buying a pair of jeans with the attributes price: 79 €, cotton grow: standard, payment: fair trade, overs. transport: plane, last row: truck are 0.1727 and the probability is 0.15. If one would change the attribute "overs. Transport" to from plane to ship the odd would increase by the factor "number in column exp (coef)". In this case the factor is 2.443 and the odds are now 0.4219 which equals a probability of 0.30. Over all respondents the overseas transport method therefore has a positive utility. Similar is the case for fair payment of the workers, a CO2-friendly cotton cultivation and regional allocation. Only price renders a result of 0.978 which means, that a price increase leads of course − the so-called snob effect is disregarded − to a decreased overall utility and reduced selection probability. As Table 3 shows, the ecological overseas transportation and the fair wages of the worker present the strongest preference when it comes to selecting the product.

Gender is expected to have clear significance on these results because literature suggest, that women are more concerned in general (Gifford, Bernard, 2011; Baker, Burnham 2001). Therefore, the next step was so compare the results in terms of gender differences. Table 4 lists the relevant exponential coefficients for each attribute.

In terms of price there barely exists a difference between men and woman. For both groups a price increase leads to nearly the same reduction of the selection probability. But when it comes to the logistic attributes one can see, that men are more influenced by overseas transport while the utility of women depends more on the last row.

Since for both groups the value is the highest, one can assume that it has the most impact on consumer behavior. For the given product (39 €, standard, fair trade, plain, truck) the men (women) show a selection probabilities of 0.10 (0.11). By changing the transport mean to ship the probability would be 0.24 (0.24). Seen the other way around, this means, that by changing the transport mean from plane to ship, one could raise the price to 122 € (114 €) to keep the selection probability constant at 0.10 (0.11).

	exp (coef) - MEN	exp (coef) - WOMEN
Price	0.975	0.973
Cotton grow	1.903	1.986
Payment	1.706	2.342
Overs. Transport	2.887	2.604
Last row	1.789	2.076

Tab. 4: Gender-specific results of the conjoint analysis

In our study, we also controlled for the impact of environmental concern on the preference structure. When it comes to selection food, 50 percent of the consumers are influenced by environmental considerations (Anderson, Hansen, 2004). Therefore, our study investigated its impact in the case of clothes. Table 5 compares the group of respondents with high environmental concern (n = 95) with those with low environmental concern (n = 91).

As one could guess, the preference for an eco-friendly cotton cultivation is a lot stronger in the group of the people with a high environmental concern; for a similar result for organic and natural meat see Gifford and Bernard (2011).

The second interesting result is, that the probability for selecting a product, which is regionally allocated in an eco-friendly train instead of a truck is higher in the group of people with the least environmental concern. These results are contradictory to our assumptions and can only be explained by an information deficit among the respondents concerning the advantages of transportation by train.

	exp (coef) - High environmental concern (first quartile)	exp (coef) - Low environmental concern (last quartile)
Price	0.971	0.974
Cotton grow	2.556	1.529
Payment	2.244	2.124
Overs. Transport	2.789	2.668
Last row	1.760	2.485

Tab. 5: Results of the conjoint analysis in regard to environmental concern

5. Discussion: Implications for Green Logistics?

In contrast to the ingredients of a product the fact of allocation almost goes unrecognized by the customer. There are concepts and ideas to overcome this: "Ecolabels" are a key source of information about a product's environmental attributes (Anderson, Hansen, 2004). Companies that engage in such certification schemes not only receive assistance in becoming more sustainable, but can also improve customer awareness due to such an accreditation. This can be leveraged as a source of competitive advantage over those companies that do not engage in eco-certification schemes (Schubert, et al., 2010). Green companies should focus their efforts on communicating the positive results of their green practices. Customers need to have these issues, and their impact on prices explained to them.

The described results of the conjoint analysis show that this is definitely also true for service components of supply chains, especially in the case of regional allocation. Here, our studied showed the contradictory effect, that people with a high ecological concern only showed a small utility increase for transport per train.

This contributes to the already existing discussion regarding possible willingness to pay for green and sustainable logistics measures − as well as production and trade conditions (fairness, ecological criteria in production). It can be derived, that "willingness to pay" is not a "one-way-street" at all, but retail and supply corporations as well as logistics service providers first and foremost have to inform customers in and at the end of the supply chain about the production and transport conditions, i.e. their sustainability impact. If clearly informed, customers are at least significantly willing to consider more sustainable products, even if there is a price premium on this.
This is also clearly different for several socio-economic clusters according to gender, income and especially social and ecological awareness − a standard marketing approach to segment customers according to this is therefore a "strategic fit" and should also be developed for logistics services.

6. Conclusion and Outlook

In this contribution we have outlined that there is still a considerable research gap existing regarding specific purchasing criteria dedicated to sustainability criteria in production and transport, notably throughout the whole supply chain, i.e. for consumer products in this case (B2C).
Therefore, a conjoint analysis with 526 customers with the buying stimulus of different variations of a jeans pant was conducted in Germany in order to identify different purchasing criteria from the customer point of view, including the long-haul transport leg (plane or ship) and the local distribution towards retail shops (truck or train).
A key finding is that the probability of selecting a jeans pant made of ecological fiber under social production conditions (fair wages) is highest among those, who have an environmental concern. This attitude, however, has barely no impact on the selection probability in terms of regional allocation and partly in terms of sustainable overseas − main haul − transportation.

Further research may establish if, for example, similar purchasing criteria are also valid for B2B products and services as well as for customers in different countries as many items (fair trade, transport) may be highly country- and culture-specific.

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Appendix

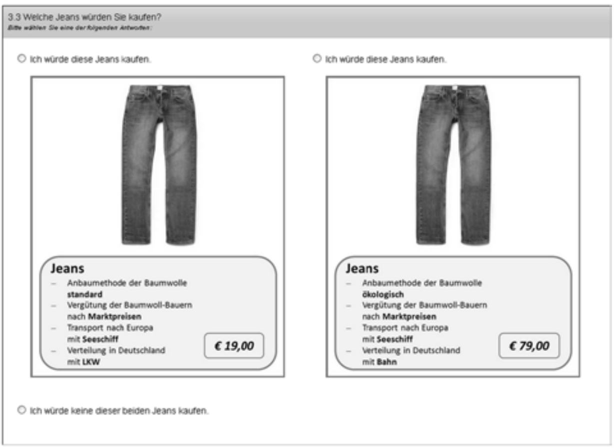

Fig. 1: One conjoint analysis choice set (example)

Information Systems and Reverse Logistics: Examining Drivers of Implementation on Multiple Case Study Scenario

Josip Maric, Florence Rodhain and Yves Barlette

Abstract

Sustainability is becoming increasingly significant for business researchers and practicioners, where Information Systems (IS) and sustainable development open up a new field of interesting issues to be addressed by scholars. In this paper we present research in progress regarding IS and reverse logistics. Information Systems, in cohesion with closed loop Supply Chain Management (SCM) process, and human resources capability development, produce an innovative service developed to increase efficiency in sustainability efforts and gain increased market value. Our research tends to focus on relationship between IS and closed loop Supply Chains, examining sustainability impact of the reverse logistics and examining organizational competitive advantage gained through sustainability goals. Empirical, rather than theoretical, research and practice regarding this concept is still in its infancy, and with our research we tend to make a contribution to the field. Research model, tools of assessment, in depth description of case studies and preliminary results are presented in the paper as latter.

Keywords: management, information systems, sustainability, reverse logistics

1. Introduction

Sustainability is increasingly becoming mainstream within management studies and practices over the past several decades. Since its definition in Bruntland report as “development that meets the needs and aspirations of the present generation without compromising the ability of future generations to meet their own needs” (WCED 1987, p. 43), sustainability found itself in the focus of research studies with an increased awareness of the global threats.

Although the term is well introduced among business practitioners and researchers, *business-as-usual* logic has still somehow drifted away from the principles of sustainability. Some of the leading scholars presented us facts justifying this claim. Sandel (2013), Harvard University professor in political philosophy, elaborated the degradation of our modern society from market-based economies into market societies. Market-based thinking has permeated all aspects of society, affecting societal norms in areas of life not traditionally influenced by markets. Hence, Mintzberg et al. (2002) in their paper presented us thoughts on the raising problem of corporations operating on a series of half-trusts which result in a sole focus of profit increase for their shareholders. Porter and Kramer (2011) elaborate a certain siege of capitalism system in recent years. Business has been seen as a major cause of social, environmental and economic problems. Companies are widely perceived to be prospering at the expense of the broader community. Presented findings give us the necessity of a shift of our modern business concept in order to allow business to harness its true potential. This would, according to Porter and Kramer (2011), drive next wave of innovation and productivity growth, as well as thinking about new leadership and managerial skills that need to be developed.

Specifically, there is a need for rethinking our business-as-usual logic in a more sustainable manner. John Elkington (1994) defined sustainability in three components – environmental, societal and economic performance (generally referred as *triple-bottom-line*). Since then, it is argued that corporation’s long-term profitability and existence are best served by balancing them with social and environmental goals (Porter and Kramer, 2006). Growing number of companies embarked these efforts.

IBM, known for its hard-nosed approach to business, is one example where their business practice in France, at their site in Montpellier, not only meets broader society and economic needs, but also offers interesting new business model which encompasses good business logic with environmental needs. Strategic thinking, imposed during the market fluctuations in the '90s, about their value chain configuration allowed them to gain competitive advantage. In other words, they embraced the transformation of their activities. IBM Montpellier case study performed by Keh et al. (2012), conducted in our laboratory for four years, has shown the benefits of reverse logistics business practice. We extend this study examining IBM aftermath with contributions for other business practitioners and by focusing on IS as well.

Hence, our research specifically is focused on examining drivers of reverse logistics implementation, presenting ethical, legal and societal implications for companies, as well as answering what is the role of IS in the process?

Paper is organized as follows: next section presents closed-loop Supply Chains. Hence, a brief discussion about the role of IS in the process follows. Research methods, research techniques of assessment and modes of analyzing and interpreting data are presented in section 3. Limitations and future work perspectives are defined in section 4. Conclusion is presented in section 5.

2. Theory Development

2.1 Reverse Logistics

Academic and corporate interest in Sustainable Supply Chain Management (SSCM) has risen considerably in recent decades. Reverse Logistics Management (RLM) is, thus, one of the research directions attracting business attention. Interests for implementation differ, either because of the potential profitability (in USA) or legislation (in European Union) (Guide et al., 2003).

Reverse logistics is a process in which manufacturer manages product return for possible reuse, revalorization or recycling (Keh et al., 2012). Reverse logistics deals with the *end-of-life* phase of products life cycle, in a closed-loop Supply Chain. Therefore, closed-loop Supply Chains include traditional forward Supply Chain Management, adding extra activities of the reverse supply chain, in order to manage the flow of secondhand products aimed to be recycled (Dowlatshahi, 2000). It is characterized with five main disposal options: remanufacturing, repair, reuse, recycling and disposal (see Fig. 1). Although it becomes essential for suppliers who have to act in accordance with environmental laws, reverse logistics is often considered as expensive and difficult to implement.

Keh et al. (2012) in their article, based on an IBM Montpellier case study, examined how an integrated reverse logistics model can enable companies to meet three main objectives: (1) provide economic opportunities through the resale or reuse of machines and parts, (2) successfully deal with environmental challenges such as waste management and legislation compliance, and (3) achieve an important social challenge in terms of local job preservation.

Although this case study reveals that reverse logistics is likely to present economic, environmental and social benefits, it still leaves opened a question of *harmonious balance* among economic, environmental and social components of the process. This offers scholars directions for future research. Research has shown that for sustainability to be truly effective, entire supply chains, not just individual partners, must operate in a sustainable manner (Carter and Rogers, 2008). Empirical, rather than theoretical, work regarding this concept is still in its infancy. Lack of empirical evidence is the major obstacle in grounding of studies which state that reverse logistics could be an opportunity for sustainable development. This gives scholars opportunity to examine the various issues as well as finer analyses, especially deepening research in the context of environmental, economical measurement impacts and social benefits on a global scale.

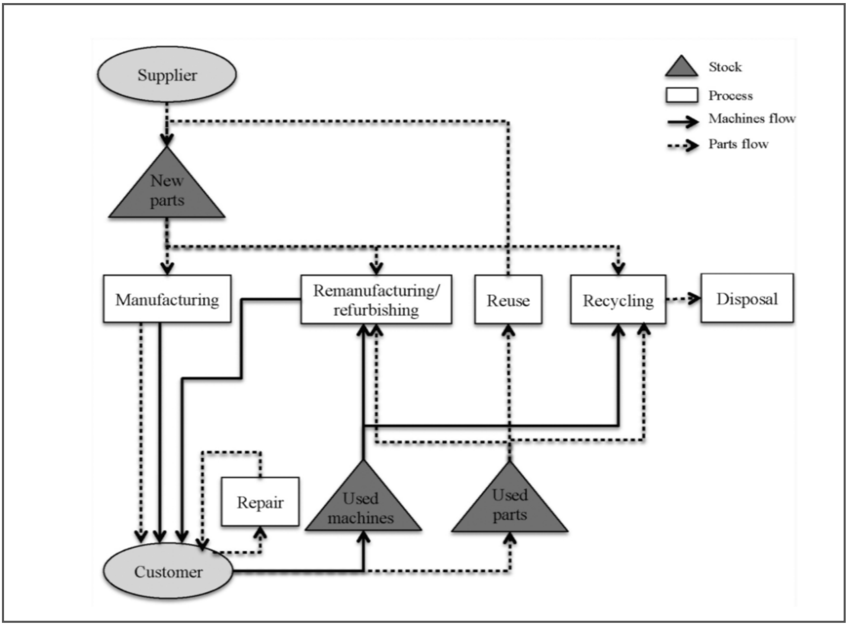

Fig. 1: The closed-loop supply chain. Keh et al. (2012)

2.2 Information Systems

Information Technologies (IT), with a radical technological breakthrough in short period of time, led to many changes and vaste spreading in the ‘90s. Recent studies have revealed that competition in the business market has heightened since the mid ‘90s, revealing that one of the main reasons is significant increase in investments and application of IT (McAfee and Brynjolfsson, 2008).

The IT sector itself contributes, by the latest figures, towards 16 percent of global GDP growth during a period from 2002 to 2007, with expectations to reach 10 percent rise for the period from 2007 to 2020 (The Climate Group report, 2008). IT industry, besides having positive GDP growth impact, has a fastest growing global footprint (GeSI report, 2010). Considering this fact, greening of IT industry proposes one of the largest economic opportunities of the 21st century.

There is an increase in the greener use and application of IT and system design. Various studies have investigated and acknowledged a link between IT and sustainable development. Researchers adopt bidirectional approaches, defining either direct and indirect (Jenkin et al., 2011), first and second order impacts under *green IT* and *IT for green* perspective (Faucheux and Nicolai, 2011) or positive and negative influence (Rodhain and Fallery, 2011). Harmon et al. (2012) defined strategic planning technology roadmaps, green IT and sustainable IT services (SITS).

Malhotra et al. (2013) presented us a study of information systems for environmental sustainability in two research streams, classifying *green IS* and *green IT*. They present green IS as the larger of both streams, referring to the study of the design, implementation and impact of information systems that contribute to sustainable business processes. Green IT, on the other hand, refers to the study of technology energy efficiency and equipment utilization. Barlette (2013) also presents Green IT (Fr. Eco-TIC), a term which overspans the initiatives for greening of IT industry and aims to reduce the ecological, economic and social footprint of IT. The goal is to reduce the nuisance related to IT manufacturing, usage and recycling.

But it is evident, after browsing through the scholar literature, that there is still a lack of assessment for IT’s impact regarding sustainability beyond energy consumption or waste management. Studies have also shown various approaches in describing the role of IS in organizational context. Transformative power in modern business logic is argued in the latest work of Porter and Kramer (2011) about *shared value* concept. They also open discussion about the necessary changes in the skills and knowledge of leaders and managers. Shift in managerial thinking and decision making is becoming, and will continue to be, largely affected by innovations, introduction of new technologies, operating methods and different management approaches.

Numerous and diverse lead authors and theories in IS underline an interplay within different management discipline fields and IS research. We propose, as our secondary set of questions, to examine the role of IS resources and its integration within closed-loop Supply Chains. Determining whether green IS plays a role within reverse logistics, and “should we innovate in terms of IS for reverse logistics?” presents meaningful contribution to theory and business practices.

3. Research Methodology

Since data related to our work are rather scarce, we chose for this specific research to conduct a qualitative research. Qualitative research methods are considered more favourable since they are rooted in social sciences and seem appropriate with scarce business examples to observe (AIS, 2013). Our qualitative research would involve the use of qualitative data to understand and explain phenomena. Qualitative research also enables us to use a variety of approaches, methods and techniques, which aligned along with sustainability assessment tools, would offer an integrated framework for the research.

Phenomena which we plan to investigate would be based on case studies, and would include sources like interviews and questionnaires, reviews of documents and texts, observations (based on fieldwork) and impressions and reactions. Grounded theory would be used as a mode for data analysis.

Tools and methods of assessment of sustainability impact which have been developed differ and they also include various protocols and international standards, incorporated into monitoring, reporting and planning processes. Environmental Management Systems (EMS), ISO standards, Corporate Social Responsibility (CSR) reports, Total Quality Management (TQM), Sustainability indicators, Global Reporting Initiative’s (GRI), Environmental-Society-Governance performance (ESG), integrated reporting, impact assessment, reputation and compliance measurement, Dow Jones Sustainability Index - are just some out of plenty. In general, existing assessment tools propose a vast pallet to serve the broader purpose for organizations, since “it cannot be expected that there will be one universal model of organizational effectiveness: it is more likely that one might expect that ‘effectiveness’ involves trade-offs and management of paradoxes” (Stoeglehner et al., 2009, p. 113).

Studying past examples of transformational innovations can be important to help develop analogies and frameworks for understanding and anticipating societal response to new innovations.

4. Planed activities, limitations and perspectives for future research

Our *research-in-progress* has planned activities to obtain concrete research findings cannot as follows:

- Designed time frame to carry out the research activities would be scheduled for the upcoming second year of our research, with consensus of the industry partners.
- Two preliminary meetings were conducted in IBM offices (with IBM supply chain managers), where they expressed their support and cooperation in the research, as well as their willingness to identify several other companies to serve as study cases, thus expanding the research pool.
- Identification of case studies is upcoming activity, where classification of the cases would be based on the process sole.

One of the research perspectives, as brought by Carter and Easton (2011), implies selection of individual industries, contrary to multi-industry studies, with the goal of identifying specific types of sustainability activities. One troubling gap, representing both limitation and perspective for future work, would be the lack of laboratory or field experiments. Performing a pilot test to compare effectiveness of the IS would be interesting for the future.

Future perspective of the research is also seen in expansion of the research on a bigger pool of companies, possibly covering different goals of reverse logistics management among European, North American and Asian companies.

5. Conclusion

Technology showed its potential to solve many of the problems human kind encountered in the past. It helped shaping the world in which we are living today and it needs to retake its position in our understanding as a tool to serve broader social purposes. We have to think about its proper place in our society.
This is why an organization with socio-economic transformed business model could contribute to positive changes and be used as a prime example to show that a business which is sustainable from a social and ecological perspective can be sustainable from a profit perspective as well.

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Analysing the Role of Rail in Urban Freight Distribution

Katrien De Langhe

Abstract

Many different types of goods are transported to and delivered in cities, resulting in some urban freight challenges, such as increased vehicle movements within the city, collection of waste and one-way traffic flows towards the city. The growing urbanisation is expected to generate extra transport movements too. The European Transport White Paper states that national governments should try to implement policies to optimise freight transport in and around the city (European Commission, 2011). One option to do this is by using more sustainable transport modes. In that context, this research examines the potential role of rail in urban freight distribution, which was once important. Firstly, several existing cases of urban freight rail are discussed and compared. This results in the identification of success and failure factors. Secondly, a typology of cities and freight is set up. Thirdly, a conceptual cost model to estimate the potential of rail transport in urban freight distribution is proposed. The approach of this research consists of literature review and an expert meeting amongst academic and industry experts. The findings show that some relevant cases of urban freight rail exist in which different cities are involved. Knowledge of the different city and freight characteristics as well as the main success and failure factors is crucial. An appropriate methodology for assessing the potential of rail for urban freight distribution is a combination of stated and revealed preference and a social cost-benefit analysis.

Keywords: urban freight distribution, rail transport, city, social cost-benefit analysis

1. Introduction

The objective of this paper is to develop the research strategy for a conceptual model in order to assess the business and/or welfare-economic feasibility of rail transport in urban freight distribution.

Many different types of goods are transported to and delivered in cities, involving different sectors and different types of goods flows. These logistics activities engender benefits such as home-deliveries and the removal of waste from the city. However, they also cause some issues in the urban freight context, such as additional vehicle movements within the city. Hence, the transport of different goods to, away from and within cities results in business, environmental and social costs. Three main trends affect urban freight distribution and thus these three cost categories.

Firstly, forecasts indicate that the transport of goods will even grow in the future (Benjelloun and Crainic, 2008; Taniguchi et al., 2001). Meersman et al. (2013) for example forecast an increase of freight transport in Belgium in ton-km for 2014 based on the anticipated movement of the main macroeconomic figures for Belgium and an increase of more than 3% between 2013 and 2018 based on the Federal Planning Bureau. As a result, the (road transport) issues mentioned here are likely to increase as well, making urban freight distribution an even more interesting research subject, given the challenges ahead.

Secondly, the growing population and urbanisation lead to extra transport movements in cities (Bous, 2001). Since freight transport and passenger mobility interact with each other, these extra passenger movements also affect freight transport to, outside and within cities.

Thirdly, an increased general awareness of the environment exists (Behrends, 2012; Dorner, 2001). The recent European Transport White Paper states that European governments should try to implement policies to optimise freight transport in and around the city (European Commission, 2011). Behrends (2012) and Ruesch (2001) suggest to use more environmentally friendly transport modes, such as rail transport. In this context, this research examines the potential role of rail in urban freight distribution.

The rest of this paper is organised as follows. Section 2 provides an overview of the use of rail in an urban freight context. Section 3 discusses the crucial city characteristics that have to be taken into account and section 4 gives an overview of different freight types. In section 5, the research strategy for the next research steps is addressed. Ultimately, in section 6 some provisional conclusions are drawn.

2. Lessons of urban rail freight distribution cases

Literature review provides an appropriate terminology and definition to discuss rail transport and urban freight distribution. Urban freight distribution is referred to as the transport of goods towards, from and within urban areas. Rail freight distribution refers to the use of light rail or freight trams (De Langhe, 2013). Within these two rail types, different rail products exist. Aspects such as the configuration of the network, frequency of the service, time of operations, etc. define the specific rail product.

The main existing rail projects in urban freight distribution are carried out in Amsterdam (City Cargo), Barcelona (freight tram scheme), Dresden (CarGo Tram), Paris (Monoprix, TramFret), Rome (multimodal urban distribution centre), Vienna (GüterBim) and Zürich (Cargo Tram, E-Tram). All rail projects have different characteristics and hence, it is useful to investigate these projects more in depth.

A general observation is that only three of the projects are (still) operational, being the CarGo Tram in Dresden, the Cargo- and E-Tram in Zürich and the Monoprix train in Paris. The other projects either stopped after a pilot period (City Cargo in Amsterdam and GüterBim in Vienna), are still in the pilot stage (TramFret in Paris), or are only hypothetical projects (Freight tram scheme in Barcelona and MUDC scheme in Rome) (De Langhe, 2013).

Analysis of the success and failure factors of the existing projects (see Table 1) learns that the most common failure factor is the interference with passenger traffic (Dresden, Zürich, Amsterdam, Vienna, Paris). Resistance from different actors (Dresden, Zürich, Amsterdam, Vienna), the initial investment needed (Dresden, Amsterdam, Barcelona), as well as the commitment of different stakeholders (Amsterdam, Vienna, Barcelona) are also crucial. Furthermore, politics (Vienna, Barcelona) and limitations of the technology can result in a failure of the project. The main success factors are the effects of the positive marketing (Dresden, Paris), new measures making road transport more expensive (Paris), cheaper, faster and cleaner rail transport (Zürich) and the transport of a low-value, non-time sensitive commodities (Zürich).

These findings are similar to what is stated by several authors. Arvidsson and Browne (2013) indicate conflicting objectives amongst stakeholders, interference with passenger traffic, radius of action, scale of the project and stakeholder involvement as the main barriers for freight trams. Regué and Bristow (2013) state that a freight tram is only potentially feasible in case economies of scale are exploited, a minimum demand is served and urban consolidation centres work efficiently, or in case niche markets are used in which the operational costs are currently high and only limited extra infrastructure is needed.

Comi et al. (2014) concluded that the involvement of stakeholders and financial implications such as who is paying and the division of costs and benefits amongst the stakeholders, are crucial variables. Other important factors mentioned are the existence of marketing benefits and the fact that rail transport is always part of a chain, i.e. pre and/or post-haulage is needed.

In order to get a more detailed insight in the projects, several criteria have been examined (see Figure 1).

Failure factors	Success factors
Interference with passenger traffic (Amsterdam, Dresden, Paris, Vienna, Zürich)	Positive marketing (Dresden, Paris)
Resistance to try something new (Amsterdam, Dresden, Vienna, Zürich)	New measures that make road transport more expensive (Paris)
Acquire adequate finance, high investment costs (Amsterdam, Barcelona, Dresden, Vienna)	Cheaper, faster and cleaner than traditional lorries (Zürich)
Conflicting objectives amongst stakeholders (Amsterdam, Barcelona, Vienna)	Non-time sensitive and low value commodity (Zürich)
Politics (Amsterdam, Barcelona, Vienna)	
Technology limitations (Amsterdam)	

Tab. 1: Success and failure factors appearing from main urban rail freight projects, Own composition based on Alessandrini et al. (2012), Arvidsson and Browne (2013), Janjevic et al. (2013), Levifve (2012), Madden (2011), Monoprix (2007), Regué and Bristow (2013)

Two main conclusions can be drawn from the analysis of these variables. Firstly, the characteristics of a city are a crucial parameter, which needs to be examined. Depending on these characteristics, a certain project is feasible in one city, but not in another one. Cities of the same size may have totally different economic functions and vice versa (Clark, 1982). Parr (2007) confirms that a general definition of a city that can be used for all purposes does not exist. The author highlights that an appropriate definition should be chosen according to the specific problem that is examined. As Behrends (2012) also highlights the importance of the urban context, a first logical step in the further research is therefore to make a typology of cities. This idea is confirmed by

Added value	Just-in-time transport, technology and potential security systems at the establishment/vehicle
Budget	Provided budget and costs
Concession	Concession period
Investment	Who is financing/funding the project
Operational aspects	Tram running time, current and maximum future frequency, number of routes, number of stops, trip length and potential limited timeframe
Stakeholders involved	Project owner, number and type of customers
Savings by adopting the project	Saved road transport (in km and movements), saved running-times, diesel, particle air pollution and other externalities
Transfer	Features of the transfer point, such as the (un)loadiing time and location and the equipment used
Transport unit	Current and future number of trams, length of the tram and tram capacity
Type of goods	Goods that are transported by the project as well as waste and reverse logistics
Use of rail infrastructure	Distance travelled on the existing tramways, use of public tramways and use of extra tramways

Fig. 1: Evaluation criteria for different projects, Own composition based on De Langhe (2013)

Arvidsson and Browne (2013), who indicate that the logistics solution for urban freight distribution does not exist and thus contextual factors have to be integrated in the analysis.

Secondly, different freight types are involved in rail projects. In Barcelona, Paris and Vienna, retail products are considered, while in Amsterdam, Barcelona, Vienna and Zürich, waste is transported by rail. Besides, drinks and textile are considered in Amsterdam and Paris. Other specific freight types are automotive parts (Dresden), beauty products (Paris), fish (Rome), goods for hospitals (Vienna) and hobby and housing products (Paris). These different freight types show that a classification of freight is a second important step in the further research (De Langhe, 2013).

3. Definition of an urban area

Urban areas are important for freight distribution. Christaller (1933) and Loopmans et al. (2011) argue that cities are interesting places for suppliers because of the high population density. Hesse (2008) pointed out the crucial role of cities for the exchange of goods. In later research, this author added that cities have always been connected to trade and are thus by definition central places and gateways to transfer goods and services to the hinterland (Hesse, 2013). Allen, Browne and Cherrett (2012) add that goods are often transported towards an urban area and from there to maximum a few final destinations.

De Langhe (2014) chose the terminology “urban area” and defines an urban area as "a (nearly) continuous compact area, with a certain minimal population density, of which a large proportion consists of commercial activities such as retail activities". An urban area in this research can as well be a small area with a high concentration of shops, as a large area with a lower concentration and this area does not necessarily equal the legal city boundaries.

After defining the urban area, a typology of different urban areas can be set up. Urban areas are distinct from each other with respect to several parameters. Figure 2 shows the parameters that are derived and applied to cities in which rail was used or is still being used for urban freight distribution.

In a next step, the potential role of rail for urban freight distribution will be examined for the northern part of Belgium, i.e. Flanders. Therefore, at least one urban area has to be determined that includes a concentration of retail activities. Retailers are the receivers of goods and producers of waste and as a consequence, they account for goods transport flows. The geographical scale of an urban area can vary between a group of retail activities, a whole Flemish city, a region in which several cities are located or Flanders as a whole.

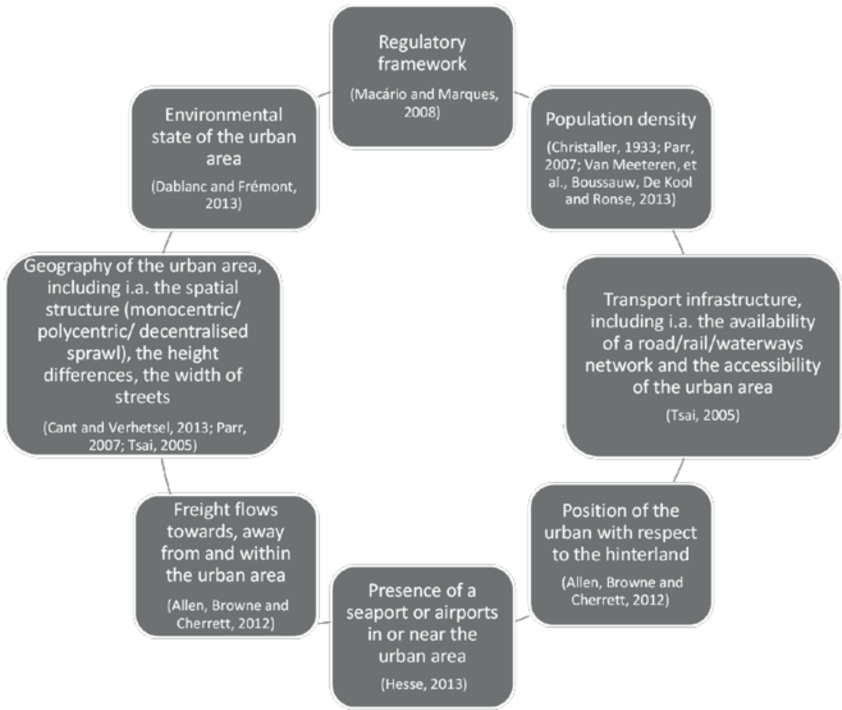

Fig. 2: Urban area parameters, Own composition based on De Langhe (2014)

Figure 3 gives an overview of the different city types in Flanders. It shows that Flanders is a dense area of cities. Two additions to this figure have to be made. Firstly, the terminology “city” corresponds to what Loopmans et al. (2011) see as a “city” and not to the legal definition of a city. Secondly, Figure 3 excludes Brussels, i.e. the white spot on the map, since it does not belong to Flanders from a political point of view. However, Brussels is a main node in the Belgian rail network, strongly connected to the Flemish rail network (see Figure 4). This rail network is mainly concentrated between Antwerp, Brussels and Leuven. As a result, Brussels is not excluded from the economic analysis.

Fig. 3: Hierarchy of Flemish cities, Loopmans et al. (2011, p.145)

Besides considering Flanders as a whole as one urban area, a specific part of Flanders can be chosen. Depuydt & Van Daele (2012) placed the RER-network of Paris on the map of Flanders (see Figure 5). The Paris' RER-network covers about one third of the Flemish area and thus, a city such as Paris may have some similar characteristics as the central part of Flanders.

Fig. 4: Part of the Belgian rail network, Infrabel (2014)

This central part corresponds roughly to the Flemish Diamond, which is the area between Antwerp, Leuven, Brussels and Ghent and is considered to be the economic centre of Flanders. Given the fact that also the rail network is the densest in this area, the Flemish diamond has potential to be the most appropriate urban area in Flanders to examine the potential of rail in urban freight distribution.

At a lower geographical level, a distinction of several urban areas can be made within Flanders. Loopmans et al. (2011, pp. 107–109) mapped different functions of the Flemish municipalities. One of these functions is the retail function. This function is important for this research, since the retail activities are one of the characteristics that determine whether a certain area is an urban area or not (see definition urban area). In order to include different sectors in the analysis, a division is made based on the NACE-code. Depending on the number of sectors represented in each municipality, the number of shops and the number of different sectors present in each municipality, a total score was calculated. With respect to this function, Antwerp is the biggest city of Flanders (De Langhe, 2013).

Fig. 5: The RER-network of Paris on the map of Flanders, Depuydt and Van Daele (2012)

4. Different freight typologies

Transport flows towards, from and within cities have some different characteristics. Allen et al. (2012) state that trips within urban areas are likely to contain more low-volume freight than trips towards urban areas. Furthermore, trips away from urban areas include more empty trips and lower load factors than trips towards urban areas. Many urban areas are net importers of goods. The same authors studied 14 urban areas within the UK and found that only two of them are net exporters. Important to note is the fact that these two cities are port-cities. Another observation is that flows within urban areas have a shorter distance than the flows to and from urban areas.
Not only the difference between intra- and inter-urban freight flows is important. Existing examples of rail in urban freight distribution show that different types of goods can be transported in this context. Depending on these freight types, the transport conditions and requirements are different. Some goods have temperature restrictions, some goods are transported in low volumes to small shops, while other goods are transported in high volumes to large shops. Depending on the type of goods, the rail transport has to be organised in a different way (Comi et al., 2014). Therefore, different subdivisions of goods are given in the next paragraphs.

4.1 Catchment area and threshold value

Porta et al. (2012) make a distinction between primary and secondary activities in an urban area. Primary activities have “a larger-than-local market or catchment area, they are typically highly skilled, larger or more specialised economic activities such as wholesale, industry and those not related to the public or not mainly serving the end-users and their location choice is more likely to be driven by a formal top-down decision-making process” (Porta et al., 2012, pp.1477–1479). Secondary activities have “a local market or catchment area and they are typically retail and services that respond to the ordinary needs of a general public on a daily or regular basis" (Porta et al., 2012, p.1479).

Similar to this reasoning, a ranking of goods can be made based on the threshold value, or the minimum turnover needed to be profitable (Christaller, 1933). Goods and services with a high threshold value are typically expensive and infrequently purchased items. Lower on the ranking, goods and services with a lower value appear, which are more frequently used. Ultimately, at the bottom of the ranking low value products can be found that are consumed on a daily basis (Clark, 1982). Tannier et al. (2012) distinguish two types of shops and services, depending on the potential user frequency. Daily frequented shops or service centres are bakers, butchers, newsagents, schools and supermarkets/hypermarkets. Weekly frequented shops or service centres are cafés, doctors, hypermarkets/supermarkets/minimarkets, pharmacists and post offices.

Table 2 gives some examples of goods ranked by threshold value. High threshold value products are only available in the largest urban areas of a region, while low threshold value products are also available in small urban areas.

Threshold value	Examples
High	Housing products, television
Medium	Pharmaceutical products, hobby products
Low	Groceries, food, catering industry

Tab. 2: Goods typology based on the threshold value, Own composition based on Clark (1982), De Langhe (2014), Tannier et al. (2011) and Wood and Roberts (2011)

Dablanc and Frémont (2013) state that retailers have a weekly delivery frequency of 4-8 times per FTE employee. Small independent retailer and hotels and restaurants have a weekly frequency delivery of 5-15 times. Chain retailers and shopping centres have less frequent deliveries per m² and their deliveries are more consolidated and transported in vehicles with a higher load factor.

4.2 The supply chain

Routhier et al. (2001) estimated that 150-200 types of supply chains exist in the city of Paris. This figure corresponds to the number of economic sectors. Dablanc and Frémont (2013) state that these supply chains differ from each other with respect to the operating times, operators and vehicles used. Gevaers (2013) also distinguishes different supply chains, based on a typology made by Boyer et al. (2005) and Figliozzi (2007). The latter author distinguishes three types of supply chains: low value and less time-sensitive products, low value and high time-sensitive products and high value and high time-sensitive products. Gevaers (2013) states that different logistics approaches are needed for different product types, i.e. a typology of last-mile subflows is needed corresponding with different freight types.

More specifically, a distinction can be made between fast and slow moving goods. Fast moving goods are too expensive to be stored decentralised. As a consequence, they are often transported directly to their final destination without intermediate stop. Distribution centres are used for cross docking purposes, not for storage. On the other hand, slow moving goods are transported to distribution centres near the final destination of the goods, in which they are stored together with goods from other companies (Tsolakis and Naudé, 2008).

Furthermore, time-sensitive freight can be divided into courier and express freight. According to Sirikijpanichkul and Ferreira (2006), courier freight consists of “door-to-door and fixed schedule delivery services mainly in inner city areas” and includes important documents, office support and technical services. Express freight is associated with “a time-definite delivery of freights – usually on the basis of the overnight priority, same day, next day, and international services – which involves a process of pick-up, consolidation, deconsolidation and delivery to final destination". Examples of express freight are fashion products, just-in-time products, perishable goods, priority items and retail products (Sirikijpanichkul and Ferreira, 2006).

4.3 Weight-driven versus volume-driven freight

Tsolakis and Naudé (2008) developed a typology of freight, consisting of bulk and non-bulk goods. Bulk goods comprise primary goods such as coals, mining and ores, and agriculture and forestry, such as grain and timber. These bulk goods are considered to be non-urban, while the non-bulk goods are assumed to be urban flows.

Within the non-bulk goods, urban heavy freight and urban light freight can be distinguished, in which heavy freight can be considered to be weight-driven and light-freight to be volume-driven. The urban heavy freight consists of industry supplies, infrastructure construction materials, residential building materials and household removals, waste removal and recycling and wholesale and retail supplies. The urban light freight includes household waste removal, mail, office and residential maintenance, office supplies, service delivery trips and small scale retail deliveries. Most light freight activities take place in an urban context and are thus urban flows. Some of the main characteristics of urban light freight are its time sensitive nature, which is even increasing over time, the use of light commercial vehicles and the small volumes to be transported (Tsolakis and Naudé, 2008). Urban light freight is a growing segment (Janjevic, Kaminsky and Ballé Ndiaye, 2013) which contributes to a large amount of total urban freight, expressed in number of deliveries and vehicle trips. In Liège, a city in the southern part of Belgium, three quarter of all deliveries in the city centre are parcels and 79% is transported by means of light commercial vehicles in 2004 (Debauche, 2007).

Light commercial vehicles are defined by Tsolakis and Naudé (2008) as "motor vehicles constructed for the carriage of goods and which are less than or equal to 3.5 tonnes". This definition includes cab-chassis, goods carrying vans, panel vans and utilities. When Janjevic et al. (2013) describe the classification of vehicles made by Debauche (2007), they count private cars, vans and estate cars as light commercial vehicles.

For this study, the classification of Tsolakis and Naudé (2008) is especially useful and leads to the hypothesis that mainly non-bulk weight-driven as well as volume-driven freight qualify for a potential use of rail transport in an urban context. This reasoning comes from the fact that both examples of transport of weigh-driven freight (e.g. Dresden, Paris) and volume-driven freight (e.g. Zürich, Rome) by rail exist. In general, B2B flows are considered, since B2C flows are too fine-grained for rail transport. However, B2C flows cannot be left completely out of the analysis given the increasing importance of e-commerce (Comi et al., 2014).

5. Developing the research strategy

A next step in the analysis is to determine an appropriate methodology to investigate the potential role of rail in urban freight distribution.

Table 3 displays different research methods used by different authors in order to assess urban rail freight distribution projects. An often-applied method is the combination of interviews or observations to forecast freight flows and to collect additional data and the conduction of a social cost-benefit analysis and the application to a case study. This method has been applied for both light rail (Alessandrini et al., 2012; Dinwoodie, 2006; Filippi, 2014; Gonzalez-Feliu, 2014; Nuzzolo, Crisalli and Comi, 2007; Nuzzolo, 2014) and tramways (Regué and Bristow, 2013).

De Langhe (2014) gives an overview of the main social and private cost/benefit variables. This overview is based on the classification of costs and benefits made by Blauwens, De Baere and Van de Voorde (2012), who distinguish investment and operational expenses on the cost side and consumer surplus and operational income on the benefit side. Since the role of rail in urban freight distribution is in the present research examined from both a business-economic and a welfare point of view, costs and benefits can be subdivided in social and private costs/benefits. The social costs/benefits consist of emissions and other externalities, while the private costs/benefits include into operating costs, investment costs and handling costs. Blauwens et al. (2012) do not make a distinction between operational and handling costs/benefits. This distinction is relevant for the present research, since it allows getting a separate insight in the road/rail operations and the handling operations.

From the analysis of the existing literature displayed in Table 3 it can be deducted that not all authors measure all cost/benefit components and not one component is measured by all authors. This might be due to a lack of data for the specific case that is examined, or because some cost/benefit components are irrelevant in some specific cases.

In order to get an in-depth insight in the actual and potential future freight demand, total freight flows and rail freight flows have to be estimated. Knowledge about these flows makes it possible to estimate the demand curve. This in turn leads to an estimation of the benefits, which equal the surface below the demand curve. This is best done based on a combination of stated and revealed preference. The rail freight demand for urban freight distribution is difficult to capture by revealed preference, since it comprises a potential and not an existing demand.

Thus, rail freight flows are estimated based on stated preference. With respect to the supply, an analysis of the existing railway and tramway infrastructure, rolling stock and services is made based on a market analysis and interviews. The combination of these two sides is in a further stage input for the social cost-benefit analysis. Additional factors, such as a potential new tramway/railway, are implemented in the model by conducting several sensitivity tests. After having applied the analysis to a specific case study, extension to other cases is facilitated by using the transferability theory (Macário and Marques, 2008) for which the different urban area and freight characteristics are input.

Author(s)	Year	Methodology
Dinwoodie	2006	Disaggregate spreadsheet cost simulations, semi-structured interviews
Nuzzolo, Crisalli, Comi	2007	Traffic counts, driver surveys, retailer surveys, O/D freight demand matrices, cost analysis
Alessandrini, Delle Site, Filippi and Salucci	2012	Monitoring of vehicles, scenarios, social and private cost analysis
Regué and Bristow	2013	Cost-benefit analysis, scenarios, face-to-face establishment survey, observational vehicle count
Filippi	2014	On-board vehicle computers, interviews, surveys
Gonzalez-Feliu	2014	Interviews, social cost-benefit analysis
Nuzzolo and Comi	2014	Stated and revealed preference, (mixed) logit model, nested model

Tab. 3: Overview of applied methodologies, Own composition

6. Conclusions

This paper offers a research strategy to develop a conceptual model in order to assess the business and/or welfare-economic feasibility of rail transport in urban freight distribution. Three main conclusions can be drawn.

A first conclusion is that the main parameters of urban areas are the geography of the urban area, the population density, the transport infrastructure, the hinterland, the presence of a seaport or airports in or nearby the urban area, the freight flows towards, away from and within the urban area, the regulatory framework and the environmental state of the urban area. Another main aspect that has to be taken into account in this research is the presence of retail

activities. With respect to Flanders, three urban areas appear to be relevant for this research, being Flanders as a whole, the Flemish diamond and Antwerp.
A second conclusion concerns the freight types that could be transported by rail transport. Different existing cases and a classification of freight show that both non-bulk heavy as well as light freight can be taken into account. For the transport by rail, mainly B2B flows are considered.
A third conclusion is made with respect to the research strategy for this study. A combination of stated and revealed preference is needed as input for a social cost-benefit analysis. This social cost-benefit analysis consists of both social and private costs and benefits. The main social costs/benefits are emissions and other externalities, while the main private costs/benefits are operational, capital and handling costs/benefits.
In further research, the social cost-benefit analysis will be carried out, applied to at least one case in Flanders. The results of this case will lead to the development of a conceptual cost-model to assess the potential role of rail in urban freight distribution.

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Truck Loading Dock Process – Investigating Integration of Sustainability

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Abstract

Truck loading docks as a bottleneck and a logistics interface notoriously plagued with misunderstandings and scheduling issues recently came to the attention of research in the wake of the 2011 report of the German federal office for goods transport. At the truck loading dock the different objectives of road haulers and warehouse operators collide having implications for the whole supply chain. This study aims to verify problems identified in earlier studies with a special focus on SME and explore the question how practitioners would include sustainability measures in that process.

A qualitative interview method was used for the investigation, including various players from the logistics industry. A focus group discussion as well as nine face-to-face semi-structured interviews were used to gather optimization and sustainability integration suggestions for the loading dock processes.

An increased need for information, a primary focus on efficiency as a method to become more sustainable, especially ecological sustainability as well as a lack of consideration of social issues were found.

The research is limited due to the small sample that naturally cannot take all perspectives into account. The perspective of truck drivers is not included.

Practitioners are to gather new ideas for the sustainability concepts as well as optimization methods for the loading dock processes in their enterprises; a long term outcome of this research project will be a best-practice catalogue.

Keywords: transport, loading docks, logistic interfaces, sustainable process improvements

1. Introduction

Truck loading docks have been identified as a major bottleneck in distribution and procurement logistics (Bundesamt für Güterverkehr, 2011). This links together two actors of the supply chain: freight forwarders or logistics service providers on one side and road haulers on the other. In a study, following up the 2011 report of the German federal office for goods transport, Hagenlocher, Wilting and Wittenbrink (2013) identified a multitude of issues regarding dock processes; these findings not only outlined implications on the flow of goods and underlying ecological and social concerns. In further scientific literature Borgström, Hertz and Jensen (2014) point out the immense cost pressure road haulers are facing in their business and outline the consequences for sustainable supply chain approaches. Additionally, publications from the German logistics industry suggests that even brief delays or traffic congestion can invalidate drivers' schedules for the complete tour (Bergrath, 2011; Lauenroth, 2012; Semmann, 2012).

Logistics service providers take the weaker role in this process; due to standardization their services are exchangeable and face immense competition. Consequently it is expected that the efficiency losses are accommodated by them. Additionally these companies are increasingly facing the demand of their customers and the general public to review their processes with respect to ecological impacts and social issues (Lieb and Lieb, 2010).

In the light of sustainable supply chain management being considered to still be at an early stage of implementation, it seems consequent to take a look how these goals can be incorporated into management concepts for the loading dock (Brockhaus, Kersten and Knemeyer, 2013). In the context of a larger federal funded project small and medium sized enterprises (SME) and their current approach to managing truck loading docks, sustainability and combining both were investigated.

2. Method

This publication is embedded in to a larger research project with the ultimate aim to present a best practice protocol for loading dock management with sustainability aspects in mind. Hence, qualitative research methods were chosen as it was vital to gain a deep understanding of problems and processes in SME with respect to including sustainability.
After conducting an initial literature review the problem was chosen to be investigated via a two stage design derived from Blumberg, Cooper and Schindler (2008, p. 207). In a first step a focus group workshop was carried out in order to outline the major dimensions and questions for SME. Semi-structured interviews as a second step were employed to generate new hypothesis and validate points made when working with the group (Charmez, 2008; Punch, 2013).

2.1 Focus group

This method allows for a guided discussion about various aspects of the problem and allows for an initial insight while maintaining a broad approach to the problem (Blumberg, Cooper and Schindler, 2008). The problems found during the workshop represent a list of current problems that SME face during the truck loading process. They were classified according to sustainability criteria. Companies and entities with practical knowledge of sustainability in logistics and/or truck loading docks were invited to attend the session in-house. Nine companies with different roles in the logistics sector, one person from a public authority and three persons from academia participated; the full listing can be found in table 1.
The participants were introduced to the project and to the triple bottom line definition of sustainability according to Carter and Rogers (2008). Subsequently the attendees were requested to write down problems on index cards that they found to be a major or to a daily disturbance regarding loading docks. The system boundary was defined as that part of the process which actually

involves the arrival on site as well as the process prior to arrival when the loaded truck was en route to the destination. The number of cards was not limited. In a second step each card was presented and the attendees were asked to either assign it to a category or to discard it as a duplicate. According to Carter and Rogers (2008) triple bottom line model categories were presented: economic issue, ecologic issue or social issue; each problem could be assigned to one, two or all of the categories, effectively yielding seven possible categories. As a concluding step participants were allowed to allot a total of three weighing points to any of the cards; cumulation was allowed. They were asked to do this as quickly as possible and according to their personal experience without discussing with each other.

The described problems, their assigned dimension as well as the cumulated rating of the group were then recorded. The discussed issues were also used to create the interview guideline and as one subset of interview labels.

2.2 Interviews

After concluding the first stage of the investigation, semi-structured interviews were conducted. It was intended to gain a deep understanding of the management process at loading docks, how these companies define sustainability and how this might integrate in their truck loading process at the docks.

Industry representatives were recruited in part from the focus group and directly invited at trade shows or conferences. Interviewees were chosen such that they were from different professions in the logistics sector. Before the interview they were presented with a questionnaire which allowed them to prepare their answers in part. Nine companies (as shown in table 1) from different parts of the logistics industry were recruited for audio recorded interviews. Most (7/9) of them were interviewed on site, so that it was possible to take a live look at the discussed processes. In a few cases (2/9) more than one person took part in the interview; this is indicated by a slash in the column "Position of Interviewees" of table 2.

Company type	SME	Number of participants from that type
Freight forwarder	No	2
Warehousing	Yes	2
Warehousing	No	1
Consulting	Yes	1
IT services for logistics	Yes	2
Public Authorities	n/a	1
Logistics services	Yes	1
Academia	n/a	3

Tab. 1: Focus Group

Three groups of questions were discussed (see table 3). After a short introduction of the company's services, the representatives were asked to describe the whole process of loading and unloading trucks at the docks and elaborate on possible optimization methods for this process. In a second step they explained their definition and understanding of sustainability and described its current implementation in their company. In the third part of the question set a brief explanation of the triple bottom line was presented: Interviewees were explained that there are multiple facets to sustainability and asked how they would conceptually integrate these thoughts in their loading processes. In the same vein participants were asked which drivers would be necessary to make them increase their sustainability efforts.

Company#	Company type	SME	Position of Interviewees
1	Production of food	No	Dispatching
2	Commerce	No	Head of Logistics / Logistics
3	Cooperation for bulky goods	Yes	CEO/Warehouse Manager/Quality Manager
4	Warehousing	Yes	CEO
5	Consulting	Yes	CEO
6	Consulting	Yes	CEO
7	Commerce	Yes	Warehouse Manager Incoming Goods / Warehouse Manager Outgoing Goods
8	Freight Forwarder	Yes	CEO
9	Logistics support services	Yes	Head of distribution and purchasing

Tab. 2: Interview participants

Audio recordings of the interviews were then analyzed. In a first step descriptive labels were used to start the analysis (Punch, 2013). As Punch (2013) stresses comparison is especially important in qualitative inquires, thus the descriptive labels were tested against all interviews in a second step. As a third step a table was compiled: It contains the labels as list of statements as well as the number of interviewees agreeing, disagreeing or no recorded response. Additionally the labels were grouped for context.

Group	Question
Loading and Unloading	What does your process for loading and unloading look like?
	In current loading and unloading processes you take part in: Which optimization possibilities would you identify
Sustainability	What is your understanding of sustainability?
	How do you implement sustainability in your day-to-day business?
Integration of sustainability in the loading and unloading process	How would you integrate sustainability concepts in the loading process conceptually?
	Which reasons would drive you to extend your sustainability concept?

Tab. 3: Interview outline

3. Results

3.1 Focus group discussion

During the focus group discussion 23 problems were generated; all of them are numbered and listed in table 4. Additionally, in the column "Sustainability dimension chosen" of the table the sustainability dimension assigned by the group is listed. The "importance rating of the problem" was generated by counting the points allotted to each problem in total.

No problems were allocated solely belonging to the ecological or to both ecological-social dimension. Most of the problems were allocated either belong to all dimensions equally (9/23) or to both, the economic and social dimension (8/23). Only one problem was assigned to the social dimension alone. The other problems were assigned to the economic dimension (4/23) or were said to include both economic and ecological aspects (2/23).

Availability of information (7/36 points) was identified to be the most important problem, the group outlined it as negatively influencing all sustainability dimensions. In the discussion surrounding this item some participants also voiced their concerns about making more information available to outsiders and also explained that there were severe doubts whether the investment in necessary information technology would justify the benefits.

Furthermore, it was discussed in the group that inefficiencies at truck loading docks may cause direct problems for the truck drivers, e.g. as they hamper their time schedules. This lone problem (5/35 points) in the social sustainability dimension was reported as being the second most important one. It was important to the group to note that warehouse operators were not generally interested in creating a negative environment for the in-house personnel nor the incoming drivers.

The third rank (each 4/36 points) is a tripartite of the cooperation with loading dock operators as well as third and fourth party logistics service providers, time slot management systems and opening hours of loading docks. When cooperating with logistics service providers some members which operated warehouses elaborated that they have found it difficult to communicate the specific on-site needs to the actual sub-contractors that haul the cargo. Obviously knowledge of the actual opening hours and assigned time slots were part of these problems, but during the workshop it was also claimed that inflexibility introduced by these constrains would cause road haulers to intentionally miss time slots or having to plan inefficient routes.

#	Sustainability dimension chosen	Problem	Importance rating of the problem
-	Ecological	None	-
	Social		
1	Social	Truck Drivers	5
	Economic		
2		Loading and Unloading times	4
3		Number of Loading Docks available	2
4		Waiting times are a cost driver	1
5		Cost allocation is difficult	0
	Ecological and Economic		
6		Cooperation with loading dock operators as well as third and fourth party logistics service providers	4
7		Documentation is still done on paper	0
	Ecological and Social		None

#	Sustainability dimension chosen	Problem	Importance rating of the problem
	Economic and Social		
8		Opening hours of the unloading point are too short	4
9		Whose responsibility is it to unload?	1
10		Language barrier	1
11		Extended Working hours	1
12		Drivers are missing information	0
13		Self-collectors don't pick up their goods	0
14		Waiting times and times spent at the docks is too long	0
	Ecological and Social and Economic		
15		Flow of information	7
16		Processes are not transparent	3
17		Waiting areas for trucks are limited	1
18		Police Checks	1
19		Opening hours of all the loading and unloading points are inconsistent	1

#	Sustainability dimension chosen	Problem	Importance rating of the problem
	Ecological and Social and Economic		
20		Systems used by the different participants are not compatible	0
21		Complexity of the whole supply chain has to be regulated at the loading dock	0
22		Warehouses do not provide enough storage	0
23		External impacts (weather, traffic jams)	0

Tab. 4: Problems identified with the focus group

3.2 Interviews

The results of the interviews were aggregated as descriptive labels into three groups: “Loading and Unloading: Overall Process” (see table 5), “Sustainability” (see table 6) and “Optimization possibilities” (see table 7). An additional group was used for cross-checking the workshop statements (see table 8). Labels in the first two groups were only included if majorities of the interviewed companies (>5) made a statement about them; all optimization possibilities were included to allow an insight to new ideas. Ideas for integrating sustainability and truck loading docks were aggregated and are listed in table 9.

3.2.1 Loading and Unloading

#	Statement	Agree/Disagree/ Not Applicable
1	A time slot management system for the loading docks is used.	7/1/1
2	The trucks do not always arrive as expected.	7/1/1
3	There are partners the company regularly works with.	6/1/2
4	There are peak times where many trucks arrive at once.	5/2/2
5	Trucks that do not arrive on time are unloaded nevertheless	5/2/2

Tab. 5: Loading and Unloading: Overall Process

It was found that most companies describe a similar process in loading and unloading: Initially the drivers sign up with the service personnel, after a certain time they are assigned to a certain dock for loading and subsequently sign out with dock service staff. Major differences were observed in this process regarding the wait and arrival times. Additionally, some minor differences in the processes were observed, but not systematically recorded. These included additional loading points for euro-pallets and staff that was specialized in handling only incoming or only outgoing trucks as well as additional security personnel.

Almost all companies agreed that they either employ a time slot management system themselves or are confronted with it. One company declined indicating that they had not found a software fitting their needs, but noted that they were looking into developing their own solution. Not applicable was noted for one interview with a company that used different solutions across independent warehouses and thus couldn't make a definitive statement. What can be noted about time slot management is specifically that the sophistication of these systems varied greatly: While some companies use a simple calendar receiving only the most important shipping notifications over the phone, others use spreadsheets and daily email notifications and a few use sophisticated web based solutions. The initial reasons for deploying these solutions vary, but during all interviews the participants stated clearly that the docks and the operating staff are limited resources.

A main problem identified during the interviews was that the trucks would not always arrive as expected. This very general label however does not fully extend the problem; during some interviews delays of days or more than two hours were reported. One company stated that some trucks would arrive a lot earlier betting on the chance that they would be processed earlier than the time slot they got initially. One other company however explicitly underlined that in today's competition road haulers could not afford to be late and claimed that trucks of his company would never be late.

The same range can be seen in statement 5 in table 5: Typically the late comers are unloaded. However, this is to be taken with a grain of salt, while two of the interviewed companies reject this thesis, three of the five that agree caution that it is done on a best effort basis.

This is mostly related to the problem that companies also report certain peak times during the day which are requested most often by the haulers or which have the most incoming haulers. Some of the dock operators note that they have a varying number of docks available during the day and some note that this is the reason for deploying a time slot management system. One observation seems worth noting: Two companies that stated they would not take trucks which are not on time, also experience peak hours and do not use a sophisticated time slot management system.

On the other hand six of the companies state that they have certain partners they regularly work with. These cooperation take very different forms. One company reported a contract collaboration which is very close to a general-cargo-alliance. Other collaboration forms are much simpler and use the knowledge of the drivers and simple negotiations over the phone as inputs with different time horizons. Rejection of this thought (one company) exposed a problem Hagenlocher, Wilting and Wittenbrink (2013) also reported: The carrier is chosen often chosen by the other side, hence, not known or tracked by the receiving enterprise.

3.2.2 Sustainability

#	Statement	Agree/Disagree/ Not Applicable
1	Sustainability has economic, ecologic and social aspects	5/2/2
2	Ecology is only achieved through efficiency	4/3/2
3	The economic aspect is the most important one when making decisions concerning sustainability.	5/1/3
4	Sustainability is integrated into day-to-day company processes.	6/1/2

Tab. 6: Sustainability

Sustainability including social and ecologic as well as economic aspects was often quite well understood in the companies asked (statement 1 table 6). Initially intended to see to which extend a triple bottom line or sustainable supply chain management model was implemented, only two of the firms asked stated that it was in there interest to achieve economic, social and ecologic goals all at once. The two not included in the group agreeing didn't think social issues were part of a sustainability strategy. Statement 2 and 3 in table 6 highlight this connotation. Only few companies asked reject that notion; one of the interviewees stated that in the future it was probable that additional kilometers would be restricted and critically noted that transporting goods across the country only for small subsequent process steps was an unnecessary luxury.
Most of the companies thought that sustainability was integrated in their company processes (statement 4 in table 6). However, taking statements 2 and 3 into account this cannot be understood as a progressive position, most of them simply stated that they achieve sustainability through increased efficiency.

3.2.3 Optimization possibilities

When discussing optimization possibilities concerning the current processes a mix of suggestions was found, all of them are shown in table 7. Two issues (statement 3 and 4) were predominant, however, their underlying cause can be summarized as one: Need for information. Companies that agreed that an improved quality of information about truck arrival times would help them to plan load sequences or preparation of cargo pick-up or intake. The idea of this quality was ranged, essentially, however interviewees articulated that it would help them to get a notification of dispatch at all and if the actual time would be confirmed in a certain time range before the actual arrival. Three companies proposed that a confirmation two hours ahead of the arrival would give them a lot more flexibility. For less than full truck loads two of the interview partners suggested to include information about the load sequence with these confirmation (statement 4, table 7). One party disagreed with both of these

optimization ideas specifically, because they felt that their time slot management sufficiently accounted for this problem. Accordingly, two companies noted that they would welcome standardized freight information in order to avoid confusion and speed up internal processes (statement 2 table 7).
More than once quality and key performance indicators were discussed, whilst some companies elaborated that they do check for certain quality features already they also noted that these quality checks are not recorded. Hence, the "black sheep" among road haulers could be denied pick-up or delivery of goods in the future (statement 6, table 7). Two companies noted that they are in the process of introducing certain key performance indicators for their loading processes. However, they were to include an ecological footprint as well (statement 7, table 7). Penalties based on these KPIs were suggested by two parties: One of them had integrated certain soft, not contract based penalties for their logistics service providers, but didn't have any implemented on the warehouse side (statements 8 and 9, table 7).
Moreover, two companies noted that they optimized their process by handing out leaflets about the on-site processes in order to address the language barrier problems. One other rejected the notion of any multi-language information, because they would never be able to address all drivers (statement 1, table 7).
Two additional, partially implemented suggestions, were made: One being to reorganize the stream of incoming good such that the warehouse takes control over the whole flow. This idea however is strategic and has certain constrains with respect to the parties the warehouse works with; one interviewed company clearly rejected that idea noting that the producers are fully responsible to deliver the goods to their door (statement 10, table 7). The other, fully implemented suggestion was to establish a safety procedure: In this case the company required wheel chocks to be placed and the truck having come to a complete stop before the loading dock door could be opened (statement 11, table 7).

#	Statement	Agree/Disagree/ Not Applicable
1	Directions for the on-site process are available in multiple languages.	2/1/6
2	Freight information for trucks should be standardized	2/0/7
3	Information: More detailed information about the cargo (type, loading sequence)	4/1/4
4	Information: Truck arrival times should be known in more detail.	5/1/3
5	Information (e.g. leaflets) about parking spaces in the area is available.	1/0/8
6	Job specific quality indicators are recorded	3/0/6
7	Key Performance Indicators are recorded	2/0/7
8	Penalties for logistics service providers are defined.	2/0/7
9	Penalties for warehouse operators are defined	1/0/8
10	The merchandise is brought in on request of the warehouse (pull from the factory, warehouse has control over own incoming stream)	2/1/6
11	There is a safety procedure for the loading dock.	1/0/8

Tab. 7: Optimization possibilities

3.2.4 Focus group discussion revisited

#	Statement	Agree/Disagree/ Not Applicable
1	Information: Communication between road haulers and logistics service providers is insufficient	4/2/3
2	It is difficult to meet the assigned time slots.	1/3/5
3	The opening hours of the different loading bays are too heterogeneous.	4/0/5
4	There is a language barrier which causes problems.	5/0/4
5	Who loads or unloads: Do truck drivers load the cargo themselves?	4/2/3

Tab. 8: Cross-checked statements from the focus group workshop

For the cross checked statements that have enough responses it was found that the interviewed partners mainly agreed with the statements gathered from the focus group workshop. The language barrier was viewed as a definitive problem. In the personal interviews some partners extended to explain that it caused road haulers to miss information on required loading tackles, time slots or other local information (statement 4, table 8).

As noted in section 3.2.3 availability of information is a problem, however not all interviewed parties quite agreed that it was a problem in practice. Two companies rejected the thesis that communication was insufficient; rather saying that they "…assume that if a 40 ton delivery is late that their agent will call ahead…"

As discussed in the focus group part of the interviewees agreed that the heterogeneity of the opening hours posed a problem (statement 3, table 8). At one of the companies that opened during the night time it was possible to observe drivers that simply had assumed that the loading bays would be closed before 6:00 am.

In terms of responsibilities concerning unloading the positions differed, but had the common denominator that it was usually agreed upon by contracts (statement 5, table 8). This is a large deviation from observations made in industry literature (Bergrath, 2011; Bundesamt für Güterverkehr, 2011). However, warehouse operators also explained that often times employed subcontractors were not informed of these agreements or did not understand them (see statement 4 and 5, table 8).

3.2.5 Integration of sustainability in the process

The answers and suggestions how the loading process could be made more sustainable were separated in four groups. Most attention was given to changes that involved the use of technology or improvement of the overall process.

As already seen in the interview data participants strived for an increased automation and use of up to date smartphone technology. The general idea here was to increase efficiency and thus reduce the ecological footprint and times the road haulers have to spend on site.

All participants also hoped for improved processes in the future; whilst on the one hand a closer collaboration with the suppliers, the exactness of the actual arrival times was also thought be improvable through required ahead notifications and reducing load times in general. The idea here is basically the same as for the technology suggestions, however, an improved collaboration with the suppliers would also allow road haulers to improve their routes through negotiating with them. On the other hand suggestions concerning the process also called for increased flexibility not only during the operative process, but also by extending opening hours. The rationale, according to the interviewees is that a greater variety of time slots would allow the haulers to plan their routes in a way more efficient for them.

In terms of suggestions concerning the social perspective sustainability more than one of the persons interviewed suggested that they try to create a more comfortable atmosphere for the drivers while waiting by providing coffee. One company said that they will try to incorporate the required breaks of the truckers in their dock assignment scheme.

A few participants also made suggestions regarding the strategy for planning new warehouses or improving existing ones: Choosing the location of the warehouse in such a way that it would take concerns of external stakeholders (e.g. surrounding residential areas) as well as pick-up and delivery processes into account. Companies also suggested to streamline the process overall, but just as combination of deliveries this, according to them, often requires close collaboration with the suppliers and is not often feasible.

How would you integrate sustainability into the process of loading and unloading?	
Technology	
Automation	Digitalization
Improving communication	Time slot management software to reduce time of trucks on site
Process	
Closer collaboration with the suppliers	Delivery of stocks during the night time.

How would you integrate sustainability into the process of loading and unloading?	
Process (continued)	
Increased flexibility concerning dock usage and arrival times at the warehouse.	Reducing loading dock contact times
Requiring drivers to notify the warehouse 2 hours prior to arrival	
Social improvements	
Providing a coffee vending machine	Matching of work breaks of the drivers with the loading time slot.
Strategy	
Streamline the processes	Reduction of empty space by combining deliveries.
Warehouse location chosen strategically	

Tab. 9:Integration of Sustainability – Suggestions by interviewees

4. Discussion

In terms of discussed problems the results are very much in line with previous findings from scientific and German industry literature. It can be confirmed that sustainability mainly requires economic drivers to be implemented as found by Brockhaus, Kersten and Knemeyer (2013).
Three major groups of problems were identified taking both the focus group and the face-to-face interviews into account: Availability of information, efficiency versus sustainability and problems handling social sustainability issues. Problems described in these groups are similar to the ones described in literature, but taking the recorded suggestions into account it is possible to gain an insight into possible solutions.

4.1 Availability of information

In both the focus group discussion (see 3.1) and the interviews (see 3.2) one of the major problems and the main optimization potentials identified by the participants was availability of information to improve the warehouse side process. The overall claim was that knowledge of the vehicles current position would allow to streamline the handling of the trucks. In the long run, so the belief, this efficiency gain would allow for economic, ecologic and social benefits. Yet on the other hand it was doubted that the potential investments for IT would be beneficial enough.
While Hazen and Byrd (2012) concluded that overall logistics companies profit from information technology, they also note that these savings are implied by more efficient processes. In this specific process, however, losses on the warehouse operator side are not to be expected; they typically have to be accommodated by the road haulers. Hagenlocher, Wilting and Wittenbrink (2013) note these costs for the different time slot management systems, as one example of information technology use, as a possible drawback. Especially because some of these systems pass the costs on to the user, requiring payment for each booking.

Literature and interviewees suggest that a broader exchange of information and improved communication processes could help to increase the degree of use of the docks as well as shorten passage times (Durmann, 2012; Hazen and Byrd, 2012). Whether this is feasible for SME and if road haulers and suppliers also benefit from this change remains elusive.

4.2 Efficiency versus sustainability

Sustainability efforts should be driven by increasing economic values – this statement seemed to be the consensus among the interviewees, denied by only one party that has sustainability efforts deeply rooted in their company values. While know from Carter and Rogers (2008) stated that a proper application of sustainable supply chain (SSCM) principles can in fact decrease cost and improve processes it seems short sighted to claim that a sole increase in efficiency in the process can improve sustainability. Especially in the discussion of social issues it seems to be the hope that by shorter contact times sustainability issues will simply move out of scope for warehouse operators.

Naturally, operators of warehouses optimize their processes towards their best performance. However, ideal processes inside the warehouse are continuous and linear. Hence, a system is needed to streamline the non-linear stream of incoming trucks. Unsurprisingly this happens by limitation of resources and is only slightly mitigated by using a management system that administers these resources.

True optimization would require a more dynamic availability of resources or long term planning. Both can be achieved through closer collaboration while planning the dock loading process. This is also reflected in the optimization suggestions gathered. Borgström, Hertz and Jensen (2014) observe that close cooperation is often avoided at the expense of sustainability. The reasons for avoiding these collaborations need to be further investigated.

Furthermore, it should be inspected how electronic systems and manual planning routines could be enhanced such that they provide an interface for collaboration between the drivers on the road and the destination. If this communication was enforced both ends could benefit from the updated information.

4.3 Social Issues

Hagenlocher, Wilting and Wittenbrink (2013, pp.45–54) and multiple sources from German industry and the German government claim that access to common rooms for recreation as well as sanitary facilities is limited or non-existent (Gieße and Voigt, 2012; Durmann, 2012). Besides these basic necessities, unplanned delays at the loading bays also cause follow-up problems for the truck drivers, because it becomes difficult to meet the schedule for the next stops. Breaks that are required by law might end up not being taken (Bundesamt für Güterverkehr, 2011).

In the results of the face-to-face and group discussion it can be seen that aspects concerning social dimensions and pressure exerted on the drivers is not part of the warehouse operators concern. In turn road haulers not only have to face the economic losses, but especially the reputation of the work of the drivers suffers – making it harder to attract good drivers (Borgström, Hertz and Jensen, 2014).

4.4 Limitations

This study is limited to nine companies yielding thirteen interview partners from different professions of the logistics sector and thus provides a very limited view into this process. Especially because road hauler companies were not available for an interview. Moreover international literature on this topic is very limited. The findings as well as studies by Hagenlocher, Wilting and Wittenbrink (2013) and Borgström, Hertz and Jensen (2014) on the other hand show how difficult it is to expand corporate social responsibilities programs down to this level, hence a more intensive study is necessary.

5. Conclusion

Truck loading docks efficiency and sustainability directly influence the performance of warehouse operators and road haulers. The implications of unplanned delay are known to all participants. The companies are aware of sustainability concepts and the prospect of customers demanding a triple bottom line or sustainable supply chain model across the whole supply chain. Economic and respectively efficiency as the main drivers for this specific interface do not fully satisfy a sustainable approach. A best practice concept for loading dock procedures is not known. Operators of loading docks must think outside their company in order to generate new concepts; it will not be enough to optimize the inside process.

Future approaches should enforce closer cooperation between the trucks on the road and their destination. This can happen through automated systems using recent digital technology. The available information and required exchange of information will help the companies participating in the supply chain to adjust. Changes not only for profit, but also for optimizing plans regarding environmental aspects, for example by choosing different routes.

Regarding social sustainability, especially as a part of corporate social responsibility efforts and in terms of job attractiveness, freight forwards as well as road hauling companies, increasingly will have to include the needs of the drivers in their concepts in a way that goes beyond acknowledging it.

6. Further Research

In a next step it is intended to derive a management approach and best practice catalogue on how to implement loading docks such that the needs of different stakeholders are accounted for. In the light of the imbalanced power, future investigations should take a look at possible collaboration models for these kind of relationships, investigating which key performance indicators companies could use and which incentives each site can offer in order to gain a competitive advantage.

Disclosure

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How to Attract Air Freight Business: Defining Critical Success Factors for Regional Airports

David M. Herold, Simon Wilde and Natalie Wojtarowicz

Abstract

Much less is known about the numerous smaller airports that collectively comprise the majority of aviation networks. A process of deregulation has left small Australian airports in the hands of local governments, with as many as 50 per cent are reporting an operating loss each year. The integration of an air cargo sector and establishing a freight value proposition can add a competitive advantage to a regional airport. Airports such as Memphis, Louisville or Dubai have grown through their close relationship with global cargo companies (like FedEx or UPS), or through manufacturing companies moving closer to the airport. Accordingly, the ability to attract carriers and air cargo traffic is crucial to the establishment of a transport and logistics hub An airport with an emerging freight hub is therefore likely to experience substantial economic growth from the freight industry, not only for the airport itself, but also for the host region.
There is little research on regional airports, however the literature suggests that the most important points of attracting air freight as external factors and are outside the airport's influence. There is a need to create demand by the development of important industry clusters around airports. This means an involvement of third parties to develop the airport and its region to achieve appropriate levels of market demand and drive down the (lack of) economics of scale. The aim of this paper is to give an overview about the literature and describes in which environment Australian regional airports currently operate.

Keywords: sustainability, regional airports, air freight, success factors

Foreword

This paper represents an early stage of my PhD research. As outlined below, the aim of the paper is to describe the current framework in which Australian regional airports currently operate and how Australian regional airports can attract air freight carriers to create an additional revenue stream. The literature review reveals six major points to describe/analyse the current situation:

- Australian context – deregulation of airports
- Ownership and Governance – regional development
- Regional and airport development
- Airport Management Efficiency
- Airport Structure
- Creating a freight value proposition

The aim of this paper is to give an overview about the literature and describes in which environment Australian regional airports currently operate. I will give an overview about the last three points; the Australian context as well as the governance and regional economic development is beyond the scope for this paper and will be included at a later stage.

This literature review forms an integral part of my PhD studies, as it describes the problem space in which Australian airports currently operate. Furthermore, the findings of this literature review form the basis for developing the research approach and the next steps in my research. Networks play an integral role in ensuring airports are managed in a sustainable manner. The current problem area will be viewed from a network governance perspective, which also forms the conceptual framework. This research approach is used to address the management challenges faced by regional airports for the resources and expertise to make the decisions to foster economic development around regional airports and eventually attract air freight business. In this context, governance covers all aspects of airport operations that are the result of decision-making by both the airport operator (private) and administering authorities (public) including airport ownership; the commercialization and privatization of airports; consultative procedures and conflicts; airport and air transport security; legislation and policy; institutional arrangements and public private partnerships. The next steps include interviews with airports and air carriers like “Rex” to further build a comprehensive view of the problem area and to further develop the research question.

I look forward to presenting my topic at the HICL. I specifically aim for further feedback of my research, and being able to gain presentation experience at an international conference at this early stage of my PhD is an invaluable opportunity for the further progress of my studies.

1. Introduction

Australian’s regional airports play a play a crucial role in the economic and social development of the nation. Regional Australia generates 65 per cent of Australia’s export income, employs over a third of Australia’s workforce, and is home to 32 per cent of the Australian population (Albanese et al., 2008). In many parts of Australia, airports remain the only practical means of access to emergency and essential services. Regional airports facilitate personal and business travel and freight, provide access to community service not available in regions such as education and health services.

However, regional airports in Australia are perishing. According to BITRE (2013), the number of regional airports in Australia has dropped dramatically from 274 active airports in 1984 to 171 airports in 2012. As many as 50 per cent of these Australian regional airports are reporting an operating loss each year (Australian Airports Association, 2012). Donehue and Baker (2012) argue that this has been the result of a deregulated environment for all Australian airports, which has transferred the financial and economic responsibility of regional airports onto local government authorities. Furthermore, they claim that the deregulation policy shows a lack of understanding of the nature of regional airports, as there are significant differences in the business orientation and structure of regional airports compared to those of much larger airport operations, such as those located in the vicinity of capital cities. As a consequence, local government authorities are facing serious challenges with respect to fulfilling the management and development of regional airports in an economic sustainable manner given that they are often lacking in financial and human resources (Donehue and Baker, 2012).

Given the importance of regional airports and the increasingly dire financial situation in which they find themselves, regional airports need to look for ways to diversify their revenue streams (Deloitte Access Economics, 2012). Major airports such as Memphis, Dubai as well as regional airports such Glasgow Prestwick have grown through their close relationship with global freight companies (like FedEx or UPS) or through manufacturing companies moving closer to the airport (Conway, 2000, The Economist, 2013).

The air freight industry has undergone considerable growth over the last two decades and is expected to grow even more. The expected growth of passenger traffic internationally is forecast to reach 6.7 billion by 2032 with an annual grow rate of 4.7%. The volume of global air freight is expected to outperform the passenger market with a annual rate of 4.8% (2012-2032). The Asia Pacific region is forecast to grow the most, averaging 5.5% per annum (Airbus, 2013).

The integration of an airfreight sector and establishing a freight value proposition has the potential to add a competitive advantage to a regional airport (Button and Yuan, 2013). In order to achieve this, the ability of a regional airport to attract carriers and air freight traffic is crucial to the establishment of a transport and logistics hub at a regional level. Kasarda and Green (2005) argue there is an established correlation between levels of air freight volume, GDP and national and regional economic development. An airport with an emerging freight hub is therefore likely to experience substantial economic growth from the freight industry, not only for the airport itself, but also for the host region.

There is little research on how to attract air freight, particularly on regional airports. Gardiner et al. (2005) identified a three-stage process of air freight carriers' factors when choosing an airport. The first stage concentrates on external factors; either the location or the market has a strong demand for freight services, the market is stipulated by a customer with a base load (such as high-value industry clusters) or is centrally located and can be operated as a hub. Similar to Gardiner et al. (2005), a report of TAWG (2012) considers the most important points of attracting air freight as external factors and outside the airport's influence. Thus, the most critical point is that airlines or air freight carrier will only decide to fly to a region if there is a business case to do so (TAWG, 2012). There is a need to create demand by the development of important industry clusters around airports, which translates into further air freight demand at the respective airport (Hudson Howells, 2012). This means an involvement of third parties to develop the airport and its region to achieve appropriate levels of market demand and drive down the (lack of) economics of scale.

The aim of this paper is to describe how Australian regional airports can attract air freight carriers to create an additional revenue stream. The literature review reveals six major points to describe/analyse the current situation:

- Australian context – deregulation of airports
- Ownership and Governance – regional development
- Regional and airport development
- Airport Management Efficiency
- Airport Structure
- Creating a freight value proposition

In this paper, an overview about the last three points (point 1: airport management efficiency; point 2: airport structure; point 3: creating a value proposition); the Australian context as well as the governance and regional economic development is beyond the scope for this paper and will be included at a later stage.

First, airport management efficiency and structural differences between regional and major airports will be explored. This includes a description of airport management capability approaches an analysis of revenue streams and operational activities. A third step will introduce the creation of a freight value proposition as a potential revenue stream. Attracting air freight carriers is a complex process and involves not only the regional airport's operational capabilities, but also – and more importantly – strategic cooperation with regional economic development initiatives to develop the airport.

There is very little published research about regional cooperation with regard to regional airports, particularly that relating to the air freight sector. Further investigation into this area is needed, particularly beyond the scope of airport and local government organisational boundaries.

This literature review forms an integral part of my PhD studies, as it describes the problem space in which Australian airports currently operate. Furthermore, the findings of this literature review form the basis for developing the research approach and the next steps in my research. Networks play an integral role in ensuring airports are managed in a sustainable manner. The current problem area will be viewed from a network governance perspective, which also forms the conceptual framework. This research approach is used to address the management challenges faced by regional airports for the resources and expertise to make the decisions to foster economic development around regional airports and eventually attract air freight business. In this context, governance covers all aspects of airport operations that are the result of decision-making by both the airport operator (private) and administering authorities (public) including airport ownership; the commercialisation and privatisation of airports; consultative procedures and conflicts; airport and air transport security; legislation and policy; institutional arrangements and public private partnerships. The next steps include interviews with airports and air carriers like "Rex" to further build a comprehensive view of the problem area and to further develop the research question.

2. Airport Management Efficiency

Although there are a wide range of airport efficiency benchmarking studies for large airports and in particular hubs, much less has been investigated at the local and regional level. A significant relationship has been found between levels of efficiency and airport size in the airport benchmarking literature. Sarkis (2000) compares hub airports from the US with non-hub counterparts using data envelopment analysis models and presents evidence of higher efficiency levels at hub airports. Oum and Yu (2004) conclude that larger airports achieve higher efficiency scores based on a variable factor productivity analysis of 76 airports around the world. Assaf (2009) applies a stochastic frontier analysis to two groups of airports in the UK and shows that the large airports are technically more efficient. Yoshida and Fujimoto (2004) analyze Japanese airports through data envelopment analysis and endogenous weight total factor productivity and conclude that the regional airports in Japan are relatively less efficient.

Carney and Mew (2003) describe three management capability approaches to increase efficiency on different levels: operational, project driven and strategic management.

Operational management capabilities are focused upon increasing the efficiency and quality of airport processes. Generally, the profit potential from management contracting lays in more efficient utilization of existing assets and through attention to cost reduction. Project management capabilities focus upon the renewal or addition of new physical capacity, such as terminals and runways, or technical systems. Project managers need an international orientation and skill in identifying the profit potential of various tenders. In addition to profitability the evaluation of management performance is assessed in terms of project realization, timeliness, and budget variances. Many of the benefits of governance reform stem not from cost reduction or increased capital investment, but from the application of a commercial mentality to the entire airport enterprise. In the airport business this means balancing public service and commercial development goals. To induce a strategic management mentality in airport managers, the state must devolve operational, financial and strategic planning autonomy (Carney and Mew, 2003).

For major airports, a strategic management approach seems able to deliver balance among conflicting and competing stakeholder claims on airport resources. Assaf (2010) found that Australians major airports improved efficiency post privatisation. This in line with Carney and Mew (2003), who observed a describe a average real decrease in service charges of 8% per annum in the first 5 years after privatization. Moreover, quality of airport service is closely monitored and standards have been maintained or increased. Melbourne and Brisbane airports have increased revenue per employee by an average of 33%. According to Adler et al. (2013a), it would appear to be preferable to outsource many of the activities necessary at an airport, including ground-handling, fire services, ambulance services, fueling, cleaning, security, car parking and snow removal. Those observed who undertake ground handling or fueling services in-house are 3% to 6% less efficient on average than those who outsource the activities.

Adler et al. (2013b) argues the relative inefficiency of smaller airports may be explained by low traffic demand relative to the minimum infrastructure necessary to produce safe and secure traffic movements. The likelihood of price regulation, public ownership and subsidy requirements are likely to impact small regional airport managerial efficiency as compared to larger airports. As a result the costs incurred per movement are substantially higher than their larger airport counterparts.

3. Airport Structure

There are significant differences in the business orientation of regional airports and that of much larger airport operations. Compared to major airports, regional airports face an infinitely higher financial pressure due to a different operational structure. According to Deloitte Access Economics (2012), 30% of total costs are attributed to payments to labour on average on major and regional airports, which reflects the high capital intensity of the airport industry.

Component of non labour cost	Major airports	Regional Airports
Services and utilities	24%	20%
Other operational costs	21%	25%
Property and maintance	23%	28%
Recoverable security costs	16%	2%
Regulation and compliance	4%	12%
Other costs	11%	12%
Total	100%	100%

Tab. 1: Non-labour cost structure by airport size, source: Deloitte Access Economics, State of Industry Survey 2012

Due to the airport's role as transport infrastructure asset, and in some cases a commercial and business precinct, there are considerable capital related operational costs. Moreover, the non-labour cost structure does not vary greatly across major and regional airports, as depicted in Table 1.

Taking into account the non-labour costs, the main three differences between major and regional airports are observed for security costs and regulation and compliance as well as for maintenance and operational costs (Deloitte Access Economics, 2012).

At major airports, security costs represent with 16 per cent a high fixed cost associated with airport operations. Smaller regional airports typically have lower levels of passenger throughput or commercial activities, reducing the level of mandated security into a marginal liability. In contrast, regional airports spend a greater share of resources complying with relevant regulations, including mandatory audits and inspections. On average major airports attribute only a small portion of the total expenses for regulation and compliance purposes. Regional airports, on the contrary, spend around three times more than larger airports (Deloitte Access Economics, 2012).

However, the most important differences why regional airports face considerable financial pressure are the maintenance and operational costs, which considerably differs from that of larger ones.

While the maintenance and operational cost requirements for regional airports are often modest, it represents more than half of all non-labour costs. Whereas major airports face relatively lower maintenance and operational costs, these costs are the main trigger for the operational losses of regional airports, as they typically lack the scale to ensure they can be financially self-sustaining (Deloitte Access Economics, 2012). Adler et al. (2013b) follows the same argument that the low utilization of the fixed infrastructure facilities results in higher average costs per unit of output than at larger airports.

The other part of the airport structure are the revenue streams: revenue streams at airports are usually classified in two forms: 'aeronautical' and 'non-aeronautical' (Australian Airports Association, 2012; Deloitte Access Economics, 2012). In broad terms, the aeronautical side of the business is made up of the fees paid for core airport-related activities such as the provision of runways and traffic operations, terminals, passenger and cargo fees, security, hangar charges and the costs associated with staff. In detail, passenger related fees represent more than half of aeronautical revenue for major airports, followed by the landing fees. This brings the share of both to almost 70 per cent of all aeronautical revenue (Deloitte Access Economics, 2012) as shown in Table 2. Whilst these numbers are representing major airports only, passenger related fees are also the primary source of revenue for regional airports (Baker and Donnet, 2012).

On the other hand, non-aeronautical revenues stem from activities undertaken in addition to an airport's operational requirements, e.g. parking, retail and office lease. The breakdown is shown in Table 3.

Landing fees	Passenger related fees	Rental for hangars	Aircraft parking	Aeronautical security recovery	Fuel levy	Other	Total
14%	54%	8%	2%	12%	1%	9%	100%

Tab. 2: Aeronautical revenue structure of major airports, source: Deloitte Access Economics, State of Industry Survey 2012

Retails lease	Office lease	Parking	Landside transport charges	Other	Total
21%	18%	26%	15%	20%	100%

Tab. 3: Non-aeronautical revenue structure of major airports, source: Deloitte Access Economics, State of Industry Survey 2012

More importantly, the report on Australian airports from Deloitte Access Economics (2012) also reveals a different structure of aeronautical revenue and non-aeronautical revenue streams between major and regional airports. At major airports in Australia, almost half of total revenue is derived from non-aeronautical sources, whereas the share at regional airports accounts only for one-quarter (see Figure 1).

According to Hudson Howells (2012), regional airports have attempted to follow the trend of major airports by creating non-aeronautical revenue streams; however, the opportunities at regional airports are more limited. Given the above business structure, regional airports tend to focus on principal transport infrastructure performance. The smaller economic and passenger base in these areas also make retail and hospitality offerings less viable. Regional airports suffer from the necessarily small scale of operations which impact average costs per unit of output and reduce the opportunities for commercial revenue generation (Adler et al., 2013b).

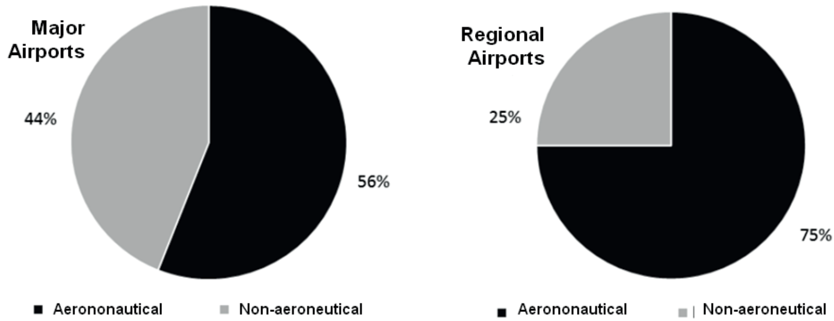

Fig. 1: Sources of revenue at Australian airports, source: Deloitte Access Economics, State of Industry Survey 2012

In the above section, the broad framework in which regional airports currently operate was identified. The following section will introduce the creation of a freight value proposition as a potential revenue stream and analyse the critical factors to establish such a proposition, particularly with regard to regional cooperation.

4. Creating an additional revenue stream via a freight value proposition

In view of the economic uncertainty facing regional airports in Australia, airport managers are looking for ways to diversify their revenue streams (Deloitte Access Economics, 2012). From an aeronautical view, major airports such as Memphis, Louisville or Dubai have grown through integrating freight companies into their operations or through building industry sectors close to the airport (The Economist, 2013). Button and Yuan (2013) argue that attracting air freight and creating a freight value proposition can add a competitive advantage to a regional airport and generate an additional revenue stream. Furthermore, Kasarda and Green (2005) add that an airport with an emerging freight hub is

therefore likely to experience substantial economic growth from the freight industry, not only for the airport itself, but also for the host region.
The air freight industry has undergone considerable growth over the last two decades and is expected to grow even more. The expected growth of passenger traffic internationally is forecast to reach 6.7 billion by 2032 with an annual grow rate of 4.7%. The volume of global air freight is expected to outperform the passenger market with a annual rate of 4.8% (2012-2032). The Asia Pacific region is forecast to grow the most, averaging 5.5% per annum (Airbus, 2013).
This demand can be further fuelled by the development of important industry clusters around airports, which translates into further air freight demand at the respective airport. There is little research on how to attract air freight, particularly on regional airports. Attracting air freight carriers is a two-way process. First, the operational capabilities, which can be seen as internal factors, should match the air freight carrier needs. Second, and more importantly, it is crucial that airports understand what drives the air freight carrier and how their destination, market profile and infrastructure will fit in the air cargo carrier's framework and strategy (TAWG, 2012). Most of these points are outside the airport's influence and can be considered as external factors. A report from TAWG (2012) indicates that government at all levels can assist regional airport growth through the involvement of economic development agencies, industry and partners, and developing policy frameworks that enable tailored local solutions dependent on the airport's needs, particularly in respect of the size of infrastructure required.

5. Conclusion

Regional airports play a critical role in regional Australia. However, as many as 50 per cent of regional airports are financially at risk. Furthermore, local government authorities, who own most of the regional airports, are unable to cope with the current challenges. The deregulation of airports and airport policy focuses primarily on major airports, while regional airports play only a marginal role for the regional economic development (Department of Regional Australia, 2013). This policy shows a lack of understanding about the different structure of regional airports, as the costs for maintenance and operations are relatively and considerably higher for regional airports compared to major airports and are not financially sustainable. Introducing a freight value proposition at regional airports in Australia could have the potential to create an additional revenue stream. Major airports as well as regional airports have benefitted from attracting air freight carriers and building industry clusters close to the airport. For regional airports, attracting airlines is a critical issue; however most of the factors underpinning why airlines choose an airport are outside the airport’s influence. Further investigation in that area is needed, particularly beyond the scope of airport and local government organisational boundaries.

This literature review forms an integral part of my PhD studies, as it describes the problem space in which Australian airports currently operate. Furthermore, the findings of this literature review form the basis for developing the research approach and the next steps in my research. Networks play an integral role in ensuring airports are managed in a sustainable manner. The current problem area will be viewed from a network governance perspective, which also forms the conceptual framework. This research approach is used to address the management challenges faced by regional airports for the resources and expertise to make the decisions to foster economic development around regional airports and eventually attract air freight business. In this context, governance covers all aspects of airport operations that are the result of decision-making by both the airport operator (private) and administering authorities (public) including airport ownership; the commercialisation and privatisation of airports; consultative procedures and conflicts; airport and air transport security; legislation and policy; institutional arrangements and public private partnerships. The next steps include interviews with airports and air carriers like “Rex” to further build a comprehensive view of the problem area and t further develop the research question.

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Early Supplier Integration in Cast Product Development Partnerships – A Multiple Case Study of Environmental and Cost Effects in the German Foundry Value Chain

Robert Christian Fandl, Tobias Held and Wolfgang Kersten

Abstract

Companies have to take sustainability into consideration, nowadays. This paper analyses the impacts of environmental and cost effects on product development partnerships in the German foundry value chain. The starting point of the paper is a survey conducted in the period, end of 2012 / beginning of 2013, covering supplier and customer integration issues on the interfaces of casting houses and their clients, in which all German foundries and customers from diverse sectors of the machine-building industry have been contacted. Based on the results, the authors collected in-depth data, via semi-structured interviews, for several complex product development projects, in order to analyse how suppliers were integrated by their customers during casting development. By analysing cross-case differences, this paper explores how environmental and cost effects impact product development partnerships. It presents a multiple case study analysis, covering four new cast product development cases of one German foundry which deals with four different machine building customers. It is shown that customer-supplier relationships appear to be related to different integration practices. The results demonstrate the substantial impact of environment and cost effects on customer-supplier relationships, and help to understand how sustainable product development partnerships should be configured, while taking the particular situation into account.

Keywords: product development partnerships, supplier relationships, environmental and cost effects, foundry value chain

1. Introduction

Collaboration between suppliers and customers in new cast product development has environmental advantages and cost effects. Traditionally, the lowest price has been the dominating supplier choosing criteria in the foundry value chain, but the industry is, to some extent, moving towards a more collaborative approach (Institute of Foundry Technology, 2014; Eisto et al., 2010). Fig. 1 shows the framework of cast development partnerships.

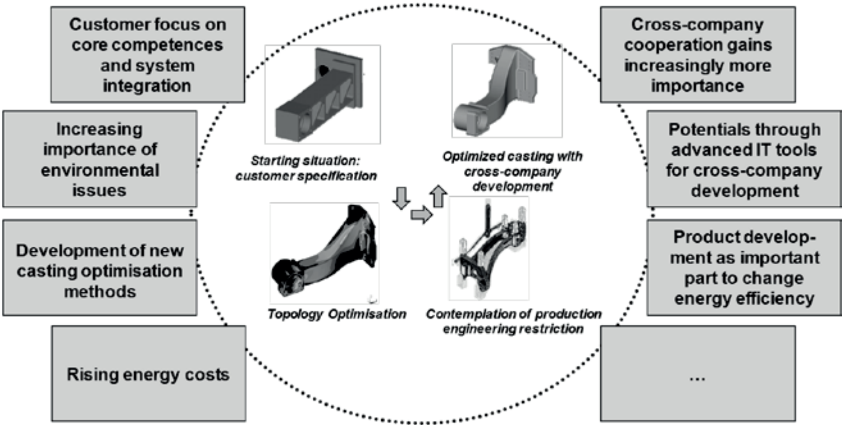

Fig. 1: Framework of cast development partnerships

In Germany, sustainability aspects are gaining increasingly more importance (against the background of increasing worldwide demand for raw materials and energy) and production is increasingly sub-contracted to low cost countries (Kuchenbuch, 2006; Vieweg and Wanninger, 2010; Kupec, 2011; Fandl et al., 2013). German foundries with high labour costs cannot compete on price alone in many cases, but they can compete with product development partnerships covering, for example, different sizes of cast production series, providing ready-to-install casting components (Saarelainen et al., 2007; Thiele and Janjis, 2013). Historically, several methodologies have been developed for evaluating, selecting and integrating suppliers in new product development (e.g. Ellram, 1987; Kamath and Liker, 1994; Peter, 1996; Petersen et al., 2005; Kirst, 2008; John, 2010), which take into account factors such as project times, product quality and project costs. However, the importance of environmental effects in the foundry value chain has been neglected.

2. Theoretical framework

2.1 Empirical survey – an overview

For period, end of 2012 / beginning of 2013, a survey was conducted which covered supplier and customer integration issues at the interfaces of casting houses and their customers. Experts from sales, product development, and management from all German iron and non-ferrous metal foundries were contacted for this comprehensive survey. A total of 1.156 potential participants were reached, from which, 215 participants successfully fulfilled the survey, which represents a response rate of 18.6%. This substantial coverage allowed generalizations to be made, together with a differentiated analysis.
One part of the survey included the current status of certifications; 87% of the foundries are certified by the DIN EN ISO 9001 standard. This standard is the foundation of further certification efforts of many companies in the foundry supply chain. Due to increasing importance of environmental aspects, DIN EN ISO 14001 (an environmental management standard), becomes increasingly more common (Fandl et al., 2013). Currently, this standard is implemented in less than half of all German foundries. The share of certified foundries, according to DIN EN ISO 50001 / EN ISO 16001, which is currently not present at very small companies of <50 employees, is significantly dependent on company size and the respective industrial sectors of their customers (Fig. 2).

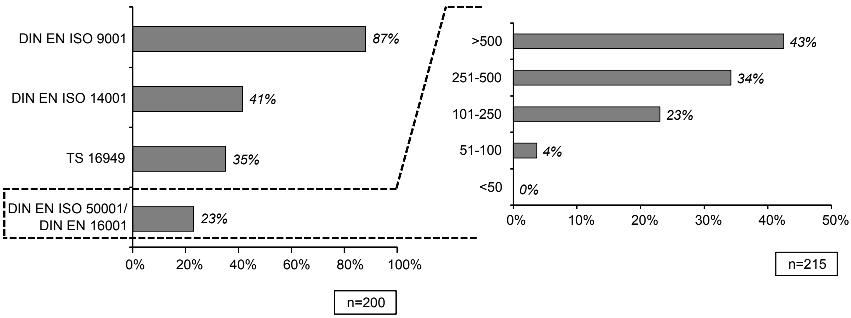

Fig. 2: Certificates of German foundries and split of DIN EN ISO 50001 / DIN EN 16001 certificated companies by size

The empirical survey confirmed that computer-aided design (CAD) software is widely used during cross-company product development projects; however, in many cases, companies use their development tools independently. The sharing of company-specific resources and applied knowledge need to be promoted systematically. Issues are often, the lack of systematic procedures and related challenges arising in the context of product development partnerships. The consideration of interfaces and coordination processes in the product development process plays an increasingly more important aspect in this context. According to the feedback of the respondents, considerable improvement potentials, such as reduction of weight, development time and development costs, as well as improvement of casting functionalities, still exist. The results of the survey reveal that most methods for process improvement, regarding ecological aspects, are currently related to the production area and less to development activities (Fandl et al., 2013). An evaluation of collected free texts identified the following areas with most foundry projects: introductions of energy management systems, heat recovery procedures and investment in more efficient furnaces and exhaust systems. Figure 3 reflects the connection between ecological aspects and collaborative product development. The majority of respondents were convinced that positive effects concerning ecological aspects could be achieved by working in a more integrative manner

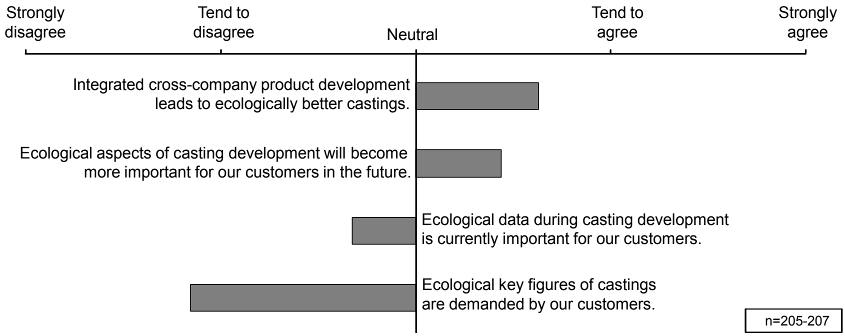

Fig. 3: Cross-company product development and ecological aspects

with their clients during casting development. The survey participants also claimed that, from their customer's point of view, environmental aspects would be a more important supplier selection criterion in the future (cp. Humphreys et al., 2003). However, ecological aspects are, currently, not considered extensively by foundry customers – most customers expect no statements or key performance indicators concerning environmental aspects from their suppliers.

Only 39% of all foundries had to provide ecological key figures to their customers. If the customers considered ecological aspects during casting development, about 89% of them were interested in energy consumption, 56% in information about CO2-emissions and only about 20% in indicators for water consumption (Fig. 4).

Ecological aspects are considered by the majority of respondents, but the importance is rated lower in casting development in relation to the production area. Furthermore, adequate assessment methods were often missing. Regarding ecological aspects, most consideration is spent on energy consumption and CO2-emissions. In summary, based on the empirical survey, it could be derived that ecological aspects are playing an increasingly important role (cp. Fandl et al., 2013).

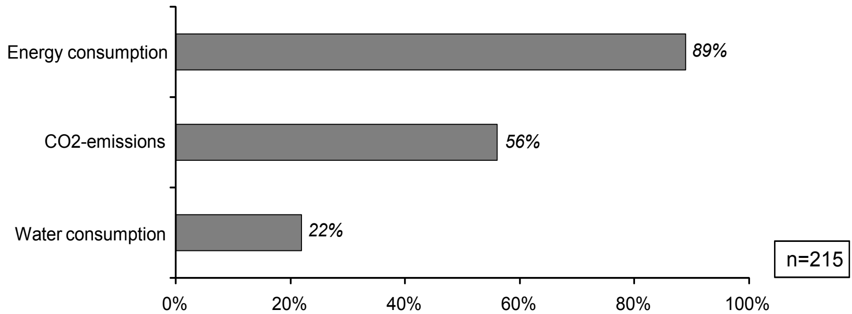

Fig. 4: Ecological data provided by foundries during casting development

2.2 Ecological aspects in the foundry value chain

Over the last decades, increasing attention has been drawn to the expected severe effects of global warming (WMO, 2013). The increasing concern puts pressure on companies to reduce their environmental impacts, not only for a particular branch of industry, but for entire supply chains (UNEP, 2012). This is evident from the trend that companies are, increasingly, being held responsible for environmental problems caused by their suppliers (Koplin et al., 2007). According to the World Energy Council, energy costs currently comprise of about 10% of the cost of manufactured products, and that this percentage could escalate to as much as 25% in the next 10-15 years (Robison, 2011).

The industry in Germany is responsible for more than 40% of total energy consumption (Neugebauer et al., 2008). The foundry industry is especially energy intensive. As a consequence, energy savings play an important role for the profitability and sustainability of every German foundry (Trauzeddel, 2009). More than 70% of energy consumption in an iron foundry is in the area of metal melting, molten metal handling and pouring (Institute of Foundry Technology, 2013; Bührig-Polaczek et al., 2014). Although melting is the biggest point of consumption (industry estimates indicate it is approximately 55% of the typical metal caster’s costs), many points of energy use present opportunities to reduce costs, significantly (Fig. 5). Following the principle that “only the measurable is manageable", the need for a standardised, consistent, and quality-assured tool for measuring and assessing the environmental and cost effects of new cast product development becomes evident.

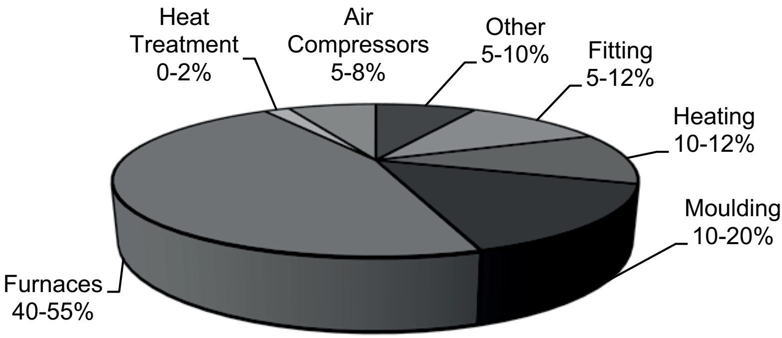

Fig. 5: Energy consumption of German iron foundries (Bosse, 2012)

2.3 Development of an IT-tool to assess environmental and cost effects

Previous literature presents several approaches for foundries to deal with environmental issues (Spall, 1997; Huppertz, 2000; Rebhan, 2001; Kuchenbuch, 2006). Based on these starting-points, an in-depth analysis of a German iron foundry was performed. As a result, an information technology (IT) tool, for the calculation of environmental and cost effects, has been created, based on the following data:

- Castings (technical product data for each individual casting)
- Installed operating resources
- Electrical energy consumption for all these individual machines and equipment (e.g. induction furnaces, motors, compressors, pumps, lighting)
- Consumption of commodities (such as natural gas, sand, binder, water)

The IT-tool contains information about the energy consumption of all the machines and technical equipment (282 individual energy-using operating

resources were covered with their load, efficiency and energy consumption) and the costs for each manufacturing process step (e.g. melting, core making and moulding, finishing) were investigated. Input parameters for the calculation are casting details, such as material, weight, number and volume of the cores and pulse time. Figure 6 shows an excerpt of a screen shot of the processes step “finishing” (covering e.g. cast fitting). Undercuts and size of the component are, especially, considered for this calculation.
This tool was used to analyse casting designs that were created by customers without the involvement of casting supplier know-how (“initial customer drawings/specifications”) as well as casting designs that have been created jointly with supplier input (“supplier integrated specifications”).

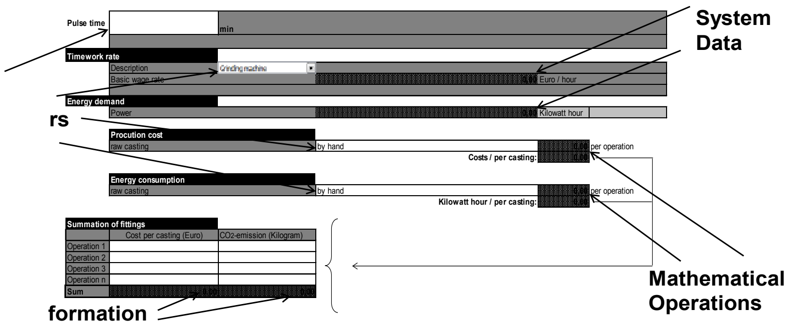

Fig. 6: A screen-shot extract of the IT-tool developed for casting part assessments

3. Research design

The research design used in this paper is a case study analysis, which explores and analyses multiple case studies. The research was designed by applying Yin’s (2003) case study principles. The ongoing research included several cases of new cast product development projects, from which four embedded cases were selected for this paper. These four comparative cases were studied to allow for in-depth understanding (McDonough, 2000) and theoretical replication (Eisenhardt, 1989; Miles and Huberman, 2014).

The case foundry is a medium-sized German iron foundry with a casting development department. The manufacturing process in the case foundry is sand casting and the foundry is certificated by DIN EN ISO 9001 and DIN EN ISO 50001 standards. The four customer companies covered are medium- and large-sized companies of the machine building industry. All the research and development (R&D) departments of the companies are located in Germany.

For this paper, the basic data were gathered by document analyses and direct involvement of, and discussions with, experts of the four development projects (Fig. 7).

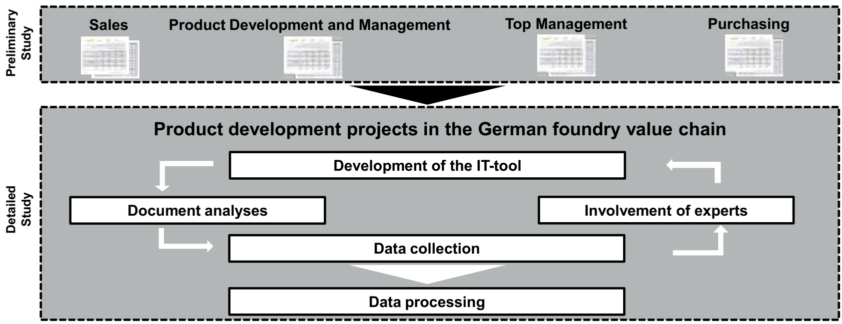

Fig. 7: Research design – an overview

A document analysis is a data collection procedure to collect data, which is already present in written (or digital) form (Prior, 2003). In this research, the collaboration process was defined to begin when a customer contacts the case foundry for the first time, concerning a new cast development project, and to end when the foundry delivers the development report with the final technical drawings and specifications.

The document analyses used the following data:

- Development requests
- Development contracts
- Company profiles of development partners
- "Activity profiles" of the people involved in the development project (e.g. analysis of all project e-mails)
- Technical specifications and drawings (in particular: detailed analysis of all changes in computer-aided design (CAD)-models during project time)
- Interview protocols and status reports
- Final development reports

The documents (CAD-models, specifications, etc.) analysed were complemented with interviews of experts involved from all customers and the casting house. The interviews were semi-structured to be able to capture each case-specific characteristic and to allow for cross-case comparisons. Twelve customer respondents were interviewed face-to-face and the interviews were transcribed (Rubin et al., 1995). These customer interviewees represented purchasing, sales, manufacturing and R&D members. Interviewed people in the case foundry represent top management, sales and R&D.

Following the results of the documents analysed and the interviews conducted with the experts, the data were analysed in two steps (Mayer, 2013). Firstly, the individual case was analysed on a stand-alone basis, in order to highlight the unique patterns of the particular case. Secondly, these patterns were compared with patterns found in the comparative cases, in order to highlight cross-case patterns and differences.

4. Four new cast product development cases

In this section, the four cases are described by discussing, for example, customer company size. For each case, the project studied is first presented (i.e. background, execution and results), and then the section ends with an overview of the projects studied.

4.1 Case 1: TORQUE ARM

This new cast development project was made in the field of “Drive and Control Technology”. The customer is one of the world’s largest companies in this field with over 37.500 employees. The headquarters are in Germany and the company is certified by the DIN EN ISO 9001 and DIN EN ISO 14001 standards. The casting supplier is located over five hundred kilometres away. The customer´s R&D department has more than five hundred employees; but less than ten of the R&D employees have a foundry background. The company uses up-to-date CAD software, finite element method (FEM) calculation tools and extensive project planning software.

The development project started in November 2011 and ended in April 2012. It was the first new cast development project with the case foundry. The customer integrated the case foundry in the development phase and provided a preliminary drawing (3D model), geometric dimensions, and material specifications, as well as further specifications at the first contact. Starting material was “EN-GJS-400” and the casting weight (raw casting) was approx. 1.520 kilograms. The casting is highly complex compared with other casting development projects, due to extensive free-form surfaces. The communication between the customer and the casting house R&D team was, mainly, undertaken via e-mails, on a regular basis. Communication via telephone was only employed occasionally. Limited secured extranet communication was used during the entire project. The customer´s employees visited the case-foundry more than three times.

The project results were, to some extent, unexpected: The material was maintained in a uniform manner, but one additional core was added to the casting process. The customer goals were achieved due to weight reduction, production cost reduction and details of the casting part (e.g. improved stiffness).

4.2 Case 2: PINION

This new cast development project was performed in the field of the “machine and manufacturing systems industry”. The customer has more than 4.000 employees, worldwide, and is certified by DIN EN ISO 9001 and DIN EN ISO 14001 standards. The casting supplier is located approx. eight hundred kilometres away. The customer´s R&D department consists of circa one hundred and fifty employees who use standard CAD software and a FEM calculation tool.

This case started in July 2012 and ended in October 2012. It was the second new cast development project with the case foundry. The casting house was integrated during the concept phase: the customer provided a drawing (3D model), geometric dimensions, load information and specifications. At the beginning of the project, the starting material was “EN-GJS-400” and the casting weight (raw casting) was approx. 1.350 kilogram. This cast part case is more complex, compared with average new cast product development projects of this company, due to the geometric shape and dimensions. The communication during the project was constantly by e-mails. The phone was only used occasionally. The customer did not visit the case foundry, during the entire project period.

The project results were rated as outstanding by the customer, as well as by the casting supplier. The customer has involved the iron case foundry in their concept phase, achieving fast project times, better product quality and lower product costs.

4.3 Case 3: MACHINE BED

Case 3 covers an engineering firm (focusing on printing and paper technology) located in Northern Germany (around one hundred and twenty kilometres from the casting supplier). It is a, relatively, small sized customer with around 120 employees. The company is not certified. The R&D department consists of only two employees using standard CAD software.

The development project of this case started in July 2012 and ended, rapidly, two months later. The customer relationship is one of the longest of the investigated case foundry: This supplier-customer relationship involved more than ten development projects in recent years. The customer integrated the case foundry in the development phase and provided a drawing (3D model), geometric dimensions, material specifications and further specifications (e.g. the required attenuation properties) at the first contact. Starting material was “EN-GJL-350” and the casting weight (raw casting) was 1.982 kilograms. The part is less complex, compared with the “TORQUE ARM” and “PINION” case parts. The communications were, occasionally, via e-mails and, rarely, by phone. The customer did not visit the case foundry during the project period.

The result was an optimised casting with internal core sand. The customer target for weight reduction was reached, but one additional core had to be added.

4.4 Case 4: CAST TAPPET

The last new cast development project covered of this paper, was made in the field of “machine and manufacturing systems industry”. This project was started by a medium-sized customer, with around 200 employees. This company is certified by the DIN EN ISO 9001 standard. The casting supplier is located less than 50 kilometres away. The customer´s R&D department consists of five employees and they used CAD software and a FEM calculation tool.

The case started in October 2011 and ended in December 2011. It was the fourth new cast development project, with the iron case foundry as development partner. Already, during the idea phase, the supplier was integrated in the development process and a drawing (2D model) and material specifications ("EN-GJS-400") were sent to the project start. Starting weight (raw casting) was 630 kilograms. This casting is similar in complexity to the "TORQUE ARM" of Case 1. The communications during the project were, constantly, via e-mails and seldom by telephone. During the project time, the customer did not visit the case foundry.

The results of the project were, partly, unexpected: the material was kept the same, but the number of cores could be reduced by four. The customer goals were achieved due to weight reduction, project cost reduction and details of the casting design (e.g. improved stiffness).

	TORQUE ARM	PINION	MACHINE BED	CAST TAPPET
Environmental management system	Yes	Yes	No	No
Geographic distance [km]	>500	>800	<120	<50
Development tools	CAD software, FEM calculation tool, project planning software	CAD software, FEM calculation tool	CAD software	CAD software, FEM calculation tool
Time line	11.2011-04.2012	07.2012-10.2012	07.2012-08.2012	10.2011-12.2011
Type of customer	New customer	Existing customer (one project)	Existing customer (over ten projects)	Existing customer (three projects)
Starting weight [kg]	1.520	1.350	1.982	630
Complexity	High part complexity	Medium part complexity	Low part complexity	High part complexity
Δ Number of Cores	+1	-3	+1	-4
Quantity [pcs.]	~10	~100	~20	~100
Integration time	Development phase	Concept phase	Development phase	Idea phase

Tab. 1: Overview of case casting development projects

5. Cross-case comparison

In this section, the supplier-customer relationships are compared with each other. In Case 4 ("CAST TAPPET"), the level of integration was deeper than in the other cases. The foundry was, already, involved in the idea phase and had the possibility of affecting design to a large degree. Previous studies suggest that early supplier integration could bring advantages in a relationship, such as speeding up the new product development process, decreasing costs, and improving the product itself (cp. Handfield et al., 1999; Petersen et al., 2005; van Echtelt et al., 2008). Of all customers, the experts interviewed agreed that early supplier integration could improve castings in many dimensions (cp. Schmidt, 2009) – specifically to reduce weight, development time and development costs as well as help achieve improved functionality of castings. For example, one development engineer interviewed at the customer in the “PINION” case, noted that, collaborative design helped reduce weight in the concept phase to a degree not possible with only in-house tools and know-how.

Over a period exceeding ten years, the case foundry has delivered several projects to the customer "MACHINE BED". In Case 3, the customer ("MACHINE BED") had requested the case foundry to take responsibility for a lower complexity of the casting in comparison to prior development projects.

The complexity of the manufactured castings seems to correlate with the CO2-savings, as well as the amortisation of development cost by production cost savings for the cases analysed (Tab. 2). “Early supplier integration is most effective when implemented designing complex components” as a R&D member of case “CAST TAPPET” stated. Based on the assessment made, a very high reduction in CO2-emissions was achieved in Case 2 (e.g. due to low casting expertise of the customer). But, also for Cases 1 and 3, a substantial level of casting part improvement, due to integrated cross-company development, could be achieved.

Another part of this research focused on cross-company development tools which were being implemented. Table 1 illustrates that all the supplier-customer relationships used 3D-CAD software. Additionally, in Cases 1, 2 and 4, FEM calculation tools were used in a cross-company interactive manner. The largest company was the only company that used project planning software for the whole project period, during the “TORQUE ARM” project.

	TORQUE ARM	PINION	MACHINE BED	CAST TAPPET
Δ-Casting weight [%]	-19.41	-30.07	-20.28	-2.38
Δ-CO2-emissions [%]	-9.74	-16.01	-10.38	-6.38
Δ-Production costs [%]	-19.07	-26.73	-15.38	-7.69
Amortisation of development costs by production cost savings	High	Very high	Medium	Low

Tab. 2: Case comparison of improvement realised

The company size difference between customers and casting houses is seen as a challenge by some interviewees, but not by all. The analysis revealed that there is a strong relationship between the level of certifications and the size of a case company: The DIN EN ISO 9001 standard is already available in mid-size companies; but, environmental standards (such as DIN EN ISO 14001) are, currently, not present at the small- or medium-sized case companies.

Additionally, customers of different sizes had different kinds of company cultures and product development process rigidities, resulting in different levels of supplier integration and communication. In the literature (e.g. Eisto et al., 2010; Monczka et al., 2000; Koufteros et al., 2007; Aune and Gressetvold, 2011), it is suggested that mutual trust, and open and frequent communication, are enabling factors in successful early supplier integration. Factors that create and nurture trust and communication are such as securing reasonable margins for suppliers, and sharing sufficient information at the first contact (Bruce et al., 1995; Chou, 2008). None of the customers allowed the case foundry to see the interfaces of their casting parts in the customer’s product or the total schedule of the overall product development project. The type of customer that a foundry has to deal with, and an industry area where a customer operates, also seem to have some influence on the relationship such as, for example, time-to-market requirements and production volume differences.

6. Conclusion and outlook

Limitations of natural resources and increasing awareness of climate changes are forcing a change of paradigms of the sustainable use of raw material and energy. The four cases that were investigated provide some insights in the current situation of early supplier integration in relationships between German iron foundries and casting customers. Based on the results of an analysis of the entire production steps of one German iron foundry, an IT-tool to assess the environmental and cost effects of casting parts was created. This tool makes it possible to calculate the CO2-emissions and production costs for each manufacturing process step for castings parts, based on their technical specifications. This tool was used to evaluate the designs of castings parts that have been engineered without involvement of casting houses, with the results that could be achieved by integrated, cross-company casting development.

Product development partnerships between casting houses and their customers seem to take different shapes and depths in German foundry supply chains. By empirically observing four new cast product development cases from the viewpoints of both the supplier and customer, we identified several mechanisms to achieve early supplier integration and improvements of ecological aspects during product development partnerships. Casting design, which has a significant effect on resource efficiency, is therefore opting for reduction in consumption, based on lightweight casting construction and a reduction of complexity. Therefore, the casting production and application of thin walls, geometrically complex castings using high strength, is a result of early supplier integration in new cast product development. In addition, the impact of product upon the environment is determined at the concept phase.

Three-quarters of the case companies are certified by the DIN EN ISO 9001 standard. Due to increasing importance of environmental aspects, the DIN EN ISO 14001 standard becomes increasingly applied. Currently, the standard is implemented in two case companies (and, also, in less than half of all German foundries). The customer interviews confirmed that CAD software and FEM tools are widely used during cross-company product development projects. Not only by interviewing customers (such as in other research studies, e.g. Handfield et al., 1999), but also by analysing actual technical drawings and specifications, considerable improvement potentials, such as reduction of weight, development time, improvement of CO2-emissions and production costs could be detected.

In summary, based on the multiple case study presented, it can be derived that ecological aspects are playing an, increasingly, important role in the foundry supply chain and that the resulting challenges could be mastered to a huge extent, by involving casting house early in the design process, in many cases.

Acknowledgements

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Sustainable Logistic Scenarios in the NSR Region

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Abstract

Freight transport between North Sea Region (NSR) countries presents high trade volumes in all Standard International Trade Classification (SITC) classes. Trade volume shifts over time depending, among others, on cost trends within the transport sector, which in turn are driven by, e.g. transport regulation. The recent EU regulations target the increase of intermodal transport in order to, among others, decrease the environmental impact of freight transport. This project provides a general approach for investigating the possible changes of transport cost within the NSR region under various future scenarios.

Firstly, three scenarios are proposed namely regulation, environment and competition scenarios which possess a different degree of including environmental cost into the transport cost calculation. After introducing the scenarios, the effects of the respective scenario on transport in terms of flows, modes and efficiencies is discussed. Secondly, generalized transport cost maps of intermodal transports scenarios (i.e. combination of road transport and short-sea-shipping) are calculated for 10 selected NSR ports/regions for the three different future cost developments. Maps are drawn which show the shift of transport costs and with this indicate the future stability of the trade flows. Thirdly, the shifts in the intermodal transport cost for the three scenarios are compared to changes in transport cost if only road transport is considered. Based on these calculations, management implications are drawn. It can be shown that establishing short-sea shipping links is cost stabilizing irrespective to the future cost development scenario if geographic distance is considered as major barrier to overcome.

Keywords: north-sea region, impedance distance, transport scenarios, intermodal transport

1. Introduction

Climate change leads to opportunities (e.g. the Northern Sea Route) as well as additional costs in the transport sector (e.g. road destruction, storm tides) due to the occurrence of more extreme weather events (Black and Sato, 2007). Some research is already conducted in order to calculate the general effects and shift in the cost structure in the transport sector considering climate change as well as to evaluate an optimal policy (Black and van Geenhuizen, 2006, Donaghy et al., 2005, Leinbach and Capineri, 2007, Rietveld and Stough, 2005). Additional to the external driven changes in the transport sector due to climate change, globalisation and market liberalization in the last decades led to an increase in trade flows which puts pressure on particular road and rail networks as well as causes pollution. Between 1970 and 2002, transport volume in the EU-15 surged about 181 percent on road networks, decreased about 16 percent on rail networks and increased about 166 percent on short-sea shipping lines. In 2010, in the EU-15 47.4 percent of goods (measured in tonne per km) are transported on roads, 39.8 percent on short-sea shipping lines, 6.8 percent by railway, 2.5 percent by pipelines and 3.5 percent by inland waterways (Leinbach and Capineri, 2007). This development is partly driven by the support of the EU for intermodal transport which includes growing unitisation (e.g. trailers and containers) within the transport sector. At the moment, the EU is intensively targeting a shift from road transport to intermodal transport in order to disburden the road networks. Moreover, it is expected that multi-user hub networks and horizontal bundling of freight transport will drive the development of the future EU transport sector (Leinbach and Capineri, 2007).

Numerous logistic models are proposed in order to organize freight resource efficient (De Jong et al., 2013). Ship transport has a potentially high economy of

scale while it offers higher fuel economy and lower emissions of harmful pollutants. Therefore, short-sea shipping is considered to be more sustainable and economically competitive than road transport (Medda and Trujillo, 2010). Recent policy of the EU seems to support this notion and a variety of research on the competiveness of short-sea shipping as part of intermodal transport was conducted in recent years (Ng, 2009). In particular the integration of ports with transportation networks serving the 'Hinterlands' seems to be one key factor in the competiveness discussion (Franc and Van der Horst, 2010, Frémont, 2008, Notteboom and Rodrigue, 2005). However, politico-economic variables have the ability to change the cost structure in this respect so that the combined transport becomes more competitive in terms of prices than road transport (Frémont and Franc, 2010, García-Menéndez and Feo-Valero, 2009) while spatial distance restricts the gains in cost efficiency of the intermodal transport by political regulations (Guerrero, 2014).
Part of the EU-Trade takes place between North Sea Region (NSR) countries. Also in this region, trade volumes shift over time depending, among others, on cost trends within the transport sector, which in turn are driven by, e.g. transport regulation. This paper provides a general approach for investigating the possible changes of transport costs in the NSR countries under various future policy scenarios. In the following, three scenarios are proposed namely Regulation, Environment and Competition scenarios. These scenarios present the background for the calculations of the changes in transport cost for 10 selected NSR ports/regions to indicate the future stability of the trade flows. Maps are drawn for each of the scenarios to present the location of cost shifts. Focus of the research is on intermodal transport, i.e. the combination of short-sea shipping and road transport. The aim is to identify critical features in the location of NSR ports which drives the transport cost structure in the NSR region and serve as basis for drawing finally management implications.

2. Methodology

2.1 Development of three different scenarios

The term scenario can be defined in many ways. In the context of this paper, a scenario defined by Ayres (1969) has been adopted '…a logical and plausible (but not necessarily probable) set of events, both serial and simultaneous, with careful attention to timing and correlation wherever the latter are salient'.

In 1995, the Danish Ministry of Transport and the Transport Council commissioned a scenario study from the Institute of Future Research in Copenhagen (Palludan et al., 1996). Based on this study report, three potential scenarios are identified to be critical for this study:

- The regulated/supra national scenario
- The environmental scenario
- The split-growth scenario

To simplify the name, the three scenarios are referred to as a*) Regulation*, *b) Environment*, and *c) Competition* scenarios hereafter. In the following, each of the scenarios is further elaborated:

2.1.1 The Regulation scenario

Referred to as the supra-national society (SUP) in Palludan et al. (1996), this scenario captures a development characterized by: "Strong political and economic integration continues within the European Union. At the same time a number of binding international agreements concerning, economic co-operation (budget co-ordinating) and the environment concerning CO2, NOx, SO2, etc. are ratified. The EU is appointed to monitor that the agreements are observed and is given authority to intervene. The transport sector is heavily regulated by the use of road pricing, making transport more expensive but less congested. Energy efficiency is central and rail and sea transport capacities are increased."

2.1.2 The Environment scenario

This scenario is a combination of an intimate society (INT) and a supra-national society (SUP), as outlined in Palludan et al. (1996). The scenario is defined as: “The family and home play a more central role in everyday life, and originality of e.g. food plays a predominate role in everyday life. Sustainability is very much in focus and each mode of transport “pays” for its own externality (full internalization). Politically, the society should also be in equilibrium, which influences both the economic, European and environmental policy.”

2.1.3 The Competition scenario

This third scenario picks up the characteristics of the market oriented society (MKT) as circumscribed in Palludan et al. (1996) and is defined as: “Europe experiences an uneven economic growth. The open market is developed with deregulation in a number of sectors such as transport and agriculture. A common agricultural policy is abandoned. The opening towards Eastern and southern Europe is primarily of an economic nature. The stabilisation of the relationship with Eastern and southern Europe is obtained through free trade and economic support, which contributes to the economic growth in the region. Transport only pays direct costs and all externalities are ignored.”

2.2 The potential effects of each scenarios

When using scenarios in transport planning, it is important to understand that each scenario not only influences all development variables, but also can have an impact on all levels of the planning process. Initially, a large number of variables were suggested to be incorporated into the analysis. However, in order to simplify by considering that not all the parameters are relevant, it was therefore decided to limit the scenarios to be described by the following three effect parameters:

- Flows (e.g. trade volumes)
- Modes (e.g. road, sea, rail)
- Efficiency (e.g. delivery time, clean tech)

The expected trend in the transport cost development depends on the combinations of scenarios and effects, which can be illustrated in a 3x3 matrix (Table 1). This extended matrix considers road transport (truck), shipping (sea), rail transport (train) as well as inland waterway transportation (inland navigations).

	a) Regulation Scenario			b) Environment Scenario			c) Competition Scenario		
	min	likely	max	min	likely	max	min	likely	max
Flows	0%	50%	100%	-25%	0%	25%	50%	100%	200%
Modes									
Truck	0%	50%	125%	25%	-25%	-50%	50%	150%	300%
Sea	-25%	50%	100%	-15%	50%	100%	0%	100%	300%
Train	0%	50%	75%	0%	50%	75%	0%	75%	150%
Inland navi-gation	0%	50%	100%	0%	100%	150%	0%	50%	100%
Efficiency									
Truck	-10%	10%	75%	10%	30%	75%	-10%	-25%	-50%
Sea	-25%	10%	50%	10%	20%	50%	0%	15%	30%
Train	-25%	10%	50%	5%	20%	50%	0%	-10%	-30%
Inland navi-gation	-25%	10%	50%	10%	20%	50%	0%	-10%	-30%

Tab. 1: Scenario Developments (General Freight Flow)

Thus, each scenario can be illustrated from three effect aspects. Due to future uncertainty, each effect is assumed to have an extreme minimum and extreme maximum value, which present the boundaries of the development. The most likely value captures the most reasonable development until 2030. These tendencies are considered to be transparent, clear and acceptable for regional decision makers, EU politicians, retailers, shippers and logistics providers. The most likely as well as the extreme minimum and the extreme maximum values in Table 1 was based on consensus and where found at a single workshop with participants from the Food Port project.

2.3 Transport cost calculation

Within the North Sea Region, there are various transport modes available for freight transport. In this research, focus is laid on the intermodal transport. In particular the combination of short-sea shipping and road transport are subject of the calculation as these are the two transportation modes which dominate the freight transport in the EU in terms of volumes (Leinbach and Capineri, 2007). In a first step, the intermodal transport cost alterations for the above-mentioned three scenarios are calculated. In a second step, the intermodal transport cost changes are compared to the road transport cost changes for the three scenarios with the help of maps.

In general, the output of the transport models can be time, cost or environmental parameters. In our model, generalised cost serves as mean to compare transport costs. In contrast to geographic distance, generalised cost (or impedance distance) is a weighted cost which includes all costs required to travel from one point to another (Sommer and Wade, 2006).

The calculation of the cost associated with the use of the intermodal transport system is based on the physical performance of the transport system. The modelling of the physical measurements and calculations of costs are calculated with a geographical information system. It is however not within the scope of this paper to give a thorough description of the functionalities of geographical information systems or the handling of digital multimodal networks as this can be found elsewhere in the literature (Jourquin and Beuthe, 1996, Jourquin and Limbourg, 2003, Kronbak, 2005, Kronbak and Brems, 1996).

As the purpose is to model the cost of freight transport, an important step in the modelling is the transformation of the physical measurements (transport distances and time) into monetary values. This is done by calculating a generalized cost for traversing each link in the network. The generalized cost for each link is composed of an addition of three cost contributions:

- Distance dependent costs
- Time dependent costs
- Fare and toll costs

The distance and time dependent costs normally apply to road transport whereas sea transport normally operates with fares.

The distance dependent cost components are for road transport typically vehicle operating costs (VOC) covering e.g. fuel consumption, maintenance, tires etc. For sea transport a distance dependent cost can also be used e.g. in cases where one lacks information on fares or when modelling tramp shipping. The distance dependent cost for each link within the network can be found as:

DDcost = (DDCC1 + DDCC2 + … + DDCCn) • TransportDist

Where *DDcost* is the total Distance Dependent cost for the link
DDCC1 … *DDCCn* is the Cost Components
TransportDist is the length of the link

The *time dependent cost* components are for road transport typically e.g. wages or depreciation of the material (including e.g. financial costs). The time dependent cost for each road link is found as:

TDcost = (TDCC1 + TDCC2 + … + TDCCn) • TransportTime

Where *TDcost* is the total Distance Dependent cost
TDCC1 … *TDCCn* is the Cost Components
TransportTime is the time used to traverse the link

In the modelling the distance and time dependent costs are modelled using a lookup table describing the costs for different link types or specific links. In the same way as for the calculation of the traverse time the calculation of the different costs elements can be made on an arbitrary classification of the transport network based on e.g. country, region, road type, truck type, wages etc.

The *fare* and *toll costs* are normally linked to either the use of a sea link, modal shift or the passage of a physical location like e.g. a toll bridge, a toll tunnel or a toll ring. The *fare* and *toll costs* for specific links are found as:

Fare & Tollcosts = FTC1 + FTC2 + … + FTCn

As for the time and distance dependent costs the fare and toll cost calculations are controlled by lookup tables. The fare and toll cost file includes more information than the distance and time cost files but the principle is the same.

The NSR region covers numerous road and sea links. The following 10 ports/port regions have been selected as example points of origin for the transport model to enable a more focused display of cost shifts:

- Immingham/Humber estuary
- Esbjerg
- Zeebrugge/Oostende
- Hamburg
- Bremerhaven
- Gothenburg
- Kristiansund/Hitra
- Forth Ports Scotland
- Rotterdam
- Calais/Dover

These ports are not chosen only because of their location within the NSR region but rather due to their differences in the integration in the local transportation network as well as freight volumes they handle on an everyday basis. So, e.g. the Port of Rotterdam was the largest port regarding container throughput in Europe in 2008 with a 12 percent share of total container throughput in Europe. The Port of Hamburg was in 2008 the second largest port in the same statistic. Additionally, the Port of Bremerhaven and Zeebrugge can be found under the Top 15 ports in Europe considering container throughput (Notteboom, 2010). In contrast thereto, the ports of Forth Ports

Scotland or Kristiansund/Hitra are located rather remotely. Moreover, as the larger ports have a history of freight transport, the Port of Kristiansund/Hitra is under construction at the moment and will have to actively establish a future transportation network. The port region of Forth Ports Scotland is located in Northern England and seeks to actively outweigh remoteness by network integration as well as a diverse portfolio on good transport services. Moreover, the middle-sized port region of Immingham/Humber estuary is located on Central England's east coast with an immediate access to main big industrial cities in England and Scotland. Within a relatively short distance to the west coast of England it also provides connections with Ireland. In contrast, the middle-sized ports of Esbjerg and Gothenburg provide access to Northern Europe from Continental Europe and Great Britain, while the ports of Calais/Dover connect historically Continental Europe with Great Britain.

With the help of the GIS (Geographic Information System) software, ArcInfo, the visual output, the cost-points maps, are obtained for these 10 ports/port regions. Hence, the transport cost calculated above is transferred into cost-points which represent the cost of reaching every point of destination from the point of origin under consideration. Approximately 366.000 cost points are calculated in the whole of Europe. These first maps can also be referred to as baseline or 'before' model.

Based on the scenarios developed above in section 1 and 2 (see Table 1), the transport cost changes for each mode of transport (i.e. road or seaway) due to efficiency and flow differences. Table 2 displays the assumed changes for the different scenarios. So, for example, an increase in trade volume (i.e. flow) and efficiency is results in a general cost decline (i.e. *Regulation* Scenario). However, as the changes differ between the modes, it can be assumed further for the *Regulation* Scenario that seaway transport cost decreases slightly more than the costs for road transport – making intermodal transport more competitive to road transport.

	a) Regulation Scenario	b) Environment Scenario	c) Competition Scenario
Road	90%	120%	70%
Seaway	85%	90%	125%

Tab. 2: Scenarios – Assumed changes in cost structure

After the changes in the cost structure for the road and sea mode are implemented (‘after’ model), cost-point maps are drawn displaying the changes in the cost structure. The cost-point difference maps are generated by subtracting the ‘before’ and ‘after’ maps. The descriptive statistics of the difference maps of the absolute transport costs are shown in Table 3.

3. Results & Discussion

In the *Regulation* scenario, it is assumed that costs for both road and sea transport decline. However, in this scenario, as described above, the sea transport experiences a slightly higher cost decrease (i.e. 85 percent in 2030 of today’s costs) than the road transport (90 percent in 2030 of today’s costs). The areas closer to the selected point of origin gain only slight cost cuts, while with increasing distance the cost savings become more severe. The maximum change in transport cost varies highly between the selected NSR ports/regions. While Forth Ports Scotland shows the highest adjustment rate of transport cost (max. 546.32 Euros), Gothenburg reaches a comparable low change in transport cost (max. 336.41 Euros). However, although Gothenburg maximum change in transport cost is the lowest of all 10 NSR regions. The NSR region of Kristiansund/Hitra displays the highest average change in transport cost (mean: 271.68). Due to the rather non-central location, however, Gothenburg, Kristiansund/Hitra and Forth Ports Scotland changes in the transport costs are dominantly of larger scales. The lowest average cost gain is experienced for the region Calais/Dover (mean: 73.94). Considering the standard deviation in the transport cost structure alteration, the NSR region Calais/Dover seems to be also the most stable one (Std. Dev. 46.26) while the NSR region Forth Ports Scotland experiences the highest variation in transport cost changes (Std. Dev. 67.38). Hence, in this scenario, ports which are more centrally located in the NSR region and with this more embedded in sea and road networks, reach lower transport cost gains but are also more stable in their cost structure than if located rather adjacent.

In the *Environment* scenario, it is assumed that cost increases for the road transport (i.e. 120 percent in 2030 of today's costs) while at the same time sea transport cost declines (i.e. 90 percent in 2030 of today's costs). Changes occur in two directions, cost increase and decrease. As the shift in transport costs are calculated as 'before' minus 'after', a negative difference is equivalent to a transport cost increase for this served area, while a positive value represents a cost decline for the area. The Port of Esbjerg is exposed in this scenario to the highest increase and the highest variation in transport cost changes (min: -691.12 Euros, Std. Dev. 100.39), while Kristiansund/Hitra display the lowest increase and the lowest variation in transport cost alteration (min: -560.92 Euros, max: 0 Euros, Std. Dev. 58.26). Hence, for this region, the cost increase for road transport is overruling the declining cost via sea links due to a lack of established sea routes. In contrast, the NSR region Immingham/Humber attains the highest cost gain (max: 187.05 Euros), while the NSR port of Gothenburg show the lowest average in transport cost changes (mean: -38.46) with also the majority of changes lower than the mean value (median: -36.36 Euros). Hence, all 10 NSR ports experience in this scenario in average an increase in transport cost due to the relatively high rise of the road transport costs which is also a part of the intermodal transport cost. The Port of Esbjerg suffers in this scenario not only from the highest transport cost increase but also exhibits the highest average of transport cost alteration (mean: -189.71). The more adjacent NSR ports which are well integrated into the road network gain here some advantage regarding the transport cost changes.

In contrast to the *Environment* scenario, the *Competition* scenario assumes a future decline of the road transport cost (i.e. 70 percent in 2030 of today's costs), while at the same time the transport cost via sea links raises (i.e. 125 percent in 2030 of today's costs). Also, in this scenario a negative difference in transport cost is equivalent to a cost increase, while a positive change in the transport cost represents a cost decline for the respective area. The highest cost increase is suffered in this scenario in the NSR region Immingham/Humber (min: -346.21 Euros), which, unsurprisingly, obtained in the former scenario the highest gain in the changes of the transport cost. However, in this scenario the Port of Hamburg displays the lowest increase in the transport cost (min: -61.20 Euros). The highest gain in transport cost can be observed for the Port of Rotterdam (max: 1207.38 Euros), while the NSR region Immingham/Humber also attains the lowest gain (max: 739.57 Euros) and the lowest average transport cost change (mean: 114.18). The highest average transport cost alteration can be observed for the port of Esbjerg (mean: 331.66). In regards to standard deviation of the shifts in transport cost, the NSR region Calais/Dover is the most stable area in our sample towards the changes (Std. Dev. 95.21) while the Port of Gothenburg shows the highest fluctuation in adaptation to the changes (Std. Dev. 187.99). Thus, in this scenario the NSR regions which are integrated well into short-sea-shipping transport networks gain the most of the transport cost alterations while central location (e.g. NSR region Calais-Dover) helps to outbalance future cost shifts.

Regulation Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Immingham/Humber	0.00	521.14	114.18	114.99	53.76
Esbjerg	0.00	423.64	126.27	115.66	53.94
Zeebrugge/Oostende	0.00	520.47	79.79	74.67	49.59

Regulation Scenario

NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Hamburg	0.00	459.43	98.31	87.37	53.11
Bremerhaven	0.00	473.56	94.93	85.50	51.50
Gothenburg	0.00	336.41	208.19	209.73	55.65
Kristiansund/Hitra	0.00	394.05	271.68	276.52	56.96
Forth Ports Scotland	0.00	546.32	181.01	193.83	67.38
Rotterdam	0.00	520.58	78.29	72.07	50.55
Calais/Dover	0.00	514.41	73.94	66.15	46.24

Environment Scenario

NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Immingham/ Humber	-571.51	187.05	-83.05	-72.77	83.96
Esbjerg	-691.12	61.68	-189.71	-180.12	100.39
Zeebrugge/ Oostende	-590.26	143.51	-95.05	-96.97	81.71
Hamburg	-610.44	75.49	-128.43	-116.49	96.44

Environment Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Bremerhaven	-638.70	95.34	-120.86	-112.27	94.58
Gothenburg	-664.77	80.34	-38.46	-36.36	67.40
Kristiansund/Hitra	-560.92	0.00	-140.95	-130.15	58.26
Forth Ports Scotland	-658.24	137.06	-45.77	-46.01	66.33
Rotterdam	-589.29	150.37	-88.18	-93.03	84.35
Calais/Dover	-578.14	159.33	-108.25	-99.87	69.02

Competition Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Immingham/Humber	-346.21	739.57	114.18	114.99	142.01
Esbjerg	-105.35	1130.50	331.66	311.48	135.31
Zeebrugge/Oostende	-244.46	1181.37	190.16	184.80	99.12
Hamburg	-61.20	1150.89	242.68	217.84	126.77
Bremerhaven	-90.20	1193.28	230.91	204.65	120.21
Gothenburg	280.76	997.16	173.22	218.63	187.99

Competition Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Kristiansund/Hitra	-64.02	841.38	278.49	307.33	142.21
Forth Ports Scotland	-173.33	878.76	292.26	277.15	153.54
Rotterdam	-254.75	1207.38	186.02	182.31	101.13
Calais/Dover	-313.33	948.81	189.98	188.69	95.21

Tab. 3: Descriptive Statistics for each scenario and selected NSR port/region with marked extreme values (absolute difference in EUR)

A brief look at the absolute difference in transport cost suggests that the more detached regions have higher gains due to the longer distance, i.e. the further one transports the freight the more cost savings one can accumulate over the distance. In order to rule out such kind of effects the relative changes of the transport costs are examined in the following. Relative changes are calculated as:

$$\frac{'before' - 'after'}{'after' * 100}$$

Thus, with the help of this transformation the above described absolute transport cost shifts are transformed into a comparable measurement which neglects the geographic location of the NSR port/region within the NSR area. Results of the transformation are found in Table 4.

In the *Regulation* scenario, the NSR region Forth Ports Scotland possessed the highest maximum changes in absolute term. However, in relative terms the NSR region Immingham/Humber experiences the highest increase in transport cost. While before the lowest absolute difference was reached by the NSR port of Gothenburg, in relative terms the NSR region of Kristiansund/Hitra obtains the lowest maximum difference. The maximum absolute average transport cost alteration was achieved before by the NSR region of Kristiansund/Hitra, which is now in relative terms higher for the NSR port of Gothenburg. The NSR region Calais/Dover acquires in absolute and relative terms, however, the lowest average loss in transport costs. Thus, changing focus from absolute terms into relative terms changes the picture slightly. Moreover, it becomes obvious that the changes in transport costs are driven mainly for the NSR ports/regions Gothenburg, Kristiansund/Hitra, and Forth Ports Scotland by the cost decrease in the sea transport, while the others NSR regions are affected mainly by changes in the road cost structure (i.e. the median of the first mentioned three NSR ports/regions are close to the 15 percent cost decrease in the sea transport which signalize that the majority of the observations are close to this cost alteration, while for the other NSR ports/regions the median is closer to the 10 percent cost decrease of the road transportation). Furthermore, due to the combination of road and sea transport, except the NSR region of Kristiansund/Hitra, the other NSR ports/regions actually realize relative cost gains above the maximum cost decrease of 15 percent (for sea links).

Regulation Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Immingham/Humber	0.00	17.64	12.92	11.11	2.02
Esbjerg	0.00	16.87	11.69	11.11	1.25
Zeebrugge/Oostende	0.00	17.55	12.09	11.11	1.87
Hamburg	0.00	16.89	11.89	11.11	1.59
Bremerhaven	0.00	17.28	11.93	11.11	1.68
Gothenburg	0.00	17.16	14.74	14.79	1.21
Kristiansund/Hitra	0.00	14.99	13.92	14.04	0.80

Regulation Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Forth Ports Scotland	0.00	17.54	14.32	14.67	1.68
Rotterdam	0.00	17.62	12.15	11.11	1.99
Calais/Dover	0.00	17.36	11.39	11.11	1.09

Environment Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Immingham/Humber	-16.66	11.05	-7.99	-7.97	7.16
Esbjerg	-16.66	7.11	-14.13	-16.66	5.00
Zeebrugge/Oostende	-16.66	10.60	-12.64	-16.66	7.57
Hamburg	-16.66	7.16	-13.23	-16.66	6.50
Bremerhaven	-16.66	9.16	-13.06	-16.66	6.90
Gothenburg	-16.66	8.53	-2.42	-2.32	4.93
Kristiansund/Hitra	-16.66	0.00	-6.16	-5.63	3.06
Forth Ports Scotland	-16.66	10.55	-3.94	-2.85	6.78
Rotterdam	-16.66	10.98	-12.26	-16.66	8.27
Calais/Dover	-16.66	9.61	-14.09	-16.66	5.28

Competition Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Immingham/Humber	-19.88	42.86	34.16	42.86	13.26
Esbjerg	-8.03	42.86	39.82	42.86	7.83
Zeebrugge/Oostende	-16.52	42.86	39.09	42.86	8.90
Hamburg	-4.33	42.86	38.87	42.86	9.35
Bremerhaven	-6.71	42.86	38.74	42.86	9.68
Gothenburg	-14.25	42.86	14.33	18.78	14.30
Kristiansund/Hitra	-2.19	42.86	15.91	17.62	9.90
Forth Ports Scotland	-7.25	42.86	28.69	28.44	12.02
Rotterdam	-17.50	42.86	39.35	42.86	8.70
Calais/Dover	-15.48	42.86	40.83	42.86	8.56

Tab. 4: Descriptive Statistics for each scenario and selected NSR port/region with marked extreme values (relative difference in percent)

While in the *Regulation* scenario some changes occur if instead of absolute difference in transport cost the relative changes are considered, in the *Environment* scenario only one alteration in the results of the extreme values can be observed. The highest variation in transport cost change is in relative terms detected for the NSR port of Rotterdam instead for the NSR port Esbjerg. While in the *Regulation* scenario the combination of road and sea transport led to higher cost gains (measured in transport cost) than the actual cost changes, in the *Environment* scenario the increase in road transport is offset by the cost decrease in the sea transport. As in the *Regulation* scenario, the observation for the NSR ports/regions Gothenburg, Kristiansund/Hitra, and Forth Ports

Scotland are also driven mainly by cost changes in the sea transport. However, in this scenario additionally the NSR region of Immingham/Humber offsets the increase in road transport cost by shifting towards sea links (see median) and therewith reaches the highest gains in the transport cost.

In the *Competition* scenario, the lowest minimum difference in relative terms is attained by the NSR region Kristiansund/Hitra instead of the NSR port Hamburg. Furthermore, the highest and lowest average relative changes in transport cost is measured for the NSR port/region Calais/Dover and Gothenburg, and not as in absolute terms for the NSR port/region Esbjerg and Immingham/ Humber. While the NSR port of Gothenburg also in relative terms scores the highest variation in transport cost changes, the lowest variation is observed in relative terms for the NSR port of Esbjerg, instead of the NSR region Calais/Dover which appear more stable in absolute terms. Examining, the median of the observations, it becomes obviously that the assumed cost increase of 25 percent for the sea transport and at the same time cost decrease of 30 percent in the road transport is translated into higher cost gains than assumed in the scenario by apparently shifting parts of the more expensive sea transport towards the more cheaper road transport. In this scenario, as well as above, the NSR ports/regions Gothenburg, Kristiansund/Hitra, and Forth Ports Scotland appears to lack the option to shift and with this maintain in the more expensive sea transport network which leads to the results that the majority of the cost points are distributed around the minimum change which is equal to a transport cost increase, i.e. cost increase for the majority of the observation which needs to be offset and therefore result in lower average transport cost gains.

After comparing the intermodal transport cost alterations between the scenarios, in a second step, the transport cost changes are compared to changes in road transport cost for the same scenarios (i.e. assuming a world without short-sea shipping links). This step is taken to point out the part of the transport cost changes driven by short-sea shipping lines. Therefore the cost changes in the three scenarios of a world containing only road transport costs are deducted by an intermodal world. In the following, the relative changes are reported (see table 5). Negative changes indicate that intermodal transport achieve higher transport cost savings under the respective scenario than the mere road transport. If the road transport is less costly than the intermodal transport under the scenario for the point of destination from the point of origin, transport cost changes are positive.

In the *Regulation* scenario, due to the assumption that sea transport cost are decreasing further than road transport, relative high cost gains for intermodal transport can be achieved compared to the road transport cost. So, from the point of origin, the NSR port Gothenburg, transportation cost can be reduced to up to 49 percent if intermodal transport is considered rather than only road transport (i.e. maximum relative change). If the point of origin is within Continental Europe, also at least 31 percent of transport cost can be saved if intermodal transport is preferred to road transport (i.e. minimum cost saving, NSR port Bremerhaven). However, in average, intermodal transport outcompetes road transport considering the rather adjacent NSR ports/regions Gothenburg, Kristiansund/Hitra and Forth Ports Scotland. Hence, the relative disadvantage of being located further away from economic important areas can be balanced out by establishing sea links to these hub centres. Regarding the variation in cost saving switching from road transport to intermodal transport, the already mentioned three NSR ports/regions Gothenburg, Kristiansund/Hitra and Forth Ports Scotland together with the NSR region Immingham/Humber display relatively high variation in cost changes (max. Std. Dev: 14.12; NSR port Gothenburg) compared to the other NSR ports/regions in our analysis (min. Std. Dev: 6.29, NSR port Esbjerg).

Regulation Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Immingham/Humber	-41.67	11.11	4.19	11.11	10.84
Esbjerg	-44.09	11.11	8.71	11.11	6.29

Regulation Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Zeebrugge/Oostende	-48.29	11.11	8.15	11.11	7.05
Hamburg	-39.94	11.11	7.97	11.11	7.44
Bremerhaven	-31.28	11.11	7.88	11.11	7.65
Gothenburg	-49.44	11.11	-12.85	-7.93	14.12
Kristiansund/Hitra	-37.20	11.11	-11.43	-8.62	10.06
Forth Ports Scotland	-41.90	11.11	-0.46	-0.10	10.88
Rotterdam	-49.04	11.11	8.36	11.11	6.90
Calais/Dover	-42.07	11.11	9.51	11.11	6.79

Environment Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Immingham/Humber	-56.25	0.00	-21.86	-16.67	8.13
Esbjerg	-58.07	0.00	-18.43	-16.67	4.71
Zeebrugge/Oostende	-61.22	0.00	-18.88	-16.67	5.28
Hamburg	-54.96	0.00	-19.02	-16.67	5.58
Bremerhaven	-48.46	0.00	-19.09	-16.67	5.74
Gothenburg	-62.08	0.00	-34.64	-30.95	10.59
Kristiansund/Hitra	-52.90	0.00	-33.57	-31.47	7.55
Forth Ports Scotland	-56.42	0.00	-25.35	-25.08	8.16

Environment Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Rotterdam	-61.78	0.00	-18.73	-16.67	5.17
Calais/Dover	-56.56	0.00	-17.87	-16.67	5.09

Competition Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Immingham/Humber	-25.01	42.86	33.95	42.86	13.93
Esbjerg	-28.12	42.86	39.78	42.86	8.09
Zeebrugge/Oostende	-33.52	42.86	39.06	42.86	9.06
Hamburg	-22.78	42.86	38.82	42.86	9.57
Bremerhaven	-11.64	42.86	38.70	42.86	9.84
Gothenburg	-35.00	42.86	12.05	18.37	18.16
Kristiansund/Hitra	-19.26	42.86	13.88	17.48	12.94
Forth Ports Scotland	-25.30	42.86	27.97	28.44	13.99
Rotterdam	-34.49	42.86	39.32	42.86	8.87
Calais/Dover	-25.52	42.86	40.80	42.86	8.73

Tab. 5: Cost comparison for each scenario and selected NSR port/region between road transport and intermodal transport with marked extreme values (relative difference in percent)

In the *Environment* scenario, intermodal transport is by definition always more cost-efficient than road transport and will be therefore not discussed further in detail. The extreme values in this scenario are the same NSR ports/regions as in the other scenarios. In contrast thereto, in the Competition scenario by assumption road transport should outcompete intermodal transport in regards to transport cost. But, looking at the calculations, it can be shown that each port of origin has at least some points of destination which are still more cost-efficient to reach by intermodal transport than by road transport. Although sea shipping transport cost in this scenario differs about 55 percent to road transport cost regarding our assumptions, the intermodal transport cost is at maximum ca. 43 percent more expensive than only road transport. Hence the combination of sea with road transport can offset extreme cost increases for one transport mode.

4. Management Implications

Based on these results, characteristics are discussed which makes a port region more vulnerable towards future changes than other regions. For this purpose, two different kinds of policy directions are considered: the risk-averse versus the risk seeking port manager.

A *risk-averse port manager* is assumed to target long-term stability of the costs irrespective of future development. For this kind of manager two options are opened up: either examining in more detail the NSR regions/port which did not score any kind of extreme value (max or min) in any of the categories described above, or analysing the ports with the lowest changes in transport costs and/or lowest standard deviation.

Regarding the first option for the *risk-averse port manager* to avoid extreme values, the NSR-ports/regions of Zeebrugge/Oostenende, Hamburg and Bremerhaven match best this criterion. Thus, these regions seem to balance out any extreme future development with the help of their geographic location, and the therewith connected embeddedness into the sea and road networks within the NSR. Regarding the short sea lines, the port of Bremerhaven possesses the highest number of shipping lines (18) in our analysis of which the majority links the region with Scandinavian regions (17). In contrast, the NSR region of Zeebrugge/Oostenende holds in our analysis only an average number of shipping links (10) which connects the region mainly with GB ports. The NSR port Hamburg is linked in our analysis with 14 other ports in the NSR region of which the majority (13) are located in Scandinavia. The one sea link, however, which connects the NSR port Hamburg outside Scandinavia, is the one to the NSR port of Bremerhaven, hence, another port with a majority of sea links to Scandinavia. Apparently, the combination of being integrated due to the geographic location into the continental European road network and at the same time via sea to Scandinavia leads to the comfortable situation to be capable to balance out any kind of future cost trends.

The second option for the *risk-averse port manager* is to target the lowest standard deviation or lowest minimum change in transport cost. Regarding the lowest standard deviation in our three scenarios, the NSR ports/regions Kristiansund/Hitra and Esbjerg display in relative terms the lowest standard deviation in the calculation of the transport cost changes. While, the NSR region Kristiansund/Hitra is relatively well able to offset price alterations in road transport (*Regulation* and *Environment* Scenario), the NSR port of Esbjerg counterbalance relatively well price increase for sea transport with price declines in the road transport (Competition scenario). Considering the lowest minimum change in transport cost, the NSR region Kristiansund/Hitra scores the best result in relative terms in the Competition scenario and in absolute terms in the *Environment* scenario. The NSR port Hamburg obtains the lowest minimum change in absolute terms in the Competition scenario. The low standard deviation in relative and absolute terms (see the *Environment* scenario) as well as the low relative change in the transport cost for the NSR region Kristiansund/Hitra seems surprisingly as this region is mainly connected via road to sea links; i.e. can be considered as rather detached and peripherally located within the NSR region. The low relative change can be seen as expression of almost non existing modal shift for the NSR region Kristianssund/Hitra given the tree scenarios. The region has due to its geographical location an extremely solid truck based hinterland and almost any destination outside this hinterland can only be served by ship.

In opposition to the risk-averse port manager, the risk-seeking port manager aims to reach the highest transport cost decline by assuming the predictability of future cost development. Thus, this kind of manager takes a chance of gaining cost reductions. Assuming the future will look like the *Regulation* Scenario (i.e. cost of sea and road transport declines); the highest gain in the transport cost difference is accumulated in the NSR region of Forth Ports Scotland in absolute terms due simply to distance to served areas. In relative terms, however, the NSR region Immingham/Humber reaches the highest gain in this scenario. If supposedly the sea transport costs decrease while at the same time the road transport costs increase as in the *Environment* Scenario, the NSR port of Immingham/Humber would be the port to examine in more detail. Despite its geographic location in the middle of GB and close to major cities, the NSR port of Immingham/Humber operates in our analysis on 12 sea links of which 3 connects the area with Scandinavian Ports, while the others bond the area with continental Europe. If, however, the opposite development is supposed to take place (i.e. cost of sea transport increase while at the same time the cost for the road transport decrease as in the Competition Scenario), the NSR port of Rotterdam would be here the example to achieve highest gains in transport costs in absolute terms. This port is located centrally in the NSR region and with this also embedded into the regional sea and road network. The latter characteristic is supported by the fact that 17 sea routes are incorporated in our analysis, of which 8 links this port to Scandinavian regions, while the other links are to GB or continental Europe.

As discussed above, the NSR ports/region Gothenburg, Kristiansund/Hitra, and Forth Ports Scotland tend to react differently towards the changes in transport costs than the other NSR ports/region selected in our analysis. Despite of Gothenburg's sea connection to 15 NSR ports of which only 3 are located in Scandinavia, it is apparently on the same track as the rather detached and peripherally located NSR regions Kristiansund/Hitra and Forth Ports Scotland.

Although, in our analysis, the latter two are only connected via road to either Bergen or Rosyth which possess some sea links but do not appear to be connected very well within the NSR region neither. Hence, these NSR ports/regions are interesting cases as by theory they should be subject to rather high transport cost increases instead of declines. However, by combining the few sea links with the rather less developed road network of the Scandinavian region (compared to continental Europe) cost gains are still possible for these regions irrespective of future price development.
In general, comparing intermodal transport cost with road cost it was shown that for each scenario establishing sea links with other NSR ports/regions creates at least some kind of transport cost advantages compared to only road transport. Certainly, the more adjacent NSR ports have a higher stake in establishing these short-sea links, however, if hinterlands should be served, cost-efficiency gains are also realized by NSR ports in Continental Europe.

5. Conclusion

Sustainability of nowadays transport costs in the NSR is evaluated in this paper. After discussing three different scenarios on potential changes in the cost structure of inter-modal transport, *Regulation*, *Environment* and *Competition* scenario, cost points are calculated in order to display the effects of the scenarios in geographic maps for 10 different NSR port/regions. It could be shown that due to location and/or integration in local transportation networks ports can balance out cost changes driven by policy decisions. Hence, future road transportation cost increase can be balanced out by sea transport cost decrease and the other way around. Advanced integration into transportation networks can offset geographic adjacency. Although, central points are more accessible than peripheral ones (considering a closed system) politically driven changes in transport cost structure is able to counterbalance geographic disadvantages. This we can show, e.g., for the NSR ports/regions Gothenburg, Kristiansund/Hitra, and Forth Ports Scotland. These NSR ports/regions are located away from central points and are mainly connected by sea links. In the *Environment* scenario, in which road transportation becomes more expensive while sea transport is the preferred mode of transport, these adjacent NSR-ports suffered the lowest average transport cost burden. However, in the Competition scenario, in which the road transport outcompete the sea transport regarding future transportation cost shifts, the three NSR ports/regions Gothenburg, Kristiansund/Hitra, and Forth Ports Scotland still could realize an average net transport cost gain. Due to the lack the option to shift from sea to road entirely, however, these gains were smaller than the ones for the other NSR ports/regions in this analysis. Hence, the ability of a port to offset transport cost changes depends on the preferred mode of transport network they are integrated in.

Based on transport cost modelling results, implications for port management are drawn. It is pointed out that a risk-averse manager of a Continental European port will be able to balance out future cost changes if he makes use of established sea links to Scandinavia and European road network. However, by combining the few sea links with the rather less developed road network of the Scandinavian region (compared to continental Europe) cost gains are still possible for these regions irrespective of future price development.

The analysis is based on established sea and road networks. However, it is shown that investing in creating new sea routes from a port management point of view might be worth as it compensates for increases in road transport cost. Hence, attracting more sea routes lead to further efficiency gains which can offset future transport cost uncertainties.

Future research should also take the rail and inland water transport into consideration, so as to provide a holistic view of transport cost development. Moreover, general freight flows are here considered only. The picture is subject to change if volumes are taken into account as well as a differentiation between fresh food transport (incl. temperature control) and other goods.

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III.
Handling Risk

Concepts Towards Robust SCM

A Service Production Planning Model Integrating Human Risk Factors

Nguyen Vi Cao and Emmanuel Fragniere

Abstract

Most models of production planning based on mathematical programming tend to assume constant technical coefficients. This assumption is realistic when the production is based on machines as it is the case in manufacturing. On the other hand, production planning in the service sector involves humans instead of machines. Consequently, the assumption that all technical coefficient of the mathematical program are constant cannot hold anymore. This is especially the case for productivity parameters related to human activity. It is well known for instance that in the service sector when administrative tasks are repetitive and boring, working overload has a direct impact on the employee productivity.

We have adapted a manufacturing planning model producing industrial goods into a service production planning model. In this service model, employees with different job status (junior, senior and expert) are handling cases of specific difficulties (simple, standard, personal and special). Then, we have introduced a variable productivity formula into the mathematical program that takes into account "plateau" levels assuming diminishing productivities. To do so the mathematical program includes integer variables as well as non-linearity and thus becomes a NLMIP (Non Linear Mixed Integer Program).

A fictitious case study is presented. The initial service production planning model with constant technical coefficient leads to solutions involving job specialization. On the other hand the model version with the variable productivity formula offers a better workload balance and more possibilities of job polyvalence reducing thus human risks such as burn-outs.

Keywords: human factor, production planning optimization, risk, service

1. Context and literature review

Human failures such as "burn-out" can impact negatively the overall supply chain. Even if this kind of "work disease" is well studied by psychologists, it is usually not integrated in production planning models. We posit that human risks are as significant as any other "conventional" production risks such as machine breakdowns or bottlenecks. This is particularly relevant in the case of service supply chains that are generally labor intensive.

Production planning models are typically described by technical input/output data. Besides these technical aspects, we introduce “soft” variables that model human risk factors like stress, fatigue or lack of motivation.

Our work to include soft variables in mathematical programs started a few years ago. At that time, the authors of this paper were working with sociologists. We developed a production optimization model adapted to couple matching (Cao et al., 2010). The goal was to optimize romantic partner attributes, and to assess how far from the optimum is the current situation. Therefore, assessing the extent to which couples are paired optimally could be realized in the light of the minimization of divorces and separations.

Reviewing the recent literature on aggregate production planning models and general production optimization models, we have noticed that the 2 main currents in research are related to the inclusion of the notion of risk in supply chain models (stochastic programming) and to the development of complex non-linear models. Thomson and Goodale (2006) are for instance exploring the notion of variable productivity through stochastic techniques. Valls et al. (2009) integrate the notion of skilled workforce with different categories of abilities. Eitzen et al. (2004) are addressing the case of multiple skills in production planning.

However to our knowledge very few research developments are devoted to the integration of soft or behavioral variables in production optimization models. For instance, the notion of flexibility as a human factor has been investigated in the context of supply chain by More and Badu (2009). MCkAy and Wiers (2006) have studied the qualitative aspects of human expertise in planning and scheduling functions.

In our paper, we assume different job statuses and thus levels of expertise (or tacit knowledge) which is to our knowledge a novel approach in production planning optimization. Closer to our modeling approach, Othman et al. (2012) are minimizing the worker's fatigue. Roland et al. (2010) model the well being of the medical staff in the scheduling model.

If we consider fields such as work psychology or behavioral organization, we notice that a lot of effort is dedicated to the study of this kind of soft variables. Let us take as an example the seminal paper by Hackman and Oldham (1976) on the notion of motivation. Unfortunately, these kind of scientific findings are rarely taken into account in production optimization models. In consequence, we believe that it is important to establish more links between management science and social sciences in order to give more realism to production planning models.

This paper is organized as follows. In Section 2, we explain how we have adapted a manufacturing planning model producing industrial goods into a service production planning model. In Section 3, we propose a variable productivity formula that takes into account "plateau" levels assuming diminishing productivities. In Section 4, we present the complete mathematical program with the variable productivity formula. In Section 5, we develop a fictitious case study involving both models. Results of both models are compared. Finally in Section 6, results are discussed and we conclude, in Section 7, with further research directions.

2. A production planning model for services

The original model structure is called "Ajax Paper Company Production Schedule" (CDC, 1977). It comes from the GAMS library of models, the well known algebraic modeling language. A paper manufacturer can produce four different types of paper on three different machines. Given a fixed capacity of each machine, a fixed productivity of each machine for the production of each type of paper, a fixed cost of each machine to produce each type of paper, a fixed demand schedule and a fixed price of each type of paper, the objective is to find a production plan that maximizes the monthly profit.

In this paper, we propose to apply the Ajax model in the case of services production that can typically be found in public administrations, advocacy offices, audit companies, fiduciaries, notaries, etc. In these companies, employees handle usually a large number of cases.

The analogy between the Ajax model with a production of tangible goods and a services production is done as follows:

- The industrial production corresponds to administrative or consulting tasks
- The goods output corresponds to cases that are handled
- The machines correspond to employees working in an administration

The mathematical formulation of the service production model is as follows:

Given:

e	employee
c	specific type of cases to handle
h_e	number of weeks the employee *e* can work
$p_{e,c}$	fixed productivity of the employee e for the case *c*
$k_{e,c}$	cost of the employee *e* to handle the case *c*
d_c	demand for the case *c*
v_c	price the client is asked to pay for case *c*
$x_{e,c}$	amount of case *c* to be produced by the employee *e*

$$max \sum_c \sum_e (v_c - k_{e,c})\, x_{e,c} \qquad (1.1)$$

Subject to

$$\sum_c \frac{x_{e,c}}{p_{e,c}} \leq h_e \qquad \forall e \qquad (1.2)$$

$$\sum_e x_{e,c} = d_c \qquad \forall c \qquad (1.3)$$

$$x_{e,c} \in \{0, 1,2, \dots\} \qquad (1.4)$$

Equation (1.1) represents the objective function. The overall profit of the production system is maximized. Equation (1.2) represents the capacity of production constraints. The workload of each employee is up to the number of weeks he can do. Equation (1.3) represents the demand constraints. The total cases handled must be equal to the demand for all types of cases. Equation (1.4) represents the non negativity constraints. The numbers of cases to be handled are non negative variables as in the Ajax initial model but it is important to notice that in our service production model continuous variables are replaced by discrete integer variables.

3. A productivity variation formula

In the model presented in Section 3, the machines productivity is constant. In the case of service production, human productivity is not as stable as machine productivity. We assume that when an employee has to handle over a certain amount of cases, its productivity decreases. It is due to fatigue, stress and lack of concentration. The employees are inclined to slow down their working activity and are then prone to make more mistakes creating quality issues. We suggest integrating human factor in the model by introducing a productivity variation.

There are many ways to vary the productivity. Below we suggest a simple manner to do that.

Given:

$p_{e,c}$ standard productivity of employee *e* for the case *c*

$t_{e,c}$ threshold that reduces the productivity of employee *e* for the case *c*

$r_{e,c}$ productivity reduction each time the threshold $t_{e,c}$ is reached

The productivity variation of employee e for the case c is given as shown below

$$p_{e,c} - \left\lfloor \frac{x_{e,c}}{t_{e,c}} \right\rfloor r_{e,c} \qquad (2.1)$$

Formula (2.1) is based on a “plateau” logic. Each time a worker reaches a threshold, its productivity is reduced. With this formula, productivity passes from the constant status to the variable status. The value of the productivity variable depends on the production plan i.e. the final decision and affects the workload of the employees, i.e. the capacity constraint.

4. The planning model with productivity variation

We can now introduce the productivity variation formula (2.1) into the service production mathematical model above to have a new model that takes into account the human factor. This formula is simple but it is important to notice that it introduces a non linearity into the initial model.

Given:

e	employee
c	specific type of cases to handle
h_e	number of weeks the employee ***e*** can work
$p_{e,c}$	fixed productivity of the employee ***e*** for the case ***c***
$k_{e,c}$	cost of the employee ***e*** to handle the case ***c***
d_c	demand for the case ***c***
v_c	price the client is asked to pay for case ***c***
$t_{e,c}$	threshold that reduces the productivity of employee ***e*** for the case ***c***
$r_{e,c}$	productivity reduction each time the threshold $t_{e,c}$ is reached
$x_{e,c}$	amount of case ***c*** to be produced by the employee ***e***

$$max \sum_c \sum_e (v_c - k_{e,c})\, x_{e,c} \qquad (3.1)$$

Subject to

$$\sum_c \frac{x_{e,c}}{\left(p_{e,c} - \left\lfloor \frac{x_{e,c}}{t_{e,c}} \right\rfloor r_{e,c}\right)} \le h_e \qquad \forall e \qquad (3.2)$$

$$\sum_e x_{e,c} = d_c \qquad \forall c \qquad (3.3)$$

$$x_{e,c} \in \{0, 1, 2, \dots\} \qquad (3.4)$$

5. Case study

In this section we create a data set representing a fictive service production in a fiduciary. We implement the initial service production model and then the same model with a variable productivity using the same data set. We solve both models and discuss the results.

In the company there are 3 job statuses: junior, senior and expert. In terms of cases to handle, there are 4 categories of cases: simple, standard, personal and special. Job status and case categories are both defined over ordinal scales. Table 1 provides working time figures in weeks in function of the job status. Table 2 indicates the employee productivity figures according to job status as well as case categories. Table 3 shows the unit production cost in $ per employee job status in function of the case categories. Finally, Table 4 provides the demand of cases per category and the price per case category.

	Junior	Senior	Expert
Number of weeks	4	3	2

Tab. 1: Employee working time

	Junior	Senior	Expert
Simple case	40	45	50
Standard case	20	25	30
Personal case	10	15	20
Special case	5	8	10

Tab. 2: Employee productivity (cases per employee per week)

	Junior	Senior	Expert
Simple case	30	40	50
Standard case	60	70	80
Personal case	140	120	100
Special case	280	240	200

Tab. 3: Production cost ($ per case per employee)

	Demand	Price
Simple case	82	80
Standard case	36	100
Personal case	25	150
Special case	17	300

Tab. 4: Demand and Price

	Junior	Senior	Expert	Total	Demand
Simple case	82	0	0	82	82
Standard case	36	0	0	36	36
Personal case	0	11	14	25	25
Special case	0	4	13	17	17

Tab. 5: Production (case per employee)

	Junior	Senior	Expert	
Simple case	2.05	0.00	0.00	
Standard case	1.80	0.00	0.00	
Personal case	0.00	0.73	0.70	
Special case	0.00	0.50	1.30	Total
Total	3.85	1.23	2.00	7.08
Max capacity	4.00	3.00	2.00	9.00

Tab. 6: Workload (week per employee and per case)

The model instance is solved using the GAMS modeling language and an appropriate solver. The optimal production plan is displayed in Tables 5 and 6 below. Table 5 indicates the repartition of cases to job status. Table 6 indicates the workload considering the case category as well as the job status.

Table 5 and Figure 1a show a complete specialization for juniors in simple and standard cases and for seniors and experts in personal and special cases. It is because cases are assigned to employees having the lowest production cost in order to maximize the profit. Table 6 and Figure 1b show an unbalanced workload as the junior employee works 3.85 weeks over 4, the expert employee 2 weeks over 2 while the senior employee works only 1.23 week over 3.

As a subsequent analysis, we have developed an additional instance of the model, with the same initial data, except that we have included the productivity variation formula (2.1) in the model along with a specific data set presented in Table 7. We see in this table that for instance when the working load reaches the threshold of 40 simple cases per week, it involves a reduction in productivity of 5 cases per week. The logic of this decline is based on the idea that simple cases are routinely handled and when their quantity is growing to a certain extent (threshold), employees are more tired and less motivated.

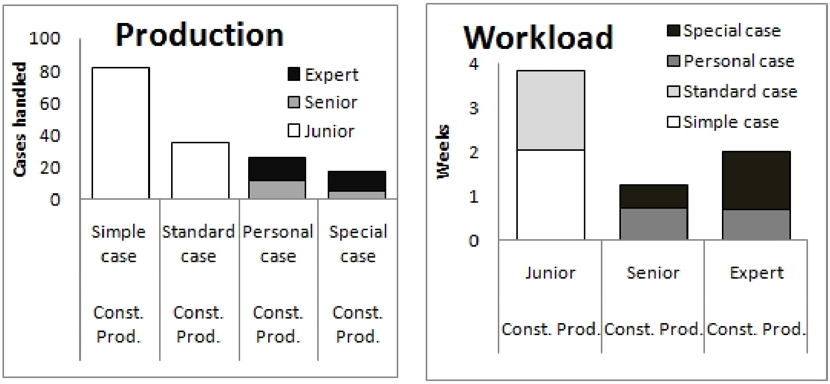

Fig. 1a and 1b: Production (case per employee) and Workload (week per employee and per case) in the constant productivity model

	Threshold	Reduction
	(cases)	(case per week)
Simple case	40	-5
Standard case	20	-3
Personal case	10	-2
Special case	5	-1

Tab. 7: Productivity reduction

The optimization of the new instance including the human variable productivity provides a different production plan. Results are presented in Tables 8 and 9 below. The optimization of this model does not lead to a global optimum since the structure of the model falls into the category of non-linear mixed integer programs that are non convex. In this case study, we have made sure that the presented solution is feasible since we have no guaranty that it is a global optimum. This model thus presents interesting algorithmic issues that will be addressed in another paper.

	Junior	Senior	Expert	Total	Demand
Simple case	81	1		82	82
Standard case	22	14		36	36
Personal case		7	18	25	25
Special case		8	9	17	17

Tab. 8: Production (case per employee)

	Junior	Senior	Expert	
Simple case	2.70	0.02	0.00	
Standard case	1.29	0.56	0.00	
Personal case	0.00	0.47	1.00	
Special case	0.00	1.14	1.00	Total
Total	3.994	2.192	2.000	8.19
Max capacity	4.00	3.00	2.00	9.00

Tab. 9: Workload (week per employee)

On one hand, we notice in Table 8 and Figure 2a a rebalancing of simple and standard cases to the senior employee who is now more involved in low key activities to ease the workload of the junior employee. Table 9 and Figure 2b show also a better workload balance as the senior employee works now 2.192 weeks over 3 compared to 1.2 weeks over 3 in the constant productivity model.

The workload of the junior employee increases only slightly while the expert's workload remains constant.

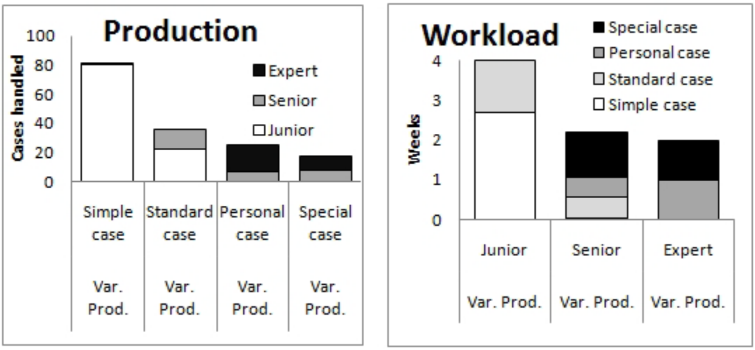

Fig. 2a and 2b: Production (case per employee) and Workload (week per employee and per case) in the variable productivity model

On the other hand, the productivity of the employees decreases for some type of cases (see Figure 3a). Besides, Figure 3b indicates that the total profit in the variable productivity model is about 2% lower than in the constant productivity model. It shows that it has a cost to prevent human risk to happen. Moreover, we also need to accept that today hyper specialization is not tenable anymore.

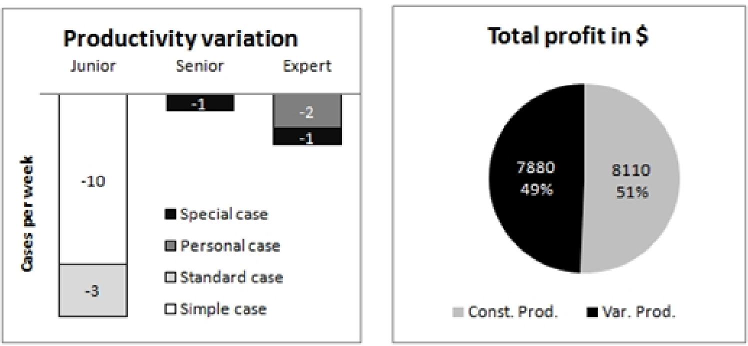

Fig. 3a and 3b: Production variation (case per week per employee) and Profit variation in dollar

6. Discussion

When we compare the 2 models together, we observe that introducing a variable productivity due to human factor leads to a completely different kind of production plan. The first model corresponds to a specialized production mode while the second corresponds rather to a balancing production mode.

In the initial constant productivity model, “easy” cases were assigned to the junior employee and complex cases to the expert and senior employees. This work distribution lies on a lowest cost logic and allows profit maximization. In the variable productivity model, assigning an important amount of the same cases to employees decreases their productivity. On one hand, the senior employee who has a low workload can take over a part of the easy cases assigned to the junior employee and a part of the complex cases assigned to the expert employee in the initial model. As the consequence, the simple and standard cases are now handled not exclusively by the junior employee but also by the senior employee and the workload tends to be more balanced between employees. On the other hand, the global workload increases in the variable productivity model with a reduction of the total profit because the cases could not be assigned only to lowest cost employees.

7. Conclusion

Production planning models that are today adapted to the service sector still keep some assumptions such as constant productivity rates that are inherited from industrial environments and machines. As a matter of fact in the service sector, humans play a primary role in the production instead of machines. Human productivity is not like machines productivity. It is more prone to variability due to stress, fatigue, boring task issues. Using standard production models present the risk that the human factor is not taken into account. For this reason, we have developed a production planning model that includes a human variable productivity formula. This formula retains different threshold levels

related to worker overload states. Each “plateau” in between the thresholds involves a productivity reduction.
To illustrate this model integrating the human variable productivity formula, we have developed a simple and fictitious case study. A professional service company (lawyer, auditing…) is handling cases of different difficulties (from simple to special cases) thanks to different statuses of employees (junior, senior and expert). With the model integrating the human variable productivity formula, we observe in the production plan a more balancing workload between employees. Besides, a same category of cases is handled by many employee statuses that improves polyvalence of the staff and allows employees to replace each other more easily. Employees execute a wider variety of tasks, are subject to less routine. Their job is more interesting and motivating. So with the new model, we are in a configuration where there is a better prevention of human risk such as saturation or burn-out. However dealing with human risk this way comes at a price.

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How to Cope with Uncertainty in Supply Chains? - Conceptual Framework for Agility, Robustness, Resilience, Continuity and Anti-Fragility in Supply Chains

Immanuel Zitzmann

Abstract

Globalization and new technologies led to the global and lean supply chains that we see today. But cost-efficiency alone does not create customer value. Goods and services have to be available at the time of demand. Shorter product-live-cycles demand volatility and external disruptions force supply chains to be flexible, adaptive as well as customer-oriented. A literature review identifies different concepts to achieve these abilities. These are: agility, robustness, resilience, continuity management, and anti-fragility. All five concepts try to handle uncertainties but pursue different approaches. At the beginning of the 21th century the idea of an agile supply chain was promoted. The goal is to flexibly react to changes. In contrast resilience aims to overcome problems. Flexibility is also part of robustness. A robust supply chain is supposed to efficiently manage fluctuation within the network. Compared to that, continuity management tries to handle threats. Parts of these threats are demand or production fluctuations put also major disruptions. To create competitive advantages out of these uncertainties is the idea of an anti-fragile supply chain. This paper compares recent concepts for the management and design of future supply chains. It also provides a conceptual framework how the different approaches interact to create synergies. An outlook for future research is also given.

Keywords: supply chain, uncertainty, handling concepts, framework

1. Introduction

Today competition takes place between supply chains, not between single companies (Lambert and Cooper, 2000). This leads to value creating networks. The focus on efficiency and the complexity of global supply chains makes them vulnerable (Craighead, et al, 2007). Not only high risks but also low-probability/high-impact as well as operational uncertainties jeopardize value creation (Klibi, Martel and Guitoni, 2010; Van Landeghem and Vanmaele, 2002; Svensson, 2000). Such dangers are increasing because of shorter product-life-cycles, market liberalization and new technologies. Therefore, management has to figure out how supply chains can be designed and operated without failure (Zsidisin, Melnyk and Gragatz, 2005). Within the literature of supply chain management the concepts of resilient/robust as well as agile supply chains are proposed. This article will look at these ideas to evaluate whether they are appropriate for handling uncertainties or not. In addition, continuity management and the idea of anti-fragility will be considered. The aim of this paper is to define these five approaches and show where differences and synergies lay. To achieve this, the structure will be as follows:

First, supply chain management and uncertainty will be defined. It is followed by the introduction of the five approaches of handling uncertainties in the third chapter. The suggestion for a conceptual framework will be introduced in chapter 4. It also outlines the differences and synergies of the different ideas. The final chapter will be the conclusion.

2. Uncertainty in Supply Chains

Supply chain management is accepted as an important field of study, but still has no single definition. For this paper a combined definition from Christopher (2006) and The Global Supply Chain Forum (Lambert and Cooper, 2000) will be used. According to them, supply chain management is "the integration of key business processes from end user through original suppliers that provides products, services, and information […] to deliver superior customer value at less cost to the supply chain as a whole". The goal is to integrate functions and processes of individual departments, locations and firms across companies' boarders to reduce costs and increase customer value (Cooper, Lambert and Pagh, 1997). Making decisions under uncertainty is part of every management process. Therefore, it has to be considered in supply chain management as well.

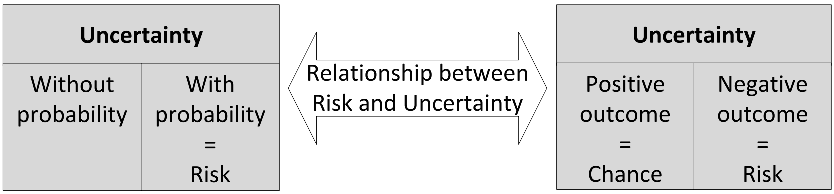

Fig. 1: Differentiation between risk and uncertainty

Uncertainty can be described as the inability to predict something (Milliken, 1987). Often the term risk is used interchangeably with uncertainty. But they are not the same. There are two opinions how they can be distinguished, as can be seen in figure 1. In both cases uncertainty is more than risk. It can be differentiated according to its predictability. If it is possible to quantify a probability of occurrence, it is called risk, if not it is called uncertainty (Knight, 1971). The second approach considers the consequences of uncertainty. If they are positive, they are called chances; if they may be negative, then they are risks (Simangunson, Hendry and Stevenson, 2012). In this paper the second point of view will be taken and the term uncertainty describes both, risks and chances. According to Tang (2006) risks can be operational or disruptive. Both can occur within the supply chain or external (Waters, 2007). Before these differentiations can be applied the concepts will be explained in chapter 3.

3. Handling Concepts in Supply Chains

Resilient and agile supply chains are suggested to handle uncertainties in value creating networks. Robustness is sometimes used as a synonym. To clarify this and also to compare them to continuity as well as to anti-fragile management the five concepts will be introduced in the following paragraphs.

3.1 Agility

In supply chain management literature the definition of Naylor (Naim and Berry, 1999) is used to describe agility (Baramichai, Zimmers and Marangos, 2007; Christopher and Towill, 2000; Mason-Jones, Naylor and Towill, 2000): “Agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile market place.” This understanding was developed in contrast to the lean paradigm (Fisher, 1997), which only works in a stable environment (Mason-Jones, Naylor and Towill, 2000). The agile supply chain on the other hand is designed to cope with changes (Christopher, 2000). The focus is on short-term demand fluctuations as well as changes in consumer behavior. An agile supply chain is able to use these changes to make profit. The idea is to design a network that is flexible and responsive as well as effective (Charles, Lauras and Van Wassenhove, 2010). It is important to note that an agile supply chain will be able to react to demand volatility and delivers a competitive advantage as it is customer focused. But it is not designed to handle uncertainties within the supply chain.

3.2 Robustness

Compared to agility, it is difficult to find a consistent definition of robustness in the context of supply chain management. One reason for this is that the term robustness is often used but not defined at all (Kastsian and Mönningmann, 2011). Vlajic (van der Vorst and Hendrix, 2008) gives an overview of different robustness definitions. In this paper robustness will be understood according to de Neufville, et al. (2004) as the “ability of a system to maintain its operational capabilities under different circumstances”. The supply chain is the system that is considered here. The operational capability that should be maintained is its goal: match demand. The following definition summarizes aspects of different authors (Goetschalckx, Huang and Mital, 2012; Klibi, Martel and Guitouni, 2010; Leung and Wu, 2004; Van Landeghem and Vanmaele, 2002) and describes a robust supply chain as: "A supply chain that is able to match demand and operate on a good cost and profit line in an uncertain environment."

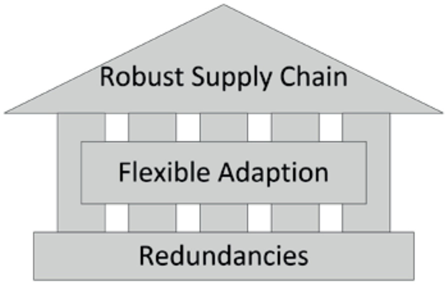

Fig. 2: Levels of a robust supply chain

The reference to costs is integrated to guarantee performance orientated management. Supply chain management literature as well as robust optimization approaches identify two levels of a robust supply chain which are visualized in figure 2 (Pan and Nagi, 2010; Leung and Wu, 2004; Van Lendeghem and Vanmaele, 2002; Mulvey, Vanderbei and Zenios, 1995; Kouvelis, Kurawarwala and Gutiérrez, 1992). These are design variables which are fixed and include redundancies. They build the foundation and provide the necessary flexibility for the second stage. Here control variables adjust to the environment and handle uncertainties. Practical tools for both levels have to be identified.

3.3 Resilience

Christopher and Peck (2004) define resilience in the supply chain context as "the ability of a system to return to its original state or move to a new, more desirable state after being disturbed". The focus of a resilient supply chain lays on major disruptions of the value creating network e.g. earthquakes, shut downs of factories or labor disputes (Sheffi, 2007). Such events have dramatic impact on the supply chain performance as can be seen in figure 3. It shows the impact of the disruption and how long it takes to recover from it. These events are not covered by traditional risk management because they are low-probability/high-impact incidents. The focus of risk management lays on high-probability/high-impact risks.

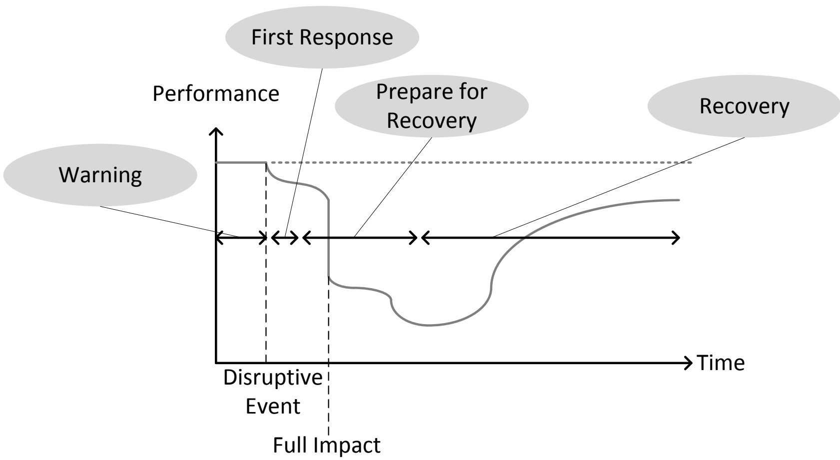

Fig. 3: Impact of disruptive events on supply chain performance (Sheffi and Rice, 2005)

Tomlin (2006) summarizes the different approaches and identifies two major qualities of a resilient supply chain: mitigation and contingency. Klibi (Martel and Guitouni, 2010) uses different terms but have the same intention by describing avoiding/transferring risks and using responsiveness as the two components of a resilient supply chain. In the best case successful mitigation means that the disruption does not affect the supply chain at all or at least reduces the impact. These strategies have to be executed before an event occurs. Responsive abilities are only applied when disaster hits, but still have to be planed and implemented into a supply chain. Pettit (Fiksel and Croxton, 2010) points out that using all strategies to create a resilient supply chain is not always the best. It is important to consider the trade-off between the cost of resilience capabilities and the vulnerability to low-probability/high-impact events.

3.4 Continuity Management

Business continuity management has its roots in disaster recovery as well as business continuity planning (Herbane, 2010). It is seen as part of the strategic management to handle the impact of crises (Adamou, 2014; Pitt and Goyal, 2004). According to the British Standards Institution (2006), Elliott (Swartz and Herbane, 2010) defines it as: "A holistic management process that identifies potential threats to an organization and provides a framework for building resilience and the capability for an effective response that safeguards the interests of its key stakeholders, reputation, brand and value creating activities." The focus of the business continuity approach lays again on disruptive events or emergencies and how to recover from them (Savage, 2002). As a management concept the integration into an organization, is essential (Elliott, Swartz and Herbane, 2010). But it is only the third step within the business continuity management process that is shown in figure 4. After the initiation, a continuity plan needs to be developed. There are different approaches to the planning process (Zsidisin, Melnyk and Ragatz, 2005; Pitt and Goyal, 2004; Savage, 2004). They range from four to nine steps and are similar to risk management concepts (Zsidisin, Melnyk and Ragatz, 2005). Although the process is designed for an enterprise, the mindset of continuity management today is a supply chain wide.

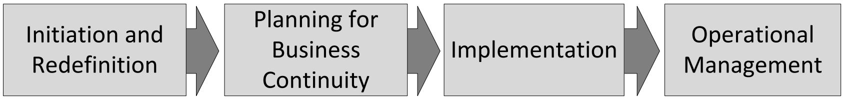

Fig. 4: The business continuity management process (Elliott, Swartz and Herbane, 2010)

3.5 Anti-fragility

The concept of anti-fragility is actually not a concept at all. It is more an idea which is promoted by Taleb (2012). It is based on his recognition of "black swans" (Taleb, 2010). These are disruptive events that have a low probability of occurrence but when they occur they have a large impact on the corresponding system. If the system is anti-fragile it would not lose but profit from the effect. In the context of this paper the system would be the supply chain. The idea of anti-fragility is to create a value network that thrives from an impact as shown in figure 5. Therefore, anti-fragility is defined as "anything that has more upside[s] then downside[s] from random events" (Taleb, 2012). How that should be achieved is not clear. A concept or framework still needs to be developed.

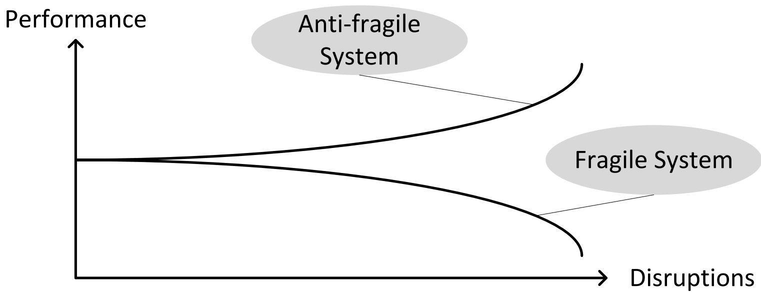

Fig. 5: Performance of anti-fragile and fragile systems

4. Differences and synergies

To interrelate the concepts introduced in the preceding chapter, we will first look at four aspects in order to identify differences and similarities. The distinction into operational and disruptive uncertainties, introduced in the second chapter, as well as the perception of uncertainties will be the foundation for this analysis. We also analyze whether the concepts handle internal or external uncertainties of a supply chain and whether they work proactively or only after an event occurs. Additionally, we will point out some special perspectives that help building a connectional framework.

4.1 Overlapping and differences of concepts

As explained before, a resilient supply chain is supposed to handle low-probability/high-impact events. In the language of Taleb (2012) these events are "black swans". They are not likely to occur at all, but when they do, the impact is dramatic. Handling them is also the aim of continuity management and an agile supply chain attempts to use them to create competitive advantages. The only concept that does not focus on disruptive events is the idea of a robust supply chain. Here the attention lies on handling operational uncertainty. Uncertainty is perceived as noise that has to be handled to create value for customers and all other members of the supply chain. Therefore, uncertainty can be described as risk, as it is in chapter 2. The same view is taken by the concept of continuity management. Although it deals with disruptive events, uncertainty is considered as a risk for business. The opposite perspective is taken by agile supply chain management and even more by the concept of anti-fragility. The latter sees disruptions as necessary and profits from them. Thus, an anti-fragile supply chain understands uncertainty as an opportunity. The same is true for agility. Changes and uncertainty should be used to create competitive advantages against other, less agile supply chains. Even if resilience is seen as the ability of a system to return to a more desirable state after a disturbance, uncertainties are considered as risks. In the best case they do not occur.

According to Waters (2007) uncertainties can appear within the supply chain or external. Agility means using opportunities in a volatile market. Therefore, this concept only focuses on external chances. Internal processes are not considered. The contrary can be said about all other concepts. Operational risks which are dealt with by robust management may occur in all internal processes as well as in the supply chain environment. As mentioned in chapter 3, examples for disruptions handled by resilient supply chain management can be earthquakes as well as factory shut downs. Therefore, risks are external as well as internal. This also can be said for the risks which are considered by continuity management. The focus is certainly more on external risks, like the 9/11-attacks, but processes within a supply chain and their vulnerability are considered as well. The same goes for the idea of anti-fragility. Anti-fragility is more a general idea than a developed concept. Nevertheless, it can be said that is reactive.

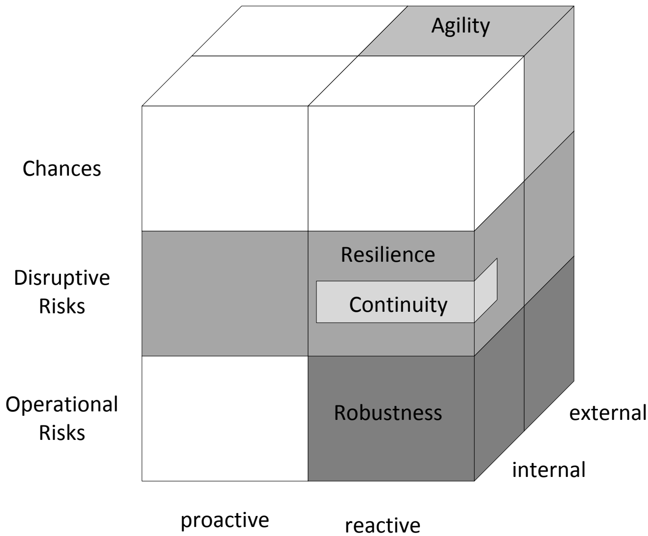

Fig. 6: Differentiation of concepts

As well as all other suggested approaches it has to be planned in advance before it is executed. But there are no actions that are taken before an event occurs. Only after appearance the system reacts. Continuity management is designed in the same way. Agility also tries to react quickly and create advantages after the incident. A robust supply chain will be able to handle operational risks with little or no adjustments. But even if no actions are necessary, it is still a reactive approach. The reasons for the risks are not tackled in advance. This is only done by resilient management. Here the mitigation of risks before they occur is part of the concept.

Before creating a framework that shows how the concepts work together, three important aspects should be highlighted. They are illustrated in figure 6 together with the previous characteristics. Both, for handling risks and for using opportunities a flexible supply chain is necessary. Thus, the main characteristics of an agile supply chain are its responsiveness and flexibility. Robust planning also enables value networks to react to a wide range of possibilities by establishing flexibility and redundancies. Klibi (Martel and Guitouni, 2010) describes these two factors as the components of responsiveness of a resilient supply chain. So, it can be said that flexibility is part of all three strategies. But even if assets have flexible abilities, they cannot be used if they are busy. Hence, redundancies are needed. Responsiveness is not possible without them.

Continuity management builds resilience. This is mentioned in the concept´s definition. It is the management of the responsiveness of a resilient supply chain. Therefore, continuity management can be seen as part of a resilient supply chain.

As already mentioned, anti-fragility is an idea but not a management concept or framework. For reasons of completeness, we will still interrelate it to the other concepts even if it is not a concept for itself. If a supply chain is anti-fragile, it will not be harmed by any kind of uncertainty, it will flourish. So, an anti-fragile system will also have the abilities of agility and resilience. As continuity management is part of resilience management it is also included into anti-fragility.

4.2 Framework of Handling Uncertainty

The purpose of this paper is to identify concepts which can handle uncertainties in supply chains. Therefore, different ideas were introduced. Figure 7 shows how some of them influence supply chain performance. In the bottom graph the variation of supply chain variables can be seen. There is the operational uncertainty every supply chain is exposed to. At three points the graph has a more then business-as-usual fluctuation. Here disruptive events occur. The first and the last are supposed to be internal, the one in the middle is market-driven.

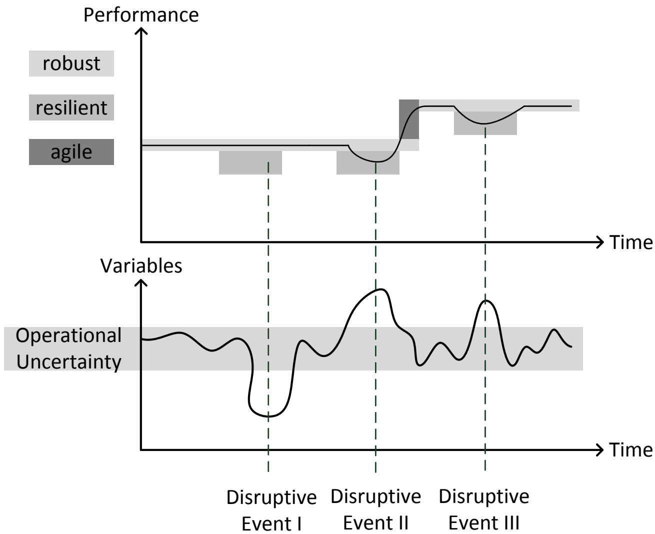

Fig. 7: Influence of robust, resilient and agile supply chain management

The upper graph shows the influence on supply chain performance when robust, resilient and agile supply chain management is executed. Note again that continuity management is also at work as it is part of resilient management. The robust approach accomplishes that operational fluctuations are mitigated so that a steady performance is possible. Resilient supply chain management allows the value network smoothly to return to its desired state after a major disruption. At the point of the second event this is a higher level of performance. Here chances are used to create competitive advantages.

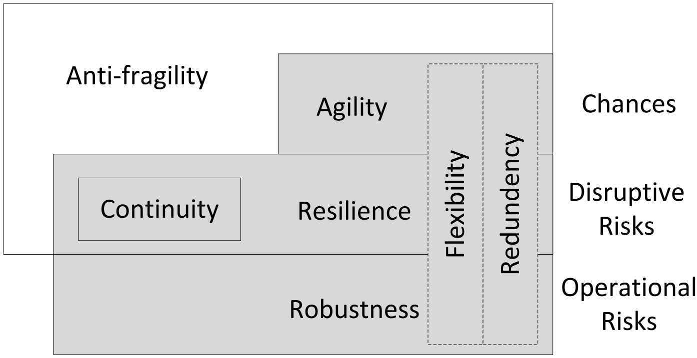

Fig. 8: Relationships between the five approaches

Therefore, it is not only resilient but also agile supply chain management that is at work. From figure 7 we can learn that robustness is the foundation of handling uncertainties. It is necessary to keep the day-to-day-business running and to prevent constant fire-fighting in cases of small fluctuations. But for major disruption, resilience is needed. In the best case, like the first event in figure 7, the mitigation-strategies of the resilient supply chain worked so far as that the fluctuation could be handled by the usual tools of the robust supply chain. In case of the second and third incident, however, reactive actions were needed. The events could not be prevented proactively. This means that resilience is only necessary when low-probability/high-impact events are possible and that it builds on robustness. Agility then is on top of these two concepts. It uses external events to direct the supply chain together with resilience into a more competitive position. Together with the realizations of the previous chapter it is possible to show the relationships of the concepts as they are depicted in figure 8. Redundancies and flexibility are main components of the three supply chain concepts. If an anti-fragile supply chain existed, it would contain agility as well as resilience. Robustness would not be part of it.

5. Conclusion

As the dynamic and complexity of global business increases, different approaches are developed to deal with uncertainties. In this paper, five concepts are introduced. Some coming directly from supply chain research, others prominent in disruption management or controversial discussed. After their presentation and comparison it turned out that the supply chain concepts are the most appropriate. In addition, continuity management could be identified as part of a resilient supply chain. The idea behind anti-fragility is most interesting. Yet, it needs more details to judge its applicability on supply chains and it is questionable whether it is more than a nice idea. Therefore, it currently cannot be used for handling uncertainties in supply chains.

This paper provides a framework for handling uncertainties in supply chains. But it is still just one step on the path to an integrated management concept. For the next steps future research should focus on:

- Identification of practical instruments
- Integration and coordination of the instruments across conceptual
- boarders
- Development of a trade-off tool

Literature on the introduced concepts provides a variety of possible instruments to handle uncertainty. But they are often vague from the point of practical application. Here specific guidelines for management need to be developed. At the moment, elements or entire tools are applied in more than one concept. Therefore, it is necessary to look at the instruments from an integrated perspective and not only from the point of view, a single approach has. This is important to avoid conflicts in their application and unnecessary costs. Thus, the trade-off between costs for handling uncertainties and its benefits have to be considered. Here the approach of Pettit (Fiksel and Croxton, 2010) may be the first step.

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Flexible Supply Chain Design under Stochastic Catastrophic Risks

Yingjie Fan, Frank Schwartz and Stefan Voß

Abstract

Real-world experiences prove that supply chains may suffer great losses or even complete break downs after catastrophic events. However, extra costs after great disasters are usually not incorporated in the supply chain costs in the existing literature. The aim of this study is to design a flexible cost efficient supply chain, which is able to keep stable supply even if great disasters happen. The supply chain is designed by initially determining the location of production facilities and choosing a transportation mode for each transportation link, and then estimating extra costs after a catastrophe occurs according to the type of the catastrophe and the structure and transportation modes of the supply chain. All variable costs, including supply chain catastrophe costs, operational costs, holding costs and transportation costs are included in the objective function of a two stage stochastic decision model. An algorithm is used to solve the model in order to get an optimal or close to optimal structure of the supply chain. Numerical results are presented. Based on computational experiments we can deduce that postponement is effective to deal with supply chain catastrophic events; slow transportation seems a viable option to leave more time for a supply chain for the adjustment of production planning after catastrophes.

Keywords: supply chain risk management, slow transportation, postponement, catastrophe

1. Introduction

Globalization makes international supply chains more and more versatile but also more complicated. Although humans have all sorts of high-tech nowadays, they are usually still not able to forecast catastrophes. Without rapid response and the right decisions, however, whole supply chains would easily break down if a catastrophe happens on any of its nodes or links. Nokia's huge success compared with Ericsson's great loss after a fire in a fabrication line of Philips on March 17, 2000 is a good example (Chopra and Sodhi, 2004). From then on, researchers pay more attention on risk management and supply chain risks.

For the purpose of developing sustainable supply chains, constructing flexible supply chains is necessary. Flexible supply chains would respond immediately if catastrophic events happen and recover quickly after such events. Flexibility can be defined as the ability to change or react with little penalty in time, effort, cost or performance (Grigore, 2007). From existing literature the characteristics of flexible supply chains could be summarized as follows: the supply chain has the ability to keep its negative impacts as small as possible after a catastrophe, and the whole supply chain is able to recover as soon as possible after a catastrophe happens.

This paper focuses on constructing a flexible supply chain through facility location and transportation mode selection under the risk that catastrophes may occur. The locations of suppliers and final product customer zones are out of our consideration in this paper since those are usually fixed and hardly to be changed. Facility location is a well-established research area (Melo, Nickel and Saldanha-Da-Gama, 2009), but we merely focus on the location of an assembling center. The assembling center and the processing center of a supply chain are often centralized in low labor cost areas or in areas with major resource availability. Usually these locations were chosen in periods when the supply and demand were stable and smooth. The diversified choices of the market as well as the harmfulness of the supply chains in times of crises motivate for thinking about a repositioning of an assembling center close to the

customer zone. A delayed finalizing of a product in this assembling center is called "postponement" (Zinn and Bowersox, 1988), which was mainly considered as a strategy for dealing with demand uncertainty in previous research. The transportation modes (air, water, rail, and road) in each case can be assumed as either fast or slow. The existing literature about slow steaming primarily focuses on freight and environmental factors. None of the previous research regards postponement or slow transportation as a strategy for dealing with supply chain disruption risks. In this paper, we provide theoretical support to the implementation of postponement and slow steaming in reality by analyzing the impacts of postponement and slow transportation to the supply chain's flexibility in an environment where catastrophic events may occur. In addition, this paper sets the pace of using postponement strategies and slow transportation in order to form a flexible supply chain under supply chain disruption risks not only in scientific research, but also in practices.
The subsequent section consists of a brief literature review. A detailed problem description is provided in the third section in order to introduce the model's background. Assumptions, the objective function as well as the constraints, and an algorithm for solving the model are presented in Section 4. Computational experiments are given in Section 5 in order to demonstrate the effectiveness of our model. The paper finishes with the conclusion in the sixth section.

2. Literature review

Supply chain risks can be classified into various levels including: operational risks and disruption risks (Tang, 2006). Operational risks refer to inherent uncertainties such as uncertain customer demand, uncertain supply and uncertain costs; disruption risks refer to major disruptions caused by natural and man-made disasters. A typology of risk sources, consisting of environmental factors, industrial factors, organizational factors, problem-specific factors and decision-maker related factors is presented in (Rao and Goldsby, 2009). Relevant literature about supply chain risk management

(SCRM) is collected and classified, e.g., in (Tang, 2006), (Kouvelis, Chambers and Wang, 2006), and (Dadfar, Schwartz and Voß, 2012). Although many qualitative analyses and quantitative models of SCRM exist, most quantitative models for managing supply chain risks focus on operational risks. In contrast, disruption risks are usually disregarded (Tang, 2006). Many researches in the academic literature focus upon single agent problems even though the nature of supply chain management (SCM) almost always involves multiple parties (Kouvelis, Chambers and Wang, 2006). Six risk management strategies with respect to environmental conditions and three moderators are presented in (Manuj and Mentzer, 2008). SCRM, as a nascent research area, has three research “gaps” (Sodhi, Son and Tang, 2012): no uniform definition of SCRM, lack of corresponding research on response to supply chain risk incidents, and a shortage of empirical research in the area of SCRM. Although a huge amount of literature exists about risk management, a good portion of it only focuses on demand fluctuations. Rather few papers point out how to cope with catastrophic events. (Woodruff and Voß, 2006) present a first attempt to deploy a progressive hedging algorithm on the supply chain production planning problem with big bang scenarios. This problem is the focus of this paper.

Postponement was introduced in the marketing literature in the 1950s and can be traced back to the 1920s in practice. Five types of postponement strategies are defined and tested in (Zinn and Bowersox, 1988). Researchers on qualitative as well as quantitative analyses of postponement strategies followed this paper, such as (Van Hoek, Vos and Commandeur, 1999), (Pagh and Cooper, 1998), (Waller, Dabholkar and Gentry, 2000), and (Guericke, Koberstein, Schwartz and Voß, 2012). The relationship between postponement and product customization is analyzed thoroughly in (Waller, Dabholkar and Gentry, 2000), who also reveal that an accelerated production decreases total costs. More specifically regarding the focus of this paper, a two-stage stochastic mixed integer linear programming model is built to solve supply chain production and distribution network design problems (Guericke et al., 2012). Advantages of postponement are shown by means of experimental results.

In order to take advantage of improved fuel economy and reduced operating costs, slow steaming was proposed (Perakis and Papadakis, 1987). It is the practice of operating a ship or a fleet of ships at a speed less than their original operating speed. Slow steaming is believed to be a low bunker consumption and environmental friendly way of shipping (Wang and Meng, 2012), whereas fast shipping is preferred by shipping companies and customers due to the extended traveling time and the increased tied-up capital of slow steaming (Meyer, Stahlbock and Voß, 2012), (Psaraftis and Kontovas, 2013).

Lean, agile and so-called leagile strategies are discussed in (Ben Naylor, Naim and Berry, 1999), (Christopher and Towill, 2000), (Mason-Jones, Naylor and Towill, 2000) and (Goldsby, Griffis and Roath, 2006). The two paradigms of lean and agile are complementary within a supply chain strategy. The decision whether to realize an agile capability or a lean manufacturing structure depends upon the location of the supply chain's members (Ben Naylor, Naim and Berry, 1999). The lean paradigm claims that “fat” has to be eliminated, while the agile paradigm must be “nimble” since lost sales are gone forever. Both agility and leanness require minimum total lead-times, and lean supply upstream and agile supply downstream are bringing both paradigms together in a beneficial way (Christopher and Towill, 2000).

It is a matter of common knowledge in the supply chain research that supply chains usually benefit from short lead times. Short cycle times and supply chain flexibility are believed to go hand in hand (Stewart, 1995). The total value to the customers ought to be an inverse proportion to the lead times in a supply chain (Johansson, Machugh, Pendlebury and Wheeler, 1993). Lead time is identified as one of the most important measures to quantify the value of a product from the customer's view (Gunasekaran, Patel and McGaughey, 2004). However, some researchers postulate that safety lead times are useful under supply uncertainties. Literature on safety lead times and safety stocks can be found in (Dolgui, Ammar, Hnaien and Louly, 2013). A framework for studying uncertainty in MRP systems which incorporates a simulation approach is presented in (Whybark and Williams, 1976). The simulation study indicates that providing safety lead times is the preferred technique under timing uncertainty, and providing safety stocks is beneficial under quantity uncertainty. Numerical experiments in (Hegedus and Hopp, 2001) indicate that optimal safety lead times increase in both supplier variability and system utilization. A simulation study in (Van Kampen, Van Donk and van der Zee, 2010) demonstrates that providing lead times is more effective with supply variability, but providing safety stocks is more effective with uncertainties in demand. In case of uncertainties of both supply and demand, providing safety lead times is more effective than providing an equivalent level of safety stocks. Considering the complexity of the design process of global supply chain networks, algorithms are proposed especially for this problem class. One method combines an accelerated Benders decomposition algorithm with a sample average approximation (SAA) to quickly solve large-scale stochastic supply chain design problems (Santoso, Ahmed, Goetschalckx and Shapiro, 2005).

3. Problem description

Fast transportation and zero inventory policies are adopted by lots of companies to accelerate capital turnover speed and reduce holding costs. Because of the lower labor costs, developing countries like China and India are the center of the world's factory. However, global distributed supply chains become more complicated and rather fragile especially if catastrophic disasters happen. The traditional approach to keep a certain quantity of buffer inventories, which is an effective way to cope with normal fluctuations of customer demand, is not valid to cope with natural catastrophe risks of global supply chains. The reason for this is that most natural catastrophes are hard to forecast, and their fluctuations exceed the time and inventory redundancies that may be provided in order to effectively deal with these catastrophes.

3.1 Supply chain structure

Often there are markets close to the area of origin as well as foreign markets which are far from original suppliers. In this paper we focus on the latter case (see Figure 1).

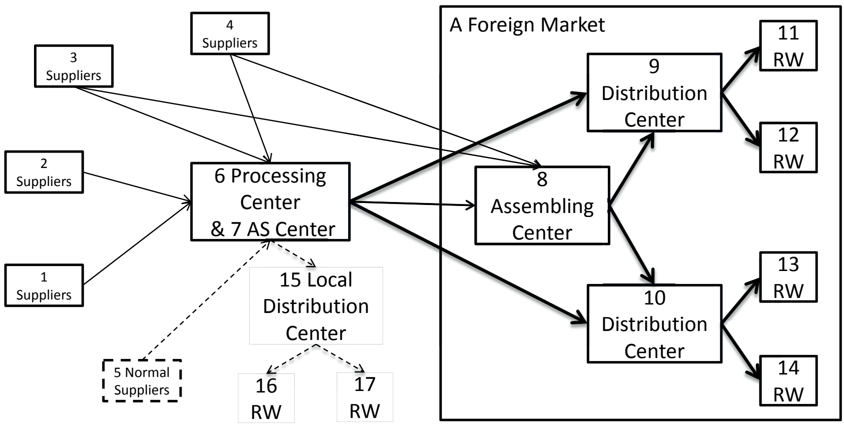


Fig. 1: Global supply chain with focus on one foreign market area

There are two ways of delivering products to foreign markets: delivering final products from the origin area, or delivering semi-finished products from the origin area and assembling them to final products in assembling centers which are close to the foreign markets. The first way results in lower labor costs and higher delivery costs; the second way, which represents a postponement strategy, results in higher labor costs and lower delivery costs. The delivery time could be short (by air transport) with a higher transportation fee and a shorter capital holding period, or long (by sea transport) with a lower transportation fee and a longer capital holding period. Our supply chain (SC) model takes into account stochastic catastrophic risks (on a node) and selects both the appropriate assembling center for a foreign market and the appropriate transportation mode for each transportation link.

3.2 Available time recovering from a catastrophe

In the following, the available time for recovering a SC from a catastrophe is determined. This time ought to be so long that the material flow does not become tardy at the subsequent node(s) of the disrupted node.

Suppose that the transportation time from node i to node j is $Trans_{i,j}$ and the booking period (order lead time) of node j from node i is $T_{i,j}$. If the order and transportation processes of an item are continuous, the available time before the tardiness of a subsequent node equals the transportation time from a destroyed node i to the next node $Trans_{i,j}$. Otherwise, if the order and transportation processes are discrete, the available time, if node i is destroyed and before tardiness occurs at node j, can be written according to:

$$\left\lfloor \frac{Trans_{i,j}}{T_{i,j}} \right\rfloor \times T_{i,j} \leq Available\ Time \leq \left\{ \left\lfloor \frac{Trans_{i,j}}{T_{i,j}} \right\rfloor + 1 \right\} \times T_{i,j} \qquad (1)$$

$\lfloor x \rfloor$: $maximum\ integer\ not\ bigger\ than\ x$ The larger $Trans_{i,j}$, the longer is the available time for recovering the SC. If the available time is sufficiently long and the emergency plan is sufficiently efficient, negative impacts are kept away from the final retailers, or even from the subsequent node of the disruption. Otherwise, it becomes more unlikely to avoid unmet demands if the available time is short. It can be deduced from (1) that a SC acts more flexibly by using slow transportation. On the contrary, slow transportation is harmful especially for perishable or stylish products which are subject to rapid obsolescence. According to this awareness, the transportation mode for these product types should be as fast as possible, or the distance between the suppliers and the customer zones should be as close as possible.

Many companies keep high levels of inventories and fast transport modes simultaneously in order to avoid unmet final demands if disruptions happen. This policy is costly and may be ineffective. Excess inventories may be useful in case of catastrophes only if they are always on a high level at each node of the SC. As a catastrophe is an unexpected event and time, location and extent of damage are not known in advance, keeping high levels of inventory all the time and using fast transport modes increases inventory costs as well as transportation costs considerably.

4. Model description

A mathematical model is built in order to verify whether the whole SC becomes more flexible in case of a catastrophe by using slow transportation modes in the SC. Our model consists of a flexible SC structure. In a first step, the location of each crucial node of the SC is chosen. In a second step, transportation modes for each connection are determined by the model in order to obtain an optimal or near optimal solution. The impact on a SC after a catastrophe varies dependent on its structure and the current transportation mode. A flexible SC is able to mitigate the impact of a stochastic catastrophe, resulting in minimal SC losses. Optimal solutions can be obtained by using exact methods for small instances; approximate solutions are obtained by metaheuristics for larger instances. The solution process of the model should be designed in a fashion that a solution after a catastrophe can be quickly calculated.

4.1 Assumptions

According to Figure 1, we focus on the foreign market. Products can be finalized in a local combined processing and assembling center or in an assembling center in the area of the foreign market. Considered nodes in the model are crucial nodes incorporating the suppliers of crucial materials/components, operational nodes (processing, assembling and distribution centers), and retailers. Each crucial node has at least one partner, who has a similar or the same function and could act as a substitute if a catastrophe happens on the original node. All catastrophic scenarios refer to these crucial nodes.

The following additional assumptions are made within our model. External help is charged with extra costs. These come from overtime work at the external site and extra transportation costs due to the farther distances from the external site to the downstream nodes of the SC. Stock outs of final products result in penalties. There is no backorder for unmet demands of the final products. Final demands are assumed to be constant. The whole SC follows the make-to-order principle. Stock-keeping does not take place in the nodes of the SC. Existing inventories are in transit inventories. Holding costs are related to the costs of the goods in transit. Slow transportation takes more time and is less costly than fast transportation on the same link. Assembling centers having shorter distances to a foreign market are assumed to have higher labor costs, and vice versa. If the assembling center in a foreign area is destroyed, the products can be finalized at the internal partner, the combined processing and assembling center, which means that assembling costs actually may decrease. Finally, within the considered time horizon no more than one catastrophic event occurs.

4.2 Model formulation

We consider a SC network Net = (N, $Conn$) where N is the set of nodes and $Conn$ is the set of arcs between the nodes. Below a formulation of the developed model is given.

Sets:

N: Set of nodes

S: Set of suppliers, $S \subset N$

RW: Set of retailers/wholesalers, $RW \subset N$

AS: Set of assembling centers, $AS \subset N$

PA: Set of processing & assembling centers, $PA \subset N$

DC: Set of distribution centers, $DC \subset N$

OP: $OP = AS \cup PA \cup DC,\ OP \subset N$

P: Set of products

P_i: Set of products $P_i \subset P$ at node $i \in N$

$Conn$: Set of transportation links between the nodes in the SC

Up_i: Set of nodes $g \in N$ which satisfies $(g,i) \in Conn$

$Down_i$: Set of nodes $j \in N$ which satisfies $(i,j) \in Conn$

$MChain_{p_i}$: Set of product p_i's potential generation processes, $p_i \in P, i \in N$

Parameters:

T: Time horizon

$OC_{p_i,i}$: Operational cost coefficient at node $i \in N$ per unit $p_i \in P_i$

$PC_{p,i}$: Purchasing cost coefficient per unit of product $p \in P$ from the supplier $i \in S$

$Cf_{p,i,j}$: Fast transportation cost coefficient per unit of product $p \in P$ from node i to node j, $(i,j) \in Conn$

$Cs_{p,i,j}$: Slow transportation cost coefficient per unit of product $p \in P$ between nodes i and j, $(i,j) \in Conn$

$C_{p,i,j}$: Transportation costs of product $p \in P$ between nodes i and j, $(i,j) \in Conn$

$Tf_{p_i,i,j}$: Time for fast transportation of product $p_i \in P_i$ between nodes i and j, $(i,j) \in Conn$

$Ts_{p_i,i,j}$: Time for slow transportation of product $p_i \in P_i$ between nodes i and j, $(i,j) \in Conn$

$T_{p,i,j}$: Transportation time for product $p \in P$ between nodes i and j, $(i,j) \in Conn$

$q_{i,j}(p_i,p_j)$: Number of products $p_i \in P_i$ needed to make one unit of product $p_j \in P_j$, $(i,j) \in Conn$

h: Per period cost coefficient of lock up capital

$V(p,\ i)$: Accumulated costs per unit of product $p \in P$ after being finished at node $i \in OP \cup RW$, or per unit purchasing price for $i \in S$

$D(i,p)$: Demand per period of product $p \in P_i$ at node $i \in RW$

$A(p)$: Per unit penalty cost coefficient for unmet demand of the final product $p \in P$

$At(p,i)$: Time period of stockout of product $p \in P_i$ at node $i \in N$

RT: (SC) Reconstruction time after a catastrophic event occurs

k: Index of catastrophic scenarios, $k = 1, \dots, K$

$T_{ex1}(i)$: Transportation time to an alternative node after a catastrophe happened at node $i \in N$

$C_{ex1}(p)$: Transportation costs per unit of product $p \in P_i$ to an alternative node after a catastrophe happened at node $i \in N$

$T_{ex2}(i)$: Transportation time from an alternative node after a catastrophe happened at node $i \in N$

$C_{ex2}(p)$: Transportation costs per unit of product $p \in P_i$ from an alternative node after a catastrophe happened at node $i \in N$

r: Probability that a catastrophe happens within the time horizon T

α: Correction factor of OC_i in case of a catastrophe at node $i \in N$

$CR(k)$: SC costs during the reconstruction time of the catastrophic scenario k

ECR: Expected SC costs during the reconstruction phase of a catastrophe

TCN: Annual SC costs without any catastrophe

TCR: Expected annual SC costs if a catastrophe happens within the time horizon T

ATC: Minimal annual expected SC costs

Decision variables:

y_i: Node $i \in N$ is part of the SC, if $y_i = 1$, otherwise $y_i = 0$

$yf_{p,i,j}$: Selection of a fast transportation mode for product $p \in P$ between node i and node j, if $yf_{p,i,j} = 1$, otherwise $yf_{p,i,j} = 0$, $(i,j) \in Conn$

$ys_{p,i,j}$: Selection of a slow transportation mode for product $p \in P$ between node i and node j, if $ys_{p,i,j} = 1$, otherwise $ys_{p,i,j} = 0$, $(i,j) \in Conn$

Objective function:

$$ATC = min\{ (1-r) * TCN + r * TCR\} \tag{2}$$

S.t.:

Annual SC costs without any catastrophe:

$$TCN = \sum_{\substack{i \in RW \\ p \in P_i}} V(p,i) * D(i,p) * T \tag{3}$$

Annual SC costs in case of a catastrophe:

$$TCR = \sum_{\substack{i \in RW \\ p \in P_i}} V(p,i) * D(i,p) * [T - RT] + ECR \tag{4}$$

Expected SC costs during the reconstruction time of a catastrophe:

$$ECR = \sum_{k=1}^{K} CR(k)/K \tag{5}$$

SC costs during RT of the catastrophic scenario k:

$$CR(k) = \sum_{\substack{i \in RW \\ p \in P_i}} \{ A(p) * D(i,p) * At(p,i) + V(p,i) * D(i,p) * \left(RT - At(p,i)\right) \}, \forall k = 1 \dots K \tag{6}$$

Costs at supply nodes:

$$V(p,i) = PC_{p,i}, \forall\, i \in S, p \in P | y_i = 1 \tag{7}$$

Costs at all nodes except supply nodes:

$$V(p_j, j) = \sum_{(i,j) \in Conn} \sum_{p_i \in P_i} \{ V(p_i, i) * q_{i,j}(p_i, p_j) + C_{p_i,i,j} * q_{i,j}(p_i, p_j) + h * V(p_i, i) * q_{i,j}(p_i, p_j) * T_{p_i,i,j} \} + OC_{p_j,j}, \forall\, j \in OP \cup RW, p_j \in P_j | y_j = 1 \tag{8}$$

Transportation costs:

$$C_{p_i,i,j} = yf_{p_i,i,j} * Cf_{p_i,i,j} + ys_{p_i,i,j} * Cs_{p_i,i,j}, \forall\, p_i \in P_i, (i,j) \in Conn \tag{9}$$

Transportation time:

$$T_{p_i,i,j} = yf_{p_i,i,j} * Tf_{p_i,i,j} + ys_{p_i,i,j} * Ts_{p_i,i,j}, \forall\, p_i \in P_i, (i,j) \in Conn \tag{10}$$

Controlling the transportation modes:

$$yf_{p_i,i,j} + ys_{p_i,i,j} \le y_i \le 1, \; yf_{p_i,i,j} + ys_{p_i,i,j} \le y_j \le 1, \forall\, p_i \in P_i, (i,j) \in Conn \tag{11}$$

Variable definition and nonnegativity constraints:

$$y_i \in \{0,1\}\ \forall\, i \in N,\ yf_{p,i,j},\ ys_{p,i,j} \in \{0,1\}, \forall\, p \in P, (i,j) \in Conn \qquad (12)$$

The objective function (2) specifies the minimal annual expected costs of the considered SC. Annual SC costs in the standard case without a catastrophic event are obtained from (3). The annual SC costs in case of a catastrophe in (4) consists of two parts: the second part calculates the SC costs during the reconstruction period of the catastrophe, which is deduced from (5) and (6); the first part quantifies the SC costs during the rest of the period if no negative effects from any catastrophe exist. Note that $V(p,i)$ in (3) and (4) is calculated by (7) and (8) with the values of $C_{p_i,i,j}$ and $T_{p_i,i,j}$ determined in (9) and (10). Constraint (11) secures that transportation between two nodes only happens if both nodes are available. Furthermore, it is secured by (11) that a selected transportation mode can be either fast or slow. (12) constitutes appropriate variables to be binary.

SC costs during a period without catastrophes can be calculated according to (3) with known binary values of $yf_{p_i,i,j}$ and $ys_{p_i,i,j}$. A period with a catastrophic event can be regarded as a three-phase process, which includes a possible stock out phase, an acceleration phase, and a temporary stable phase. The SC may suffer a short time span with unmet final demands (first phase). In this case, a temporary production and transportation planning occurs in order to accelerate production and transportation processes and meet the final demands as much as possible. This approach represents the acceleration phase and can be operated with internal or external help. A temporary stable status can be achieved in the third phase by determining an appropriate transportation mode based on the new formed structure with internal or external help if the recovery time is sufficiently long. The potential difference between plans of the last two phases is that transportation modes may differ. But since the time span to recover from a catastrophe is usually difficult to forecast, the accelerating plan is typically used in the third phase of a catastrophe, too. For a particular catastrophic scenario $k\ (k = 1 \dots K)$, $CR(k)$ can be deduced in this way. Below this approach is explained in more detail.

First of all, costs and time consumptions will be changed in the SC after a catastrophe occurs at node $i \in S \cup AS \cup PA$. The tardiness time for product $p \in P_j$ at node j, $At(p,j)$, $\forall\ (i,j) \in Conn$, can be calculated. The operational cost coefficients $OC_{p,i}$ are changed for nodes $i \in OP \cup RW,\ p \in P_i$, or the purchasing cost coefficients $PC_{p,i}$ are changed for $i \in S,\ p \in P_i$. Transportation fees and transportation times are also changed due to the new route from/to the alternative node.

In case of $i \in PA$ for each $p \in P_i$ calculate:

$$OC_{p,i} \leftarrow OC_{p,i} * (1 + \alpha)$$

Other values will be changed as follows:

For all $(g,i) \in Conn, (i,j) \in Conn$ calculate:

$$At(p,j) = T_{ex1}(i) + T_{ex2}(i) - T_{p,i,j}$$

$$T_{p,g,i} \leftarrow T_{ex1}(i), \quad C_{p,g,i} \leftarrow C_{ex1}(p)$$

$$T_{p,i,j} \leftarrow T_{ex2}(i), \quad C_{p,i,j} \leftarrow C_{ex2}(p)$$

In case of $i \in S$ for each $p \in P_i$ calculate:

$$PC_{p,i} \leftarrow PC_{p,i} * (1 + \alpha)$$

Other values will be changed as follows:

For all $(i,j) \in Conn$ and $p \in P_i$ calculate:

$$At(p,j) = T_{ex2}(i) - T_{p,i,j}$$

$$T_{p,i,j} \leftarrow T_{ex2}(i), \quad C_{p,i,j} \leftarrow C_{ex2}(p)$$

In case of $i \in AS$ and an alternative node $i' \in PA$ for each $p \in P_i$ calculate:

$$OC_{p,i} \leftarrow OC_{p,i'} * (1 + \alpha)$$

Other values will be changed as follows:

For all $(g,i') \in Conn, (i',j) \in Conn$ calculate:

$$At(p,j) = \max\{0, T_{p,g,i'} + T_{p,i',j} - T_{p,i,j}\}$$

$$T_{p,g,i} \leftarrow T_{p,g,i'}, \quad C_{p,g,i} \leftarrow C_{p,g,i'}$$

$$T_{p,i,j} \leftarrow T_{p,i',j}, \quad C_{p,i,j} \leftarrow C_{p,i',j}$$

Secondly, accelerate the transportation on all transportation links $(g, m) \in Conn$ when $At(p_g, g) > 0$ and check the values at node $m \in N$ which are on the downstream side of the destroyed node.

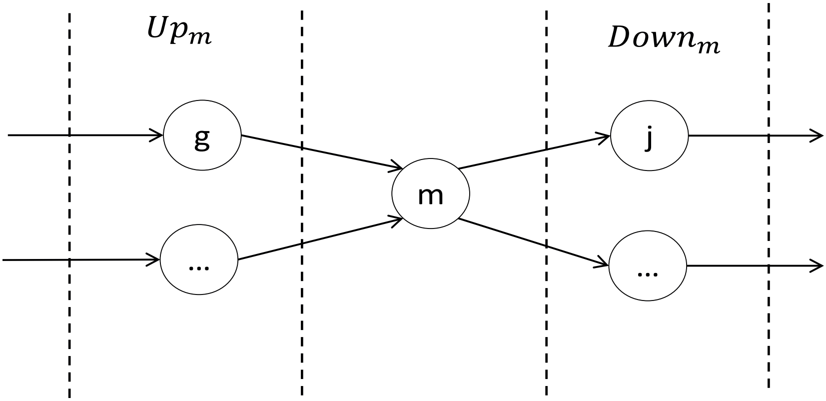


Fig. 2: Upstream and downstream node set

For each downstream node $m \in N, p_m \in P_m$ and $g \in Up_m, p_g \in P_g$ calculate:

If $At(p_g, g) > 0$

$$At(p_m, m) \leftarrow \max_{p_g \in MChain_{p_m}} \{0, At(p_g, g) - (T_{p_g,g,m} - Tf_{p_g,g,m})\}$$

$$T_{p_g,g,m} \leftarrow Tf_{p_g,g,m}, \; C_{p_g,g,m} \leftarrow Cf_{p_g,g,m}$$

$$yf_{p_g,g,m} \leftarrow 1, \qquad ys_{p_g,g,m} \leftarrow 0$$

The tardiness time of each final product can be calculated for each retailer/wholesaler node. Obtain $V(p_m, m)$ through the iteration of (8) for all downstream nodes of the destroyed node m, and then deduce TCR through (4). Eventually, the objective function value will be calculated through (2).

4.3 Algorithm

An algorithm in order to calculate the objective function value consists of the following steps:

Step 1: Fix values of binary variables y_j and get the connection set $Conn$
Step 2: Fix values of binary variables $yf_{p_i,i,j}$ and $ys_{p_i,i,j}$ for each transportation link $(i,j) \in Conn$
Step 3: Assume the case that no catastrophe occurs. Calculate the annual total costs TCN, which can be obtained through (3) and (8)
Step 4: Get TCR in case of a catastrophe
Step 5: The objective function value based on the determined SC structure and transportation modes according to Steps 1 and 2 is acquired.
Small scale problems could be optimized by an exhaustive search. Meta-heuristics or PH (progressive hedging) could be used for large scale problems.

5. Computational Experiments

In this section the experimental design as well as computational results are presented. Suppliers include both crucial and normal suppliers. A final product could be finished in an assembling center, which is located close to the foreign market, or in the combined processing and assembling center, which is located close to the origin suppliers. All products should be processed in a processing center and an assembling center. Final products are sent to distribution centers/warehouse centers at first, and then they are distributed to local retailers. We do not consider the type of a catastrophe in our experiments; we only care about its location. A catastrophe could happen in an experiment at one of the crucial suppliers, at the processing center, or at the assembling center. If one of the crucial suppliers breaks down, an alternative partner of the destroyed supplier will provide the same components or similar components with higher purchasing costs and higher transportation fees.
If a processing center is damaged by a catastrophe, all products will be sent to an alternative processing center. The processing costs at this alternative processing center, the transportation time as well as the transportation fees are increased due to overtime working costs and longer distances from and to the alternative processing center. Final products can be assembled at a combined

processing and assembling center which represents a common policy for the majority of companies, or at an assembling center, which is established close to the foreign market. With respect to this assembling center we suppose that it operates with increased assembling costs. If the assembling center is destroyed, the final products can be assembled at the combined processing and assembling center with lower assembling costs. Note that a totally destroyed center for combined processing and assembling consequently leads to an interruption of both manufacturing and assembling activities at this site.

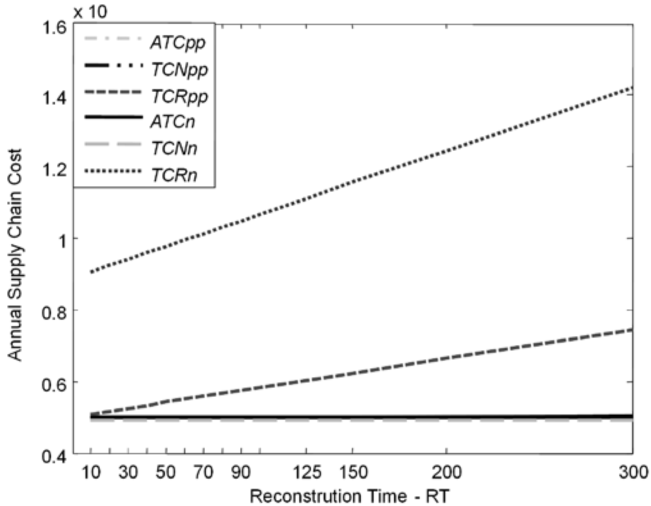
The SC in our experiments incorporates 14 nodes (see Figure 1). The assembling center could be located at nodes 7 or 8, which represents the first stage decision. Transportation links are fixed after the location of the assembling center is determined. The second stage variables determine the transportation mode for each link. The optimal annual SC costs are calculated after the first and second stage decisions are made. We use an exhaustive search to try all possibilities of all variable values in order to find the optimal solution. Motivated by the huge negative impacts from catastrophes that may happen at upstream nodes of the SC, six catastrophic scenarios with respect to six crucial nodes are considered in our experiments: four crucial suppliers, the combined processing and assembling center, and the foreign assembling center. Since catastrophes happen randomly, we assume that these six nodes have the same possibility to get destroyed. For the transportation links holds that the transit times in the slow mode are assumed to be nine times longer than in the fast mode, and similarly, that transportation fees in the fast mode are assumed to be nine times higher than in the slow mode.

We performed three analyses for two problem instances P1 and P2 in each case: In the first analysis, we determined optimal annual SC costs depending on different reconstruction times RT, which may be within the parameters of 10 days and 300 days (see Figures 3 a and b). In the second analysis, we identified optimal annual SC costs depending on different holding costs (see Figures 4 a and b), and in a third analysis, the optimal annual SC costs were calculated depending on different tardiness cost coefficients (see Figures 5 a and b). The problem instances P1 and P2 equal in each analysis regarding their SC structure, but differ significantly regarding several parameter values. For example, in the first analysis, in P2 the distances are longer than in P1, and in the second and the third analysis, in P2 diverse cost coefficients like purchasing or production cost coefficients are higher than in P1.

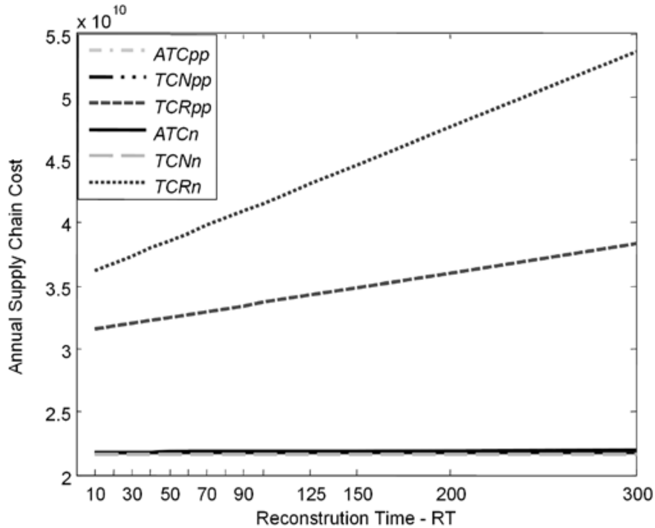
In Figures 3, 4 and 5, six different types of annual SC costs are illustrated: $ATCpp$ and $ATCn$, which can be calculated from (2), are the expected annual SC costs in case of using or not using postponement, respectively. The probability r that a catastrophe occurs within the considered time horizon is assumed to be 1%. The holding cost coefficient h is assumed to be 0.01. $TCNpp$ and $TCNn$, which can be obtained from (3), are the annual SC costs with and without applying postponement if no catastrophe occurs. $TCRpp$ and $TCRn$, which can be received from (4), are the corresponding costs if a catastrophe occurs within the time horizon.

All solutions are generated by Matlab R2013a on a Windows PC (i5-3570 Core, 3.40 GHz, 8.00 GB RAM, Windows 7 Enterprise). The solution time for a group of six SC costs with each value of RT/holding cost coefficients/tardiness cost coefficients are between 69 s (seconds) and 79 s. The average time used for each group of SC costs of P1 and P2 in the first analysis are 71.27 s and 74.99 s, respectively; these times are 72.16 s and 74.86 s in the second analysis, and 71.59 s and 71.77 s, respectively, in the third analysis. The output times of P1 and P2 in the first analysis are below one second in all cases. The numerical results of the first analysis are presented in Figure 3.

Figure 3 reveals that if no catastrophe happens within the considered time horizon T, the annual SC costs do not vary a lot. However, if a catastrophe happens in the considered time horizon, the annual costs increase dramatically, particularly if the implementation of a postponement strategy is not taken into account. TCRn in the figure of problem instance P2 (see Figure 3 b) increases faster than in problem instance P1 (see Figure 3 a).



(a) P1



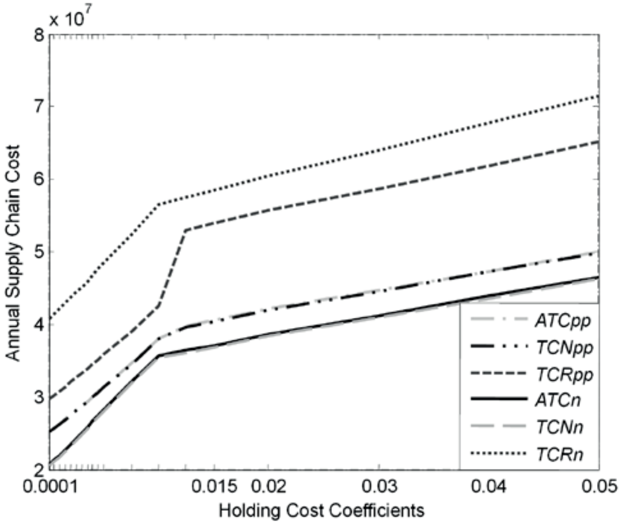
(b) P2

Fig. 3: Annual SC costs for P1 and P2 depending on the reconstruction time

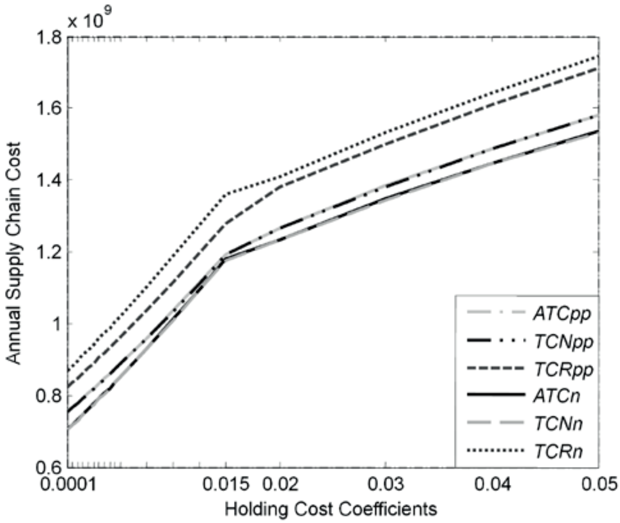
The optimal solution if postponement is taken into account predominantly uses slow transportation. Only one link from one of the distribution centers to one of the retailers uses fast transportation. The optimal solution if postponement strategies are not taken into account determines a slow transportation mode for the links from the suppliers to the combined processing and assembling center. For the remaining links a fast transportation mode is selected. The optimal solutions in our first analysis provide for both SC structures (with and without postponement), that slow transportation modes are selected for transportation links originating from suppliers, and fast transportation modes are selected for links outgoing from processing centers.

In Figure 4, the numerical results of the second analysis are displayed. The cause of the inflection points at the holding cost coefficients around 0.01 in Figure 4 a and 0.15 in Figure 4 b is that at these values a change of the transportation mode takes place. We can deduce that the decision of transportation modes rely on the holding cost coefficients. Optimal solutions of both structures (with and without postponement) use slow transportation if the holding cost coefficients are very low (below 0.0075). More and more links use a fast transportation mode if the holding cost coefficients increase and all links use a fast transportation mode if the holding cost coefficients are above 0.03.

As mentioned above, purchasing costs in P2 are decuple of P1. The structure with postponed assembling performs better for lower purchasing costs. This is constituted by the fact that the optimal transportation modes in SCs with implemented postponement strategies always choose slow transportation for some links. If the purchasing costs increase, the holding costs of cargo which traverses the SC on links with the slow transportation mode increase very fast. From this point of view, we can conclude that postponement and slow transportation are more beneficial if the purchasing costs of the required components are lower.

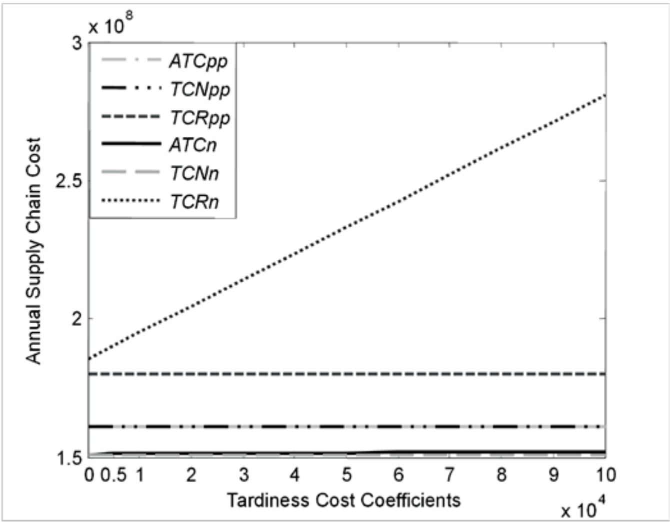


(a) P1

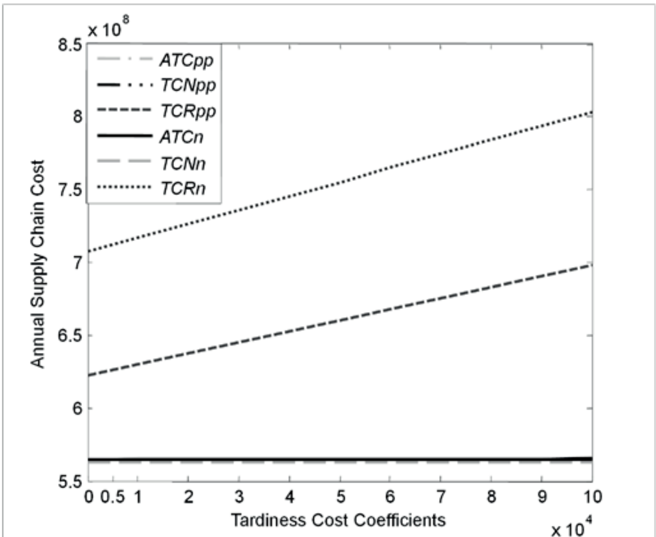


(b) P2

Fig. 4: Annual SC costs for P1 and P2 depending on holding cost coefficients



(a) P1



(b) P2

Fig. 5: Annual SC costs for P1 and P2 depending on tardiness costs

Figure 5 visualizes the numerical results of the third analysis. In the third analysis, the purchasing costs of instance P2 are also decuple of instance P1. It can be seen from Figure 5 that in case of lower purchasing costs (see instance P1), a variation of tardiness cost coefficients has no impact on $TCRpp$, but a considerable impact on $TCRn$. The reason is also that the transportation modes are different. Five links are slow transportation modes with the implementation of postponement strategies in P1, but only one slow transportation mode is adopted for the structure without using postponement strategies. The optimal solutions of both structures with and without the implementation of postponement in P2 consist of seven links using fast transportation and five links (from suppliers to the processing center or the assembling center) using slow transportation. When purchasing costs are higher, more links adopt fast transportation with the implementation of postponement. More fast transportation links reduce the flexibility of the SC, which is the reason why $TCRpp$ in P2 is not as stable as in P1.

6. Conclusion

This paper deals with the idea to incorporate postponement as a strategy to operate supply chains in case of disturbances. In case of catastrophic events our results allow for deducing some important insights. Postponement strategies are advantageous if the probability of a catastrophic incident in a SC is high. If postponement strategies are not considered, costs are higher if a catastrophe happens at a node of the SC, especially if the reconstruction time of the destroyed node is long. Slow transportation is preferred if capital holding costs are extremely low, and fast transportation modes are preferred if holding costs are higher. Increasing tardiness costs have no negative effects if no catastrophe occurs, but the annual SC costs increase extremely if a catastrophe happens. Annual SC costs increase a little faster with rising transportation link distances if postponement strategies are not taken into account than in the case that postponement strategies are considered.

If no catastrophe occurs, optimal solutions with or without an implementation of postponement strategies do not differ very much. But if a catastrophe happens at any SC node, the SC costs without the implementation of a postponement strategy increase dramatically. One important aspect is that postponement strategies come along with slow transportation. This does not mean that slow transportation should be used for all transportation links in a SC, but for a few of them – especially for the transportation links from the original suppliers. Slow transportation is not selected in this context due to the cheaper transportation fees, but due to the fact that transportation links with slow transportation modes consist of the capability to accelerate the product flows. Finally, this results in a more flexible supply chain. Moreover, this paper also provides the theoretical basis for companies to choose the transportation mode for each transportation link. It also gives the insight that slow steaming, as a typical slow transportation mode, not only benefits the natural environments, but also benefits the whole SC.

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A Risk Management Approach for the Pre-Series Logistics in Production Ramp-Up

Patrick Filla and Katja Klingebiel

Abstract

Due to continuing derivatisation and increasing customer requirements, automotive development projects constantly become more complex. With a shortening time-to-market, the critical ramp-up phase of a new or updated automobile is susceptible to a variety of disruptions. As the project duration is naturally restricted, a high number of unscheduled ad-hoc resources are regularly installed to achieve the previously set qualitative targets within the given time limits. For early risk mitigation, current approaches in research and industry focus on the measurement of either technical product degrees or process maturity degrees in the development process. Nevertheless, it is clearly understood, that pre-series logistics bridge both viewpoints and thus still hold significant potential to reduce project risks. Consequentially, this paper presents a methodology that assesses the risk of process-wise and quality-wise delays. After discussing the specific risk profiles within logistics processes in the automotive ramp-up phase, the application of purpose-designed product maturity degree indicators and structured knowledge from historical projects is illustrated. The developed approach enables to identify critical processes in the production readiness process. The paper concludes with a summary and an outlook on further research.

Keywords: ramp-up, pre-series logistics, risk management, production development

1. Introduction

Rising customer demands and increasing market saturation necessitate complex business strategies to ensure the competitiveness of manufacturers in the automotive industry (Nyhuis, Klemke and Wagner, 2010, p. 3). Continuous derivatisation responds to the market situation by developing new customers and satisfying existing ones (Fitzek, 2006, p. 4). Short leading positions in a single product segment have economic potential for amortizing the new product (Bischoff, 2007, p. 12). Integrated product life cycles are getting shorter by coupling the development processes (Hertrampf, Nickel and Stirzel, 2008, p. 237). Due to the highly technical and organizational interdependences, new and updated car projects further increase in complexity with derivatisation and shortening strategies (Franzkoch and Gottschalk, 2008, p. 55).

The series ramp-up phase (in the following abbreviated to 'ramp-up'), as the last step before start of production (SOP), critically presents the challenge to transfer the product from its project environment to series production. The complexity drives a high amount of uncertainty in development projects and causes a high rate of process-wise failures and disruptions. Approximately 80% of all failures appear in the ramp-up phase, though 75% of all failures originated from the previous development and planning phase (Wildemann, 2002, pp. 4–5). Research and industry have developed methodologies and approaches to reduce these disruptions. Despite the known advantages of risk management during the ramp-up phase, there are few logistic implementations for this stage (Kuhn, Wiendahl, Eversheim and Schuh, 2002, p. 3).

Section 2 organizes pre-series logistics into the product development process and presents the control of the ramp-up phase. Additionally, the risk profile of pre-series logistics is discussed. Section 3 uses the critical path method to present an approach to identify critical processes in the production readiness process by rating the indicators. Section 4 then verifies this method. The paper concludes with a summary and an outlook on further research.

2. Pre-series logistics in ramp-up processes

Despite the increased attention to the ramp-up phase in the last years, there is no standardized definition. Moreover the definition and description of the pre-series logistics tasks are different (Bischoff, 2007, p. 4) (Knüppel, Tschöpe and Nyhuis, 2012, p. 428) (Kuhn, Wiendahl, Eversheim and Schuh, 2002, p. 12). The following section discusses the state of the art and presents the risk profile of the pre-series logistics.

2.1 Ramp-up management

The ramp-up phase is characterized as the period between product development and series production (Fjällström, Säfsten, Harlin and Stahre, 2009, p. 179) or as the final stage in the development process (Ulrich, Eppinger, 2011, p. 12). To distinguish the innovative non-product related research and the product related development, the early phase is often called 'series development'. The start of the pre-series is triggered by varying criteria, highlighted in the literature. One such trigger is the switch from prototype production to pre-series automobiles production (Urban and Seiter, 2004, p. 58). Pre-series automobiles are built under conditions similar to series production, using mass production components and tools to prove the series readiness (Fitzek, 2006, p. 2). The definition for the end of ramp-up differs in two points of view: Some sources attribute the end of the ramp-up phase to the achievement of full capacity (Terwiesch and Bohn, 2001, p. 1) (Zäh and Möller, 2004, p. 13) while others attribute it to the production of the first series automoblie (SOP or also called as Job No. 1) (Doltsinis, Ratchev and Lohse, 2013, p. 85) (Fitzek, 2006, p. 55).

The pre-series phase ends up in theory with the SOP, as the firm now produces automobiles acceptable for customers. In practice, many departments support the start of series production to ensure product and process quality until full production capacity is achieved. Pragmatically, expansion is appropriate. To define the phase and tasks more precisely, the sub-phases of ramp-up are categorized by the 'production ramp-up', which starts with the SOP and ends up with the achievement of full capacity production (Schuh, Stölzle and Straube, 2008, p. 2).

The ramp-up phase until SOP is divided into the pre-series and zero series, a function of the targeted process and product quality (Fitzek, 2006, p. 2). In practice, the division of the pre-series into two phases allows a step-wise transition from project to series processes. The pre-series I aims to produce automobiles under conditions similar to series production to prove the reproducibility, a method known as the 'production try-out'. A special assembly line for the pre-series or the future series assembly line produces the pre-series products using mould assembled components for mass production (Pfohl and Gareis, 2000, p. 1198). Pre-series phase II ensures the process and product quality is a an customer acceptable product level. The zero series is the last step before SOP, and serves as a 'buffer' that hands over responsibility to the series facilities (Fitzek, 2006, p. 55).

Figure 1 visualizes the discussed product development process and classifies the logistics tasks, which are described in the following section.

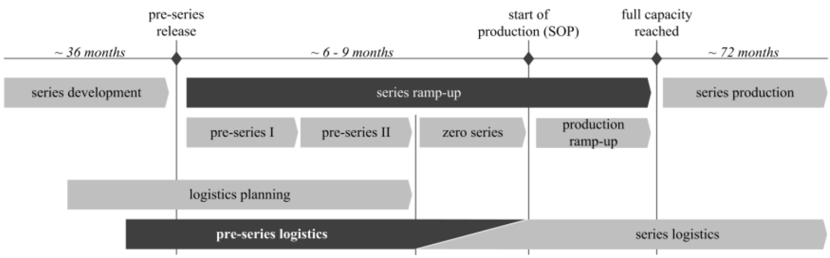

Fig. 1: The series ramp-up process

2.2 Pre-Series Logistics

The logistics activities before SOP are organized into operative and planning tasks. Logistics planning ensures that the production time and quality of the assembly lines are acceptable for series production (Doch, Rösch and Mayer, 2008, p. 144). Using existing material flows of other series productions, pre-series logistics tests the production time and quality prior to SOP. Permanent changing components up to SOP require special logistics processes and cause a distinction between pre-series logistics processes and series logistics processes (Doch, Rösch and Mayer, 2008, p. 146). Romberg and Hass define the pre-series logistics as an "already series process close department with the tasks to ensure the technical quality of components from external suppliers, to coordinate the material flow for supply of pre-series production and to coordinate the information flow in the pre-series phase itself" (Romberg and Haas, 2005, p. 16). The pre-series logistics is based on tasks of the series logistics: just-in-sequence coordination, warehouse management, program planning and production scheduling (Schulte, 2008, p. 371). The permanently changing bill of material requires a program readiness prior to the SOP that guarantees the availability of the ordered component construction version until the pre-series automobile production starts. Moreover, it implements a change management process that coordinates the information-flow for the entire change process across involved departments (Schneider, 2008, p. 166).

2.3 State of the art in risk management of pre-series logistics

Pre-series logistics is responsible for special functions during the ramp-up. It connects and transfers the technical product from the project development environment to the process-oriented series production (Schneider, 2008, p. 166). There are limited references in literature that discuss risk management for the automotive ramp-up phase. Present research is dominated by financially driven performance measurement systems in form of controlling tools (Nau, Roderburg, Klocke and Park, 2012, p. 233). Within highly complex ramp-up projects, costs often cannot be explicitly defined for each process. Thus, the applicability of financial approaches is limited, so non-financial solutions have typically been used. Current approaches provide methodologies for analysis and control for the ramp-up management that focus on either the product or the process, but acknowledge the importance of the interface. Weinzierl defines key performance indicators for components (e.g. technical quality) and weighs them for each ramp-up phase. He offers a model of aggregation that derives the overall product maturity (Weinzierl, 2006, p. 59). Hegner solves the problem of information, as the definition of components and processes changes often in the early phases, by concentrating on key performance indicators for each phase in an automotive ramp-up process. Random trend analysis is used to forecast the development situation, such as looking at the key performance indicators, and formulates the ramp-up curve (Hegner, 2010, p. 3). Different key performance indicator based approaches support stable processes by identifying disruptions and enhancing process chains. Nau et al. present a risk assessment method for hybrid manufacturing technologies based on simulation and the Quality Function Method (Nau, Roderburg, Klocke and Park, 2012, p. 233). Risse uses historical information to define a planning approach for different structure ramp-up processes while considering the prospect of optimization (Risse, 2003, p. 222). Gentner provides key performance indicators for development projects which measure efficiency by evaluating process inputs and outputs (Gentner, 1994, pp. 14–15). Czaja focuses on pre-series supply chain indicators. His empirical survey analyzes process quality between the manufacturer and supplier (Czaja, 2009, p. 345). Schmahls proposes a performance measurement system to identify and reduce technical and process-related disruptions near the assemby line from a production oriented point of view (Schmahls, 2001, p. 151). The gap in understanding the interface between technical project environment and process oriented departments in pre-series logistics is one of the main reasons for disruptions (Filla and Klingebiel, 2014).

The ramp-up phase and pre-series logistics are characterized by a high degree of uncertainty (Urban and Seiter, 2004, p. 58) which gets proved by the high degree of disruptions. The business strategies of the manufacturer create a highly complex network of process stakeholder and highly complex technical automobiles with many interdependences between the components and modules (Nagel, 2011, p. 36). The transfer from the technical development to series processes challenges the implementation of stable reproducible processes considering recurring change requests. The complex opacity of interdependencies causes uncertainty, which creates unexpected consequences. Thus, risk methodologies as described in ISO 31000 "Risk management - Principles and guidelines" (IDW, 11.09.2000, p. 3) cannot be used because fluctuating demand depends on the project phase. Moreover, it is not possible to define fixed key performance indicators to show standardized risks (Filla and Klingebiel, 2014).

Results of a survey focusing on the risk profile of a pre-series logistics demonstrate the highly variable requirements for a controlling tool (Dietrichs, 2012, pp. 47–48) (Filla and Klingebiel, 2014). The survey stresses pre-series I as the phase with the highest logistical disruption frequency. Usually these disruptions had to be resolved 'very fast' or 'fast', requiring high effort and the use of unscheduled resources to avoid negative downstream effects. The disruptions in the zero series are described as very critical but were rated by experts as unpredictable and therefore not considerable in a risk management methodology. Regarding especially these disruptions a suitable risk management for the pre-series logistics has to consider indicators from the technical development phase and should focus on the pre-series I. During the pre-series II risk management loses its applicability and a performance measurement should thus take precedence.

However, this methodology does not yet exist. The following section presents a new approach that uses indicators and the critical path method to mitigate risks in pre-series logistics processes. The indicators should cover process-wise and quality-wise information to narrow the gap between the product development and series production (Pfohl and Gareis, 2000, p. 1190). Existing approaches offer indicators that can be used for the methodology. Example indicators from Hertrampf, Nickel and Stirzel (2008, p. 237), Juzek and Berger (2013, pp. 400–401) and Wanner (2009, p. 87) are shown in figure 2.

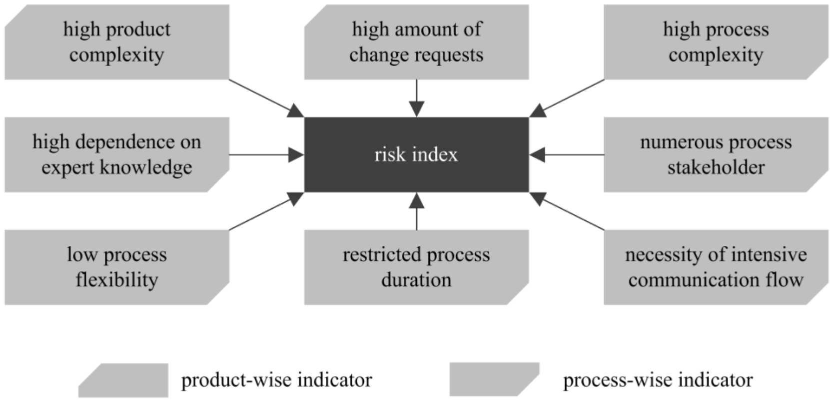

Fig. 2: Exemplarily risk indicators

3. Risk management approach to identify critical logistics processes in the ramp-up phase

The step-wise optimization of the pre-series logistics process chain (see figure 3) is structured into three risk management tasks that follow the generic risk process (Meier, 2011, lead text). The first step in the loop is the preparation of risk management. Risk sources need to be identified. This can be done, for example, by use of historical projects (Nau, Roderburg, Klocke and Park, 2012, p. 232). The results support to deduce risk indicators, which are necessary to identify and analyze risks in the following steps. Example risk indicators can be seen in figure 2. Risk management preparation finishes with an analysis of the specific process chain, which should be optimized. The second step (which will be explained in detail later) identifies the most critical process in the chain and develops and implements risk mitigation plans. Finally, the risk management plan must update its indicators and risk evaluations to adapt to changing conditions.

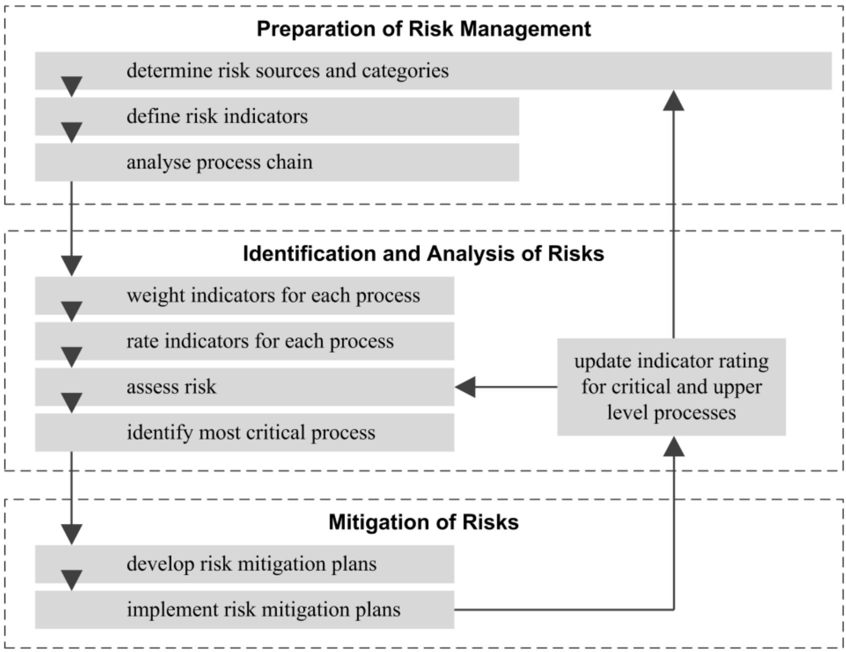

Fig. 3: Risk management process

To develop the identification and analysis approach, linear process chains and linear process level were assumed. A linear process level reduces the complexity by structuring the basic processes into major processes and sub-processes. Identification starts in the major process level, using the defined risk indicators. This process is repeated on the critical processes on the lower level, which in turn update the risk indicators of their downstream processes. All assumptions and the steps for the risk analysis can be seen in figure 4.

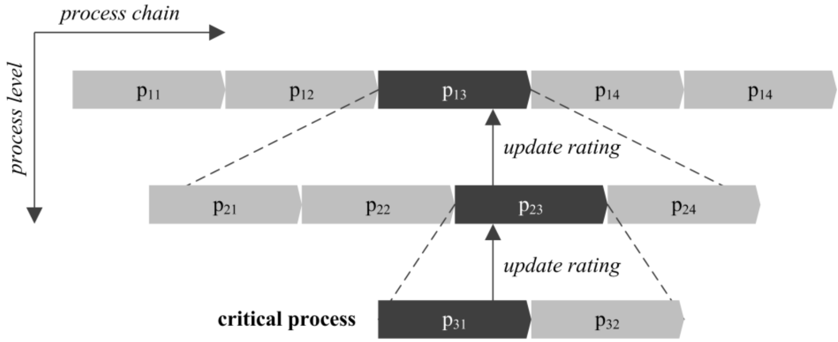

Fig. 4: Risk identification approach

The set of all processes is called 'P', defined by the order 'j' of the processes in the chain and the process level 'i'.

$$P = \{ p_{ij} \} \;\; \forall \;\; i,j > 0$$

The identification approach uses the set of previously defined risk indicators 'C' to analyze the risk rating. The number of indicators is represented by 'm'.

$$C = \{c_k \mid k = 1 \ldots m\}$$

Each process gets rated by all defined indicators. The changing demands in the ramp-up process require the dynamic use of the indicators for each process in the chain. A weighting matrix 'W' fulfils the demand and shows the impact of each indicator 'c' on each process 'p' (see also table 1). The impact weight 'w' is classified between 0 (indicator is not relevant) and 'n' (high relevance). The number of rating options 'n' depends on the individual ramp-up project. As more rating are added, the analysis becomes more descriptive, but also more complex.

$$W = \{w_{ijk} \mid i,j,k > 0\}$$

$$w_{ijk} \in \{0 \ldots n \mid n > 0\}$$

Similar to the weighting matrix 'W', the matrix 'R' assesses each process using the known indicators (see also table 1) showing the process criticality. The classification of the rating is between 1 (indicator fit is insignificant) and 'q' (indicator fits perfectly). The knowledge and experience of experts (employees with ramp-up experience of different car projects) are one of the most important data source for ramp-up projects, this approach focusses willful on it (Bischoff, 2007, pp. 31–32). The rating factor 'r' uses the same indices ('i', 'j', 'k') as the weight factor.

$$R = \{r_{ijk} \,|\, i,j,k > 0\}$$
$$r_{ijk} \in \{0 \ldots q \mid q > 1\}$$

	$\boldsymbol{p_{11}}$	$\boldsymbol{p_{12}}$	...	$\boldsymbol{p_{1\,max}}$
$\boldsymbol{k_1}$	r/w_{111}	r/w_{121}	...	$r/w_{1\,max\,1}$
$\boldsymbol{k_2}$	r/w_{112}	r/w_{122}	...	r/w_{1max2}
...	...	...	...	...
$\boldsymbol{k_m}$	r/w_{11m}	r/w_{12m}	...	$r/w_{1\,max\,m}$

Tab. 1: Exemplarily weight / rating matrix for the first process level (i = 1)

The risk index 'x' for a process consists of the single indicator rating and weight.

$$x_{ij} = \frac{1}{n * q} * \frac{1}{m} * \sum_{k=1}^{m} w_{ijk} * r_{ijk}$$

Assuming linear process chains and level the process with the highest potential for risk mitigation the most critical process are identified by the risk calculation top-down. After the critical process has been identified the weights and ratings are updated.

4. Use case - Quantification Results

The method mentioned above was applied to the automotive industry. This case focusses on a ramp-up project of a new developed automobile. The risk indicators were worked out previously with experts in interviews (25 experts of the pre-series logistics were consulted - most of these experts had already supported more than five ramp-up projects, in most cases in different functions and departments). The 24 indicators are divided into 11 product-wise and 13 process-wise indicators and were weighted by the experts with one of three options, 'low impact', 'medium impact' and 'high impact'. The indicators comprised for example the 'stability of the bill of components', the 'number of stakeholder' and the 'readiness of heavy items', the full set cannot be presented here due to the confidentiality agreement. Rating options were limited to 'low accordance', 'medium accordance' and 'high accordance'. The risk calculation results have been clustered as:

$$low\ risk\ (0 \leq x \leq 0{,}33)$$
$$medium\ risk\ (0{,}33 < x \leq 0{,}66)$$
$$high\ risk\ (0{,}66 < x \leq 1)$$

The example processes were the planning and production of 673 pre-series vehicles. The indicators for the risk identification were rated and weighted for each single week in the product development process. The disruption analyses of the project data identified 130 postponed prototypes, 42 postponed pre-series I automobiles and 172 postponed pre-series II automobiles. The zero series had no postponements. Using the presented risk management method, 57,8% of all pre-series productions were labelled as "risky" due to their high risk index, which totals to 389 automobiles. The difference to the in fact postponed cars is in total +45 (= +13%). Similarly, 35,6% of produced vehicles were rated as "medium risk" and 6,7% with a "low risk".

Considering the identified risks according to the calculation methodology, the risk management approach provides progress in risk mitigation and ensures the development timeline. The results show that the risk management approach is applicable to identify the probability for disruptions.

5. Conclusion and future work

The risk profile of pre-series logistics shows the benefits and challenges of risk management during the ramp-up phase. Considering the high levels of uncertainty in this early phase, the effort to acquire relevant data (key performance indicators) is often not justifiable. As a solution, the knowledge of experts and information from previous ramp-up projects can be applied to identify risks more easily. Nevertheless, the uncertainty of information and data necessitates information integration in the business process. The presented risk management approach enables the successive identification of critical processes using both process-based risk indicators and product-based risk indicators to show risk. Future research will examine the assumed linear relation between processes and furthermore consecutive risk mitigation plans need to be analyzed and integrated in the overall approach.

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The Imbalance of Supply Risk and Risk Management Activities in Supply Chains: Developing Metrics to Enable Network Analysis in the Context of Supply Chain Risk Management

Christian Zuber, Hans-Christian Pfohl and Ulrich Berbner

Abstract

From a supply chain management point of view, the flow of goods in a supply chain can be viewed as a network of goods-exchanging actors (Carter, Ellram, and Tate, 2007; Gomm, and Trumpfheller, 2004). While supply chain management activities include requirements-planning and the ordering of goods in value-added networks, activities in supply chain risk management are dedicated to the prevention of possible shortages and their negative impacts. Due to limited resources, risk management activities are usually focused on the most critical goods (Wente, 2013; Zsidisin et al., 2004). This leads to the assumption that for less critical goods, the effort for risk management activities deviates from the actual risk management demand. In order to identify these imbalances and network-related effects, metrics are developed in this paper to measure the existing level of efforts of risk management activities and the level of supply risks concerning the different supplier-buyer relations in a supply chain. In order to integrate the metrics and to locate the need for further risk management activities in a supply chain, measures of network analysis are used.

Keywords: supply chain risk management, risk metrics, supply risk, network analysis, structural holes

1. Introduction

Supply chains have become more vulnerable due to enlarged supply chain complexity and the increased occurrence of natural and man-made disasters over the past years (Munich Re, 2012; Zentes et al., 2012). Among the developments causing increased complexity are globalization (Blecker and Kersten, 2006) as well as concepts which are supposed to facilitate lean supply chains, such as just-in-time (Zsidisin et al., 2005) or single and dual sourcing approaches (Wagner and Bode, 2006). The increased severity of potential risk sources combined with the growing vulnerability of supply chains leverages the negative consequences in case risks do occur (Christopher and Peck, 2004; Jüttner et al., 2003). There is empirical evidence proving that increased supply chain vulnerability has a negative impact on supply chain function and efficiency (Tang, 2006) as well as on the financial performance of the supply chain partners (Hendricks and Singhal, 2005).

Despite growing challenges, there are still numerous gaps in supply chain risk management in research and practice (Sodhi et al., 2012). Most risk management approaches focus on a company-internal perspective or consider dyadic supplier-buyer relations in terms of supply risk management (Henke, 2009; Kajüter, 2007). Network-oriented supply chain risk management approaches which integrate information about supply risk and existing risk management activities on different tiers are hardly implemented (Wagner and Bode, 2006).

Due to limited resources, risk management activities are usually focused on the most critical goods (Wente, 2013; Zsidisin et al., 2004). This leads to the assumption that for less critical goods, the effort for risk management activities deviates from the actual demand for risk management. In this paper, metrics are developed to measure the existing level of efforts of risk management activities and the level of supply risks concerning the different supplier-buyer relations in a supply chain. The metrics must be normalized and independent from characteristics of specific supplier-buyer-relations to enable risk-related network analysis of supply chains. An example is used to illustrate the possibilities of network analysis for research in supply chain risk management and to evaluate the usage of the developed metrics.

2. Operationalizing the Analysis of Supply Risk and Risk Management Activities in Supply Chains

The understanding of supply chain management in research and practice has changed over the last decades. Even though network thinking was beginning to develop in the early 1990s, supply chain management was seen as the management of (single) supplier-buyer relations (e.g. Christopher, 1992; Harland, 1996) and multiple sourcing was seen as an important strategy to reduce uncertainty in purchasing (Puto et al., 1985). But further network-related effects on the supply side were hardly being taken into account. Due to the rising complexity in global value-added networks (Handfield et al., 2013), the importance of considering network-related effects in supply chains is increasing (Trkman and McCormac, 2009). Especially in times of uncertain and volatile markets, short product life cycles and their imperative of fast supply chain adaptations (Kotler and Casoline, 2009), supply chain vulnerability is an important topic for many companies (Christopher and Peck, 2004).

In this context, the localization of supply risks in a supply chain is as important as the knowledge about the impact of risk management effort on different levels of a supply chain. The supply chain in the context of risk analysis can be described by actors as nodes of a network, whereby the ties represent the risk, the effort of risk management activities, or a relation of either of them, respectively. Consequently, in the following two sections an introduction to the understanding of supply chain risk management from the perspective of network analysis is presented, followed by the development of metrics for measuring supply risk on the one hand and efforts of risk management activities on the other hand.

2.1 Supply Chain Risk Management from the Perspective of Network Analysis

In the broad field of value-added analysis, there are good examples of the usefulness of network analysis in management science. For example, Gokpinar, Hopp, and Iravani (2009) have shown that reasons for network vulnerability can be identified using methods and instruments of network analysis in the case of product development. The usage of the general measures related to network analysis, such as centrality or brokerage, also allows the identification of the vulnerable points of a supply chain.

In terms of network analysis, the supply chain consists of a set of actors (companies as nodes). In this context, the ties between the actors can represent the levels of logistics flows (goods, information, financials, rights; Pfohl, 2004) as well as resulting performance characteristics (e.g. supply risk or efforts incurred). Thus, the size of a network (number of actors) and its density (number of existing ties compared to the number of possible ties) represent measures for the vertical integration of an industry or otherwise defined value-added networks. Regarding supply chain risk, a higher size and density means a higher number of failure sources as well as a higher possibility of using counter-activities. Most important in this case is the definition of the network and of the understanding of a supply chain.

In terms of network analysis, by definition a network is not closed, which is also a correct assumption for a value-added network. In differentiation, a supply chain is a more specific definition of relevant ties from the perspective of one actor who is called Ego in network analysis (see Figure 1). Related actors are called Alter. An Ego acts in different supply chains, which in sum form a supply network. Such a differentiation allows the inclusion of network-related effects in supply chain risk analysis, which the broad discussion of supply risks in supplier-buyer relation cannot afford to do. Network analysis allows the combination of analysis of the whole value-added network and of supply networks or single supplier-buyer relations. Block modeling (Ferligoj, Doreian, and Batagelj, 2012; White et al., 1976) to identify groups of actors with specific grades of vulnerability in the value-added network is only one possibility for network analysis in supply chain (risk) management out of plenty other analysis possibilities (Hanneman and Riddle, 2012). The challenge is to identify the correct meaning of the different measures of network analysis in terms of supply chain (risk) management.

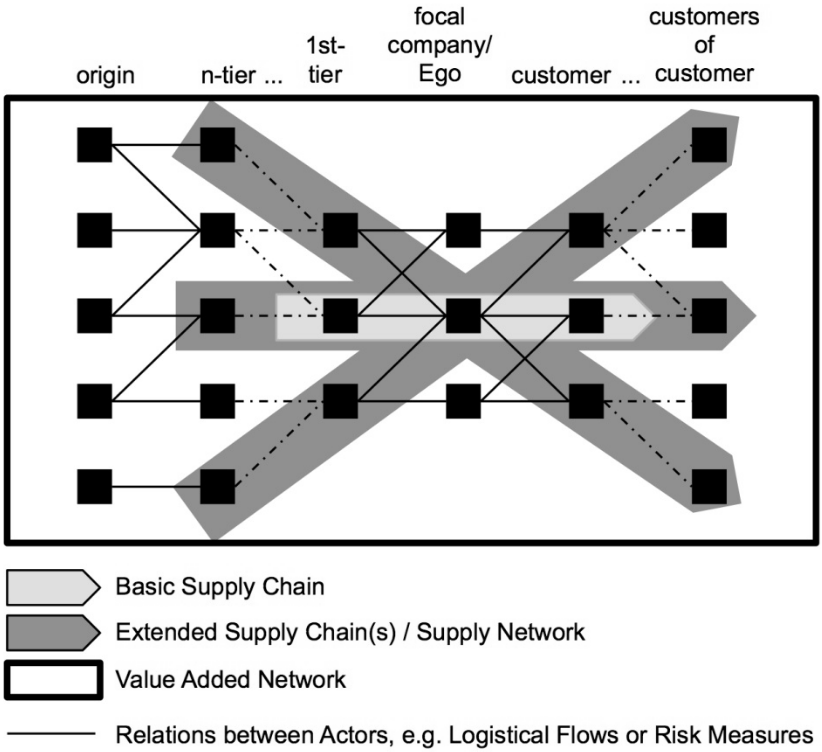

Fig. 1: Differentiation of Supply Chain Definitions

In this paper, we concentrate on structural hole measures to demonstrate the benefit of network analysis for supply chain risk management. Based on structural holes in a network, the status of each actor can be defined. For supply chain risk management it is an advantage to know about weak actors in the value-added network or to identify indirect dependencies on second-, third-, or fourth-tier suppliers. Measures to identify structural dependencies of actors in a supply chain are necessary to identify the demand of management and further activities (e.g. Carter, Ellram, and Tate, 2007).

According to the structural hole theory by Burt (1992), the advantage of an actor in a network is based on its control over the spread of goods or services between him as an Ego and his Alters as well as between the Alters. "A structural hole exists where two points are connected at distance 2, but are otherwise separated by a long path." (Scott, 2013: 87). An actor that bridges such a structural hole has a position of advantage – or, in other words, he might constrain the other actors. The measures for structural holes developed by Burt (1992) are based on such dyadic constraints as well as on dyadic redundancy. Dyadic redundancy describes how often a tie between A and B is redundantly existent by considering further actors. In supply chains this would require the involvement of intermediaries. This case is not considered any further. The measure of dyadic constraints describes how an Ego is constrained by Alters based on the existence of specific relations. Thus, this measure is dependent on the size of the network and its density. This makes it difficult to compare networks (or in our case supply chains) with a different structure using the measures of structural hole theory (e.g. Bruggeman, Carnabuci, and Vermeulen, 2003).

Each dyadic constraint will be summed up to the general measure of network constraint. Network constraint describes the total constraint of one actor based on every relation in his neighborhood or in the whole network, respectively. Furthermore, it is necessary to look at the structure of the constraint. Accordingly, the network constraint of an actor can be based on one dominant Alter (high hierarchy) or it can be spread over several Alters (low hierarchy) (Hanneman and Riddle, 2012). Regarding supply chain risk management, the last case indicates risk diversification in the supply chain.

Mostly, the analysis of structural holes in social networks is based on binary data (a relation is present or not) (Hanneman, and Riddle, 2012), even though the analysis of weighted relations is also possible. We will demonstrate in chapter 3 that in case of supply chain risk management, weighted relations must be taken into account. Hence, adequate metrics of supply risk and risk management activities in supply chains are necessary. Such metrics will be developed in the next section.

2.2 Supply Chain Risk Management: Metrics and Activities

In research and practice, various definitions of the terms risk and supply chain risk exist (Lipshitz and Strauss, 1997; Pfohl et al., 2010). While risk can be seen as the uncertainty concerning a decision situation (Romeike and Hager, 2009), supply chain risk is often understood as any situation that might have a negative impact on the supply chain function (Wagner and Neshat, 2010). Consequences of the occurrence of supply chain risks are described as supply chain disturbances (short term effect) or disruptions (long term effect) (Pfohl et al., 2010).

Supply chain risk management can be understood as all activities on a technological, personal, and organizational level which are employed to reduce supply chain risks (Kersten et al., 2007). Those activities are often divided into activities facilitating either robustness or resilience of the supply chain (Sheffi, 2005; Sodhi et al., 2012). While activities of robustness (e.g. redundancies implemented by dual- or multi-sourcing approaches) ensure that companies inside the supply chain are able to “buffer” occurring risks, activities of resilience allow supply chain partners to flexibly react to any disturbance or disruption and to return to the original condition after the risk occurred (Sheffi, 2001). In order to become resilient, supply chains implement activities like supply chain wide risk management processes and risk management committees, frequent supplier audits, and activities of (risk) information exchange among the supply chain partners (Kajüter, 2007; Wente, 2013).

Possible sources of risk are usually measured by their potential impact as well as their probability of occurrence (Sheffi et al., 2012). In literature, different typologies of risk sources do exist (Sodhi et al., 2012). While those typologies vary, the described risk types can be summarized as the types 'supply chain-external' (environmental risks, contextual risks), 'supply chain-internal' (demand risks, supply risks, resource risks, network risks) and 'company-internal' risk (process risks, operational risks, organizational risks) (Christopher and Peck, 2004; Jüttner et al., 2003; Pfohl et al., 2008). These risk types are often interlinked with each other (Pfohl et al., 2011).

Due to the high number and variety of potential risk sources, identifying and assessing those risks in order to define appropriate risk management activities is a complex task. Hence, heuristics are developed that simplify the assessment of supply risks in supply chains (Wagner and Bode, 2008). This is done for example by reducing supply risk to the parameters of product risk or supplier risk (Moder, 2008; Wente, 2013). Transaction cost theory can be used as a theoretical foundation for developing metrics for measuring risk. The transaction’s risk can be seen as dependent on factors like transaction specificity, transaction uncertainty, and transaction frequency (Moder, 2008). The character of supply chain transactions usually depends on the supplier and on the product itself. The supplier’s specificity is closely tied to its exchangeability. For example, in the automotive industry there are certain first-tier suppliers with key knowledge who cannot be substituted easily. Therefore, supplier specificity increases supplier risk. Also, some suppliers might be used over a long time span and proved to provide high quality products, while others are new and it might not be easy to evaluate their reliability. Hence, supplier uncertainty can increase supply risks. The relation between supplier frequency and supplier risk is less clear than the others. While the frequency with which a supplier is used indicates a higher number of total transactions and implies elevated transaction know-how limiting risk occurrences, the transaction number itself is closely tied to risk probability. So in practice there is a higher need to evaluate this relationship since it might be dependent on the particular situation. Since the dependencies on the product level can be derived in a similar way, they will not be described in detail.

Besides supply chain risks, risk management activities on supply chain level have to be taken into account. Those activities include supply chain collaboration in order to facilitate resilience and the building of robust networks with alternative supply paths and methods of redundancy on corporate level, e.g. safety stock.

Due to the complexity of supply chains, it is impossible for a single party to assess and manage existing risks alone – supply chain cooperation is necessary (Cao and Zhang, 2006). The activities listed in literature can be divided into frequent and infrequent activities (Böger, 2010; Kajüter, 2003; Wente, 2013): Concerning frequent activities, integrated risk management procedures and regular workshops/committee meetings can be installed. Supplier audits can also be performed frequently and information can be shared, e.g. by setting up appropriate IT instruments. Information can be shared about arising risks or about best practices concerning risk management (Kajüter, 2003). Infrequent collaborative activities include the setup of a shared risk management organization, the implementation of risk management methods, and instruments for shared usage as well as initial supplier audits.

Robust networks can support the supply chain risk management by providing alternative supply sources and by making alternative logistics service providers available. By providing this kind of redundancy, companies can react to occurring risks with no or only little harm to the supply chain operation.

To prepare for risk occurrences, companies often use redundancy (corporate robustness) either in safety stock or in production capacity (Jüttner et al., 2003). While those activities are easy to implement they are also costly and in the case of safety stock only allow bridging the gap in cases of disturbances which are strongly limited in their time of occurrence.

An outline of possible risk management activities which can be implemented at the supply chain level is given in Figure 2. In our network-based approach, we will focus on activities in the area of collaboration, since there are only a few research attempts in that area so far (Sodhi et al., 2012).

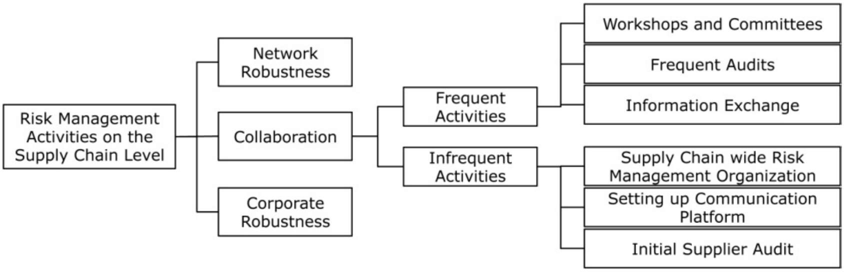

Fig. 2: Risk Management Activities on the Supply Chain Level

Based on the metrics derived and described above, we propose the following model (see Figure 3):

A supply chain's performance can be measured by the three factors shown in Figure 3 (Wieland, 2012). Empirical research has shown that supply chain performance is related to collaborative risk management activities (Wieland, 2012). Factors like product risk determine the level of risk management effort that has to be applied (Wente, 2013). Hence, a metric to calculate the adequacy of risk management collaboration depends on the supply risk on the one hand and on the risk management activities on the other hand.

In order to derive a metric which describes the adequacy of risk management collaboration, we assume that the level of collaborative risk management activities are proportional compared to the level of supply risk. While the supply risk of a supplier S providing product P to recipient R can be described by $Risk_{SRP}$ the related collaboration effort can be described by Col_{SRP} ... In order to achieve comparability of activities and risk levels, we normalize both metrics on a fixed interval, e.g. the [0,1] interval.

This yields $RiskN_{SRP} = \frac{Risk_{SRP}}{\max(Risk_{ijk})}$ and $ColN_{SRP} = \frac{Col}{\max(Col_{ijk})}$. Based on these metrics, a ratio metric can be defined in order to measure the adequacy $ARat_{SRP}$ of implemented risk management efforts. The ratio metric reflects the assumption of a proportional relation between the level of collaborative risk management activities and the level of supply risk:

Ratio metric: $ARat_{SRP} = ColN_{SRP}/RiskN_{SRP}$

The derived metric will increase monotonically if the adequacy of collaborative risk management activities increases. As stated above, risk management research shows that determining risk management activities and aligning those activities with existing risks is not easy. In practice, risk management activities are often only introduced for high-level supply risks (Sheffi, 2005).

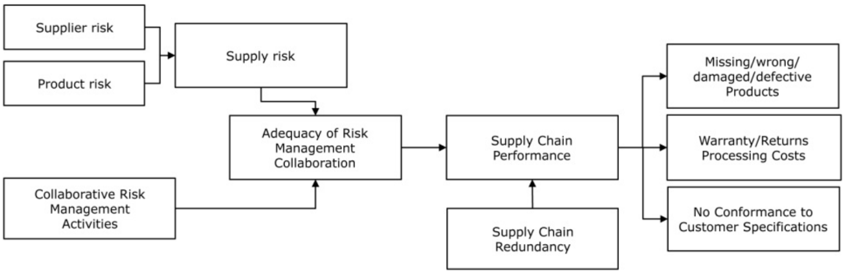

Fig 3: Risk Management Activities, Supply Risk, and Risk Management Performance

This implies that there are often no risk management activities implemented for low-level supply risks as well as for medium-level supply risks. While the decision to not implement activities concerning low-level risks might be adequate, a qualitative evaluation of expert interviews in automotive industry has shown a misfit concerning the effort of risk management activities at medium-level risks. This results in an U-shaped graph when plotting $ARat_{SRP}$ over $RiskN_{SRP}$ (see Figure 4).

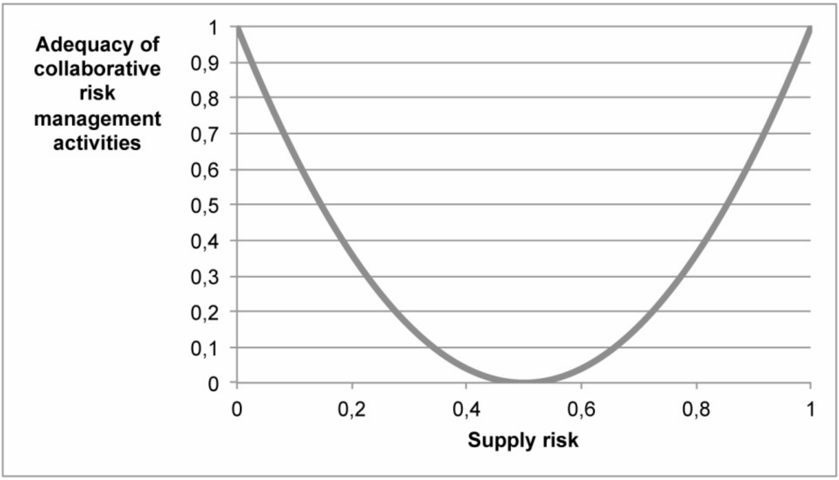

Fig. 4: The U-shaped Relation of Adequacy of Collaborative Risk Management Activities and underlying Supply Risk

3. The Usage of Risk Management Metrics in Network Analysis

In the following, the developed metric will be evaluated based on an example from the automotive industry through network analysis. Three general questions are of main interest:

1. Which network-related effects in a supply chain can be identified through using risk management metrics in network analysis?
2. Why should the effort for risk management activities be considered?
3. How stable are measures of network analysis regarding different types of metrics?

3.1 A fictitious Supply Chain of the Automotive Industry

In the automotive industry, the OEM usually represents the focal supply chain company, which sources critical components from its first-tier suppliers. In our example, the OEM CarManu (O1) is supplied with cockpits from CoreSup (S2).

CoreSup is the single supplier for cockpits for a certain car type. It is supplying CarManu just in sequence. Hence, the product sourced from CoreSup is critical, because it is a central part for assembling the car (see product risk O1-S2 in Table 1). The supplier itself is weighted with a high supplier risk, too, because no other supplier can deliver the cockpits for that specific type of car (see supplier risk O1-S2 in Table 1). Because of this above-average supply risk, the OEM CarManu and CoreSup invest high effort into collaborative risk management activities (see Col_{SRP} in Table 1). CoreSup itself sources electronic modules following a dual sourcing approach from the two suppliers LowWageCorp (S4) and StableCorp (S3). While the product itself has low risk, LowWageCorp is of high risk but offers cheaper prices, while StableCorp is of low risk but offers above-average prices. Both second-tier suppliers, LowWageCorp and StableCorp, have to source the same microchip from the supplier SemiCon (S5). Because the microchip is not a central part for the product offered, but SemiCorp cannot easily be substituted, the overall supply risk seen from LowWageCorp and StableCorp is above average (see $Risk_{SRP}$ for S3-S5 and S4-S5 in Table 1). In order to deliver the products with cheap prices, LowWageCorp cannot invest much in collaborative risk management activities, neither on sourcing nor on distribution side.

While the given example is fictitious, it does very well represent actual automotive supply chains where the OEM often does not know where its second-tier or even first-tier suppliers source their materials from. Furthermore, the fictitious supply chain meets the assumption of a u-shaped interrelation between the adequacy of collaborative risk management activities in supply chains and the normalized supply risk.

Supplier-Buyer-Relations	O1-S2	S2-S3	S2-S4	S3-S5	S4-S5
$Product\ risk$	7	2	2	3	3
$Supplier\ risk$	7	2	5	6	6
$Risk_{SRP}$	7	2	3,5	4,5	4,5
Col_{SRP}	7	2	1	3	2
$ARat_{SRP}$	1	1	0,29	0,67	0,44
$ASub_{SRP}$	1	1	0,64	0,79	0,64

Tab. 1: Levels of Supply Risk $(Risk_{SRP})$ and Collaborative Risk Management Effort (Col_{SRP}) in the fictitious Supply Chain (where 7 represents high and 1 low criticality/risk/effort) and the resulting Weights $ARat_{SRP}$ and $ASub_{SRP}$ (relevant for section 3.2.3)

3.2 Risk Management and Structural Holes in Supply Chains

The point of reference for the following analyses is the weighted example supply chain. The relations between the actors are weighted with the ratio metric $ARat_{SRP}$ (see Figure 5). In the following, network-related effects on the basis of the analysis of structural holes are discussed. Furthermore, through the analysis of structural holes in the supply chain, the necessity of considering the effort of risk management activities will be examined. The software UCINET 6 (Borgatti, Everett, and Freeman, 2002) is used for all analyses presented in this paper. Due to the consideration of overall network-related effects, the analyses are related to the whole network and not only to the 1-step Ego-neighborhood.

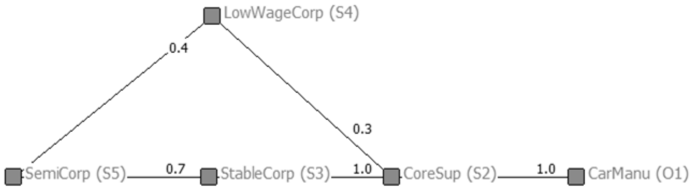

Fig. 5: The fictitious Supply Chain with $ARat_{SRP}$ weighted Supplier-Buyer Relations (printed with Netdraw)

3.2.1 Identifying Network related Effects in Supply Chains

The first question that needs to be answered concerns the relevance of considering weight relations for risk management analysis in supply chains. Figure 6 shows two areas of measures for identifying structural holes: The dyadic constraints present how intense the constraints for each actor as Ego (in the row) of Alters are. In our case, CarManu is mostly constrained by CoreSup, due to the single and only relation that CarManu has. The different intensities of constraints from StableCorp and LowWageCorp due to their role as actors of a dual sourcing concept with different levels of adequacy of collaborative risk management activities ($ARat_{SRP}$) are interesting. Regarding $ARat_{SRP}$, CoreSup is more constrained by StableCorp (0.19) than by LowWageCorp (0.02). This is caused by a higher probability that LowWageCorp cannot deliver (low $ARat_{SRP}$ means higher imbalance and probability of disruptions). In consequence, CoreSup is more dependent on a functioning supplier-buyer relation with StableCorp, which is represented by the higher dyadic constraint measure. The mutual constraints between SemiCorp on the one hand and StableCorp and LowWageCorp on the other hand are caused by the unique position of SemiCorp in the supply chain as the origin of the value chain.

With $ARat_{SRP}$ weighted Supplier-Buyer Relations

Dyadic Constraint

		1 CarM	2 Core	3 Stab	4 LowW	5 Semi
1	CarManu	0.00	1.00	0.00	0.00	0.00
2	CoreSup	0.19	0.00	0.19	0.02	0.00
3	StableCorp	0.00	0.36	0.00	0.00	0.16
4	LowWageCorp	0.00	0.16	0.00	0.00	0.36
5	SemiCorp	0.00	0.00	0.36	0.16	0.00

Structural Hole Measures

		1 EffSize	2 Efficie	3 Constra	4 Hierarc
1	CarManu	1.000	1.000	1.000	1.000
2	CoreSup	3.000	1.000	0.397	0.241
3	StableCorp	2.000	1.000	0.520	0.107
4	LowWageCorp	2.000	1.000	0.521	0.115
5	SemiCorp	2.000	1.000	0.521	0.117

Fig. 6: Structural Hole Measures with $ARat_{SRP}$ weighted Relations in the fictitious Supply Chain

As mentioned above, the dyadic constraints are summed up as the network constraint measure (see number 3 in section “Structural Hole Measures” of Figure 6). Regarding this measure, CoreSup is less constrained by the other actors and the higher-tier levels are more constrained. In contrast, the hierarchy of the constraints is vice versa. CoreSup is more constrained by only one other actor than the other actors are, even though CoreSup has the most relations (see Figure 6). These different levels of hierarchy are one main point of interest and demonstrate why it is necessary to consider different levels of adequacy of risk management activities. Compared to the results of structural hole analysis for the binary network (no weighted relations are considered), the general network constraints of every actor are nearly the same. But there is no hierarchy given, so that every Ego is equally constrained by his Alters (see Figure 7).

Binary Supplier-Buyer Relations

Dyadic Constraint

		1 CarM	2 Core	3 Stab	4 LowW	5 Semi
1	CarManu (O1)	0.00	1.00	0.00	0.00	0.00
2	CoreSup (S2)	0.11	0.00	0.11	0.11	0.00
3	StableCorp (S3)	0.00	0.25	0.00	0.00	0.25
4	LowWageCorp (S4)	0.00	0.25	0.00	0.00	0.25
5	SemiCorp (S5)	0.00	0.00	0.25	0.25	0.00

Structural Hole Measures

		1 EffSize	2 Efficie	3 Constra	4 Hierarc
1	CarManu (O1)	1.000	1.000	1.000	1.000
2	CoreSup (S2)	3.000	1.000	0.333	0.000
3	StableCorp (S3)	2.000	1.000	0.500	0.000
4	LowWageCorp (S4)	2.000	1.000	0.500	0.000
5	SemiCorp (S5)	2.000	1.000	0.500	0.000

Fig. 7: Structural Hole Measures with binary Relations in the fictitious Supply Chain

Thus, weighted supplier-buyer relations are necessary to identify network-related effects in terms of constraint and to deliver information about the structure of the constraints in a supply chain. A high level of constraint does not need to be critical for an actor. But if in addition the actor is mainly constrained by only one other actor (high hierarchy), he might see a need for action in terms of risk diversification.

3.2.2 The Necessity of Considering Risk Management Activities

The second point of interest is whether the consideration of the imbalance of risk management activities and supply risk leads to different network related effects in the supply chain.

With $RiskN_{SRP}$ weighted Supplier-Buyer Relations

Dyadic Constraint

		1 CarM	2 Core	3 Stab	4 LowW	5 Semi
1	CarManu (O1)	0.00	1.00	0.00	0.00	0.00
2	CoreSup (S2)	0.31	0.00	0.03	0.08	0.00
3	StableCorp (S3)	0.00	0.10	0.00	0.00	0.47
4	LowWageCorp (S4)	0.00	0.19	0.00	0.00	0.32
5	SemiCorp (S5)	0.00	0.00	0.25	0.25	0.00

Structural Hole Measures

		1 EffSize	2 Efficie	3 Constra	4 Hierarc
1	CarManu (O1)	1.000	1.000	1.000	1.000
2	CoreSup (S2)	3.000	1.000	0.416	0.359
3	StableCorp (S3)	2.000	1.000	0.571	0.342
4	LowWageCorp (S4)	2.000	1.000	0.508	0.043
5	SemiCorp (S5)	2.000	1.000	0.500	0.000

Fig. 8: Structural Hole Measures with $RiskN_{SRP}$ weighted Relations in the fictitious Supply Chain

Compared to the point of reference (Figure 6), considering just the supply risk leads to marginally higher constraints of CoreSup and StableCorp (Figure 8) of about 5%. The main difference can be observed in a different hierarchy. In the case of considering supply risk, CoreSup and StableCorp are much more dependent on only one actor, whereas LowWageCorp and SemiCorp have constraints spread in the network. In terms of supply chain risk management, this means a spread of possible disruptions, too: StableCorp might compensate the probability of disruptions on the sourcing and delivery side of LowWageCorp.

Even though this effect is less surprising because of the different characteristics of the used metrics, the shift of the origin of the constraints is interesting. Regarding the dyadic constraints of CoreSup, StableCorp, and LowWageCorp in Figure 8, using $RiskN_{SRP}$ as a metric leads to a concentration on the borders of the supply chain (columns 1 and 5). Hence, considering the imbalance of risk management activities and supplier risk provides a better basis for the derivation of network-related effects and the need for further risk management activities. Of course, this must be evaluated using a larger set of supply risk and risk management activities in a supply chain. But this result also shows that structural hole measures represent the risk distribution in a supply chain properly (see $RiskN_{SRP}$ in Table 1).

3.2.3 Comparing different risk metrics in Network Analysis

In the analysis of the point of reference, a ratio metric has been used to weight the supplier-buyer relations. To test the stability of the structural hole measures, we introduce a subtractive metric $ASub_{SRP}$:

Subtractive metric: $ASub_{SRP} = 1 - \max\{RiskN_{SRP} - ColN_{SRP}, 0\}$

Unlike the ratio metric that represents a proportion or balance, the subtractive metric assumes a substitution or elimination of collaborative risk management effort through supply risks. In comparison to the subtractive metric (see Figure 9), the ratio metric leads to marginally higher network constraints (3% to 10%). The main difference again lies in the structure of the constraints, where the origins of the constraints of LowWageCorp are evenly spread. This is caused by the balance of the imbalances on the sourcing and delivery side of LowWageCorp (see $ASub_{SRP}$ in Table 1).

The reason for the occurrence of this balance cannot be discussed here due to missing empirical data. But besides this very specific effect, the structural hole measures are very robust and independent from different metrics.

With $ASub_{SRP}$ weighted Supplier-Buyer Relations

Dyadic Constraint

		1 CarM	2 Core	3 Stab	4 LowW	5 Semi
1	CarManu (O1)	0.00	1.00	0.00	0.00	0.00
2	CoreSup (S2)	0.14	0.00	0.14	0.06	0.00
3	StableCorp (S3)	0.00	0.31	0.00	0.00	0.19
4	LowWageCorp (S4)	0.00	0.25	0.00	0.00	0.25
5	SemiCorp (S5)	0.00	0.00	0.31	0.20	0.00

Structural Hole Measures

		1 EffSize	2 Efficie	3 Constra	4 Hierarc
1	CarManu (O1)	1.000	1.000	1.000	1.000
2	CoreSup (S2)	3.000	1.000	0.346	0.061
3	StableCorp (S3)	2.000	1.000	0.507	0.039
4	LowWageCorp (S4)	2.000	1.000	0.500	0.000
5	SemiCorp (S5)	2.000	1.000	0.506	0.031

Fig. 9: Structural Hole Measures with $ASub_{SRP}$ weighted Relations in the example Supply Chain

4. Conclusion

In this paper, the usefulness of network analysis for supply chain risk management has been demonstrated through structural hole measures. Describing structural holes in a supply chain can process the identification of network-related effects on the basis of imbalances of supply risk and risk management activities. The presented example is very promising for further analysis, because the intensity of network constraints proved to be very robust to different metrics. The main benefit of using network analysis is the possibility of locating imbalances in terms of possible supply chain disruptions and the resulting dependencies of other actors in the supply chain, which has been evaluated by the different levels of hierarchy based on different metrics.

Furthermore, the developed metrics represent a first approach to determine the adequacy of collaborative risk management activities. Empirical data needs to be collected in order to advance the developed metrics and to test their practical applicability and explanatory power. Initially, the model that has been developed will have to be tested and quantified using statistical methods (e.g. factor analysis and correlation analysis) in order to determine the impact of product risk and supplier risk on supply risk on the one hand and to study the mitigating effect of collaborative risk management efforts on the other hand.

In conclusion, a further development of metrics to enable the identification of network-related effects in supply chains is necessary. Even though network analysis seems to be a very promising approach for supply chain (risk) analysis, further research needs to be done to identify relevant and possible fields of application, caused by a different understanding of networks in social network analysis with hierarchically independent actors and supply chains as a hierarchical network due to the different value-adding levels.

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Risk Assessment in Managing the Blood Supply Chain

Phongchai Jittamai and Wijai Boonyanusith

Abstract

Blood supply chain system involves blood collection, processing, inventory management, and distribution in the network. Blood has its unique characteristics that make its supply chain to be more complex and dynamic than the traditional one. Most research in the blood supply chain management focuses on logistics and practices in operation. However, there is a lack in the study of risk management in this aspect. Supply Chain Risk Management is a new paradigm in the blood supply chain, which can be explored further to manage risks in the complex and dynamic supply and demand networks. A hierarchy based model of supply chain risks was applied as a conceptual research framework to classify risks into four sub-chains; namely, physical, financial, informational, and relational sub-chains. Empirical data were collected by group brainstorming with experts and practitioners as well as by information audits in order to identify risks in the blood supply chain context. Risk assessment was conducted based on two angles, the likelihood of occurrences and the consequences. A summary risk score was calculated for each risk to analyze the values of the risk. Results of risk assessment were presented in a risk matrix to represent the impact of risks in the blood supply chain. This evaluation supports practitioners to prioritize issues in the blood logistics management in order to identify risk management strategies. The contribution of this research is discussed in order to arrive at an innovative and more effective approach to cope with risks and uncertainties in the blood supply chain management.

Keywords: risk, risk assessment, risk management, blood supply chain

1. Introduction

Risk management has become a critical component of supply chain management. Supply Chain Risk Management is a strategic imperative approach to support complex challenges in the global business. Nowadays, extant research has focused on identifying sources of uncertainty and the risk deriving from them. Risk identification consists of quantifying risks and assessment. This information can be used to derive risk management strategies in the supply chain.

Blood supply chain system involves blood collection, processing, inventory management, and distribution in the network. Demand in the blood usage caused by the illness of human, which cannot be controlled. Blood supply acquires from donors who have willingness to donate. Uncertainties in blood demand and supply are unavoidable. Blood has an expiration date, which is usually within a short period of time after acquiring. Moreover, the needs for blood occur unpredictably and uncontrollably. These aforementioned characteristics make blood supply chain to be more complex and dynamic than the traditional one. Thus, it is essential to study for a well-managed approach in order to utilize blood to its maximum benefit, which is the key performance indicator of the blood supply chain.

Most research in the blood supply chain management focuses on logistics and practices in operation. However, there is a lack in the study of risk management in this aspect. Supply Chain Risk Management is a new paradigm in the blood supply chain, which can be explored further to manage risks and uncertainties in the supply and the demand networks. The type of risks in the blood supply chain can be classified by the primary flows of the traditional supply chain; physical, financial, informational, and relational flows. This framework can be used to identify and assess risks in order to better represent the overall blood supply chain risk perspective.

Blood shortage and blood outdating are two main uncertainties that affect the whole supply chain the most. Shortage occurs when there is insufficient of blood in the inventory to response to high demands. It may lead to the lack of enough blood for treatments. Outdating happens when available blood cannot be utilized and expired. Disposal cost is required to get rid of expired blood (Boonyanusith and Jittamai, 2013). These uncertainties can be defined as the impacts in the blood supply chain and their risks can be evaluated in order to manage and utilize the whole supply chain effectively. Thus, this study aims to assess risks in managing the blood supply chain in order to prioritize risk management issues for practitioners in the network.

2. Literature review

2.1 Risk definition

It has been challenging to demonstrate a definition for the term of 'risk' for both academics and practitioners for many years. There are probably many definitions from authors on each theme (Ritchie and Marshall, 1993). The reason for this variety of definitions indicates different academic and professional disciplines in the specific backgrounds, decision contexts and problems. Sitkin and Pablo (1992) had defined risk as being 'the extent to which there is uncertainty about whether potentially significant and/or disappointing outcomes of decisions will be realized'. In the supply chain context, Zsidisin (2003) had described risk as 'the potential occurrence of an incident or failure to seize opportunities with inbound supply in which its outcomes result in a financial loss for the firm'. March and Shapira (1987) had defined it as 'a variation in the distribution of possible supply chain outcomes, their likelihood, and their subjective values'. According to these definitions, a risk is a potential failure of flows between the components of the supply chain. This variability can possibly affect the flows of information, materials, and money in the supply chain network.

2.2 Risk components

Risk comprises three components (MacCrimmon and Wehrung, 1988). These three components must be readily identifiable and measurable, leading to formulaic and precise resolution. The risk components are briefly described as follows.

2.2.1 Likelihood of occurrence

The likelihood of occurrence or probability of a particular event or outcome can be expressed in objective terms or in subjective terms, each being capable to measure. Objective measurement relies on previous accounts of the occurrence of such events. Subjective assessment of the likelihood of occurrence relies on the translation of previous experience. Practically, it is probable to apply subjective judgments on any objective data.

2.2.2 Consequences

The consequences of the particular event or outcome occurring are usually expressed as a multiple of simultaneous outcomes, many of which interact with one another.

2.2.3 Exposure

The exposure or causal pathway leading to the event has an important implication for risk management. Understanding the nature, sources and causes of factors that generate the events, which might influence the type and scale of consequences and the likelihood of occurrences are fundamental requirements for effective risk management.

2.3 Supply chain risk management

Supply Chain Risk Management (SCRM) represents a more proactive approach to manage risks in the supply chain in order to avoid potential unexpected consequences (Ritchie and Brindley, 2009). The main components of SCRM would incorporate the following clusters of activities as below.

2.3.1 Risk identification and modeling

This activity aims to identify the sources and characteristics of risks, what may trigger them and the relationship to the supply chain performance in terms of effectiveness and efficiency.

2.3.2 Risk analysis, assessment, and impact measurement

It is an analysis of the values of the risk by the likelihood of occurrence and potential consequences assessment.

2.3.3 Risk management

Risk management proposes the considering alternative solutions, judging their respective merits, selecting solutions and undertaking the implementation.

2.3.4 Risk monitoring and evaluation

It aims to monitor, control, and manage solutions, and assess their impact on business performance outcomes.

2.3.5 Organizational and personal learning

It is knowledge, experiences, and lessons transferring among members within the organization and its associated supply chain members.

2.4 Blood supply chain management

Blood supply chain comprises of logistics activities, which affiliate links between nodes within the network including blood donors, blood centers, blood banks in hospitals, and patients (Pierskalla, 2004). Blood supply can be collected from a single source, only voluntary human (Chapman, Hyam and Hick, 2004). Blood collection and production are main functions of blood centers, which are located in different regions. Blood processing is to detect blood screening and to determine blood group and type of such primary resource. This process also includes the separation of blood components to produce other blood products. These products are stored in the inventory of blood centers. Then, blood centers allocate and distribute blood products to various hospitals in the network by proper transportation (Williamson and Devine, 2013). Blood bank has a main responsibility in managing blood products within the hospital. It performs logistics activities as inventory tasks related to the acquisition and requisition of blood. Blood products must be reserved by doctors and cross-matched in preparation before usage. Blood also needs to be warmed to adjust temperature before transfusion to patients (Jennings, 1973). Monitoring and tracking blood are important safety issues as well. An effective logistics management in blood supply chain will increase the effectiveness in blood utilization (Lowalekar and Ravichandran, 2013), which is the key performance indicator of the blood supply chain.

2.5 Research framework

Faisal (2009) proposed a hierarchy based model of supply chain risks in order to prioritize them. The model presented the types of risk in supply chain classifying into four sub-chains; physical, financial, informational, and relational, following Cavinato (2004), Spekman and Davis (2004), and Jüttner (2005).

2.5.1 Physical sub-chain

Physical sub-chain represents traditional logistics, in the activities of transportation, warehousing, handling, processing, manufacturing, and other utility activities. They can be termed as the risk in physical flow of the supply chain. Risks in physical sub-chain are classified into 10 types, which are delays, disruptions, supplier capacity constraints, production technological changes, transportation, inventory, procurement, capacity Inflexibility, design, and poor quality risks.

2.5.2 Financial sub-chain

Financial sub-chain deals with the flow of money in the supply chain. Risks due to the flows of cash between organizations, incurrence of expenses, and use of investments for the entire network, and accounts receivables and payables processes can be classified under financial risks. Major risks in financial sub-chain are represented in 10 types, which are cost/price risk, business risks, fiscal risks, untimely payments, settlement process disruption, volatile oil prices, lack of hedging, investment risks, unstable pricing, and exchange rate risks/currency fluctuations.

2.5.3 Informational sub-chain

Informational sub-chain carries the physical and financial chains through the processes and information systems and technologies applied to create activities and trigger product flows and service utilization. Risks in materials flows are not associated to the risks in information flows. Risks in informational sub-chain can be broadly classified by Faisal, Banwet and Shankar (2007) as information security/breakdown risks, forecast risks, and information systems/information technology outsourcing risk.

2.5.4 Relational sub-chain

Relational sub-chain relates to the linkages between demand and supply sides as well as logistics organizations among them. The type of the relationship affects the supply chain risks (Ojala and Hallikas, 2006). Risks in relational sub-chains are categorized into 5 types, reputational risk, lack of trust risk, legal risk, intellectual property rights risk, and collaboration risk (Barratt and Oliveira, 2001; Callioni and Billington, 2001).

This study aims to assess risks in managing the blood supply chain. Initially, the research framework was developed by applying a hierarchy based model of supply chain risks (Faisal, 2009). A brainstorming with the experts in the blood supply chain was discussed in order to identify the associated types of risk in this study. Irrelevant types of risk were partially removed. Only 10 types of risk remain, covering all 4 sub-chains as well. The research framework is presented in Figure 1. The definition of each type of risk in this study is described in the next section.

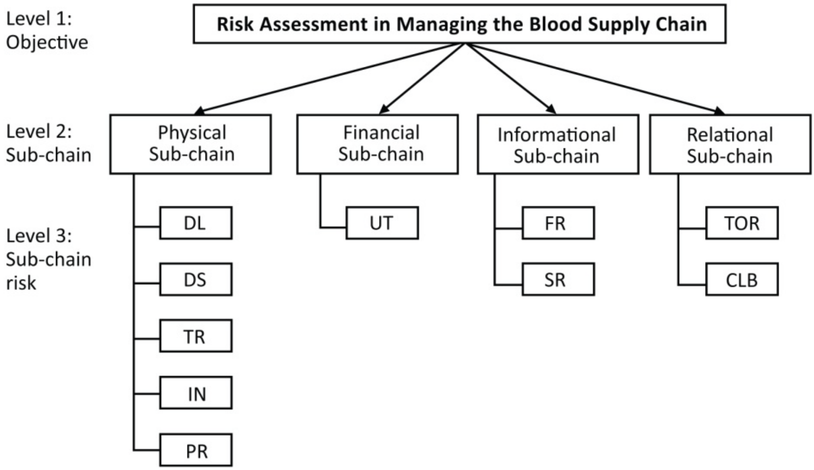

Fig. 1: Research Framework, A hierarchy based model of risks in blood supply chain management

Abbreviations: DL= delay; DS=disruption; TR=transportation; IN=inventory; PR=procurement; UT=untimely payment; FR=forecast; SR= information security; TOR=lack of trust; CLB=collaboration.

3. Methodology

This study was carried out using semi-quantitative risk analysis method in order to identify and assess risks in managing the blood supply chain. The main purpose of this method is to present the overall risk framework, which can reflect all related risks, better than the traditional analyses. The method simultaneously provides the level of risk description linked to the values of the risk. It is regularly used if the risk's value cannot be explicitly quantified. Moreover, it usefully lessens the erroneous scoring in risk assessment based on the experts' experiences.

Initially, a hierarchy based model of supply chain risks was applied as a research framework to classify risks into four sub-chains; namely, physical, financial, informational, and relational sub-chains. Empirical data were collected by group brainstorming with the experts and practitioners in the blood supply chain context in order to identify and assess such risks. The research steps were conducted according to SCRM activities as mentioned in section 2.3.

3.1 Risk identification

Risk identification is a fundamental step in the risk management. By identifying the risks, a group of decision-makers have become aware of events that cause uncertainty. The risk identification focuses on recognizing future uncertainties for managing these scenarios.

This study applied a hierarchy based model of supply chain risks. Then, the researchers had discussed the framework with the experts in the blood supply chain management context to identify the associated types of risk in this study. Insignificant types of risk were partially removed and there were 10 categories remaining, covering all 4 sub-chains. It was able to represent an overview of risk in the blood supply chain. Blood shortage and outdating were applied to identify the impacts of such types of risk. Brainstorming with the experts group in the blood supply chain management context was conducted to express these risk definitions as described briefly in the following.

3.1.1 Physical sub-chain risk

Risk in physical sub-chain consists of delay, disruption, transportation, inventory, and procurement risks. Delay risk (DL) is defined as delay in blood allocation and distribution in the network. The delay in obtaining blood causes blood shortage for usage within the system. It affects blood expiration as well. Disruption risk (DS) refers to various uncertainties such as power failure, fire, and uncontrolled lab equipment malfunctioning in the blood inventory. Disrupted logistics process for a period can affect blood processing and production and inventory management directly. Transportation risk (TR) associates with the uncertainty in the transport of blood. Due to delays, temperature fluctuations and unstandardized packaging in delivery have significant effect on the quality of blood for further usage. Inventory risk (IN) involves the uncertainty in managing blood in the inventory. Storing excess blood units in a certain time can increase blood expiration rate without usage. Allocation a small amount of blood products can cause shortage condition in the inventory system. Blood distribution without analyzing the utilization rate has impacts on shortage and outdating in the network. The uncertainties in managing blood inventory directly affect blood utilization. Procurement risk (PR) is the requisition of more blood than the actual demand. The excess amount of blood in the requisition may lead to a lack of blood for distribution to other hospitals in the network.

3.1.2 Financial sub-chain risk

Financial sub-chain risk involves untimely payment risk (UT). It is defined as the delay of the blood requisition cost payment by the hospitals. This may lead to additional opportunity cost for further operations in the blood logistics tasks.

3.1.3 Information sub-chain risk

Information sub-chain risk includes forecast and information security risks. Forecast risk (FR) occurs when there is an imbalance of blood demand analysis to meet supply. This leads to an inaccurate planning to acquire blood. Information security risk (SR) relates to the instability of information management system and its network system. Such system may be damaged by unexpected incidents such as virus, worms, system failure, and so on. It may affect the logistics activities during a daily blood operation.

3.1.4 Relational sub-chain risk

Risk in relational sub-chain risk composes of lack of trust and lack of collaboration among members in the network. Lack of trust risk (TOR) concerns with the confidence level in the blood distribution for fulfilling its requisition in the network. Staff are not conscious of the actual demand for blood usage in the system and blood demand is uncertain. Collaboration risk (CLB) occurs when there is a lack of properly information sharing between the blood center and hospitals. Blood controlling and monitoring cannot be achieved without an appropriate information system linkage within the network.

3.2 Risk assessment

Risk assessment is an important process to select suitable management actions for the identified risks in the supply chain. The two components of risk, the likelihood of occurrences and the consequences of risk events, are assessed separately on a five-class scale, applied from Hallikas, et al. (2004). Tables 1 and 2 present the assessment scales for the likelihood of occurrences and the consequences of risk events.

Rank	Subjective Estimate	Description
1	Very unlikely	Very rare event
2	Improbable	There is indirect evidence of event
3	Moderate	There is direct evidence of event
4	Probable	There is strong direct evidence of event
5	Very probable	Event recurs frequently

Tab. 1: Likelihood of Occurrences Assessment Scale

When assessing the subjective probability of the risks, the experts' own experiences and organizations' performance are used and incorporated. Some risks may increase the likelihood of occurrences and some may decrease. The potential consequences were assessed from the viewpoint of the experts in the blood supply chain management context. The data collection for risk assessment is described in the next section.

Rank	Subjective Estimate	Description
1	No Impact	Insignificant in terms of the blood utilization, both shortage and outdating
2	Minor impact	Single small impact
3	Medium impact	Causes short-period difficulties
4	Major impact	Causes long-period difficulties
5	Catastrophic impact	Directly affect highest rates of blood shortage and outdating

Tab. 2: Consequences Assessment Scale

3.3 Data collection

Blood supply chain involves linkage among blood donors, blood centers, blood banks in hospitals, and patients. This study focuses on risk assessment in the blood center because it is a superior level performer of technical proficiency in the blood supply chain. It performs both routine and specialized operations in blood collection, blood processing, blood components production, blood inventory management, blood allocation, and blood distribution, covering all significant logistics activities in the network. Hospitals by themselves do not have enough sufficient capacity to acquire blood for further use. Thus, the blood center is a proper and legitimate organization for the study of risk assessment to manage blood in the supply chain.
This research is a novel study to explore the risk management in the blood supply chain. Data collection was conducted in the blood supply chain context in Thailand as a case study. Generally, the blood supply chain management in Thailand is similar to other countries' context. The National Blood Center is a central organization for blood operation management and it decentralizes to 12 Regional Blood Centers (RBCs) all over the country. The Regional Blood Center VII, Ubon Ratchathani province, is one of 12 RBCs in Thailand. It serves

7 northeastern provinces of Thailand to allocate blood to more than 100 hospitals in the network. Empirical data were collected by brainstorming with experts and practitioners in the blood center in order to identify and assess all types of risk. The research findings are presented in the next section.

4. Research findings

The research findings are categorized into three sub-subjects; values of the risk, risk matrix, and risk diagram. Values of the risk are derived by the expert panel discussions in order to analyze the risk assessment. Risk matrix is used to categorize the level of risks into the overall risks perspective. Risk diagram presents the risk management strategies according to risk assessment. The results are presented as follows.

4.1 Values of the risk

This study uses the following formula to evaluate the score of each risk from the likelihood of occurrences and the consequences (Mitchell, 1995).

Risk score = likelihood of occurrences * consequences

Risk consequences are categorized into two types; shortage and outdating. Panel discussions with the experts at the blood center were held in order to obtain the risk values. Each risk score was calculated as its likelihood multiplied by a sum of each risk-consequence category. Values of the risk illustrated in Table 3 yields the risk scores used to prioritize risks in the supply chain.

Considering the likelihood of occurrences in each type of risk, untimely payment risk has the highest likelihood of occurrence. Transportation risk happens occasionally. The types of risk that are not likely to occur are disruption risk, inventory risk, procurement risk, lack of trust risk, information security risk, and collaboration risk. Delay and forecast risks are not likely to take place.

Type of Risk	Likelihood	Consequences		Risk Score
		Shortage	Outdating	
1. DL	1	4	1	5
2. DS	2	3	3	12
3. TR	3	2	3	15
4. IN	3	4	4	18
5. PR	2	3	2	10
6. UT	4	1	1	8
7. FR	1	3	2	5
8. SR	2	2	1	6
9. TOR	2	1	1	4
10. CLB	2	3	1	8
Total		26	19	

Tab. 3: Values of the Risk

The consequences of each risk type were assessed in terms of effectiveness of the blood supply chain, blood shortages and blood outdating. For blood shortage, inventory risk has the highest risk score, followed by disruption risk, procurement risk, and collaboration risk, respectively. Lack of trust risk has the lowest risk score. For blood outdating, transportation risk has the highest risk score, followed by inventory risk. Delay and lack of trust risks have the lowest risk scores.

Moreover, prioritizing of the risk score has a significant impact on the overall utilization of blood. Inventory risk has the highest risk score, followed by transportation, disruption, and procurement risks, respectively. Risks with lower scores listed in descending order are untimely payment, collaboration, information security, delay, forecast, and lack of trust risks. The total risk scores have shown that the risks in the blood supply chain management identified in this study have significant impact on blood shortage over blood outdating.

4.2 Risk matrix

When all risk types have been evaluated, it can be expressed in the risk matrix. The purpose is to demonstrate the overall risk, showing risk level from low to high. Moreover, it can be used to establish methods to reduce the likelihood of occurrences or the consequences of each risk. The risk matrix is shown in Figure 2.

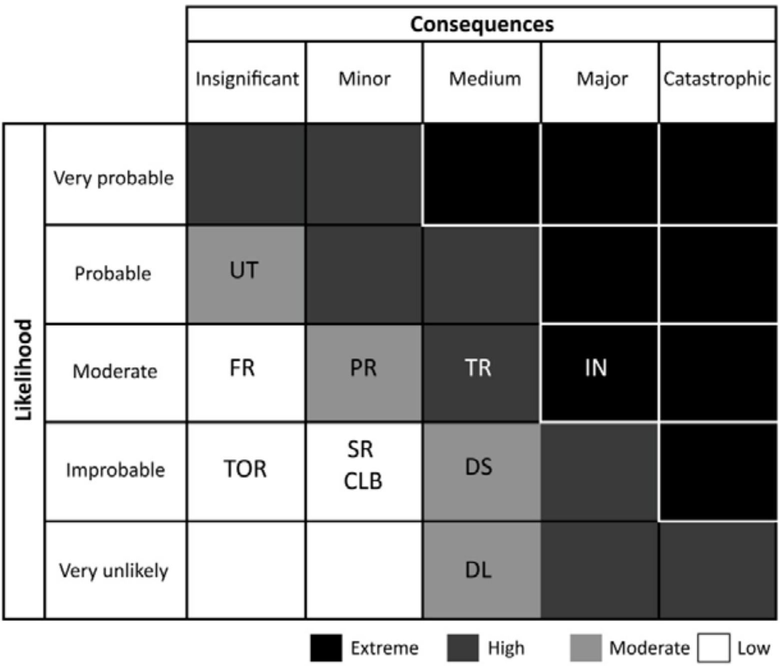

Fig. 2: Risk Matrix

This study classified risk levels into 4 levels; low, moderate, high, and extreme. Low level risk composes of lack of trust, information security, collaboration, and forecast risks. Moderate level risk composes of delay, disruption, procurement, and untimely payment risks. High level risk composes of transportation risk. Extreme level risk composes of inventory risk.

4.3 Risk diagram

Risk diagram is constructed using results from the aforementioned sub-section. Risk diagram is used to define strategies to respond to various risks in the appropriate levels. The strategic risk management framework has been adapted from the work done by Centrec Consulting Group LLC (2002). It is divided into 4 quadrants as follows.

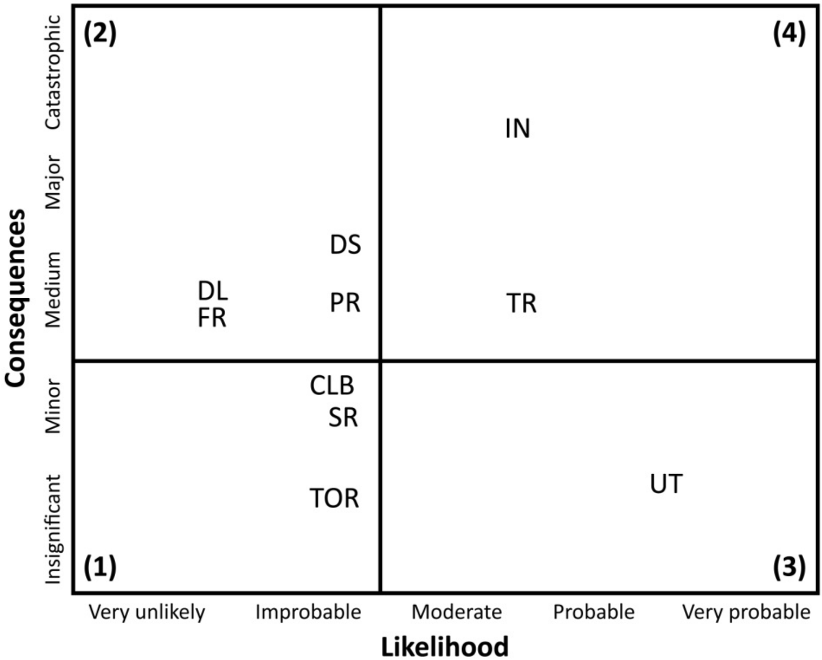

Fig. 3: Risk Diagram for the Quadrants of Likelihood/Consequences

Brainstorming with the experts in the blood center is as essential approach to identify guidelines to manage risk in this context. Summary of expert discussion is presented below.

The acceptable risks in the first quadrant are lack of trust, information security, and collaboration risks. These risks are insignificant because of their unlikely occurrence and low impact. However, the confidence in the blood requisition and distribution between blood center and hospitals is in a satisfactory level. For information security risk, the practitioners should check the equipment of computer and network system quarterly. For collaboration risk, the linkage of information within the blood supply chain system can be better managed by enhancing the cooperation among hospitals in the network to share blood information properly.

Risks that are relatively low occurrence but have high impact are categorized in the second quadrant. They should be managed by transferring or sharing associated risks with other related members in the supply chain. Risks in this quadrant include disruption, procurement, delay, and forecast risks. Disruption of logistics processes in the blood operation usually occurs during the times when accidents happen. These incidents cause higher demand of blood than in the normal period and staff have to put more effort to cope with this difficult situation. Blood center and hospitals should ensure the plan to reserve blood in order to support hospitals when such events occur. In order to minimize procurement risk, blood center and hospitals should work together closely to disclose supply and demand information so that blood allocation can be managed effectively. Blood delay generally occurs in the distribution process. Transportation for blood should be scheduled for distribution in a timely manner. Demand forecasting is hard to analyze. Hospitals should have the instruction for blood demand analysis in each period to predict the rate of blood usage in order to support blood collection planning by blood center.

Risk that needs to be mitigated is shown in the third quadrant. Untimely payment risk relates to the delayed payment of the cost of requested blood.

Blood center must urge the hospitals to pay the bills on schedule or set up rules to request blood and payment criteria.

Risks that need to avoid are presented in the fourth quadrant. They are transportation and inventory risks. Even though these risks occur moderately, they have significant and direct effect on blood shortage and outdating. Hospitals must control the transportation environment to ensure the quality of transported blood to be on par with the national and the international standards in order to avoid transportation risk. Risks in blood inventory management are associated with uncertainties in both blood supply and demand. Constructing a balance between blood supply and demand is an appropriate strategy to minimize and avoid such risks. Blood center should emphasize on the proper blood collection plan as well as the blood allocation and distribution to the hospitals based on the actual needs of the patients within the hospital network. Moreover, information sharing enhancement can reduce uncertainties and risks in the imbalance between blood supply and demand. Applying the blood management information systems that can be linked among the blood center and the hospitals in the network is an essential tool to monitor and control the blood logistics activities within the network effectively.

5. Discussion and conclusions

Blood supply chain comprises of logistics activities, which affiliate links between nodes within the network including blood donors, blood centers, blood banks in hospitals and patients. Its system involves blood collection, processing, inventory management, allocation and distribution, transportation, and blood bank operation. Blood demand and supply are uncertain, which are hard to manage. Blood has an expiration date and can be used within a short amount of period. The needs for blood generally occur unpredictably and uncontrollably. An effective logistics management in the blood supply chain will increase the effectiveness in blood utilization, which is the key performance indicator of the blood supply chain. Most research in the blood supply chain management focuses on logistics and practice in operation. However, there is a lack in the study of risk management in this context. Supply chain risk management is a new paradigm in the blood supply chain, which can be explored further to manage risks and uncertainties in the network. This study aims to identify and assess risks in managing the blood supply chain.

This study was carried out in semi-quantitative risk analysis method in order to identify and assess the risk in the blood supply chain management. A hierarchy based model of supply chain risks was applied as a research framework to classify risks into four sub-chains; namely, physical, financial, informational, and relational. A brainstorming with the experts in the blood supply chain management was discussed in order to identify the associated types of risk in each sub-chain. Irrelevant types of risk were partially removed. There are only 10 types of relevant risks remaining to study that covered all 4 sub-chains. The risks in physical sub-chain consist of delay, disruption, transportation, inventory, and procurement risks. The risk in financial sub-chain involves untimely payment risk. The risks in informational sub-chain comprise of forecast and information security risks and the risks in relational sub-chain include lack of trust and collaboration risks. Data were collected by group brainstorming with the experts and practitioners in the blood supply chain context. The research steps were conducted by the Supply Chain Risk Management, which incorporates risk identification, risk assessment, and risk management.

Risk identification was conducted by experts group in the blood center. The two components of risk, the likelihood of occurrences and the consequences of a risk event, were assessed separately on a five-class scale in order to analyze the values of the risk. Blood utilization, shortage and outdating, were applied to assess the impacts of the risks' consequences. By prioritization of the risks in the supply chain to enhance blood utilization, inventory risk has the highest risk score, followed by transportation and disruption risks. The overall risks in this study have impact on the blood shortage over the blood outdating. Risk matrix was applied to categorize risks into 4 levels; low, moderate, high, and extreme. The high level consists of transportation risk while inventory risk is in the extreme level. Discussions with the expert groups have brought an initiation plan to manage risk in the blood supply chain.

In conclusion, the well understanding in risk assessment can support the practitioners in making better decisions and management of risks for any single blood center as well as the whole blood supply chain network. This study provides valuable information for practitioners and researchers in a certain level. It improves the understanding of all related risks, their likelihood of occurrences and consequences, providing a good basis for managing risks in the blood supply chain. There is a necessity for further research using more extensive data. It would be beneficial to further analyze the other aspects of risk and its effects in the blood supply chain management.

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Supply Chain Risk Management in International Trade Operations Between Germany and Brazil

Meike Schroeder and Renato Barata Gomes

Abstract

While different aspects of export barriers and supply chain risks in companies have been discussed in literature intensively, there exist only a small number of current, international studies analyzing supply chain risks that might occur in companies during international trade operations between Germany and Brazil.
Thus, the aim of this paper is to identify and classify potential risks that might occur during international trade operations between German and Brazilian companies compromising the supply chain management. Moreover, supply chain risk management measures will be compiled to support entrepreneurs in managing those risks.
In the remainder of the paper, at first the theoretical background is provided for risk and supply chain risk management. Afterwards, a literature review of existing studies related to export problems is given and the research methodology for the empirical part is described. Subsequently, the empirical results of expert interviews, that have been conducted so far, reflect the work in progress. In addition, first developed measures are presented regarding operational risks. Finally, the paper finishes with a conclusion and further research.

Keywords: Supply chain risk management, Brazil, Germany, international trade

1. Introduction

Brazil as the third largest country in the American continent with 8.5 million km², poses big challenges to the development of infrastructure projects capable of integrating the 26 states, one Federal District and 5.570 cities. Logistics system in Brazil is currently unbalanced and dependent on the road transportation corresponding to 58% of the total transportation modals, followed by the railroad (25%), aquatic (13%), pipeline (3.6%) and air transportation (0.4%) (Coutinho 2013). One of the most important indicators of the road transportation system's quality is the extension of paved roads. In Brazil approximately 13% of the total roads are paved compared to 68% in the United States (9.8 million km2).

Railroad transportation is normally indicated as the best transport modal for distances over 800km and larger volumes of goods such as commodities. Therefore, rail transportation should be the most indicated modal for cargo transport in continental countries such as Brazil. However, Brazil has currently little over than 30 thousand km of railways in operation (CFA 2013), mostly concentrated in the regions southeast and south, compared to 224 thousand km in the United States (FRA 2014).

Five ports are responsible for most of cargo transport among all Brazilian ports. Together, Santos (southeast region), Itaguaí (southeast region), Paranaguá (south region), Rio Grande (south region) and Itaqui (northeast region) ports transported 221 million tons in 2012, representing approximately 70% of the total transport among all Brazilian ports (Antaq 2013).

In the last decade Germany has been continuously ranked among the top five exporters to Brazil. From 2000 to 2013 Germany's exports to Brazil increased more than 200% (MDIC 2014). In 2013 Germany exported approximately 1.5 trillion US$ dollars F.O.B. (Free on Board) to Brazil, from which 95% accounted for manufactured products, 4.6% semi manufactured and 0.4% were commodities (MDIC 2014).

Although international trade has increased considerably over the last decade, cross-border co-operations are associated with numerous challenges and barriers (Bauerschmidt et al. 1985, Christensen et al. 1987).
While different aspects of international export barriers have been discussed in scientific studies, a detailed analysis of risks that might compromise the supply chain during international trade operations between Germany and Brazil is rare. This paper seeks to close this research gap.

2. Current State of Research

2.1 Risk and Supply Chain Risk Management

Supply chain management plays an increasing role in international trade operations, whereby supply chain management can be defined as "*the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole*" (Christopher 1998, p. 15).
International trade involves important elements related to supply chain management such as international negotiation, purchasing, law, customs management, foreign exchange policies, international tax management, inventory management, etc. There are risks involved on each aspect of international trade mentioned above.
The term risk is widely discussed both in academia and practice. In the context of business economics risk indicates a potential loss or damage and therefore means the opposite of a chance (March et al. 1987). It may influence the flow of products, services, finance and information. Therefore, supply chain risk can be defined as "*the damage – assessed by its probability of occurrence – that is caused by an event within a company, within its supply chain or its environment affecting the business processes of more than one company in the supply chain negatively*" (Kersten et al. 2011, p. 154).
In order to cope with this large variety of potential supply chain risks, companies should implement a supply chain risk management. This paper is

based on the definition of Norrman et al. (2004, p. 14) by those supply chain risk management is understood as "*to collaboratively with partners in a supply chain apply risk management process tools to deal with risks and uncertainties caused by, or impacting on, logistics related activities or resources*".

The typical supply chain risk management process encompasses the following steps: risk identification, analysis, handling and control (Terry 1972).

The first step*, risk identification*, is often considered as the most important one since only those risks which have been identified can be managed afterwards. There exist different methods for risk identification, such as interviews, checklists, or failure mode and effects analysis (FMEA). Depending on the applied method to identify risks, a risk classification may support the process step. There are a large variety of potential risks which may occur during company's business and also a large number of approaches for classifying them. Risks can be classified in many different ways and from different perspectives (Christopher et al. 2004).

Tummala et al. (1996), for example, use the severity level to classify risks. Therefore, they differ between catastrophic, critical, marginal and negligible risks. According to Narasimhan et al. (2007) supply chains need to be robust at three levels; strategic, tactical and operational. That's why they only take these three categories into account for classification. Baumann et al. (2006) use the same categories, but still divide the category operational into financial and hazard. Sheffi (2005) differentiates between financial, strategic, hazard and operations vulnerability. Here, operations vulnerabilities include everything related to business disruptions. Hazard vulnerabilities include random disruptions and malicious disruption (Sheffi 2005).

The second step of the supply chain risk management process deals with the risk analysis. In this context, the gathered risks are assessed by indicating the likelihood of occurrence and possible damage. Subsequently, the risks are prioritized in preparation for the risk handling step. *Risk handling* represents the third step of the risk management process. Strategies are selected that target at avoiding, reducing, transferring, sharing or taking the risk (Norrman et al.

2004). In the last step, *risk control*, it is reviewed whether the measures applied have been effective. The risk management process should be run through iteratively because single risks or the whole risk situation may change over time (Eberle 2005, Kersten et al. 2012).
In the next chapter, existing studies about export barriers are described.

2.2 Existing studies about export problems

From a company perspective, exporting is an attractive foreign market entry and expansion alternative (Katsikeas et al. 1994). Therefore, different kinds of barriers to the export activities have already been studied since the 1960s, especially by international marketing scholars (Bilkey 1978, Bauerschmidt et al. 1985).
Within various studies the researchers have identified obstacles to exporting covering different countries. There have been very few studies about export problems focussing Brazil or/and supply chain risk management. In the following, some international studies are described as exemplary. It is not claimed that this list in complete.
Katsikeas et al. (1994) for example, investigated exporting problems encountered by indigenous Greek manufacturing firms from a ethnocentric perspective, in the context of a relatively small European country. Their results show that firm size, and export market experience are crucial in explaining perceptions of exporting problems. Finally, Katsikeas et al. provide guidance to public policy makers, but on a very general level, e.g. to reduce export pricing constraints or to create more customized programmes which help firms to develop export strategies.
O’Rourke (1985) confirmed in his survey of Pacific Northwest agriculture firms that small business differ in exporting practices, attitudes and problems from larger business. While large firms saw transportation costs, trade barriers and foreign competition as the major obstacles to increased exports, small firms pointed out that their major obstacles concern their own resources in terms of limited capital etc.

Sullivan et al. (2007) analysed export incentives by collecting data from managers in the European forest production industry and exposed that European managers perceive an important difference between the strategies versus tactical dimensions of exports. Naidu et al. (1993) also emphasized the effects of incentives and suggested implications for policy makers in export assistance in terms of designing effective export assistance programs, such as to define the objectives clearly.

Da Silva et al. (2001) analysed the perceptions of export barriers to the Mercosur by top executives of Brazilian companies located in the state of Rio de Janeiro. In addition, they made a comprehensive literature review by presenting a compilation of export barriers derived from previous international studies that investigated each barrier. They explored which obstacles ranked as most important were related specifically to Mercosur markets.

Blos et al. (2009) analysed the supply chain risk management in the automotive and electronic industries in Brazil and showed the importance for a good supply chain communication by detecting supply chain vulnerabilities. Finally, they made suggestions but on a very general level, like e.g. to implement supply chain risk management and business continuity management training program, and to create an executive management position of chief risk officer.

In summary, there exist different studies analyzing export barriers, but only a few of them are focused on supply chain risk management and on Brazil and seldom considered both perspectives – Germany and Brazil. They all apply their methods in different regions and branches, which makes it difficult to transfer their results to the supply chain management. Furthermore, most publications provide guidance to public policy makers, recommendations on the company’s level are rare.

3. Research findings

3.1 Research Design

Based on the literature review and the identified research gap this article aims to identify and classify potential risks that might occur during international trade operations between Germany and Brazil and that might compromise the supply chain management. Moreover, supply chain risk management measures will be compiled to support entrepreneurs in managing those risks. For this purpose, the paper is based on the qualitative research style (Blaxter et al. 2006). Interviews have been conducted to get a better understanding of which risks might occur.

The complexity of the research question requires a qualitative approach in form of personal interviews. Furthermore, export-related risks address a sensitive issue. Hence, it was of great importance to build trust with the company representatives. By choosing personal and individual conversations a willingness to answer questions in a greater depth and an open discussion was achieved between the interviewer and the selected interviewees.

The authors conducted first expert interviews in the core time from April until June 2014. Table 1 gives an overview of the experts.

For this, interviewees from German and Brazilian companies were selected. Until now, a total of four firms were studied; two companies based in Germany and two companies based in Brazil. All companies interviewed develop business in both countries. Therefore, the answers express the point of view of both countries regarding supply chain risks of German companies exporting to Brazil.

The interviews were conducted according to a half-standardized interview guideline. Most questions were open questions. The interviewees were asked to name the most important risks that might occur for German companies operating in Brazil. In addition, they were asked to describe their experience handling these risks. At the end, the interviewees were able to express wishes and recommendations.

No.	Company	Interviewee	Company Size
A	Manufacturing Company (Germany)	Supply Chain Coordinator Brazil and Argentina	T/over: 1 billion EUR; Employees: 3,900
B	Shipping Carrier (Germany)	Container Stock Coordinator South America	T/over: 5 billion EUR; Employees: 4,491
C	Trading Company (Brazil)	Co-founder and Managing Director	T/over: 2,2 million EUR; Employees: 5
D	Manufacturing Company (Brazil)	Industrial Automotive Product Business Manager	T/over: 1,9 billion EUR; Employees: 7,910

Tab. 1: Overview of company representatives interviewed

3.2 Results of the expert interviews

The risks mentioned in the interviews can be assigned to the four main aspects, related to the classification of Sheffi (2005): Governmental and general risks, financial risks, hazardous risks and operational risks.

Analyzing the aspect *governmental and general risks*, different main critical risks were listed by the experts. The first one is the abrupt Brazilian government changes in import and export rules and legislation. It was unanimous among the interviewees that those changes impact directly import and export operations. Moreover, some changes might even make these operations unfeasible. The second critical risk is the unclear and complex tax system in Brazil. Brazilian and German experts agree that the complexity of the Brazilian tax system has a negative impact in international trade between both countries.

The independency between federal, state and municipal tax policies makes it difficult for foreign companies to develop export cost analysis, because each selected state and city will have a different tax system. Third critical risk describes the failure of the Brazilian government in completing its acceleration plan for the short-term expansion of railways, ports and roads. Although there are a federal interest to speed up logistics infrastructure in Brazil to sustain Brazilian growth, in reality those projects have not been completed according to plan. This issue relates to the fourth critical risk which describes the lack of developmental support from the Brazilian government as well as difficulty for companies to develop a plan for industrial development due to political and economic unrest. As further risks, corruption and excessive bureaucracy in governmental offices were mentioned, which increase the costs of doing business in Brazil, as well as the slowness of customs clearance processes when compared to other American countries.

Regarding the *financial risks*, the most critical risk listed by all interviewees was the currency fluctuation. Brazilian imports from Germany are affected when Euro gets stronger against the Brazilian currency Real. As mentioned previously, Germany is one of the most important trade partners of Brazil. Many companies in the Brazilian industry rely on German products using its machines, tools and technologies in their production processes. Therefore, currency fluctuation impacts directly Brazilian companies' import processes and budget plan on a daily basis – vice versa in Germany. Fuel prices were also appointed as a major risk, by one interviewee located in Brazil and one in Germany. International Trade has a complex logistics system requiring commonly the integration of multimodal transportation. Ocean freight industry is controlled by a few large corporations with high influence in the freight rates levels. Therefore, worldwide fuel prices have direct impact in international trade costs as well. As another risk, the high interest rate for financing projects was listed. Brazilian banks charge high interest rate for credit lines making it difficult for small and medium-sized enterprises to develop and compete with larger corporation which have more resources to fund their projects or to negotiate better rates with local and international banks. This issue relates to the next minor risk pointed out which is the high amount of financial resources to develop a successful import program. Companies willing to import products from Germany need to create a purchasing plan at least 3 to 6 months in advance. Due to the logistics complexity, long lead time and all risks involved, companies must plan an inventory buffer in order to avoid shortage. Customs clearance costs are very high due to the high taxes charged in Brazil and are normally paid upfront impacting directly companies' cash flow.

Regarding *hazardous risks* strikes generated by labor unions were pointed out by the experts. In addition, high costs and time expenditure to transport goods from ports to remote areas in the country were distinguished. Lack of multimodal integration and the dependence of road transportation in Brazil combined with the low quality level of infrastructure turn to be a logistics bottleneck in the supply chain. Besides, main ports and roadways are currently functioning at their maximum and there is no space for additional capacity. Therefore, during export season of soy grain, oil and meal, logistics capacity in many Brazilian ports is overloaded. Another critical risk described was related to the floods in the southern industrial regions of Brazil. Floods in the southern part of Brazil due to high rain volume have been occurring, in the past years, at least once a year causing difficulties for accommodating and unloading vessels at the ports. It is common that vessels skip the affected ports and navigate to the nearest sea port increasing total freight costs. This natural disaster overloads port capacity occasioning one week to one month delay in import and/or export processes. One minor risk described by the experts was the intermittently availability of water and other energy supplies impacting the productivity of many Brazilian industries that do not have a backup energy system when the public power grid fails.

Against the background of *operational risks* the damage and theft of products during delivery due to bad road quality and security for road transport was distinguished by the experts. Those issues impact directly in extra delays during delivery. Due to bad road conditions, trucks often need to stop on the shoulders for maintenance increasing the risk of product theft.

Summarizes the major operational risks mentioned by the interviewees.

	Operational Risks	
Security lapse	Theft of products during delivery; products get damaged, because there are no improvements in road quality and security for road transport.	B, C, D
Forecasting errors	Forecasting errors in all parts of the supply chain; difficulty in forecasting price and shipment volume due to unclear tax system; unreliability in forecasting	A, C, D
Availability of reliable and quality suppliers	Loss of reputation and supply chain disruption due to bad service provided by third party service providers; suppliers are unreliable and must be constantly	A, B, C, D
Skills shortage	Shortages of qualified and experienced personnel.	A, D
Lag in lead times	Lag in lead time due to longer lead times between import and completion of finished goods; extra time and money spent on transporting finished goods from remote	A, C, D
IT Infrastructure problems	Poor IT infrastructure and data management systems; internal processes and tools are slow in adapting to the quick changes in IT systems and new	A, D

Tab. 2: Major operational risks mentioned by the interviewees

Moreover, forecasting errors in all supply chain levels were mentioned as a critical risk by all experts. Forecasting errors in production time, logistics transit time, customs clearance time and cost planning are common issues Brazilian importers have to go through during daily activities. Those errors lead to bad planning and uncertainty during international trade operations. At the same time, such lack of planning affects directly the exporters who cannot plan their production to serve an inconsistent market demand.
Another risk refers to the high costs of operating in Brazil. Considering developed regions in Brazil, their costs can reach the level of the main global metropolis. Besides, Brazilian low tax zones are situated in remote areas which, most of the time, turn to be unattractive for foreign companies to invest.
All interviewees agree in the critical risk which is the lower level and lack of commitment of service providers. Companies normally have to hire internal resources to monitor and manage their suppliers increasing operational costs. Probably one of the main causes for this issue is the low availability of skilled personnel. Although education investments in Brazil have been increasing significantly over the past decade, there is still a shortage in skilled human resources in the country.
Another risk identified is that, due to the longer lead times between import and completion of finished goods, companies operating internationally have to plan and develop long-term sourcing programs requiring more investment capacity and skilled personnel which previously had been analyzed already as an existing issue in Brazil. Poor IT infrastructure and data management systems were listed as further operational risks. This issue leads to poor forecasting and planning for companies due to lack of records and information that can be used to manage business processes.

4. Compilation of measures

Chapter four focuses on risk mitigation and hence on measures especially to manage the above identified operational risks. Table 3 illustrates possible measures for the operational risks which were mentioned by the experts during the interviews. They were combined with measures named in Kersten et al. (2009, 2012).

Use of special bins designed for transport security to improve safety measures for goods, parking on guarded parking areas or establishing long-term insurance contracts improving maintenance/servicing of the logistical equipment are e.g. measures to close the security lapse.

Forecasting errors can be reduced by compiling aggregated forecasts together with supply chain partners. Investing in IT tools to track international shipment can be an additional measure.

The availability of reliable and quality suppliers can e.g. be ensured by claiming supplier's audit, by establishing customer relationship management for building trust or by choosing Brazilian international supply chain partners that have international experience.

Investing in scholarship for employees or stimulating internships to promote international experience for the employees are e.g. measures allocated to counter skills shortage.

A proactive reporting of delayed transports or the involvement of logistics suppliers during purchasing plan can reduce loading time after production delivery. Furthermore, integrating international trade software into the existing Enterprise Resource Planning (ERP) or investing in ERP software with incorporated international trade module are measures that help overcoming IT infrastructure problems.

Operational risks	Measures
Security lapse	Choosing route of transport/transport time with regard to safety issues; parking on guarded parking areas; preventing and improving maintenance/servicing of the logistical equipment of the mode of transport; use of special bins designed for transport security to improve safety measures for goods; establishing long-term insurance contracts.
Forecasting errors	Improving forecast together with SC partners; compiling aggregated forecasts together with supply chain partners, invest in IT tools to track international shipments.
Availability of reliable and quality suppliers	Claim supplier's audit; customer relationship management for building trust; including incentives into the contract; choosing Brazilian international supply chain partners that have international experience.
Skills shortage	Investing in scholarship for employees to improve skills; stimulating internships to promote employees' international experience; exploring existing governmental educational programs and possible incentives to increase level of skilled resources.
Lag in lead times	Holding available logistical buffer capacity; proactive reporting of delayed transports; involving logistics suppliers during purchasing plan in order to reduce loading time after production delivery.

Operational risks	Measures
IT Infrastructure problems	Investing in international trade specialized software to manage import and export processes; integrating international trade software into the existing ERP; investing in ERP software with incorporated international trade module; defining performance indicators to monitor and control main risks and communicating them to the supply chain in order to create action plans to overcome issues.

Tab. 3: Operational risks measures

The results of this chapter show that there is a miscellaneous number of identified measures, which companies can use in order to manage their Brazil-related operational risks. The compilation of measures may be used by the companies to intensify their supply chain risk management. However, it should be taken into account that there will be a need for company-specific adaptation when implementing the identified mitigation measures. Selected measures must tightly focus on the company's financial and human resources. In addition, the type of industry as well as the export destination should be thoroughly considered, because they might require differently weighted measures.

5. Conclusions and further research

In this paper the results of conducted expert interviews are presented related to potential risks that might occur during international trade operations between Germany and Brazil and that might compromise the supply chain management. The identified risks were assigned to the four risk classifications: governmental and general risks, financial risks, hazardous risks as well as operational risks. Moreover, a miscellaneous number of measures have been compiled which

can be used by companies in order to manage their Brazil-related operational risks.
Further research is needed in order to strengthen the evidence of this work. Additional expert interviews will be conducted with German and Brazilian companies during the next months. Subsequently, the results of the different industries should be compared by prioritizing industry-related risks.
In conclusion, it should be observed that supply chain risk management is an important approach to operate successfully in Brazil in the long term, but due to the large number of identified governmental, general and financial risks, the supply chain risk management should be embedded in a holistic enterprise risk management approach.

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The Forest Supply Chain Management: An Entropic Perspective

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Abstract

The Supply Chain (SC) represents a complex and dynamic open system characterized by a dissipative structure and positive entropy (Wang, 2008). To better understand the SC dynamic behavior, we present in this paper a conceptual framework to explain how the SC complexity can decrease the operational performance and the value-added creation. A review of the literature shows that the SC positive entropy is a source of its inherent unnecessary uncertainty and its underperformance. Indeed, the non-linear interactions between the SC actors and their incapacity to share relevant information represent a source of several entropic behaviors.

To reach our research objective, and after presenting the literature review of the SC complexity, we show that the incapacity to share relevant information and the ineffective traceability information management can represent a SC positive entropy amplification source. Then, we highlight how a traceability system and automatic information sharing process can reduce the Wood SC information dissipation and improve the wood allocation. After that, we use empirical results from the European project "Indisputable Key" to highlight how Radio Frequency IDentification (RFID) traceability system can create "negative entropy" in the Wood SC, and improve the wood allocation by quickly allowing companies to access relevant wood information. Since the forest-wood sector is a low economical margin sector; any wood allocation improvement would be a source of added value and a competitive lever for companies.

Keywords: supply chain system, entropy-negentropy, traceability system, forest supply chain, french case

1. Introduction

These past few years, the environment in which companies evolve has become more and more complex, with increasing demand variability and reducing companies' visibility (Forrester, 1958). Therefore, SC is becoming a central organizing units in nowadays' industries (Miles and Snow, 2007). SC is a complex network of business entities (e.g., suppliers, manufacturers, distributors, service providers, warehouses, customers) involved in the upstream and downstream flows of products/services, finances and information (Sanders, 2012; Carter et al., 2014; Ellram and Cooper, 2014). According to Mentzer et al. (2001) and Min et al., (2008), SC exists as a natural phenomenon whether it is managed or not. It represents a system composed of many companies with both convergent and divergent interests, which generates an ago-antagonistic system where both cooperation and competition strategies drive the SC dynamic (Zouaghi and Spalanzani, 2009) and affect its operational performance (Wang, 2008).

The management of the SC, which is dominated by the cooperative paradigm, is based on a systemic and strategic integration of SC flows and processes within and across companies with the objective of reducing costs, improving customer satisfaction and gaining competitive advantage for both independent companies and the SC as a whole (Mentzer et al. 2001). Among the key SC management domain, with note the presence of the information flow management and the performance management (Lambert, 2008). Consequently, and in order to apprehend the SC complexity management, we will focus on the relationship between the information flow management and the overall SC performance in the context of the French forest-wood sector, believing that performance could be improved through more effective release and use of accurate information.

Indeed, we consider the SC as inherently a complex system (Saikouk et al., 2012) due to its dynamic and decentralized characteristics (Bozarth et al., 2009. Serdarasan, 2013, Leeuw, 2013). We define the SC as a dynamic and a complex system composed of autonomous firms that interact with one another in order to fulfill a common goal. To understand the SC system complexity, we will focus on the dissipative nature of the information flow. In fact, the SC system complexity depends on the quality of information sharing mode between the SC actors. Beamon (1999) considers information as a fundamental component for each activity of any company system. He considers the quality of a decision as a function of the quality of the information available in the system.

However, information dissipation phenomenon within complex systems such as SC limits access to some relevant information in the decision making process. Swink and Robinson (1997) cited by Manuj and Sahin (2011) illustrate the potential role of Information systems as moderators for reducing decision-making complexity when designing the SC networks.

The study of the SC complexity has not been widely addressed in the field of wood industry, particularly, in the French forest-wood sector. The SC literature deals mainly with forest-wood sector in North Europe and North America, with mostly an operational and optimization research approach, focusing primarily on large industries and, to a less important degree, wood bio-diversity. Considering the fact that the French forest-wood sector companies' size and the richness of the bio-diversity are quite different from the Nordic regions, the French Wood Supply Chain (WSC) is more complex and needs a system theory approach to understand how its static complexity can both affect its dynamic complexity, relative to information dissipation and entropy, and its overall performance. According to Bozarth et al. (2009), the information sharing difficulties and the SC complexity impact negatively its industrial performance.

In this article, we use system theory and SC complexity management to provide a conceptual framework highlighting that increased effective information traceability management between SC members reduces the SC information dissipations and increases wood allocation through the French WSC. Empirical results from a case study on traceability system are used to identify the effect that an effective information traceability management, through an RFID system

has on the WSC performance, in terms of wood allocation and added value creation.
In the next section of the paper, we start by presenting what a complex SC system is and why the French WSC is on, while highlighting the concept of entropy and information dissipation it engenders

2. Supply chain system, entropy and information dissipation

Complexity has gained more and more importance as an explicative approach in various scientific fields, particularly in management sciences. Complex systems have been defined in the literature by several authors. Weaver (1948), states that a complex system is made up of a large number of parts that interact in a non-simple way. Simon (1962) considers that in complex systems the whole is more than the sum of its parts. Yates (1978) affirms that every system that have one or more of the following five attributes is complex: (1) significant interactions, (2) high number of parts, degrees of freedom or interactions, (3) non-linearity, (4) broken symmetry and (5) non-holonic constraints.
According to Flood and Carson (1988) cited by Bozarth et al., (2009) the complexity of a system increases when one of its parts is not available for others, which may be explained by the asymmetry of the system or the existence of a non-holonic constraints that escapes the central system control. The non-holonic constraint has been described by Flood and Carson (1988, p.27) as "go off and do Their Own Thing".
According to Yates' (1978) definition, we can say that SC is a complex system since we can observe one or more of the following features in it: (a) various companies; (b) high number and variety of relations, processes and interactions between and within companies (c) processes and interactions are dynamic; (d) several levels of the system are involved in each process; and (e) the quantity of information needed to control the system is huge. To illustrate the concept of

non-holonic constraints in the context of SC system, Bozarth et al., (2009) gave an example of a SC "with multiple downstream demand points that independently place orders on a centralized supply point without regard to the supply constraints or needs of other demand points". The more the SC is complex the more the traceability becomes a major issue in its management as the complexity of a system depends exponentially on its size

Casti's (1979) cited by Frizelle and Woodcock (1995) and Sivadasan et al., (2002, 2006) distinguish between two classes of system complexity: (1) static or structural complexity and (2) operational or dynamical complexity. Static or structural complexity is associated with the variety embedded in the system, involving the variety and the interdependences of the subsystems with the large number of elements of the system. It can be measured by the number and variety of processes and products involved and the interactions between them (Frizelle & oodcock 1995). The operational complexity is associated with the system dynamism, the connectivity between the sub-systems with its inherent uncertainty. Inherent SC chain uncertainties arise when the activities of supply chain actors are not in harmony with one another. It can be measured by the positive entropy contained in the SC system. Based on Frizelle and Woodcock (1995), who has been among the first to use this distinction to study complexity in manufacturing systems, Sivadasan et al., (2002) cited by Sivadasan et al., (2006) suggest an information-theoretic entropy-based methodology to measure quantitatively the operational complexity of supplier-consumers systems associated with the uncertainty in information transfer of the internal and interface system. When dealing with SC system complexity, a third type of complexity, namely decision-making, which involves both static and dynamic complexity, should be considered (Manuj and Sahin, 2011).

We note that the decision making complexity involves both static and dynamic aspects of complexity and it is associated with the information relevance that should be considered when making a SC related decision. These three complexities (static, dynamic, and decision-making) are interrelated.

From the static perspective, the decision making process in the SC system becomes complex when making a decision goes beyond the human capacity (Simon, 1974). From the dynamic perspective, the nonlinearity, the dynamic and the unexpected SC system behavior makes the decision making process more complex. As result, the complexity of decision making in the SC is directly related to the volume and the relevance of the information contained in the system. In other words, the decision making complexity depends directly on the positive entropy or the missed information that characterized the SC system at a given time. When dealing with SC complexity, two major approaches of complexity measurement researches can be distinguished: studies using the SC metrics (Beamon 1999; Vachon & Klassen 2002) and studies using theoretic information (Frizelle & Woodcock 1995; Sivadasan et al. 1999; Efstathiou et al. 2002; Sivadasan et al. 2002a; Sivadasan et al. 2004; Sivadasan et al. 2006; Wu et al. 2007; Martinez-Olvera 2008).
Considering the dependency of SC activities on information, we will focus on information sharing mode to apprehend the management of the SC system inherent complexity. To better understand the information transfer in the SC system, we consider the idea of entropy from its theoretical and mathematical basis. In the information theory, (Shannon, 1948) considers the entropy as the probability of information loss in a communication. Indeed, entropy measures the amount of missing information needed to describe the state of a system. Positive entropy is a measure of the level of informational disorder between SC system actors and characterizes the probability of information loss within the system. In general, entropy grows if nothing is done. This means that information loss is a growing phenomenon but may be regulated by negative entropy, called negentropy. The more entropy is present, the more dissipative the SC becomes. In an open system like the SC (Wang, 2008), entropy is used to describe the system disorder degree.
Overall, we can say that the SC is a complex entropic system characterized by its dissipative structure (Prigo-gine, 1955), and that entropy increases if nothing is done to reduce the system inherent uncertainty. In practice, we can use and

detect this entropy to master the operational complexity in sharing information process between the SC system actors. Based on this, and after presenting the French WSC, we will show how traceability systems can create a negative entropy, which is an essential factor in system organization, as it allows to measure the degree of order creation in the system, permits the system to self-regulate (Brillouin, 1959), and moderates information dissipation within it.

3. The French Wood Supply Chain

In this section, we will first describe the specific characteristics of the French forest-wood sector to explain the complexity of its SC.

First, we have to mention that there is a large number of foresters in France, which affects dramatically the potential of wood mobilization and limits the development of the economic relationships between the foresters and the wood industries. In fact, the French forest-wood sector is fragmented into heterogeneous multi-activities actors. At the upstream level, there are a large number of foresters and small enterprises that are situated between the forests and sawmills, which lack technologies and production capacity investment. At the downstream level, there are large companies such as furniture companies and paper mills. The fragmentation of the sector and the variety of resources don't encourage firms to form networks, which explains the low level of integration in the sector. A study was conducted in 2008 by the Department of Regional Planning in France (AGRESTE) and the Technological Institute FCBA to highlight the important fragmentation level of the French forest-wood sector. This study allows us to show that the different activities necessary to transform wood in France require, in fact, the intervention of several heterogeneous actors. We believe that this fragmentation doesn't create the appropriate conditions to better share information, and simplify/standardize data exchange process between companies. According to the FCBA in France, the standardization of information in the forest-wood sector represents a major issue in the absence of a unique data referential system adopted by all actors in the sector.

According to Simchi-Levi et al. (2000) the lack of integration within a SC can be explained by the format of the exchanged data, which leads to relevant information loss. The increasing uncertainty about the qualitative properties and the measurements of logs reduces the companies' visibility, regarding scheduling and planning of their production and logistic capacity, which prevents them from providing the right product to the right client. The logs properties' visibility problem is central in our approach, which pushes us to first define what visibility is. According to Gattorna (2009), visibility is “the identity, location, and status of entities transiting the SC, captured in timely messages about events, along with planned and actual dates/times for these events”. The loss of this ability to "see" and share information increases the opacity of the SC system, which, on the one hand, pushes companies to organize themselves into "Silos" approaches, and on the other hand, leads them to focus on their local objectives. The visibility on material flows movement from supplier to consumers enhance the SC performance (Joshi, 2000) like inventory management, product allocation and asset utilization (Delen et al., 2007). In fact, the SC management role is to eliminate the barriers by enabling the synchronization and sharing of valuable information among trading partners (Kouvelis et al., 2006). In our case, to enhance the wood SC visibility, in terms of wood quality and quantity, we consider sharing information as one of the most effective ways of improving SC visibility and performance.

Moyaux et al., (2007) considers sharing information as a mechanism of coordination that can reduce the bullwhip effect. This latter is characterized by high inventories level and long lead-time which estimated by 6 to 12 months in the wood industry. The bullwhip effect results from the information asymmetry triggered by their incapacity of actors to share information. We can also add that there is a direct relationship between Bullwhip effect and operational complexity (Ahmad and Alireza, 2006). These factors reduce the logs recovery rate due to the inadequacy of the supply and demand, leading to a lower product quality, growth and service levels in the SC (Joshi, 2000). Holweg et al., (2005) show that collaboration within the SC and the visibility can reduce the Bullwhip Effect and improve the quality of service, reducing inventory levels and stock-outs probability.

The wood SC (WSC) represents for us a relevant example to highlight the effect of the complexity, information dissipation and entropy on the SC visibility, information sharing and operations performance. Indeed, the WSC has a divergent structure (Vila et al., 2006) characterized by a single entry point to the raw material at the forest level (upstream) and several access points to the different wood product market (lumber, paper, wood energy…). As the WSC is divergent and interrelated in terms of multiple products coming from a single input, the relative pricing between some of these products can be dynamic.

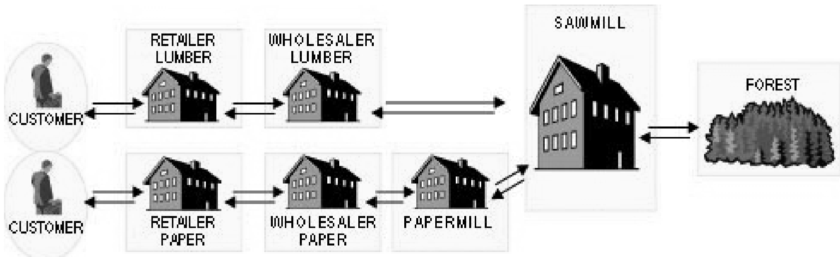

Fig. 1: The divergent nature of the forest products industry supply chain is simulated by dividing the material produced at sawmill into chips and lumber (Wood Supply Game at FOR@C)

The French WSC is both fragmented into many autonomous but interdependent companies (also asymmetric) because most of the activities in the first transformation, particularly at the forest, are not available to the companies of the second transformation. This asymmetry is characterized by a non-holonic (uncontrollable) constraint which represents the harvesting activities that escapes the control of companies in the second transformation.

This explains the decoupling point of the WSC at sawmills level. We can conclude that the WSC represents a complex and dynamic system. Moreover, the WSC complexity is increased by the interweaving of logistic flows to extract value from sawmills wastes to produce the co-products (paper pulp and energy), which makes it even more difficult to manage.

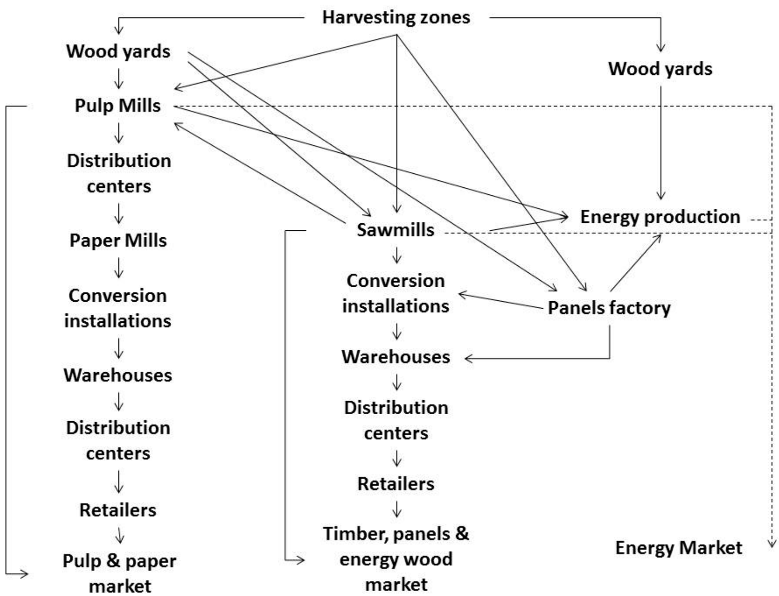

Fig. 2: The forest products value chain flows complexity

This figure shows the interweaving of forest product value chain making the WSC more complex. In fact, the WSC has traditionally been considered as complex with the presence of several intermediaries between resource extraction, manufacturing, and end use (Sinclair, 1992).

The complexity of the French WSC is amplified by the diversity of wood. In fact, wood has always been considered a homogeneous structure and a bulk material, while in reality it is a non-homogeneous biological material and its properties depend on growing conditions (growing season, natural regeneration or planting, etc. …). Depending on its essence and its properties, logs differ in terms of their appearance, durability, strength, etc. Every wood market has its special requirements in terms of wood species and properties. This situation changes the design of the French WSC from a traditional SC based on mass production to a mass customization SC, particularly in the furniture industry (Bullard et al., 2002). The French WSC "V" structure makes it essential to maximize value extraction through the availability of information about logs properties. The access to information can help effectively manage the WSC operational complexity in order to deliver the right wood to the right end user. A lack of knowledge of quality of wood leads to an under-usage of wood, which represents a wasting of natural resources and a waste of business profitability. To maximize WSC added value, selecting the right logs for a specific end-use is a demanding in relevant information. The challenge in the WSC actors is to accelerate and standardize the access to relevant information by automating the information sharing between the WSC actors.

Wood supply uncertainty can arise due to unpredictable (wood properties) and uncontrollable (non holonic constraint and "V" WSC structure) factors affecting wood supplier changing frequency, time specificity of materials, delivery frequency and fluctuations in the selling price (Ho et al.,2005).

To conclude this part, we can state that the French WSC represents a high level of static and dynamic complexity. It is fragmented and contains heterogeneous actors, both in terms of size and culture, equipment and use of information technology. This complexity makes the French forest wood non-competitive at the European level despite its potential in terms of wood richness, variety and available quantities. In the next, part, we develop our conceptual framework, after which we use empirical results from a European project "Indisputable Key" to support it.

The research objective is to develop a conceptual framework to explain how the SC entropic behavior can decrease the operational performance and the added value creation that in the case of the French wood SC. Toward the end, we apply a research methodology consisting on reviewing relevant literature in the field of SC management and system complexity theory and The RFID traceability system application in the management of the SC. For the empirical evidence, data collected from a pilot project in the use of RFID system in

Europe to limit the dissipation of information on the wood quality is going to be used.

Our initial investigations on the use of RFID in the French WSC have revealed a lack of initiatives to implement RFID to trace the wood. The explanations we have noted are various but could be summarized in two main reasons which are financial (the cost of the RFID tag compared to the value of the log should not exceed 1%, while the current biodegradable tag cost exceeds this limit) and organizational and technological ones. This is the reason why opted to use the results “Indisputable Key” which we will present in the latter part.

We have seen that the French WCS is an extremely complex system. This complexity could be categorized into three types: the static complexity, the decision making complexity and the dynamic complexity. According to Blecker et al. (2005) Complexity in a SC can be observed within a firm, between the firms and in their interactions. It is also possible to categorize the WSC complexity on the basis of its origin (internal sources, supply/demand interface sources and external sources) (Blecker et al. 2005). As we have said, this article focuses only on the inherent complexity.

Therefore, we can resume the French WSC complexity characteristics according to their origin (Internal, supply/demand interface) and to their types (static, dynamic, decision making). In the context of this article, we are only focusing on the inherent WSC complexity, the external origin of complexity will be covered.

Within a WSC, all types of complexity should be considered to improve performance of all the WSC actors and facilitate their integration.

Three generic approaches emerge in the literature of the SC complexity: complexity management, complexity reduction and complexity prevention. We believe that the first approach would be to reduce/eliminate the source of unnecessary uncertainty, which is the information dissipation in the SC system, by measuring a negentropy index. Then we can manage and prevent any additional unnecessary complexity. It is important to differentiate between necessary complexity that the customer/market is willing to pay for and unnecessary complexity that brings no additional benefits to the company/supply chain, but rather involves additional costs (Frizelle and Efstathiou, 2002). Within the WSC, all types of inherent complexity should be considered to improve SC actors' performance and facilitate their integration. To deal with SC complexity, three generic approaches emerge in the literature: complexity management, complexity reduction and complexity prevention. To cope with the French WSC complexity, we consider as a first approach the reduction and elimination of all sources of unnecessary uncertainty, considered to be the information dissipation, by measuring and increasing the negentropy index. Then, we can manage and prevent any additional unnecessary complexity.

	Internal	Supply/demand interface
Static	High number of wood product variety Divergent structure of the wood SC	High species diversity High number of wood SC actors in France Fragmentation of the wood SC
Dynamic	Process uncertainties Log properties and quality uncertainty Forecast driven bullwhip effect	The interweaving of forest product value chain Different languages Lack of visibility Lack of process synchronization
Decision making	Basic IT system especially for accounting Small business	Open loop traceability system Wood SC heterogeneous IT Non holonic constraint and WSC asymmetry

Tab. 1: Drivers of the French wood SC complexity

We propose a conceptual framework to highlight first the negative impact of the SC complexity, through information dissipation and positive entropy, on the operational performance in terms of revenues, product allocation and process variability. According to systems theory, SC can be considered as a complex and dynamic system composed of autonomous firms that interact with one another contributing to fulfilling or not a common goal. When SC actors have convergent goals, they cooperate and share information which creates an organization factor called negentropy or order index. In the opposite, when SC actors have divergent goals, they compete without sharing information increasing entropy or disorder degree. In our case, we consider that actors from the second transformation must cooperate and share demand information with actors of the first transformation to enhance their own performance, through getting visibility on the supplied wood properties, which is vital to eliminate or reduce the unnecessary complexity (reduce information dissipation or entropy).

Our focus is to reduce decision making complexity by eliminating and reducing unnecessary source of uncertainty. In this matter, Manuj and Sahin (2009) have developed a model to identify antecedences of SC decision making complexity supported by the existing literature. However, their word didn't take into account the decision making complexity related to the product properties uncertainty. In our article we try to fill this gap by considering the effect of product relevant information availability on the decision making complexity.

In order to deal with the static and dynamic complexity drivers, which make the French WSC a complex system, the implementation of a Closed Loop Traceability System (CLTS) can help capture and conserve all available logs relevant information throughout the wood value chains and then transform it into knowledge to improve decision making. A CLTS must to be interoperable with all information systems in the WSC without generating an organizational change or triggering additional cost. According to (Wang, 2008), promoting the use of advanced technologies (RFID systems) in the SC could increase the negentropy creation and decrease the positive entropy negative impact on the SC performance. Indeed, making all information flows visible throughout the SC is a part of twelve rules for better managing and preventing material flows uncertainty (Childerhouse and Towill, 2003). Concerning the nature of the SC performance, we consider as performance criteria the product selling value.

The more information is quickly available on the product, the better its value and its sale revenues get (De Marco et al., 2012).

SC entropic Behavior	Some RFID negative entropy	Authors
Information loss Information sharing	Improves information integrity. The use of RFID as a sole channel of information sharing between companies	Fosso Wamba and Boeck (2008), Zaharudin and al. (2007)
Information imperfection	Tracks products precisely and improves the accuracy of the information.	Lee and al. (2004), lee and Ozer (2007), Hesse (2007), cannon and al. (2008), Lapide, L. (2004)
Lack of item level visibility over information flows and inventory levels	Improves item level visibility and inventory information management. Improves visibility in real time (provided of effective management information)	Fosso, Wamba and Boeck (2008), Zahou (2009), Wang and al. (2008)
High uncertainty, decision making complexity, product sales revenues	Contributes to uncertainty decrease in the SC and improves decision making. Process cost saving, promise large potential benefits from revenue growth, increases sales	Cannon and al. (2008), Lin and al. (2006), Zhou (2009), De Marco and al. (2012).

Tab. 2: RFID positive impact the SC entropic behavior

According to Prigogine (1955) system theory, complex systems are dissipative and entropic systems. Entropy is inherent to complex system and it increases if

nothing is done to reduce the system information dissipation. We suggest a conceptual framework to highlight the role of closed loop architecture traceability at the item level in enhancing the product/process visibility, moderating the operation complexity and optimizing wood allocation at each step processing in the SC. To mitigate the SC entropic behavior, RFID systems can have a moderator by manifesting negative entropy.
This can be consolidated by the following conceptual framework:

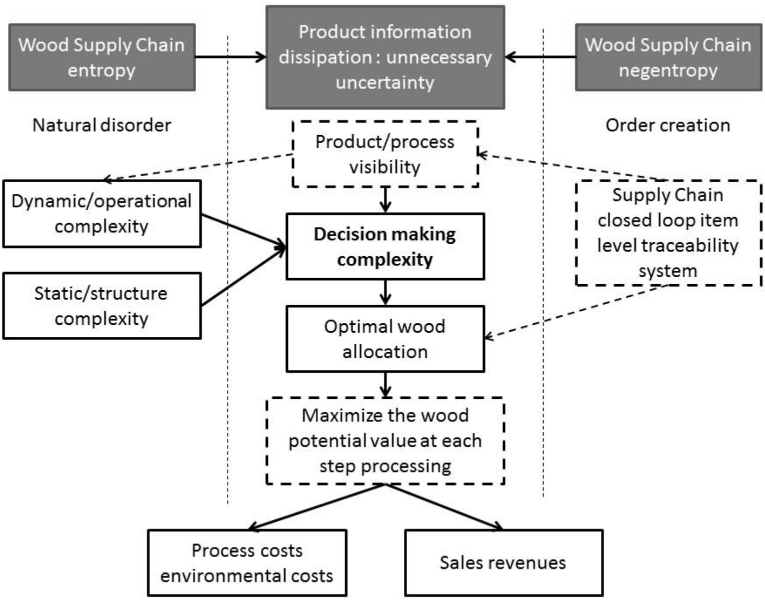

Fig. 3: Conceptual framework: the French wood SC is an entropic SC

4. Traceability based Negentropy in Wood SC

Traceability is defined by the ISO9000: 2000 as: "the ability to trace the history, application or location of an entity by means of recorded identifications.» According to Alfaro and Rabade (2009), the use of traceability information can improve SC management. The ability to track and locate products accurately in

SCs can lower inventory levels. By incorporating traceability information with SC management, Wang et al., (2010) consider traceability systems as a key factor that can improve the operations management in the Food SC. In terms of tracking and tracing functionalities Fritz and Schiefer (2009) consider various principal traceability concepts: (1) Backward tracing for the origin of a product, (2) Forward tracing for the position of a product, (3) Backward tracing for the history of a product and (4) Forward tracing for the movement of a product. In the literature, several authors discuss the role of traceability in SCM with more security and regulatory dimensions (Fritz et al., 2009, Wang et al., 2010; Trienekens et al., 2011).

We can explain the security interests in the Food SCM by the maturity of the European legislation in food traceability and the need for transparency. However few theoretical models are mobilized in order to demonstrate the contribution traceability systems in the WSC.

According to the French National Center of Traceability and GS1France, there are two architectures of the traceability systems. The traceability system is in "closed loop architecture" when the SC companies are adopting a common protocols and standards of communication that enable interoperability and secured/controlled information sharing. When traceability system is in "open loop architecture", where the SC actors don't have homogenized traceability systems, discontinuities can be observed in information flows. The good functioning of a traceability system essentially depends on the interoperability of inter-organizational information systems.

The first results of a battery of interviews that we conducted with the Association "AB" in the region Rhône Alpes in France and some experts of the FCBA allow us to conclude that a CLTS like RFID system would achieve several objectives, among which we highlight the following: achieving material economy by improving the efficiency of wood through better adaptation of the production tool to different types of wood, enhancing the transparency of wood products with eco-labels, reassuring end users about the quality and correctness of their choices of wood, secure the modes exchange of products and establishing a consciousness of belonging to a wood SC. However, the implementation of a RFID system represents a considerable financial and organization challenge for the WSC actors. At the moment, there is no finished project to explore the potential of RFID system benefits in the French forest wood sector. Fortunately, the project "Indisputable Key", a European research project launched in October 2006 by a consortium of 28 partners from five countries with a budget of € 12.8 million, provides us with some reliable field data. According to the project public reports, more than 25 million m3 of raw material go to waste, equivalent to several billions € in Europe, and more than 20 % of final products do not correspond to customers demand. The principal source of waste is the information loss along at each step of wood processing in the SC. To cope with these economic and ecological wastes, the ultimate objective of the project was to develop a methodology and a traceability based RFID technologies that can improve the use of wood and optimize forest production through minimizing WSC environmental impacts. To achieve this goal, the technical solution was to use automatic traceability system and standardize all data communication within and between actors in the SC.

As a final result, we can observe in the figure 4 that a certain quantity of product information (original, cutting wood, measuring input sawmill, sorting products, etc.) is collected by different equipment and production machines are available during the process in progress, but most of the information os lost during the following process.

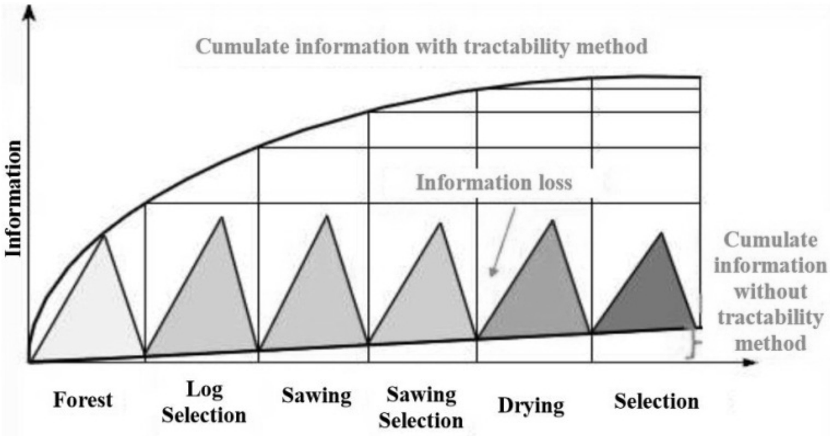

Fig. 4: Scheme of information losses at each step during wood SC (source: www.indisputablekey.com)

Figure 4 shows that the quantity of information accumulated without a traceability system is significantly lower than the quantity accumulated with a traceability system. Unfortunately, the major simulation outcomes with real world production studies and development are presented in two confidential reports that are not available to the public. In general, the D1 24 final report recognizes the capacity of RFID system to maximize the wood potential value by providing eco-certified products and wood quality adapted to the demand at the right price. We can summarize RFID empirical benefits in the wood SC in the following points:

- Reducing wood quality losses due to inappropriate storage by 10 to 20 %;
- Improving knowledge about the origin of wood with full traceability in each specific board;
- Improving production efficiency: up to 10% better yield estimated to more than 1 400 millions € on EU basis;
- Reducing loss of timber. Even a 10% reduction represents a potential on EU basis is estimated to 80 million € annual payback.

By analogy to our conceptual framework, these empirical results represent a proof of the concept of information dissipation within a complex system such as the WSC, highlighting the relevance of using a traceability system using a biodegradable RFID technology. French WSC actors particularly sawmills, were able to stop traceability cuts and restrict the loss of information. This project has shown that the main interest of the SC traceability in forest is the capitalization of information and acceleration of the access to relevant information by having a real image of wood evolution status at each stage of wood industry.

This reduces both the quantitative information dissipation and the loss of its relevance, which is generally due to errors of interpretation by the various companies, given that the structure and forms of information are different in the wood sector. According to Saikouk et al., (2011), the use of RFID system can regulate the entropic dissipation in SC systems.

Entropy characterizes complex systems dissipative structure as informational common disorder between companies. Generally, entropy grows if nothing is done. This means that information loss is a growing phenomenon but may be regulated by negative entropy, called negentropy. Consequently, information quality, quantity and the mode of sharing constitute important elements that contribute to making the SC system more stable. We suggest that an effective management of the SC can be reached through creating order by Negentropy based RFID traceability system. The traceability in the forest context aims to improve the process operational complexity control and add value to product by helping decision makers to select the right logs characteristics to meet the end user specifications. Poor decision making can contribute to operational complexity amplification.

5. Conclusion

As we have seen in this paper SC represents an inherent complex system. In fact, we can distinguish between three types of supply chain complexity: First, a static or structural complexity depending on the number of companies within the system, the variety of these companies and the non-linearity of the system. Second, a dynamic or operational complexity depends on dynamism, the interactions between the companies and the high level of uncertainty. Third, the decision making complexity results from both static and dynamic complexity. In this paper we have focused on the wood supply chain complex system uncertainty characterized by its entropy due to its dissipative structure.

Supply chain dynamics fluctuate between order and disorder. Fundamentally, organization of a supply chain system is the creation of order out of current disorder by effective management. The more a supply chain is organized, the less the subsisting entropy. This entropy materialized by information dissipation and remains a source of inherent supply chain system operational complexity.

We have also seen that the French WSC is a divergent industrial process which is fragmented into many autonomous interdependent actors that usually have heterogeneous information systems. The WSC is also asymmetric due to the fact that one of its parts is not accessible to the others actors and has a non-holonic constraint. This constraint escapes from the control of the French WSCS second transformation industries. In addition, in the French WSC the traceability system follows an open loop architecture increasing the risk of information loss. This makes the WSC as complex entropic system in which information dissipation increases over time. To cope with this dissipation, we have suggested the concept of Closed Loop Traceability System as a Negentropy based system creating order. In fact, in the WSC the role of a traceability system is to capture and automatically conserve and provide relevant information about the wood quality and evolution in different process over the WSC from the forest to the different market. Finally, we relied on the Indisputable Key project results to confirm our theoretical development. As seen above, the implementation of a RFID item level system to track and trace wood from the forest to the market is a very big challenge for the professionals. Recognizing the role of RFID in improving actors' operations performance and their competiveness, as well as the forest eco-interests and the RFID decreasing cost (Moore's law) should improve the adoption of RFID in the French WSC.

In our further research we will develop a dynamic system based simulation model to first, highlight the impact of the Negentropy on the WSC industrial performance especially for the sawmill industries and then simulate the impact of different non-holonic constraints on the French WSC entropic behavior system. We will also develop a Negentropy index to measure the impact of a traceability system on reducing information dissipation, which is the main source of unnecessary uncertainty.

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A Multi-Agent Based Approach for Risk Management in a Port Container Terminal

Lorena Bearzotti and Rosa Gonzalez

Abstract

The growth of foreign trade and globalization emphasize the weaknesses of extended supply chain in front of occurrence of disruptive events that impact differently (deviation, disruption, disaster) the normal operation, in some cases the consequences are temporary but the worst scenario is when the event produces a permanent cessation of its activities. Then the ports are a strategic actor because if they have problems with their operations the others in the supply chain will be affected negatively, so the ports resilience determines the level of resilience of multiple supply chain in which they participate.
Because of this it is necessary to have tools that provide support to the process of risk management in order to have proactive and reactive, responses to the different disruption events that may occur in its operation. In this paper a multi-agent approach to risk management in container terminal is presented.

Keywords: risk management, event management, multi-agent system, container port terminal

1. Introduction

The transfer and storage of containers at port terminals has been growing in recent years. This situation has forced the port terminals have information systems with the goal of to improve the functioning, efficiency and level of customer service. This is achieved through a combined effort of all actors involved in the operations of a port terminal.

The study to improve the operations of a port terminal is necessary because it is a key node in multiple global supply chains, so any problems in the port may affect related organizations. The port terminals are essential in the country import and export processes. Ports are interfaces between different modes of transport and are typically combined transport centers where the products are manipulated, manufactured and distributed. An efficient port requires not only infrastructure, superstructure and proper equipment, but also good communications and a dedicated management team, qualified and motivated and trained workforce.

The container port terminals have a key place called "container yard" where the containers are temporary stored, so their administrators perform research and analysis aimed at improving its management.

In the yard management one of the problems to be addressed is the risks and disruptive events management. The risk and event management permit to analyze and understand the origin and consequences of disruptive events, as well as determine the answers that are provided against its occurrence. The ability of a system to respond to a disruptive event without losing their ability to function is known under the concept of resilience. (Mansouri, 2009; Sanchis, 2011). The event management is defined as the component of the systems management container terminal that reduces the gap between planning and execution, with the objective of minimizing the impact of an event on a plan that is running. (Bearzotti, 2012).

This paper presents a proposal for risk managing in the container yard of a port terminal. This proposal consists of a multi-agent focused on the analysis of disruptive events and the generation of actions to reduce the impact of the event model.The paper is organized as follows, in the next section the problem description and review of the literature was performed. The proposed model is presented in section 3, while a case study is developed in Section 4. Conclusions and future work are presented in Section 5.

2. The Risk Management Problem in a Container Terminal

2.1 The Risk and Event Management Problem

Risk management is the identification, assessment and prioritization of risk after that the risk management includes the coordination and economical application of resources to minimize, monitor and control the probability and/or impact of disruptive events.

Risk can come from uncertainty, natural causes, social causes, procedures, etc. The risk management goal is reducing the vulnerability and ensuring continuity.

The event management is understood as the component of risk management to reduce the gap between planning and execution systems in order to minimize the impact of an exception or deviation from a current plan allowing in turn the visibility and agility with a consequent resilient (Bearzotti, 2012, 2013). The event management is the activity en risk management process where the actions are analyzed when a risk is a certainty.

2.2 Risk and Event Management in a Container Yard

The port is a convergence point; today is a major node of convergence in international transport and trade, and it is the point of contact between land and sea transport. It needs to improve their process in terms of its agility and ability to respond to unforeseen events. For this, a system that can respond to changes and disruptions in the port terminal is very necessary tool to enhance resilience in the port.

The Container Port Terminal has three principal areas: Quay, Yard and Gate. These areas are related and if one of them has a problem may impact the others. But the Yard is the key element because a bad management in the Yard will be bad operations in Quay and Gate.
One of the main functions of a container terminal is the container transfer to and from ships at Quay. On the other hand the Yard also is related to the Gate giving and receiving containers either by truck or by train. For these operations, the Yard has resources that are used in function-oriented storage and movement of containers in the terminal planning.
In an ideal situation, the plans are executed without problem, but there is variability in the execution. Disruptive events cause deviations in the plan execution and in the expected result.
It is essential in the yard operation that plan will be with slack to handle events that occur in the plan execution. If the slack is used then the event consequences are minimized.
An event management system in the container yard seeks to mitigate the impact of disruptive events using slacks current plans, thus avoiding re-planning. An event management system can generate improvements in the administration of the yard and its relation to the Quay and the Gate.

2.3 Related Work

In this section the related work are presented, specifically to yard event management systems there is not many related work. There are papers related in the monitor and control area.
Gronalt et. al. (2008) present an study about risk in a container terminal. They propose a risk evaluation with three steps: 1) terminal description (internal factors, network factors and environment conditions); 2) risk identification and classification; 3) for each risk, to determine risk consequences. After that a vulnerability analysis is made.
Loh and Thai (2012) indicate the port role in the supply chain. They do an analysis related with the port risks and propose a holistic management model.

Najib et. al., (2013) propose a process for managing risks related to containers on drugs suspicion, establishing a set of rules for inspection. It proposes a framework for multi-agent systems focused on high-risk containers.

MOCONT (Monitoring the Yard in Conteiner Terminals) (Bozzo et. al., 2001), is a monitoring and control system for a container port terminal. This system uses GPS with sensors to monitor container movements and their position. There are three modules: Location Module, Visual Identification Module and Synchronization and Communication Module.

Ngai et. al. (2011) propose a study case for the prototype: ICADSS (Intelligent Context-Aware Decision Support System), to monitor in real time the operations in the Hong Kong container terminal. This system uses a sensors network USN (Ubiquitous Sensor Network).

Zeng et. al. (2011) propose a mathematical model for events in Quay. First, the Berth Allocation Problem (BAP) is presented. After a disruption management is described.

Bearzotti et al., (2012) present an approach for supply chain event management. This work is focused in the mitigation of events in supply chain.

3. A Multi-agent Model for Event Management in a Container Yard

In this section a yard container port terminal event management multi-agent conceptual model is presented YEMS (Yard Event Management System). The PASSI methodology (Cossentino, 2003) is used in the model description.

The YEMS model has six agents: EIA (Execution Interface Agent), PIA (Planification Interface Agent), SEMA (Space Event Management Agent), REMA (Resource Event Management Agent), Resource Agent and RE (Relations with the exterior).

The PIA and EIA agents have the function of to interact with the planning system and execution system. The SEMA and REMA agents manage the events related with space and resources. The agent Resource represents the resources in the Yard, its function is coordinating the tasks with the SEMA and REMA agents. RE agent is related with the Quay and the Gate to colaborate in the event management.

The next sections the different agents are presented and how they are related.

3.1 A Conceptual Model for Event Management

YEMS interact with the event management system in Quay and Gate, this is important when a disruptive event affect the terminal. In the Figure 1 the different subsystem are presented. In other hand YEMS is related with the planning and execution systems. There are agents specialized in these interrelationship.

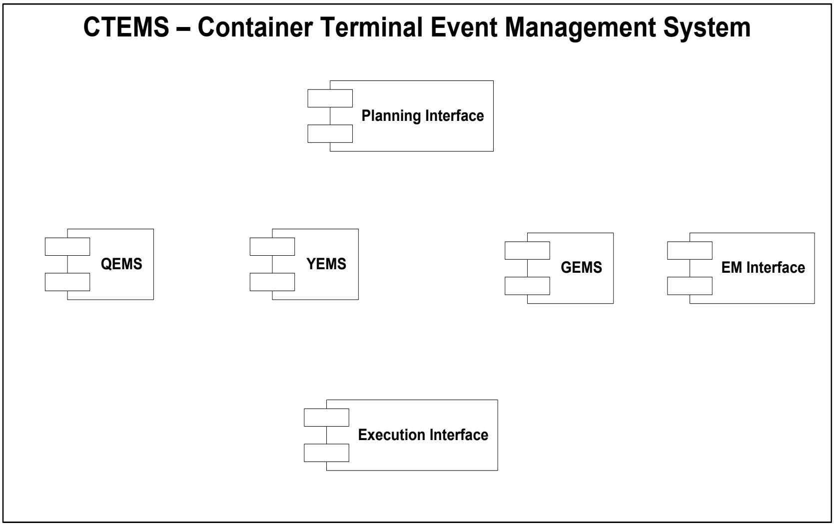

Fig. 1: Container Terminal Event Management System - Subsystems

The YEMS receives the plan from Planning System and the events from the Execution System. When a disruptive event can not solve in the quay or gate, the event management in these subsystems sends a call for participation to YEMS.

3.2 Agent PIA

This agent performs the task communication between YEMS and planning level. Get updates and planning and communicating if an exception occurs. Upon receipt of planning makes the difference between planning and resource spaces, initializing the amount of resources that should be considered in the YEMS. PIA sends schedules to respective agents (Resource agent and SEMMA agent).

Use Case	Description
Receive Plan	Plan related with resources and spaces from Planning System, with this information it sends the information to SEMA agent and to Resource Agent.
Inform Exception	Send an exception message to planning system when a disruptive event cannot solved.
Consult	Consult if there is a change in the plan

Tab. 1: PIA Uses Case.

3.3 Agent Resource

This agent represents each resource within the yard and manages tasks. It contributes to cooperation and works with other agents. Check availability for additional tasks and delivery proposals for performing tasks. This agent contains two lists, a list of the tasks set by planning to have the first priority to be executed and a second list of tasks requested from other resources, which have made a second priority. These last recourse is performed only when the time available to perform them, that is, when not performing a task from the list of first priority.

Uses Case	Description
Check availability of resource	Review each resource and check availability for extra task.
Check task list	Check the task list searching for time to do an extra task.
Assign task	If there is availability, a task is asigned to the resource.
Enter resource	This UC register the information about the resources.

Tab. 2: Agent Resource Uses Case.

3.4 Agent SEMA

This agent manages the spaces within the yard. Get and set space planning and which are available. This manager check availability of spaces and allocating containers involved in an event. Also it participates in the cooperative when it comes to an external event. In the latter case provides alternative spaces according to features delivered by the request for cooperation. Also makes a negotiation with the resource agents when trying to coordinate a task either, mobilizing, positioning or removing a container. Finally a proposed solution delivery if they reach a settlement proposal or an exception if the search is negative spaces available.

Uses Case	Description
Receive Event Space	The Agent EIA notifies about an event related with the space in the yard.
Manage Space Event	With the information, the agent begins the process to find an action plan.
Check space availability	This UC finds spaces in the yard.
Assign space to container	This UC register the information about the container in the available space.
Send proposed solution	Notify to EIA the new plan.
Send exception	If there is not solution, it sends the information about the exception to PIA agent.
Manage external event	Receive information. Consult space availability and inform propose to RE agent.
Initialize spaces	Receive planning information. Set availability of spaces.
Coordinate Task	Coordinate task of moving and positioning with resource agents.

Tab. 3: Agent SEMA Uses Case.

3.5 Agent REMA

This agent manages the resource events. Get the event and consulting resource availability of a resource agent to perform additional tasks, thus distributing the tasks of the affected resource among other resources. If negotiations are successful make a settlement proposal and sends it to EIA agent, otherwise make an exception and sends it to the PIA and EIA agents.

Uses Case	Description
Receive Resource Event	The Agent EIA notifies about an event related with the resource in the yard.
Manage Resource Event	With the information, the agent begins the process to find an action plan.
Check resource availability	This UC finds resources available in the yard.
Assign space to container	This UC register the information about the container in the available space.
Send proposed solution	If a solution exists notify action plan.
Send exception	If there is not solution, it sends the information about the exception to PIA agent.

Tab. 4: Agent REMA Uses Case.

3.6 Agent RE

This agent is responsible for communication with the external actor (or Quay Gate) when requested cooperation to resolve an event that occurred in its domain. Receives the request and determines whether cooperation is a request for space, or resource allocation. For the first two sends an availability check to the respective agents (SEMA or Resource) in the case of an application for allocation refers to the allocation request either one or more spaces or containers of a task to one or more resources. This allocation request may be a response to Quay Gate or a proposal previously submitted by YEMS space before the application or resource.

Uses Case	Description
Receive Request	Quay or Gate sends a request.
Send Request	Send the request to SEMA or REMA
Order Allocation	Request allocation of spaces or tasks to a resource. This action is in response to the proposal previously submitted by this agent to the request for cooperation from the outside.
Send proposals	Receive proposals from the SEMA agents and REMA and then sent to external stakeholders.

Tab. 5: Agent RE Uses Case.

3.7 Agent EIA

The agent in charge of receiving events from the monitoring system and communicate them to the corresponding agents is. Also manages the congestion event, negotiating with external actor Gate entrance dwell time of containers (or trucks) yard to thereby relieve it.

Uses Case	Description
Receive Event	Get captured by the monitoring system event. The YEMS consults to establish what type of event it is. It requests a data update to PIA agent.
Notify Event	Send the request to SEMA or REMA
Congestion Management	If the data indicate that the event is an event of congestion, then this use case takes over. According to a set time of "backwardness" of operations in patio, sends a request to terminate the entry of vehicles through the Gate of the use case Send request time, for a period equal to time set as "backwardness."
Analize time proposals	Analize the answer sends from Gate for the extra time.
Notify action plan	Notify the answer plan to execution system

Tab. 6: Agent EIA Uses Case.

4. Study Case: San Antonio Port

This preliminary model has been tested with information from the container port terminal in San Antonio Port. Some events were simulated and the behavior of model analyzed. Yard port terminal operations planning and execution was developed. This scenario consists of a window of 40 hours of operation of the terminal. It has created a planning yard detailed spaces and resources with their respective missions to store and mobilize import containers and export terminal. It considered the arrival and departure of six ships with the respective containers to be unloaded and loaded at these for this schedule.

After establishing the overall planning, involving the shipping planning, yard planning and spaces, we proceeded to simulate the execution of operations to carry out the provisions of this general planning. For the simulation of the execution of operations Monte Carlo simulation was used to establish statistical distributions among other things, the arrival times of containers between the Gate, service times by Reachstackers container, the working times of Gantry cranes (on the Quay), and so on, always under the care of these details were as representative of the reality of a terminal of its kind. And then the simulation was done considering various events. In the event presentation pre and post-event state is detailed, highlighting the main changes resulting from the implementation of the action plans offered by the YEMS.

5. Conclusion and Future Work

In this paper the risk and event management problem in the port terminal container yard is presented and a model is obtained. In the Supply Chain, a port terminal is a strategic actor which converge multiple global supply chain. Because of this is important propose a solution to the risk and event management in this domain. The events impact in a terminal can cause considerable losses and impact on other actors in the global supply chain. It arises is why the interest in having information systems that enable the management of disruptive events within a port terminal. This model emerges as a precedent in the development of a software solution that is able to provide timely and effective plans deviations answers.

A multi-agent called YEMS model has been developed under the PASSI methodology. This multi-agent model was designed to manage internal events (resources, space and congestion) and external events generated in the Quay Gate and subsystems. The main agents are: EIA (this agent is the interface between YEMS and Execution System, it receives the disruptive events and notifies the plan changes), PIA (it is the interface with Planning Systems; it receives the plan and notifies the exceptions), SEMA (it manages the space on yard events, also it participates in the coordination process when an extern event is received), REMA (it is similar to SEMA but it has to manage events related with resources), Resources (this agent represents the resources in the yard, there will be an resource agent by each resource considered in the plan) and RE (the relationship with the other sub-system is carried out by this agent). This model offers the first action oriented in the disruptive event mitigation process.

The future works include the model implementation and the model validation with a study where the proposal will work with real events in a simulated environment in first place. In the future and with the alliance with a port terminal the information system will be test in a real environment.

Another future work is developing the risk and event management in the gate and quay, and the three model integration.

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About HICL

Since 2006 the annual conference Hamburg International Conference of Logistics (HICL) at Hamburg University of Technology (TUHH) is dedicated to facilitate the exchange of ideas and contribute to the improved understanding and practice of Logistics and SCM. HICL creates a creative environment which attracts researchers, practitioners, and industry thinkers from all around the world.

Innovation is increasingly considered as an enabler of business competitive advantage. More and more organizations focus on satisfying their consumer's demand of innovative and qualitative products and services by applying both technology-supported and non technology-supported innovative methods in their supply chain practices. Due to its very characteristic i.e. novelty, innovation is double-edged sword; capturing value from innovative methods in supply chain practices has been one of the important topics among practitioners as well as researchers of the field.

This volume, edited by Thorsten Blecker, Wolfgang Kersten and Christian Ringle, provides valuable insights into:

- Innovative and technology-based solutions
- Supply chain security management
- Cooperation and performance practices in supply chain management

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